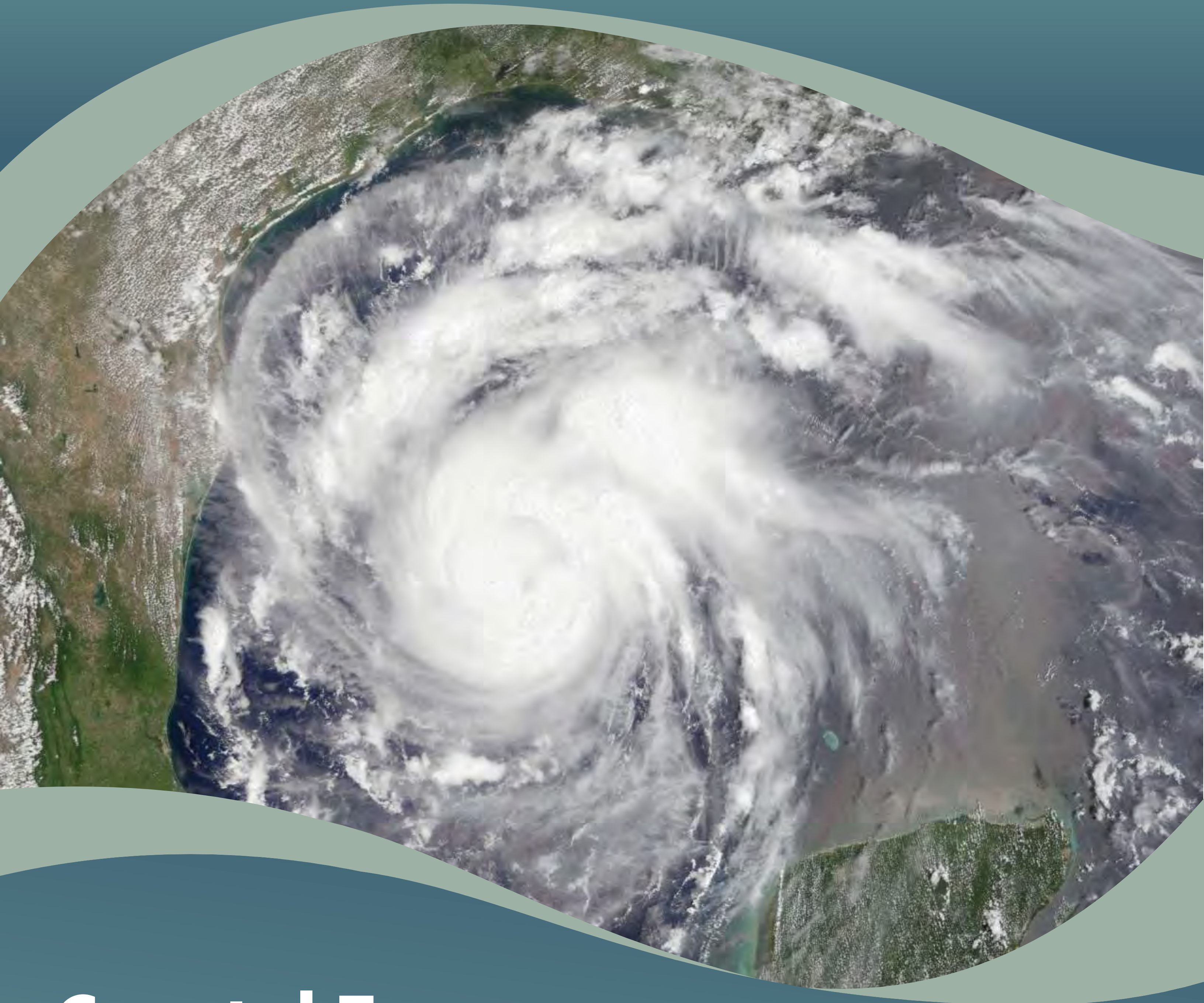
Galveston District
Southwestern Division

October 2018



Coastal Texas Protection and Restoration Feasibility Study

Draft Integrated Feasibility Report and Environmental Impact Statement

US Army Corps of Engineers ®

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

EXECUTIVE SUMMARY (*NEPA REQUIRED)

In November 2015, the U.S. Army Corps of Engineers (USACE) in partnership with the non-Federal Sponsor (NFS), the Texas General Land Office (GLO), began the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) to determine the feasibility of alternatives to enhance, restore, and sustain the environment, economy, and culture along the Texas coast. This Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) documents the examination and selection of the Tentatively Selected Plan (TSP).

The environmental, engineering, economic, and social analyses conducted to determine which alternative best addresses the coastal hazards that negatively impact the Texas coast were conducted in accordance with USACE procedures and guidance. Following identification of the TSP, the impacts of each of the alternatives considered were evaluated in accordance with the procedures under the National Environmental Policy Act (NEPA). The USACE and GLO identified the alternative during the TSP Milestone Meeting, held on May 30, 2018. The Chief of Planning and Policy approved the release of the DIFR-EIS for concurrent public review, policy review, and Independent External Peer Review. The USACE Project Delivery Team (PDT) and the GLO will analyze and address comments received during the concurrent reviews to assist with the development of the Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS).

Since the document presents a recommended Federal action, the USACE must satisfy the NEPA process to ensure that all alternatives and potential impacts are disclosed, and public comment is included. Through the NEPA scoping process, agency coordination, and the many iterations of the NEPA alternatives screening process, the study team considered 92 different components and potential alternatives before ultimately arriving at a reasonable range of alternatives carried forward in the DIFR-EIS. The USACE feasibility process and NEPA process are jointly addressed within an integrated report, rather than a feasibility document and a companion EIS. Figure ES-1 illustrates the key elements of the NEPA process, and Figure ES-2 presents how the complementary processes are integrated into the DIFR-EIS.

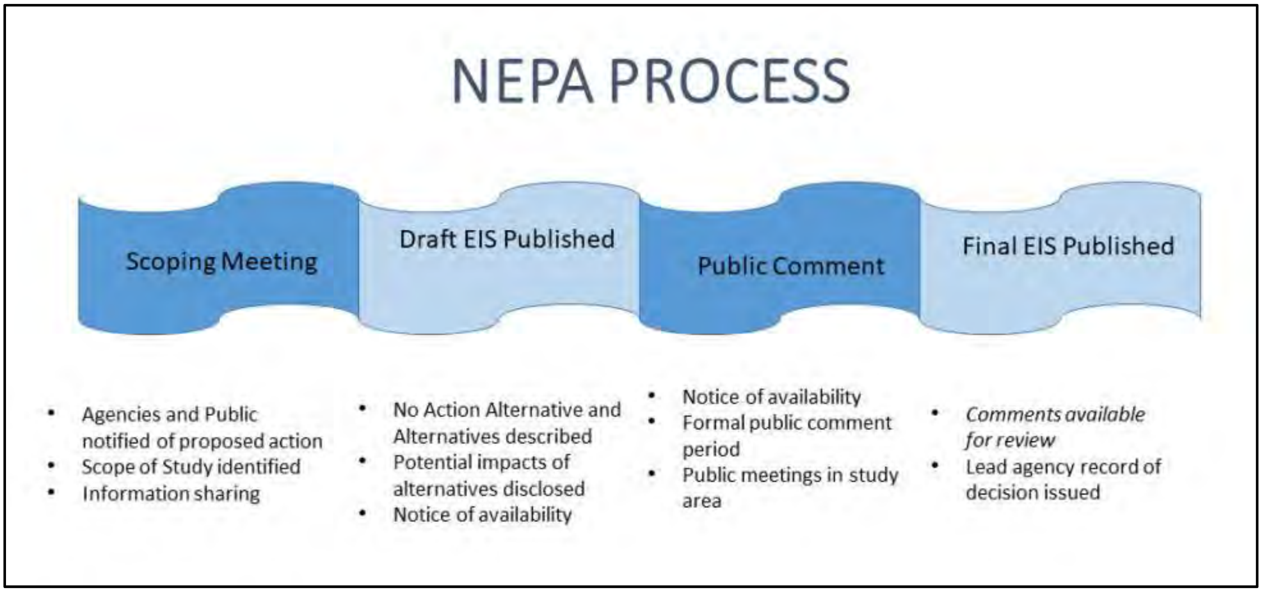


Figure ES-1: NEPA Process

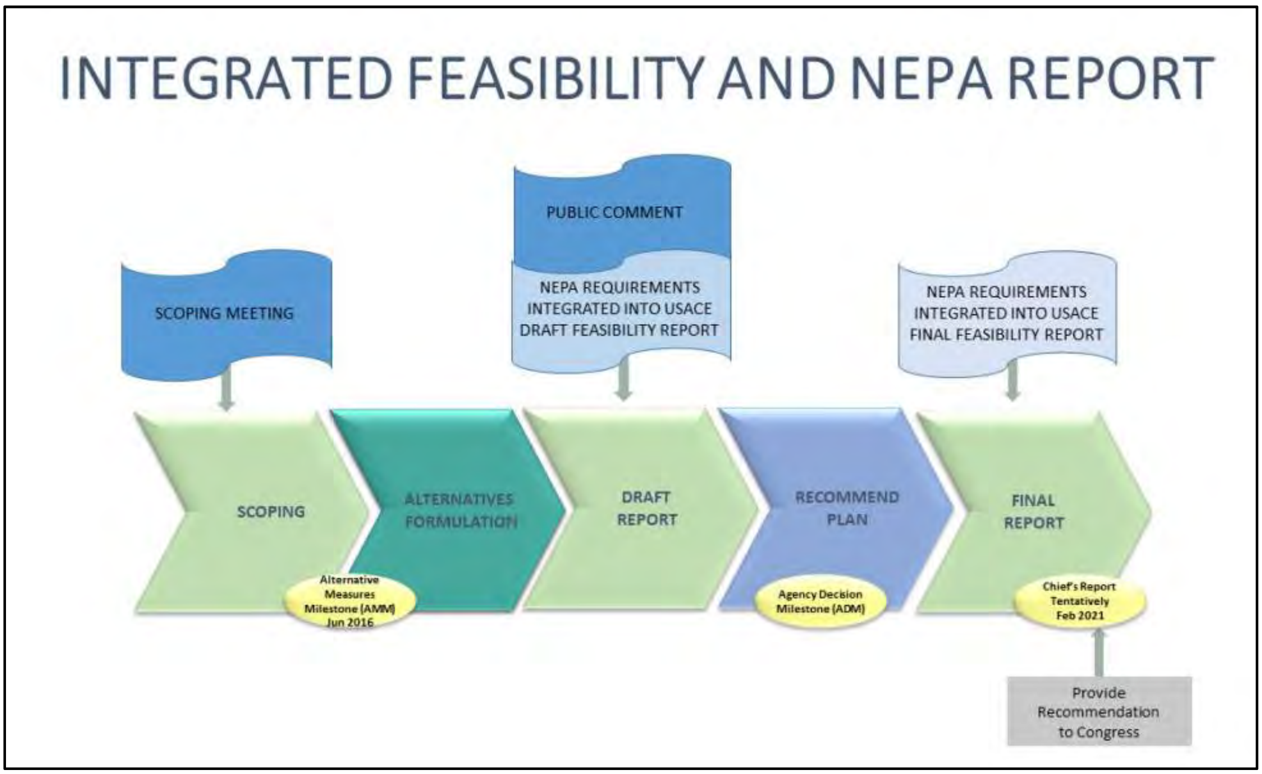


Figure ES-2: Integrated Feasibility and NEPA Report

What is included in an EIS?

- ***Summary:*** A summary of the EIS, including the major conclusions, area of controversy, and the issues to be resolved.
- ***Table of Contents:*** Assists the reader in navigating through the EIS.
- ***Purpose and Need Statement:*** Explains the reason the agency is proposing the action and what the agency expects to achieve.
- ***Alternatives:*** Consideration of a reasonable range of alternatives that can accomplish the purpose and need of the proposed action.
- ***Affected Environment:*** Describes the environment of the area to be affected by the alternatives under consideration.
- ***Environmental Consequences:*** A discussion of the direct and indirect environmental effects and their significance.
- ***List of Preparers:*** A list of the names and qualifications of the persons who were primarily responsible for preparing the EIS.
- ***List of Agencies, Organizations, and Persons*** to whom the EIS were sent.
- ***Index:*** The index focuses on areas of reasonable interest to the reader.
- ***Appendices (if needed):*** Appendices provide background materials prepared in connection with the EIS.

AUTHORITY

The Coastal Texas Study is being performed under the standing authority of Section 4091, Water Resources Development Act of 2007, Public Law 110-114.

> "Sec. 4091. Coastal Texas Ecosystem Protection and Restoration, Texas.
>
> (a) In General. — The Secretary shall develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ER in the coastal areas of the State of Texas.
>
> (b) Scope. — The comprehensive plan shall provide for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.
>
> (c) Definition. — For purposes of this section, the term ''coastal areas in the State of Texas'' means the coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, marshes, coastal wetlands, rivers and streams, and adjacent areas."

STUDY PURPOSE

The analyses conducted by the USACE and GLO for the Coastal Texas Study's DIFR-EIS will determine the feasibility and impacts of constructing large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternative plans to restore and enhance the State's ecologic coastal features and reduce the risk of coastal storm damage. The CSRM alternative plans consist of structural features that include levees, floodwalls, surge barrier gates (both navigable and environmental flow control gates), and breakwaters. The ER alternative plans consist of nonstructural features that include habitat restoration and shoreline erosion control through marsh, beach/dune, and island restoration. These features will address critical coastal ecosystems in need of restoration, including wetlands, seagrass beds, sea turtle nesting habitat, piping plover critical habitat, bird island rookeries, and Federal and State wildlife refuges. The DIFR-EIS also includes a No-Action Alternative.

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

As a powerful economic engine and an invaluable environmental treasure, the Texas coast is integral to the success of the State and the Nation. Its natural resources, such as beaches, dunes, wetlands, oyster reefs, and rookery islands, provide more than just recreational opportunities. They play a critical role in protecting coastal communities from storm surge and flooding. These coastal resources also contribute to the State and national economies by safeguarding and supporting industries. This includes petroleum refining, petrochemical, chemical and plastics manufacturing, waterborne commerce through the expansive network of Texas ports, commercial and recreational fishing, and tourism.

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

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

The region is growing, and jobs are being created because the country needs what flows from Texas's coast. This includes tourism, recreational fishing, commercial fishing, and the State's ports, intracoastal waterways, and energy production. Texas's transportation and energy hubs cannot be replicated anywhere else. As long as there is a need for what the Texas coast provides ecologically and economically, residents, businesses, and local stakeholders will continue to work and make the Texas coastline their home, all while adapting to changing coastal conditions.

Report Purpose

- Summarize the development and comparison of alternative approaches to reduce risk of coastal storm damage and restore the Texas Coast
- Describe the current decision point in selecting a plan and seek public comment
- Disclose potential impacts of plans considered to comply with NEPA

STUDY SCOPE

The Federal authorization for the Coastal Texas Study directs that the study's scope be a comprehensive approach for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence. Scoping for the Coastal Texas Study included input from the public, USACE and GLO, and consideration of prior studies. This included the GLO's 2017 Texas Coastal Resiliency Master Plan (Plan), which highlights the value of the coast, its resources, and the hazards that endanger coastal communities. The 2017 Plan also presents resiliency strategies and recommended nature-based projects to mitigate the impacts of coastal hazards. The GLO is currently working on the 2019 Texas Coastal Resiliency Master Plan to address the natural and built environments as they pertain to resiliency for coastal communities. The 2019 Plan will be complete and presented to the Texas Legislature in 2019. The two GLO Plans will continue to be used in the evaluation and refinement of the Coastal Texas Study to help address the coastal issues affecting the Texas coast. This includes wetland/habitat loss, water quality and quantity, impact to fish and wildlife, impact on marine resources, Gulf of Mexico (Gulf) beach/dune erosion, bay shoreline erosion, coastal flooding, and storm surge damage.

A concerted effort was made to ensure that scoping and evaluation was inclusive. An interagency team of Federal, State, local agencies, and Indian nations were invited to meet monthly to discuss study progress and formulation issues related to the Coastal Texas Study. Study team members shared updates on pending decisions and sought comment and approval of methods to assess performance and impacts of features proposed to reduce risk and restore habitat and natural coastal processes. Interagency workshops were held throughout the planning process to consider restoration measure performance metrics, screen and refine restoration alternatives, and review assumptions.

The Planning Modernization 3x3x3 rule was established in February 2012 to ensure an expedited, economical, and focused study process and limits studies to 3 years and $3 million, with three levels of vertical team integration (District, Division, and Headquarters). For the Coastal Texas Study, the USACE PDT and Vertical Team determined that the scope of the project was beyond the Planning Modernization 3x3x3 rule. Therefore, a strategy was developed to scope the study and apply for an exemption from the 3x3x3 rule. An exemption to the 3x3x3 rule was developed and approved by the Deputy Commanding General for Civil and Emergency Operations with a total study cost of $19.8 million. The exemption consisted of a waiver for time and cost. However, the report still followed the USACE SMART (Specific, Measurable, Attainable, Risk Informed, Timely) Planning Principles. Approval by the Assistant Secretary for Civil Works was received on November 10, 2015. The Feasibility Cost Sharing Agreement was executed on November 16, 2015.

Study Scope

- Defines the range of the study, which issues should be considered, and the relative range of solutions to evaluate
- Study Authority states the scope is to create a thorough plan for the protection, conservation, and restoration of critical resources, habitat, and infrastructure (roads, fire stations, hospitals, etc.) from the impacts of coastal storms, hurricanes, erosion, and subsidence
- "Scoping" was the first phase of the study when the public and various agencies, including the Texas Parks and Wildlife Department and U.S. Fish and Wildlife Services, shared concerns and project ideas
- Coastal Texas Study team included concepts developed by others -Texas A&M, Rice SSPEED Center, Gulf Coast Community Protection and Recovery District, and international agencies

LOCATION

The study area for the Coastal Texas Study consists of the entire Texas Gulf coast from the mouth of the Sabine River to the mouth of the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystems along the coast of Texas. The study area encompasses 18 coastal counties along the Gulf coast and bayfronts that are in the Texas Coastal Zone Boundary from the Texas Coastal Management Program. The study area has been divided into four sections: upper Texas coast, mid to upper Texas coast, mid Texas coast, and lower Texas coast. The upper Texas coast encompasses the Sabine Pass to Galveston Bay area and includes Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria counties. The mid to upper Texas coast is comprised of the Matagorda Bay area and includes Matagorda, Jackson, Victoria, and Calhoun counties. The mid Texas coast covers the Corpus Christi Bay area and includes Aransas, Refugio, San Patricio, Nueces, and Kleberg counties. The lower Texas coast encompasses the South Padre Island area and includes Kenedy, Willacy, and Cameron counties.

Location

- Study area includes 18 counties along Texas Gulf coast
- Includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, borrow sources, and adjacent areas that make up the interrelated ecosystems along the coast of Texas

STUDY NON-FEDERAL SPONSOR

The GLO is the NFS for the Coastal Texas Study. Following the execution of a feasibility cost share agreement in November 2015, the GLO actively participated in the scoping of the study and contributed a non-Federal cost share, which includes work-in-kind and contracting with GLO professional service providers. The GLO worked alongside the USACE on the DIFR-EIS in the formulation and screening process and will provide continued assistance throughout the entire Coastal Texas Study process.

The State of Texas is a possible construction sponsor. The GLO is also working to identify construction sponsors on the local level. Local construction sponsors could include local governments, such as counties, cities, levee improvement districts, drainage districts, municipal utility districts, or other special taxing entities that could be created for this specific project.

PROBLEMS AND OPPORTUNITIES

Significant environmental and economic impacts result from the continual erosion of the Texas coastline, with specific impacts to wildlife areas, wetlands, barrier islands, and residential and commercial property (Figure ES-3). Relative sea level rise (RSLR), which is a combination of land subsidence and sea level rise, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

The specific problems identified for the Coastal Texas Study include problems related to:

- Coastal communities including residential populations and the petrochemical industry becoming increasingly vulnerable to life safety and economic risks due to coastal storm events;
- Critical infrastructure throughout the region including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools becoming more at risk of damage from coastal storm events;
- Existing Hurricane Flood Protection Systems, including systems at Port Arthur, Texas City, and Freeport, which do not meet current design standards for resiliency and redundancy and will be increasingly at risk from storm damages due to RSLR and climate change;
- Degradation of nationally significant migratory waterfowl and fisheries habitats, oyster reefs, and bird rookery islands within the study area occurring due to storm surge erosion; and

- Water supply shortages due to increasing conflicts between municipal and industrial water supply and the ecological needs of coastal estuaries and ecosystems.

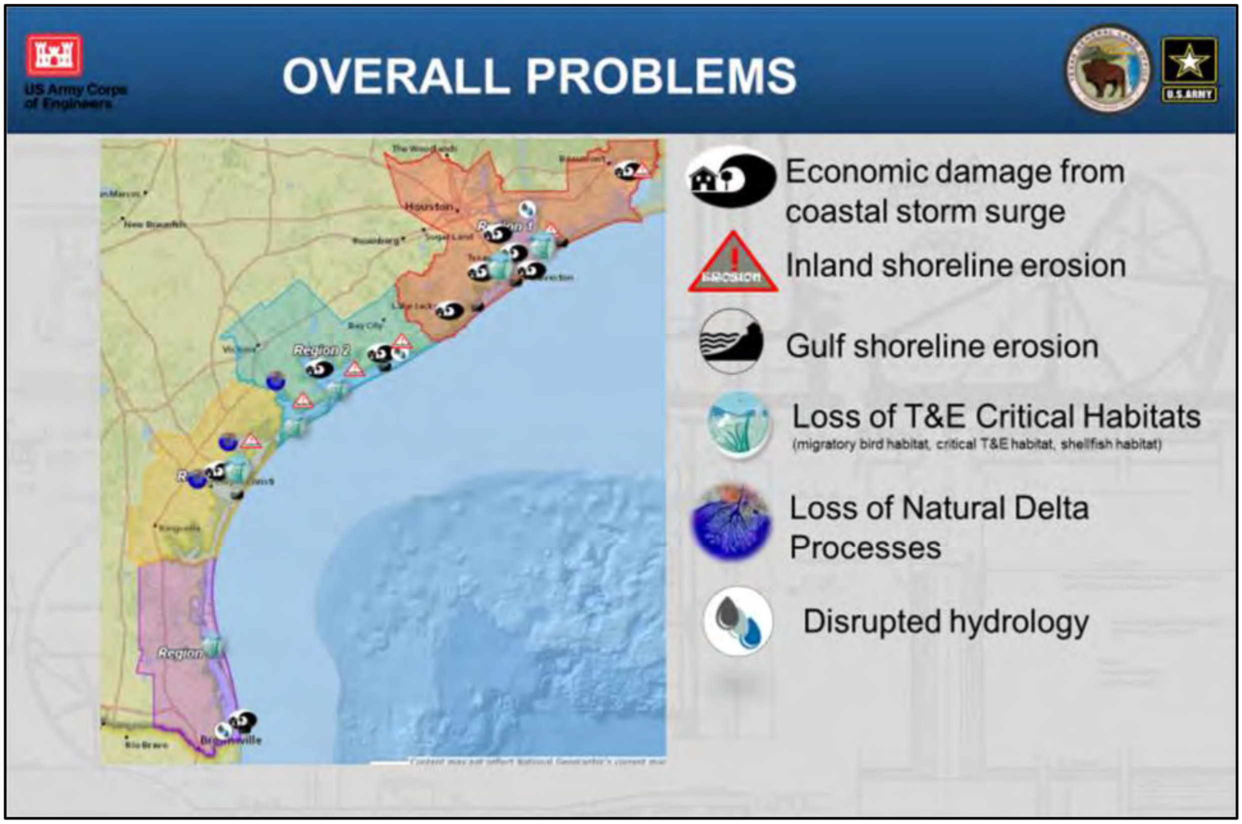


Figure ES-3: Overall Problems Identified for the Coastal Texas Study

The specific opportunities identified for the Coastal Texas Study include the opportunity to:

- Provide CSRM alternatives to reduce the risks to public, commercial, and residential property, real estate, infrastructure, and human life;
- Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induced storm damages;
- Increase the reliability of the Nation's energy supply by providing alternatives that will potentially lessen damages to refinery infrastructure caused by coastal storm events;
- Enhance public education and awareness to coastal storm risk;
- Restore the long-term sustainability of coastal and forested wetlands that support important fish and wildlife resource within the study area;
- Restore the barrier island environments to promote long-term sustainability of the fish and wildlife resources that rely upon those ecosystems;
- Improve the water quality in coastal waters through marsh and oyster reef restoration;
- Use available sediment within the system beneficially;

- Support programs that promote long-term erosion reduction of the Gulf coast and bay shorelines and limit erosion potential during future coastal storm events;
- Protect threatened and endangered species habitat; and
- Enhance ecotourism and recreational opportunities.

PLANNING OBJECTIVES

The main objective of the Coastal Texas Study is to recommend an alternative that will reduce the risk to lives and property associated with coastal storms in addition to providing ecological benefits, including enhancing shoreline stability and restoring coastal ecosystems.

The objectives listed below were developed from problem and opportunity statements and used to guide the plan formulation for the TSP. The proposed alternatives were evaluated throughout the study and in greater detail as the alternative screening progressed.

The following planning objectives for the 50-year period of analysis were used in formulation and evaluation of the CSRM alternative plans:

1. Reduce economic damage to businesses, residents, and infrastructure;
2. Reduce risk to human life from storm surge impacts;
3. Enhance energy security and reduce economic impacts of petrochemical supply-related interruption;
4. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.);
5. Incorporate regional sediment management, including beneficial use of dredged material from navigation and other operations;
6. Enhance functionality of existing storm surge risk reduction systems (locally and Federally constructed), including evaluation of impacts due to RSLR; and
7. Enhance and restore coastal habitat that contributes to storm surge attenuation, where feasible.

Additionally, planning objectives for formulation and evaluation of ER alternative plans for the 50-year period of analysis include:

1. Restore fish and wildlife habitat such as coastal wetlands, forested wetlands, bottomland forests, oyster reefs, beaches, and dunes;
2. Reduce saltwater intrusion into sensitive estuarine systems;
3. Reduce erosion to barrier island, mainland, and interior bay and channel shorelines; and
4. Improve water quality in coastal bays and estuaries with restoration of marshes and oyster reefs.

Environmental policies require that fish and wildlife resource conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. In the evaluation process, care was given to preserve and protect significant ecological, aesthetic, and cultural values, and to conserve natural resources. Alternative plans were formulated to reduce the risk of damages from coastal storms, as well as avoid environmentally significant resources. Where impacts could not be avoided, impacts were quantified, and a mitigation plan was formulated.

FORMULATION OF ALTERNATIVE PLANS

The objective of the Coastal Texas Study is to develop a comprehensive plan that will help manage risks associated with coastal storms within the study counties while avoiding and minimizing impacts to the region's environmental resources. The study team recognized that risk reduction alternatives will include traditional CSRM and ER components, which work together to reduce habitat loss over time and enhance the performance of other measures over time. Distinction between CSRM and ER features is necessary within the report to identify objectives, quantify the benefits of each, and document the formulation process; however, the TSP is formulated to achieve an integrated system of risk reduction actions.

How were different project ideas identified (Plan Formulation)?

How were they compared to select a plan (Alternatives Analysis)?

Feasibility analysis is a standardized process to ensure that Federal recommendations are evaluated consistently.

- What could solve the problems? (measures)
- Do those actions meet project objectives? (performance)
- Do those actions avoid constraints? (implementable)
- Can the measure be constructed and maintained to address the damages or problems (Engineeringly Feasible)?
- Do they produce more benefits than costs (Economically Justified)?
- Do they meet project objectives without unacceptable environmental impacts (Environmentally Acceptable)?

The TSP is the plan that best meets these objectives.

Public and agency review begins with the release of the DIFR-EIS.

Once technical and policy review confirms the evaluation and selection, it is the Recommended Plan.

CSRM and ER measures were developed and evaluated through several iterations of screening and assembled into alternatives to address specific needs for the Texas coast. Consistent with the USACE SMART Planning concepts, screening and evaluation of these alternatives relied largely on available existing information. The final array consists of a No-Action Alternative and two final action alternatives, the Coastal Barrier Alternative and the Bay Rim Alternative, which each include three components, a CSRM measure to address storm surge in the upper

Texas coast, a CSRM measure to address erosion in the lower Texas coast, and an ecosystem restoration plan for areas along the coast. The primary difference between the two final alternative plans is the alignment of the CSRM measure in the upper Texas coast. The CSRM measure planned for South Padre Island, as well as the ER measures along the coast, do not vary across the final two action alternatives.

The Coastal Barrier Alternative includes a combination of CSRM structural features along the seaward portion of the study area in addition to a Galveston ring levee, a nonstructural feature on the west side of Galveston Bay, beachfill in the lower Texas coast, and ecosystem restoration along the coast. The upper Texas coast CSRM system begins at High Island and crosses Bolivar Peninsula and Galveston Island with a storm surge barrier across Bolivar Roads.

The Bay Rim Alternative includes a combination of CSRM features along the West Galveston Bay Rim that extend westward around Texas City, in addition to a Galveston ring levee, beachfill in the lower Texas coast, and ER along the coast. The West Galveston Bay Rim CSRM system begins at Baytown and extends down the entire westside of Galveston Bay, around Texas City, and ends near the Galveston-Brazoria county line.

The proposed upper Texas coast CSRM measure that addresses storm surge may potentially cause the most substantial impacts. Therefore, the engineering analysis presented in Appendix D of the DIFR-EIS supported conceptual development of the distinct alignments, originally Alternative A and Alternative D2 (as referenced in Appendix D), to achieve CSRM and assess impacts of those features. The beachfill feature proposed to address erosion within the lower Texas coast is also detailed within Appendix D of the DIFR-EIS.

Nonstructural and structural measures were developed and considered to address study objectives. The nonstructural measures considered include buyouts or relocations, structure raising, flood warning systems, and floodplain management. The structural measures include new coastal and inland structural barriers, improving existing hurricane risk reduction systems and construction of new hurricane risk reduction systems, raising roads, Gulf shoreline restoration (beach and dune restoration, nearshore breakwaters), Gulf Intracoastal Waterway (GIWW) erosion protection, marsh restoration, oyster reef restoration/creation, and salinity/water control structures.

This DIFR-EIS presents the results of the CSRM and ER alternatives analysis and selection of the TSP through an iterative process based on economic, engineering, social, and environmental factors. The performance of the CSRM and ER Final Array of Alternatives was measured, then evaluated and compared against other CSRM or ER alternatives to identify a TSP. The evaluation included a comparison of the future without-project condition and the future with-project condition.

Performance

- Performance is estimated with mathematical models that simulate water surfaces by combining physical characteristics of the study area with probabilistic risk sources, such as frequency, intensity and duration of storms, and possible storm tracks (Figure ES-4).
- Project performance compares the outputs of these models across different plans.
- Model accuracy is tested by simulating historical storms to compare model results with observed characteristics.

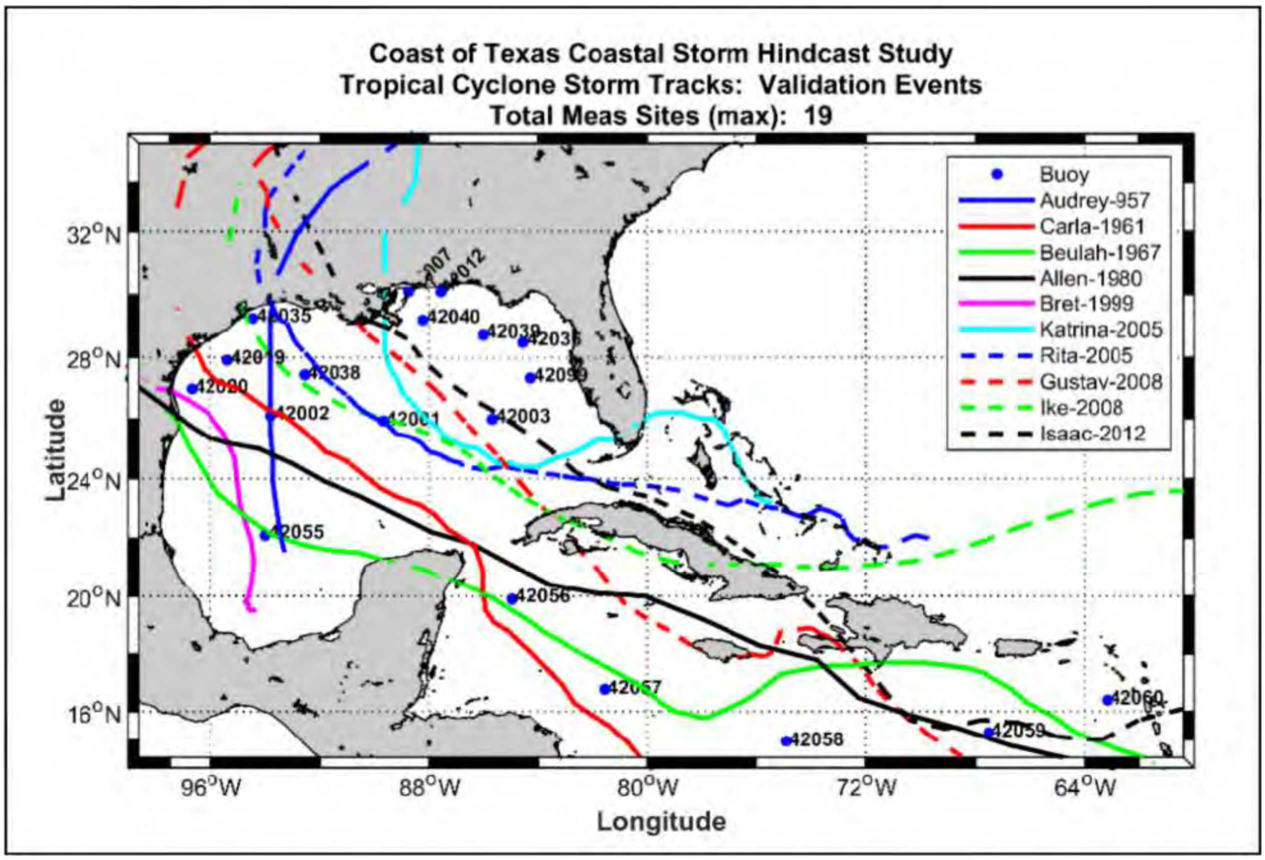


Figure ES-4: Storm Tracks

TENTATIVELY SELECTED PLAN

The TSP, identified as the Coastal Barrier Alternative, is a systemwide plan that best meets the study objectives, and when compared to the other action alternatives and the No-Action Alternative, most effectively reduces risk from coastal storms and habitat loss (see Figure ES-5 below). The TSP consists of the Coastal Barrier Alternative, the South Padre Island CSRM Measure, and the Coastwide ER Alternative 1-Scale 2.

Tentatively Selected Plan

Coastal Barrier System, South Padre Island Beachfill, and Comprehensive Ecosystem Restoration (including marsh, island, and beach/dune restoration)

- Coastal Barrier – Structures along Bolivar Peninsula and Galveston Island to reduce storm surge (levees, floodwalls, seawall improvements)
    - Surge gates within Bolivar Roads including large gate for ship traffic and smaller gates for water flow
- South Padre Island Risk Reduction = Beach and Dune Nourishment
- Ecosystem Restoration = 9 projects along areas of the Texas Coast (see map below)

The Coastal Barrier Alternative is a risk reduction system made up of the following features: floodwalls (inverted T-walls), floodgates (both highway and railroad floodgates), seawall improvements, drainage structures, pump stations, and surge barrier gates. The largest feature of the Coastal Barrier Alternative is at Bolivar Roads between Bolivar Peninsula and Galveston Island, which includes surge barrier gates that are made up of navigable floating sector gates and environmental lift gates, and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap. The alignment includes four reaches: Eastern Tie-in Reach, Bolivar Peninsula Reach, Galveston Ring Levee/Floodwall Reach, and West Galveston Island Reach in addition to features located at Clear Creek Channel and Dickinson Bayou. The study team will focus on the scale of the level of risk reduction for the TSP in the future planning and design phases. Individual features such as levee heights, flood heights, pump station sizes, nonstructural features, and alignments would be optimized. For planning purposes for the DIFR-EIS, the team evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island; however, the team recognizes that there are opportunities to optimize the design and alignment to minimize impacts to existing structures and the environment on the peninsula and island. Future design efforts would focus on where engineered dune systems maybe appropriate versus levees and floodwalls.

The South Padre Island CSRM Measure consists of approximately 2.2 miles of dune and beach restoration along the barrier island on the Gulf and includes a renourishment interval of 10 years.

The ER component of the TSP (Coastwide ER Alternative 1-Scale 2) has been formulated to address habitat loss and degradation from coastal processes through ER measures that are intended to restore and create habitat and support structural CSRM efforts by providing a natural buffer from coastal storms. The ER measures proposed in this study are a combination of features formulated in specific geographic locations to restore diverse habitats and provide multiple lines of defense.

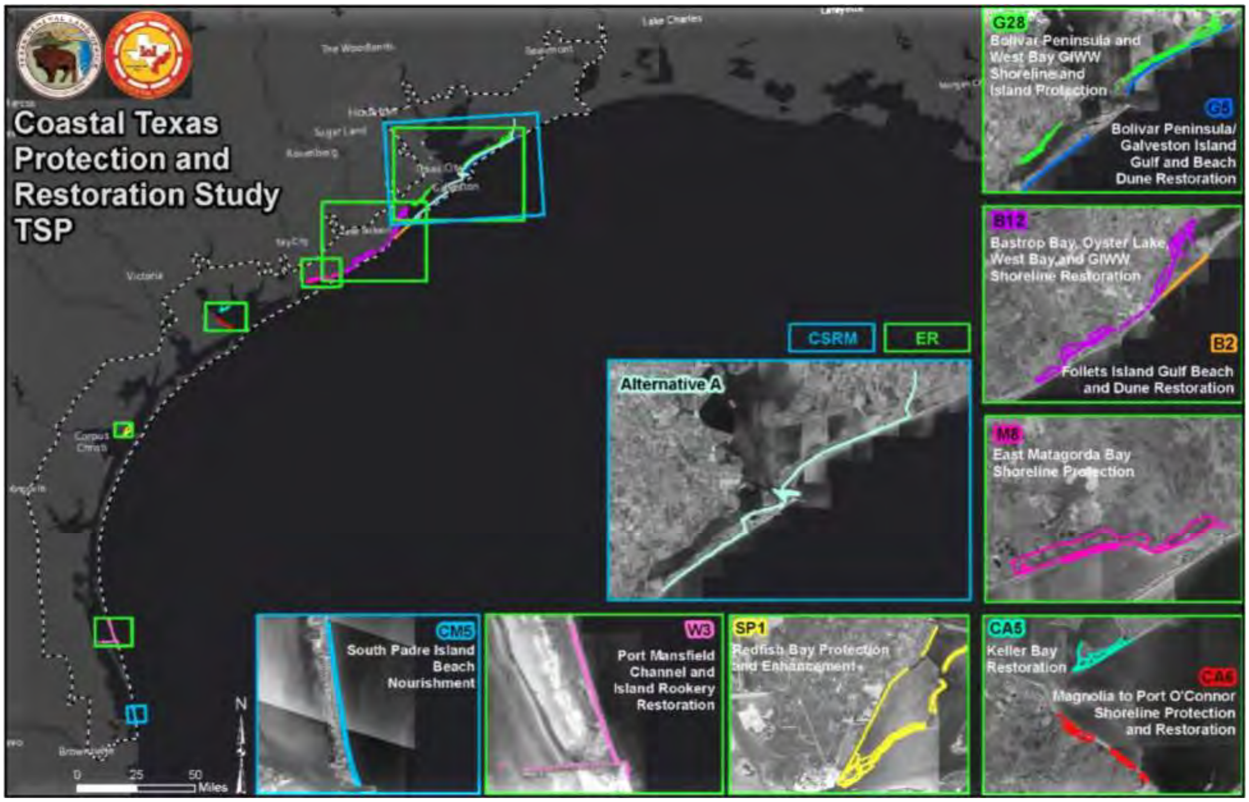


Figure ES-5: TSP – Coastal Barrier Alternative

In areas that would convert to open water or unconsolidated shoreline over the period of analysis due to RSLR, additional footprints are proposed for marsh restoration, referred to as out-year marsh nourishments. The timing of the additional marsh restoration has been proposed for 2065 to allow time for the marsh to mature in anticipation of RSLR, although implementation is subject to change in response to actual sea level change and the adaptive management plan.

ER includes the following nine ER measures:

1. G-5 – Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration
   - Restoration of Gulf shorelines from High Island to the Galveston East Jetty and restoration of Gulf shorelines west of the Galveston seawall.
2. G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection
   - Shoreline protection and restoration through the nourishment of marshes that are eroding and degrading and construction of breakwaters along unprotected segments of the GIWW on Bolivar Peninsula and along the north shore of West Bay,
   - Out-year marsh nourishment (in year 2065) in areas that are expected to convert to open water or unconsolidated shoreline over the period of analysis due to RSLR,
   - Restoration of a bird island that protected the GIWW and mainland in West Bay, and

- Addition of oyster cultch to encourage creation of oyster reef on the bayside of the restored island in West Bay.

3. B-2 – Follets Island Gulf Beach and Dune Restoration
    - Restoration of the beach and dune complex on Gulf shorelines of Follets Island in Brazoria County.
4. B-12 – West Bay and Brazoria GIWW Shoreline Protection
    - Shoreline protection and restoration through the nourishment of eroding and degrading marshes and construction of breakwaters along unprotected segments of the GIWW in Brazoria County,
    - Construction of rock breakwaters along western shorelines of West Bay and Cow Trap Lakes,
    - Addition of oyster cultch to encourage creation of oyster reef along the eastern shorelines of Oyster Lake, and
    - Out-year marsh nourishment (in year 2065) in areas that are expected to convert to open water or unconsolidated shoreline over the period of analysis due to RSLR.
5. M-8 – East Matagorda Bay Shoreline Protection
    - Shoreline protection and restoration through the nourishment of eroding and degrading marshes and construction of breakwaters along unprotected segments of the GIWW near Big Boggy National Wildlife Refuge and eastward to the end of East Matagorda Bay,
    - Restoration of an island that protected shorelines directly in front of Big Boggy National Wildlife Refuge,
    - Addition of oyster cultch to encourage creation of oyster reef along the bayside shorelines of the restored island, and
    - Out-year marsh nourishment (in year 2065) in areas that are expected to convert to open water or unconsolidated shoreline over the period of analysis due to RSLR.
6. CA-5 – Keller Bay Restoration
    - Construction of rock breakwaters along the shorelines of Keller Bay in order to protect submerged aquatic vegetation and marsh,
    - Construction of oyster reef along the western shorelines of Sand Point in Lavaca Bay by installation of reef balls in nearshore waters, and
    - Out-year marsh nourishment (in year 2065) in areas that are expected to convert to open water or unconsolidated shoreline over the period of analysis due to RSLR.
7. CA-6 – Powderhorn Shoreline Protection and Wetland Restoration
    - Shoreline protection and restoration through the nourishment of eroding and degrading marshes and construction of breakwaters along shorelines fronting portions of Indianola, the Powderhorn Lake estuary, and Texas Parks and Wildlife Department Powderhorn Ranch State Park and Wildlife Management Area.
8. SP-1 – Redfish Bay Protection and Enhancement

- Construction of rock breakwaters along the unprotected segments of the GIWW along the backside of Redfish Bay,
- Restoration of Dagger, Ransom, and Stedman islands in Redfish Bay, for a total of six islands,
- Construction of breakwaters on the bayside of the restored islands, and
- Addition of oyster cultch to encourage creation of oyster reef between the breakwaters and island complex to allow for additional protection of the Redfish Bay complex and submerged aquatic vegetation.

9. W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration
   - Restoration of the hydrologic connection between Brazos Santiago Pass and the Port Mansfield Channel via dedicated dredging of the Port Mansfield Channel,
   - Restoration of Mansfield Island (a bird rookery island),
   - Construction of additional rock breakwaters around Mansfield Island, and
   - Restoration of sediment transport across the Port Mansfield Channel to the Gulf shoreline north of the Port Mansfield Channel jetties; this would allow for reoccurring nourishment of the North Padre Island beach and dune complex.

The Coastal Barrier Alternative and South Padre Island CSRM Measure fulfill the focused CSRM planning objectives and maximize net benefits, consistent with protecting the environment in accordance with national environmental studies, applicable Executive Orders, and other Federal planning requirements. Likewise, the Coastwide ER Alternative 1-Scale 2 includes measures that would restore the natural features of the Texas coast, including beach and dune complexes, oyster reefs, bird rookery islands, and wetland and marsh complexes, which work to support a diverse array of habitats and conditions necessary for coastal resiliency and mitigation of damages caused by coastal storms and RSLR.

Ecosystem Restoration	
Beach Restoration G-5 B-2 W-3	• Place beach quality sand on beaches • May include dune restoration or creation • Creates habitat for many organisms, including threatened and endangered species
Breakwater G-28 CA-6 B-12 M-8 CA-5 W-3 CA-6	• Rock to be placed along the shoreline to reduce waves • Reduces erosion
Marsh Restoration G-28 B-12 CA-6 M-8	• Add sediment to existing wetlands and areas that were previously wetlands • Plant wetland plants • Creates habitat for many species, including commercially and recreationally important fish, crabs, and shrimp
Island Restoration G-28 M-8 SP-1 W-3	• Restore and/or create islands • Islands help protect shorelines and submerged aquatic vegetation (SAV) • Provides habitat; especially for nesting birds (rookeries)
Oyster Reef M-8 SP-1 CA-5 B-12 G-28	• Place material for oysters to grow on (clutch, reef balls, or other similar materials) • Increases oyster population, provides habitat for other organisms, and helps reduce wave energy

The TSP cost, presented in Table ES-1, have been broken into a code of accounts. Both the coastwide ER plan and the two CSRM recommendations are included in the total cost estimate.

Table ES-1
TSP Costs

Description	Grand Total for TSP Low – High
Real Estate Cost:	
01-Lands and Damages	$2,155,908,000–$2,313,170,000
02-Relocations	$60,939,000–$60,939,000
Subtotal Real Estate Cost (100 percent Non-Federal)	*$2,216,847,000–$2,374,109,000*
Construction Costs	
06-Fish and Wildlife	$675,621,000–$905,766,000
10-Breakwaters and Seawalls - ER Island Restoration	$1,002,774,000–$1,403,884,000
11-Levees and Floodwalls CSRM and ER	$2,919,993,000–$5,478,840,000
12-Navigation, Ports, and Harbors – ER Marsh	$1,309,815,000–$1,833,742,000
13-Pumping Plants	$1,048,097,000 – $1,220,583,000
15-Flood Control and Div Str	$297,627,000 – $297,627,000
15-Flood Control and Div Str – "Big Gate"	$5,097,492,000 – $6,304,361,000
17-Beach Replenishment	$3,642,213,000–$5,085,453,000
30-Engineering and Design	$3,074,013,000–$4,348,008,000
31-Construction Management	$1,822,090,000–$2,573,502,000
Subtotal Design and Construction Costs	$20,889,735,000–$29,451,766,000
Total Project Cost (rounded)	**$23,106,582,000–$31,825,875,000**

The ER features have been formulated to achieve meaningful ecosystem restoration along the Texas coast, and to address the habitat loss and impairment that occurred over many years of inattention. The scale of the ER measures proposed in the TSP and the cost of those measures reflect the magnitude of the impairment of the coastal environments and the need to preserve them as a natural risk buffer that will naturally complement the structural features in the study area.

The cost estimates for the CSRM alternatives were developed by incorporating unit costs and quantities from the Gulf Coast Community Protection and Recovery District report and revising their estimates to be consistent with USACE cost practices. The greatest ranges in estimated costs are associated with design and construction of the 1,200-foot gate complex and floodwall construction along the backside of Galveston. The range for gate design and construction is relatively wide to account for variability in fabrication and transportation estimates. Existing port facilities and infrastructure along the backside of Galveston make construction of a floodwall in that area difficult and account for the range in estimated costs for floodwall construction. What makes this project unique is the magnitude of the job and the need to transport borrow material for levee construction onto Bolivar Peninsula and Galveston Island. The utilization of commercial sources for borrow and their continued availability in the future is a substantial risk, particularly if the transportation distance increases. The study team has used the best information available at the time of the development of the DIFR-EIS for cost of the TSP. The study team will continue to develop and refine project costs in future planning and design phases of the study; however, risk contingency markups were included in the estimate to cover unknowns, uncertainties, and/or unanticipated conditions at this time. Due to these uncertainties, the costs are currently presented as a range in Table ES-1.

Project (TSP) Estimated Costs

$23,106,582,000–$31,825,875,000

ENVIRONMENTAL COMPLIANCE

The TSP is likely to have environmental impacts, and therefore, an EIS is being prepared and integrated with the feasibility report. The Notice of Intent to file the EIS was published in the *Federal Register* on March 31, 2016. The U.S. Fish and Wildlife Service (USFWS) actively participated in the impacts evaluation and environmental modeling and is preparing a draft Fish and Wildlife Coordination Act Report; their preliminary recommendations have been incorporated into the DIFR-EIS. The USACE prepared a Draft Biological Assessment that will be submitted to the USFWS and National Marine Fisheries Service for review. The Biological Assessment determined that the TSP would be likely to adversely affect five listed species, including piping plover, red knot, and three species of sea turtle (green, Kemp's ridley, and loggerhead), due in part to dredging and fill material placement associated with construction activities. Additionally, seven listed species may be affected, but are not likely to be adversely affected. The USACE is proposing to execute a Programmatic Agreement among USACE, the Texas State Historic Preservation Office, and any NFS to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities. There is potential for new construction and improvements to existing structures to cause effects on historic properties; however, the numbers of properties that may be affected are not extensive. Intensive cultural resources investigations to identify and evaluate any historic properties within proposed construction areas will be conducted prior to construction.

POTENTIAL ENVIRONMENTAL IMPACTS

The DIFR-EIS addresses the potential impacts of the proposed features on human and environmental resources identified during the public interest review. Alternative plans were formulated to reduce the risk of damages from coastal storms as well as avoid environmental resources. Where impacts could not be avoided, impacts were quantified, and a mitigation plan was formulated. All factors that may be relevant to the proposed alternatives were considered and are detailed in Appendix C-1 to the DIFR-EIS. The following provides a brief description of the potential impacts that were identified.

Strategic planning initiatives were integrated during the development of the features to minimize and mitigate impacts associated with the structures. Preliminary studies conducted by the USACE show that the surge barrier gates proposed as features of the Coastal Barrier Alternative may affect wetland functions by constricting tidal exchange and the associated sediment transport and altering hydrosalinity gradients. This, in turn, could potentially impact the ecology of the Galveston Bay estuary and the fish, birds, and wildlife species that depend on the resources provided by wetland and marsh habitats. Steps would be taken to avoid, minimize, and reduce any potential impacts to the best extent practicable. Additionally, estuarine modeling conducted by the USACE shows that construction of the surge barrier gates could reduce flow into and out of Galveston Bay and increase velocities along the opening of the gates during specific times. These effects could have long-term impacts on estuarine habitats and fauna within the bay. Construction of the CSRM alternatives, specifically the Coastal Barrier Alternative, could also cause an overall decrease in sediment within the bay system post storm events as a result of the loss of overwash and increase the erosional impacts due to localized turbulences, which would affect marsh sustainability within the area.

Potential Environmental Impacts

- **Measures designed to avoid and minimize impacts**
  - The project **must** mitigate for impacts that cannot be avoided.
  - Mitigation is an action or feature taken to compensate for the lost resource.
- **DIRECT impacts to wetlands in Galveston Bay**
  - Levees and other structures will go through wetlands (exact alignment will be refined in future planning and design phases, which will change the estimated amount of impacts).
  - These impacts will be mitigated by constructing wetlands in another location within the Galveston Bay system.
- **INDIRECT impacts to wetlands in Galveston Bay**
  - Surge barriers may impact the flow of water through Bolivar Roads.
  - Modeling estimated the amount of the potential impacts to wetlands from the barrier.
  - Wetland impacts will be mitigated by constructing wetlands in another location within the Galveston Bay system.
- **Positive impacts from Ecosystem Restoration by reducing erosion, creating more habitat, and protecting existing habitat**

The Coastal Barrier Alternative would provide a level of protection to tidal and freshwater wetlands north of the alignment by serving as a physical barrier against erosion forces during storms. The South Padre Island CSRM Measure would restore the beach and dune complex along South Padre Island and would likely help preserve existing wetland and marsh habitats on the bayside of the measure by providing increased protection from storm surges. Additionally, habitat restoration measures would restore the natural features of the Texas coast that provide habitat for many Federally threatened and endangered species and State species of concern, provide protection to upland areas from flooding caused by RSLR and storm surge, and stabilize the coastline by absorbing energy from ocean currents and vessel wakes.

PUBLIC INVOLVEMENT, REVIEW, AND CONSULTATION

Extensive public scoping, stakeholder communication, and resource agency coordination has been maintained throughout the development of the TSP. Information regarding CSRM and ER problems and opportunities was collected during a series of scoping meetings that were held in February and March 2012 as part of the Sabine Pass to Galveston Bay Feasibility Study and is being used for this study. Separate scoping meetings were held in Palacios, Corpus Christi, and South Padre Island in August 2014 to collect additional information for the remainder of the Texas coast.

A series of stakeholder meetings were held in 2012 and 2014 that focused primarily on communicating the goals and progress of the study with local governments and agencies. Resource agency meetings were held monthly from 2016 to present to provide an opportunity for agency feedback and study progress updates. Additional meetings/workshops were held to discuss specific study topics such as ER screenings, Habitat Evaluation Procedure/Wetland Value Assessment, mitigation, etc.

AREAS OF POTENTIAL CONCERN

There are risks that the TSP will require refinement and change because of technical, policy, and public comments on the DIFR-EIS. Currently the following potential areas of concern are listed below.

San Luis Pass Closure

A closure at the natural pass at the west end of Galveston Island is not recommended as part of the TSP. The anticipated risk reduction benefits do not outweigh the potential negative environmental impacts of closing off the last remaining natural pass along the Texas coast.

Several factors contribute to the low benefit stream. Many of the structures and assets that would be protected as a result of the closure are already elevated above surge heights or are at a ground elevation that limits surge impact.

There is also limited surge risk when factoring in the full probability of potential storm directions. Finally, the pass and the adjoining West Bay are very shallow and constitute only 10 to 12 percent of the water exchange between West Bay and the larger area of Galveston Bay. This condition minimizes the risk of surge being transmitted to the larger area of Galveston Bay where there is a greater number of structures and assets at risk from storm surge.

Rainfall Extremes, Interior Drainage, and Pumping Capacity Determination

Several features are proposed that reduce exposure to storm surge, which will require interior drainage and pumping capacity evaluation with concurrent probability of rainfall extremes to ensure that rainfall within the CSRM features do not induce damages. The draft plan has included pumping equipment for all gates and within the Galveston ring levee. The specific technology and capacity will be refined in future planning and design phases as additional design detail is completed.

Cost-Share Allocation

Several measures proposed within the plan will require cost-share with Federal or State agencies. The cost share has not been presented in this report. In future planning and design phases, real estate investigations and an individual point cost estimate will be completed, which will allow for apportionment of cost sharing in the final report.

Implementation Plan

A detailed implementation plan will be developed in future planning and design phases. The plan will be subject to project authorization, appropriation and availability of funding, full environmental compliance, and execution of a binding agreement with the NFS in addition to identification of long-term operation, maintenance, repair, rehabilitation, and replacement. To evaluate cost and benefits, a linear construction schedule and funding stream was assumed for planning purposes for the draft report. The project will be constructed based on Congressional approval of authorization and the appropriation of construction funds, which could differ from the planning schedule used in this DIFR-EIS. A continuous funding stream would be needed to complete this project within the anticipated timeline shown in this report.

Nonstructural Formulation

The TSP would include nonstructural measures along the west side of Galveston Bay to address residual damages from wind-driven bay surges. Elevation is a common approach already being undertaken by residents and businesses in the study area. Due to the general uncertainty associated with structures' first floor elevations and locations in the floodplain, additional structure inventory investigations would be undertaken to evaluate which structures are at risk if this alternative is moved forward. The focus would be on the approximately 10,000 structures between the State Highway 146 and the bay rim.

Managed Retreat

Managed retreat is often cited as an alternative approach to coastal storm risk over time given the frequency of storms and sea level rise. The PDT recognized a distinction between managed retreat, where resources are withdrawn from the vulnerable areas over time in an organized and coordinated manner, and ad hoc retreat, where resources within vulnerable areas are abandoned or relocated after storm events or sea level change.

Managed retreat was not considered to be cost effective as a stand-alone alternative. The study area includes costly resources and infrastructure that support regional and national productivity. Costs to relocate petroleum refineries, port facilities, and the transportation infrastructure required by those resources would be larger than the costs of a structural solution that reduces risk to these facilities. The PDT considered managed retreat as one type of nonstructural solution which would be implemented to complement structural features and to adapt structural features as residual risk increases over time.

Barrier Improvement Act of 1990

Coastal Barrier Resources System designated units are located on Bolivar Peninsula in the TSP. The USACE Galveston District is currently consulting with USFWS to ensure that the proposed project evaluated in this DIFR-EIS is in compliance with Coastal Barrier Resources Act policies. The designated units were created to minimize loss of human life by discouraging development in high-risk areas, reduce wasteful expenditures of Federal resources, and to preserve the ecological integrity of these areas. The laws prohibit all Federal expenditures or financial assistance, including flood insurance, for residential or commercial development in the designated units. The study team recognizes that in these areas, construction of a levee/floodwall or engineered dunes would be needed to form a comprehensive barrier for the upper Texas coast. With the study sponsors support, the NFS has agreed to fund all costs attributable to the in-unit portions of the barrier system. Currently, approximately 12.4 miles of levee/floodwall or engineered dunes are included in the designated units and would be solely funded and constructed by the NFS.

If the features constructed by the NFS are in or affect the course, condition, location, or capacity of navigable waters or the discharge of dredge or fill material into waters of the U.S., the NFS would require a USACE Regulatory Permit to comply with the requirements set forth in the Rivers and Harbors Act of 1899 and the Clean Water Act. It would be possible for USACE Regulatory to adopt portions of this DIFR-EIS to complement their review. Specifically, if the Biological Assessment covers the entire project area, including the in-unit portions of the barrier system, then it would be possible for the USACE's Regulatory Review to include the adoption of those documents to avoid the duplication of effort. Finally, USACE Regulatory reviews would require separate authorizations from State Agencies (Texas Commission on Environmental Quality and the Texas General Land Office, respectively) for compliance with Section 401 of the Clean Water Act (401 Water Quality Certification) and for authorization under the Texas Coastal Management Program and the Federal Coastal Zone Management Act.

The USACE Galveston District will continue to consult with the USFWS to ensure that the proposed project ER features evaluated in this DIFR-EIS are in compliance with Coastal Barrier Resources Act policies. However, for the CSRM features, the study team determined that formal consultation will not be required because impacts in the units will not involve Federal expenditures or financial assistance within the system, as discussed above..

MAJOR FINDINGS AND CONCLUSIONS

The Coastal Barrier Alternative is identified as the TSP. In the upper Texas coast, the “Coastal Barrier with complementary system of nonstructural measures (Alternative A)” associated with the Coastal Barrier Alternative was identified as the TSP and the National Economic Development (NED) plan as determined by the evaluation criteria for the upper coast of Texas. This portion of the plan reduces economic damage from coastal storm surge flooding to businesses, residents, and infrastructure in the areas of the Galveston Bay system. The upper coast of Texas CSRM TSP would prevent an estimated $970 million to $1.288 billion in total equivalent annual hurricane/

tropical storm surge damages, depending on the future RSLR scenario, during a period of analysis from 2035-2085. One of the key differences between the Coastal Barrier Alternative and the Bay Rim Alternative is satisfying the planning objectives of risk reduction to critical infrastructure and enhancing the functionality of existing storm surge risk reduction systems. The Coastal Barrier Alternative fully meets both of these planning objectives since both the region's critical infrastructure and existing storm surge risk reduction systems would be within the system.

The South Padre Island CSRM Measure (Reaches 3 and 4) and the Coastwide ER Alternative 1-Scale 2 were refined through multiple screenings efforts to meet specific needs and opportunities within the study area. Along with the Coastal Barrier, the South Padre Island CSRM Measure (Reaches 3 and 4) was also identified as the NED plan, while the Coastwide ER Alternative 1-Scale 2 was identified as the National Ecosystem Restoration plan.

With the inclusion of a coastwide range of ER measures, such as gulf beach and dune restoration, GIWW and bay shoreline and island protections, and island rookery and hydrologic restoration, the plan meets many of the planning objectives set forth in the beginning of the study. Table 4-27 in Chapter 4 of the DIFR-EIS provides an overview of the how the different portions of the ER plan meet the overall planning objectives. Additionally, many of the ER measures included in the plan would supplement many of the overall CSRM planning objectives by serving as a natural buffer from some storm impacts to the area's infrastructure.

The South Padre Island CSRM plan (Reaches 3 and 4) included in the TSP would contribute to both the ER and CSRM study objectives. Although the main objective is to reduce economic damage from coastal storm surge flooding to businesses, residents, and infrastructure in the highly developed area of South Padre Island, the action would also reduce erosion to the barrier island and would in turn prevent breaches of the island system, which could impact the sensitive estuarine systems behind the islands.

Consistent with current USACE guidance the planning efforts focused on developing and comparing distinctly different plans based on the general geographic location for addressing risk reduction. The TSP is considered the NED plan when focusing on the general geographic location and features. Once a strategy for the risk reduction system has been selected, the study team will focus on the scale of the level of risk reduction for the TSP in future planning and design phases. Individual features such as levee heights, flood heights, pump station sizes, and nonstructural features would be optimized in future planning and design phases and presented with the final recommendation.

To ensure that all applicable laws and policies are addressed for the TSP, this DIFR-EIS will undergo public, policy, and technical review. The PDT will address any outstanding issues raised during the review and confirm the analyses in this DIFR-EIS and recommendations to move forward with development and completion of a FIFR-EIS.

What's Next?

- Draft Report is reviewed by the **public** (with time to send comments for the study team to review), **resource agencies, USACE and GLO leadership, and external technical experts.**
- PDT addresses issues raised during the review period.
- USACE Chief of Planning and Policy Review considers public comment and confirms analyses and recommendations at the Agency Decision Milestone .
- PDT prepares and publishes a Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS) for public, state, and agency review.
- A Chief's Report is prepared.
- The Recommended Plan is refined in a Design Phase (Figure ES-6).
- Construction is dependent upon Congressional authority and funding.
- The project will be maintained after construction by a local sponsor.

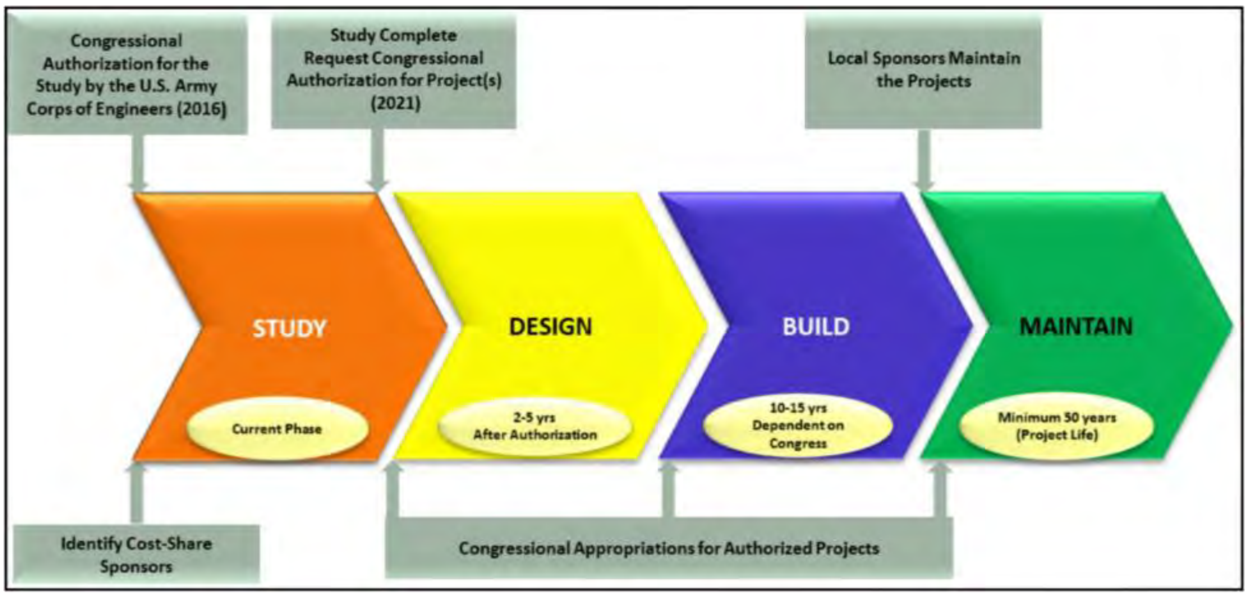


Figure ES-6: Next Steps in the Coastal Texas Study Process

Table of Contents

Page

List of Appendices

Figures

Page

Tables

Page

Acronyms and Abbreviations

°F	degrees Fahrenheit
AAHU	Average Annual Habitat Unit
ADCIRC	ADvanced CIRCulation
AdH	Adaptive Hydraulic
AMT	Adaptive Management Team
ATR	Agency Technical Review
BA	Biological Assessment
BCR	benefit to cost ratio
BEG	Bureau of Economic Geology
BOEM	Bureau of Ocean Energy Management
bpd	barrels per day
BU	beneficial use
CAA	Clean Air Act
CAP	Continuing Authorities Programs
C-CAP	NOAA Coastal Change Analysis Program
CE/ICA	cost effectiveness and incremental cost analyses
CEPRA	Coastal Erosion Planning and Response Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CIAP	Coastal Impact Assistance Program
CSRM	coastal storm risk management
CWA	Clean Water Act
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
cy	cubic yards
DEIS	Draft Environmental Impact Statement
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
EFH	essential fish habitat
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ER	ecosystem restoration
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIFR-EIS	Final Integrated Feasibility Report and Environmental Impact Statement

FM	Farm-to-Market Road
FWOP	future without-project
FWP	future with-project
FY	fiscal year
GCCPRD	Gulf Coast Community Protection and Recovery District
GDP	gross domestic product
GIWW	Gulf Intracoastal Waterway
GLO	Texas General Land Office
GOMESA	Gulf of Mexico Energy Security Act
Gulf	Gulf of Mexico
HCFCD	Harris County Flood Control District
HEC-FDA	Hydrologic Engineering Center Flood Damage Analysis
HEP	Habitat Evaluation Procedure
HFPP	Hurricane Flood Protection Project
HFPS	Hurricane Flood Protection System
H-GAPS	Houston-Galveston Area Protection System
HSI	Habitat Suitability Index
HTRW	hazardous, toxic, and radioactive waste
I	Interstate Highway
IEPR	Independent External Peer Review
LERRD	Land, Easements, Rights-of-Way, Relocation, and Disposal Areas
MAMP	Monitoring and Adaptive Management Plan
MBTA	Migratory Bird Treaty Act
mcy	million cubic yards
MLLW	mean lower low water
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NAVD 88	North American Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NFS	non-Federal sponsor
NGO	non-governmental organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
NRDA	Natural Resources Damage Act

NWR	National Wildlife Refuge
O&M	operation and maintenance
OMRR&R	operation, maintenance, repair, replacement, and rehabilitation
PAL	Planning Aid Letter
PCB	Polychlorinated biphenyl
PDT	Project Delivery Team
PL	Public Law
PPA	Project Partnership Agreement
ppt	parts per thousand
PWOP	present without-project
PWP	present with-project
REMI	Regional Economic Models Inc.
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States
RSLC	relative sea level change
RSLR	relative sea level rise
S2G	Sabine Pass to Galveston Bay Feasibility Study
SAV	submerged aquatic vegetation
SCS	Soil Conservation Service
SH	State Highway
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SLOSH	Sea, Lake and Overland Surges from Hurricanes
SLR	sea level rise
SMART	Specific, Measurable, Attainable, Risk Informed, and Timely
SSPEED	Severe Storm Prediction, Education, and Evacuation for Disasters
SWG	USACE Galveston District
T&E	Threatened and Endangered
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Program
TDSHS	Texas Department of State Health Services
TNC	The Nature Conservancy
TPWD	Texas Parks and Wildlife Department
TSP	Tentatively Selected Plan
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
USACE	U.S. Army Corps of Engineers
USC	United States Code
USFWS	U.S. Fish and Wildlife Service

VOC	volatile organic compound
WMA	Wildlife Management Area
WRDA	Water Resources Development Act
WVA	Wetland Valuation Assessment

1.0 INTRODUCTION AND PURPOSE (*NEPA REQUIRED)

1.1 INTRODUCTION

This Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) for the Coastal Texas Protection and Restoration Study (Coastal Texas Study) examines Coastal Storm Risk Management (CSRM) and Ecosystem Restoration (ER) opportunities within 18 coastal counties in Texas, which include the entire Texas Gulf coast. The DIFR-EIS presents the investigation of comprehensive water resources management for the Texas coast to ensure public safety and benefit to the Nation, while balancing the primary missions of navigation, flood and hurricane storm damage reduction, and environmental stewardship. This DIFR-EIS will be used to inform decision makers, stakeholders, and the public of the tradeoffs that should be considered in future decisions in order to maintain existing coastal storm risk levels and/or reduce coastal storm risk along the Texas coast.

1.1.1 Ecological Diversity

The Texas coast is an ecologically diverse and nationally significant coastline. The biological and economic productivity of the Texas coast is extraordinary. The coast encompasses many native plant and animal populations and provides nursery, nesting, and foraging areas for fish and wildlife; it also reduces the impacts of coastal hazards to the human environment.

Texas has 367 miles of Gulf shoreline and 3,300 miles of estuarine shoreline that host hundreds of thousands of acres of beach and dune systems, lagoons, seagrass beds, oyster reefs, and tidal marshes. More than 95 percent of commercially and recreationally important Gulf of Mexico (Gulf) finfish and shellfish species, and 75 percent of the Nation's migratory waterfowl depend on these wetlands at some point in their life cycle. These biological and geomorphic systems are the foundation for much of the coast's productivity, economy, and quality of life.

Resources of National Significance

- *Critical Coastal Ecosystems* – wetlands, seagrass beds, oyster reefs, sea turtle nesting habitat
- *Threatened and Endangered Species*
- *Critical Habitat* – piping plover and whooping crane
- *Central Flyway Migration Corridor*
- *Padre Island National Seashore*
- *National Estuary Programs* – Galveston Bay and Corpus Christi Bay
- *Laguna Madre* – rare hypersaline lagoon
- *National Wildlife Refuges*
- *Commercial Fisheries* – oysters, shrimp, finfish
- *Nursery Habitat*

1.1.2 Economic Diversity

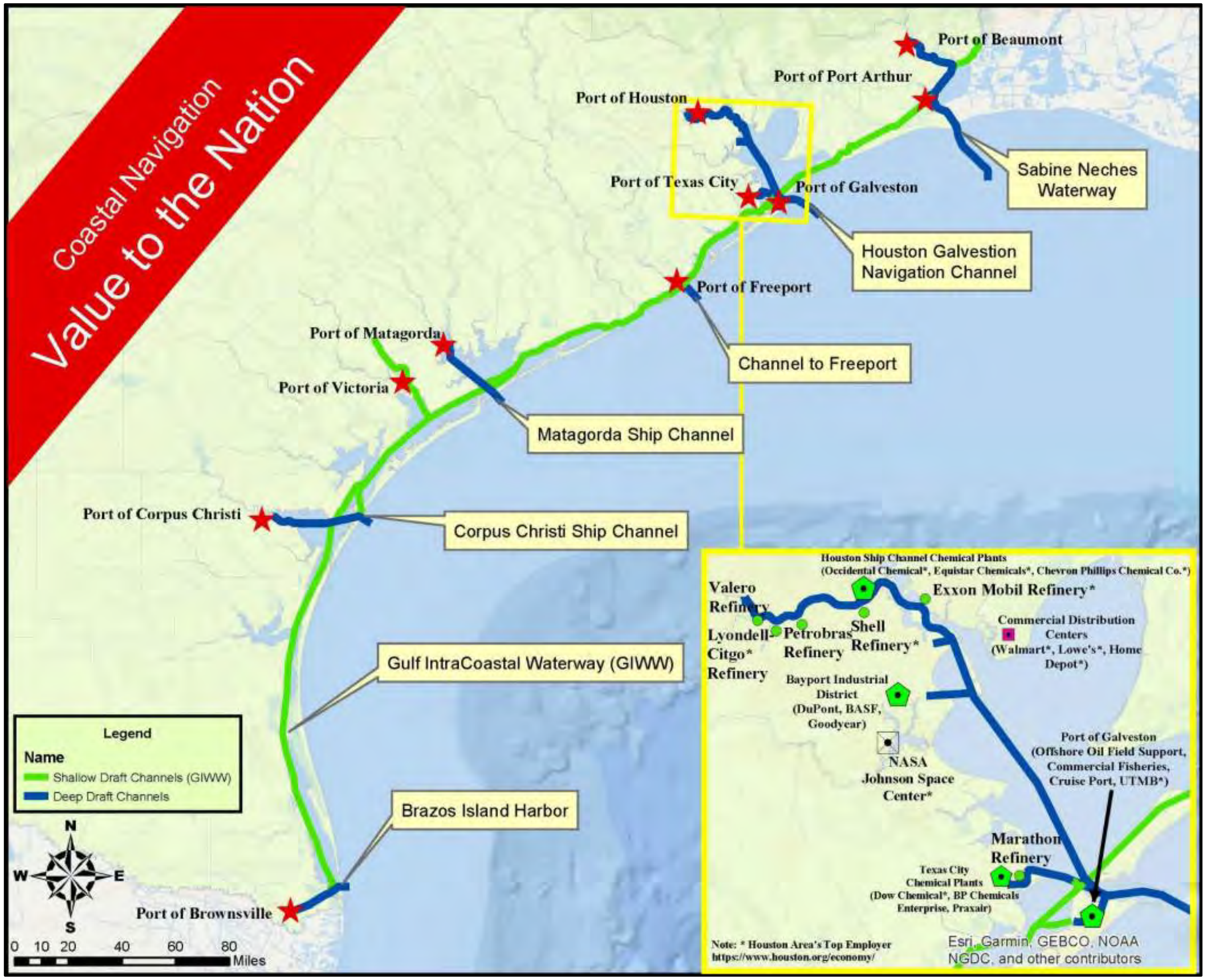
The Texas Gulf coast's contributions to the regional and the national economy are many, ranging from energy and agricultural industries, the port system and military transportation, to commercial fisheries, tourism, and recreation.

Texas is one of the Nation's top states for waterborne commerce, with Texas's coastal ports generating over $82.8 billion in economic value to the region. More than 500 million tons of cargo pass through Texas ports annually, including machinery, grain, seafood, oil, cars, retail merchandise, and military freight. The State's maritime system is a critical gateway to international trade and provides Texas with a multitude of economic opportunities through the movement of waterborne commerce. Texas is one of the Nation's leading states in the maritime industry, handling 15.8 percent of total U.S. cargo between 2007 and 2011. Texas ports managed 20.1 percent of the Nation's total export tonnage during this period, making it the Nation's leading export state. Texas ports also received 26 percent of the total foreign tonnage handled in the U.S. In addition, Texas ports offer critical links to other modes of transportation throughout the United States, such as major railroad lines and trucking routes. In 2010, 7.4 million tons of intermodal rail freight were shipped from Texas, the Nation's third-highest total. These vast economic benefits highlight that the shutdown of even a single Texas port can deliver a devastating blow to State and national economies as experienced in 2008 when Hurricane Ike came ashore near Houston and Galveston.

Although this is not a navigation study, navigation is an integral element of the study issues. Six deep-draft navigation channels and the Gulf Intracoastal Waterway (GIWW) provide valuable transportation infrastructure for the energy industry, military deployments, and the movements of consumer products in and out of the State, including the Nation's fourth largest metropolitan area (Houston) (Figure 1-1). Houston is the number two national port by volume; however, all of the Texas ports play an integral role in the movement of energy products to market and are home to four of the eight largest refineries in the country (providing 25 percent of national refinery capacity) including most of the National Petroleum Reserve. Port Arthur is also the number one port for military deployments, and the GIWW is the third busiest shallow-draft channel in the United States.

The GIWW plays a key role in all economic sectors. It is the Nation's third busiest inland waterway, with the Texas portion handling over 63 percent of its traffic. Over $25 billion of cargo passes annually through the 406-mile section of the GIWW that runs along the Texas coast.

The lower right inset of Figure 1-1 shows the area around Galveston Bay. The largest employer in Galveston County is the University of Texas Medical Branch on Galveston Island with over 11,000 employees. The second largest employer is the National Aeronautics and Space Administration with 3,000 employees (*Houston Business Journal*, 2015). Other top-10 employers include 2 of the countries' largest refineries, Marathon and Shell; several large petrochemical plants, including Dow, BP, and Enterprise; and other industrial facilities (Greater Houston Partnership, 2017a).



Note: Listed companies could have changed ownership and names

Figure 1-1: Texas Navigation Channels

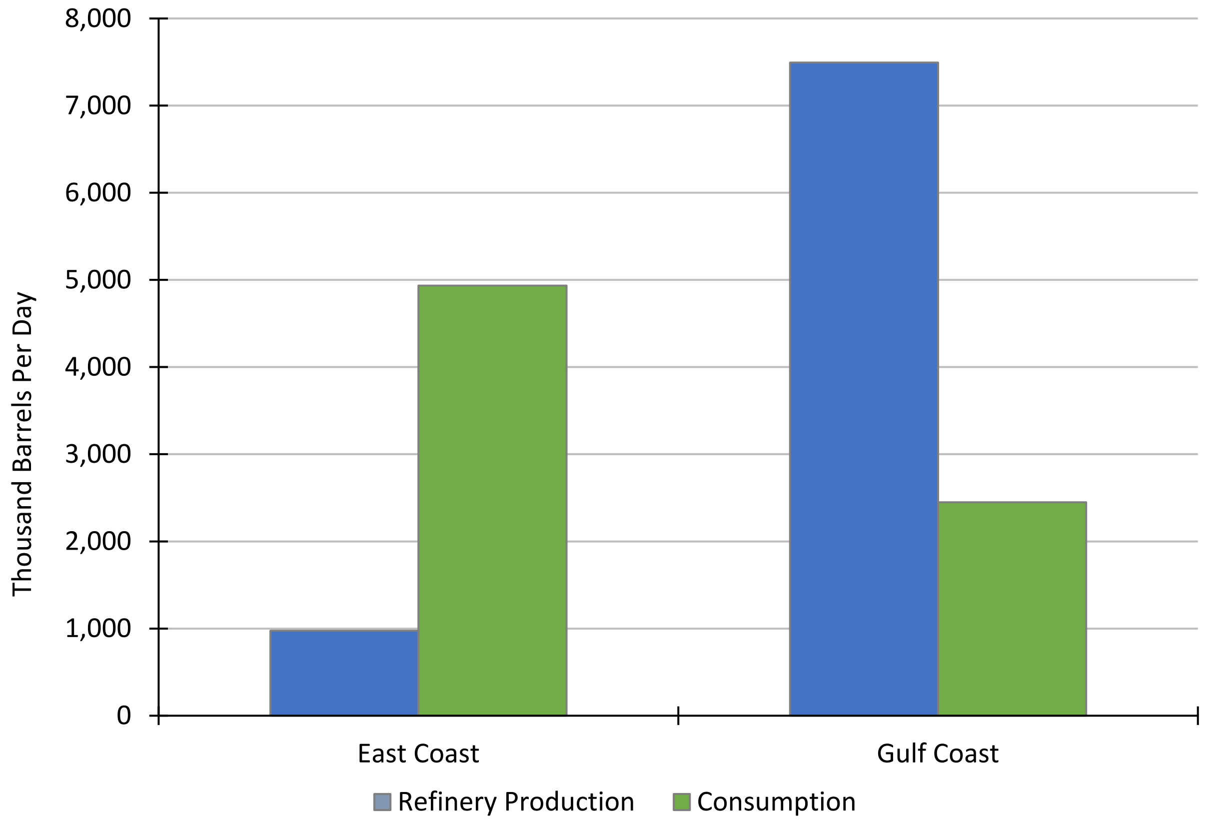
Access to navigation transportation has been a growth driver for the economy of the Texas Gulf coast since the early days of the independent Republic of Texas. The growing economy in turn drives a growing population in the coastal regions. Separating economic growth from coastal risks in this nationally important region is not possible, but there is an opportunity to reduce the risks while the Nation pursues economic strength.

The Texas Gulf coast plays a key role in the domestic energy security of the Nation. Much of this activity takes place around the upper Texas Gulf coast, home to over 4,000 energy-related companies and 14 of the 20 largest oil pipeline companies in the Nation (Greater Houston Partnership, 2017b). Overall, the 29 Texas refineries represented 30 percent of the Nation's total refining capacity in 2017 (U.S. Energy Information Administration, 2018). The upper Texas coast has a distillation capacity of more than 8.6 million barrels of crude oil daily. This area exported more than $59.1 billion of petroleum and coal products in 2014, supporting more than 1.1 million jobs through exports (International Trade Administration, 2015). This is by far the largest segment of the State's export market, making it one of the top commodities shipped through Texas ports. With respect to imports, 63 percent of the value of waterborne imports in Texas in 2014 were petroleum and petroleum products.

Gulf coast refineries in Louisiana and Texas produce 7.5 million barrels per day (bpd) of fuels, and only 2.5 million of those barrels are consumed in the region. The other 5 million barrels are sent to other parts of the country, primarily the East Coast, which only produces 1 of every 5 barrels it consumes. Texas refineries in Houston, Port Arthur, and Corpus Christi send about 2.5 million barrels to the East Coast every day via pipelines, barges, and tankers (Figure 1-2). Texas refining capacity in the study area is about 5 million bpd, with about 2.5 million of those barrels from Galveston Bay (U.S. Energy Information Administration, 2016).

Commercial fishing has long supported local and state economies. Texas A&M University documented the contribution of the Texas shrimp fishery, the largest commercial fishery in Texas, as a major part of the Texas marine economy. Between 2003 and 2012, shrimp landings accounted for 85 and 87 percent of Texas commercial fish landings by weight and value, respectively. Direct and indirect effects of the Texas shrimp fishery include purchases of goods and services by the shrimp-harvesting sector from other local industries and induced effects due to expenditures by those benefiting from the increases in local business activity (individuals employed due to the shrimp industry, such as shrimp vessel deckhands). Four different types of impacts are estimated: employment (number of jobs due to the shrimp fishery), labor income (combined income of those employed as a result of the shrimp fishery), value added (the shrimp fishery's contribution to gross domestic product [GDP]), and output (the effect of shrimp fishery direct spending on overall economic activity). In an average year the Texas shrimp fishery contributes approximately $167 million to the Texas economy (Ropicki et al., 2015).

Outstanding fishing, birding, and waterfowl-hunting opportunities, as well as family outings to the beach, make the coast the second most popular tourist destination in Texas, keeping the economy strong and creating jobs for both coastal residents and inland workers. Tourists visiting the Texas coast in 2014 spent $19.7 billion traveling in this region, over $10.4 million at hotels and motels alone. A 2016 study for the Texas Parks and Wildlife Department (TPWD) estimated annual regional economic impacts of marine recreational fishing in the Galveston



Source: U.S. Energy Information Administration (2016)

Figure 1-2: East Coast and Gulf Coast Transportation Fuels Production versus Consumption

Bay system to be the creation of 1,607 jobs, $55.7 million in labor income, $87.2 million in value-added (contribution to Texas GDP) per year, and $152.1 million economic activity per year. This economic activity is measured as the spending on trips themselves in the region, not goods such as fishing gear, rods, boats, etc. Similarly, total annual economic impacts of marine recreational fishing in the Upper Laguna Madre system was estimated to be 594 jobs, $21.2 million in labor income, $32.9 million in value-added (contribution to Texas GDP), and $58.0 million in output (sales value of goods and services) (Texas General Land Office [GLO], 2016).

1.1.3 Nation's Defense

Three Texas ports are designated by the Department of Defense as "strategic military ports," providing surface deployment and distribution for strategic military cargo worldwide. The Port of Beaumont, Port of Port Arthur, and the Port of Corpus Christi all serve in the U.S. Maritime Administration's National Port Readiness Network, supporting deployment of U.S. military forces during defense emergencies. For example, the Port of Beaumont handles more military cargo than any other port in the United States. In addition to military cargo, the Texas coast literally fuels the Nation's military, as well. The Texas coast delivers a larger volume of energy products, such as jet and diesel fuel, to the U.S. military than any other state. Furthermore, the majority of the Nation's strategic petroleum reserves are located near Houston.

1.1.4 Human Environment

Although the Texas Gulf coast is ecologically diverse and industrial sectors play a key role in our national economy, the people living and working in the coastal region are, by far, the most valuable and vulnerable assets. Texas's 18 coastal counties make up less than 6 percent of the State's land area but contain 24 percent of the State's population. The population living within the coastal counties of Texas is expected to increase from 6.1 million in 2010 to 7 million in 2020, and to over 9 million by 2050.

1.1.5 Risk

In light of changing landscapes, all of the biological and economic resources along the Texas Gulf coast face challenges. Although environmental conservation and storm surge risk reduction efforts have advanced along the coast, stressors such as catastrophic weather, coupled with a rise in relative sea level, have taken a toll on coastal areas. For example, the Galveston area experiences a major hurricane on average every 18 years. Storm surge from Hurricane Ike reached 20 feet and pushed water almost 30 miles inland in places (Berg, 2009).

Relative sea levels could rise by 1 to 6 feet over the next 50 years. Also, major coastal storms could increase in intensity, and the intensity of precipitation events is likely to increase. Depending on the severity and rate of changes of these impacts, there could be significant impacts on the communities along the Texas Gulf coast. A 4-foot increase in sea level could affect a quarter of interstates and arterials and nearly 75 percent of port facilities on the Gulf coast (Climate Change Science Program, 2008).

Substantial Gulf shoreline and barrier beach erosion, greater than 30 feet per year in some areas, compromises risk reduction of communities, industry, critical infrastructure, and coastal habitats making them more vulnerable to storm surge and flood damage. Similar to Louisiana's "Multiple Lines of Defense Strategy," the Texas Gulf coast is highly dependent on natural features like barrier islands, marshes, and ridges, in addition to a complement of man-made structural (seawalls and levees) and nonstructural features (elevating structures) to protect the area and economic resources from storm surge and flood damage.

1.2 STUDY AND PROJECT AREA

The study area consists of the entire Texas Gulf coast from the Sabine River to the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystem along the coast of Texas. This area is where project impacts would likely occur. The Texas shoreline is characterized by seven barrier islands: Galveston, Follets, Matagorda, St. Joseph's (San José), Mustang, Padre, and Brazos. Bolivar Peninsula also acts like a barrier island due to its location along the Gulf shoreline. These barrier islands serve as the backbone for the Texas Gulf coast. A key feature of the study is the GIWW, which parallels the Texas coast and can be found directly behind the barrier island systems. The study area encompasses 18 coastal counties along the Texas coast and bay fronts and can be divided into four areas: upper Texas coast, the mid to upper Texas coast, the mid Texas coast, and the lower Texas coast (Figure 1-3).

Locations of potential alternative plans and area that may be directly and indirectly impacted by construction or operations were limited to the Texas Coastal Zone Boundary. This was selected as the project area under the initial steps of the plan formulation process. Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent developed lands were all included.

1.3 PROBLEMS AND OPPORTUNITIES, NEEDS, GOALS AND OBJECTIVES, AND CONSTRAINTS (*NEPA REQUIRED)

Identifying problems, needs, opportunities, goals, and objectives ensures unity of purpose throughout the planning process. Solving problems and taking advantage of these opportunities provide a basis for effective solutions. Due to the large scope of the study area, the problems, needs, opportunities, goals, and objectives were first reviewed based on the entire Texas coast from the Sabine River to the Rio Grande. The existing conditions and No-Action/future without-project (FWOP) conditions described in the subsequent sections 2.0 and 3.0 of this DIFR-EIS, in addition to the relevant reports and studies listed in Table 1-1, were used to guide the development of these key initial planning criteria and goals.

It is important to understand that when discussing the environmental settings and the initial plan formulation process, the DIFR-EIS focuses on the four areas of the Texas coast listed in the study area. As the planning process progressed, the planning criteria and goals were further refined along with the study area. Due to the complexity of the Texas Gulf coast, the four study areas were further developed into planning regions. Additional discussion related to the planning regions can be found in Section 4.0 and in the Plan Formulation Supporting Information (Appendix A); however, the Project Delivery Team (PDT) continually referred back to the following problems, needs, opportunities, and objectives listed below to ensure that a comprehensive plan was developed for the entire Texas Gulf coast.

1.3.1 Problems and Opportunities

Problem Statement: Given the area's low elevation, flat terrain, and proximity to the Gulf, the people, economy, and unique environments are at risk due to tidal surge flooding and tropical storm waves. In addition, continued loss of natural surrounding ecosystems will contribute to the regions' loss of biodiversity. Land subsidence, combined with rising sea level, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

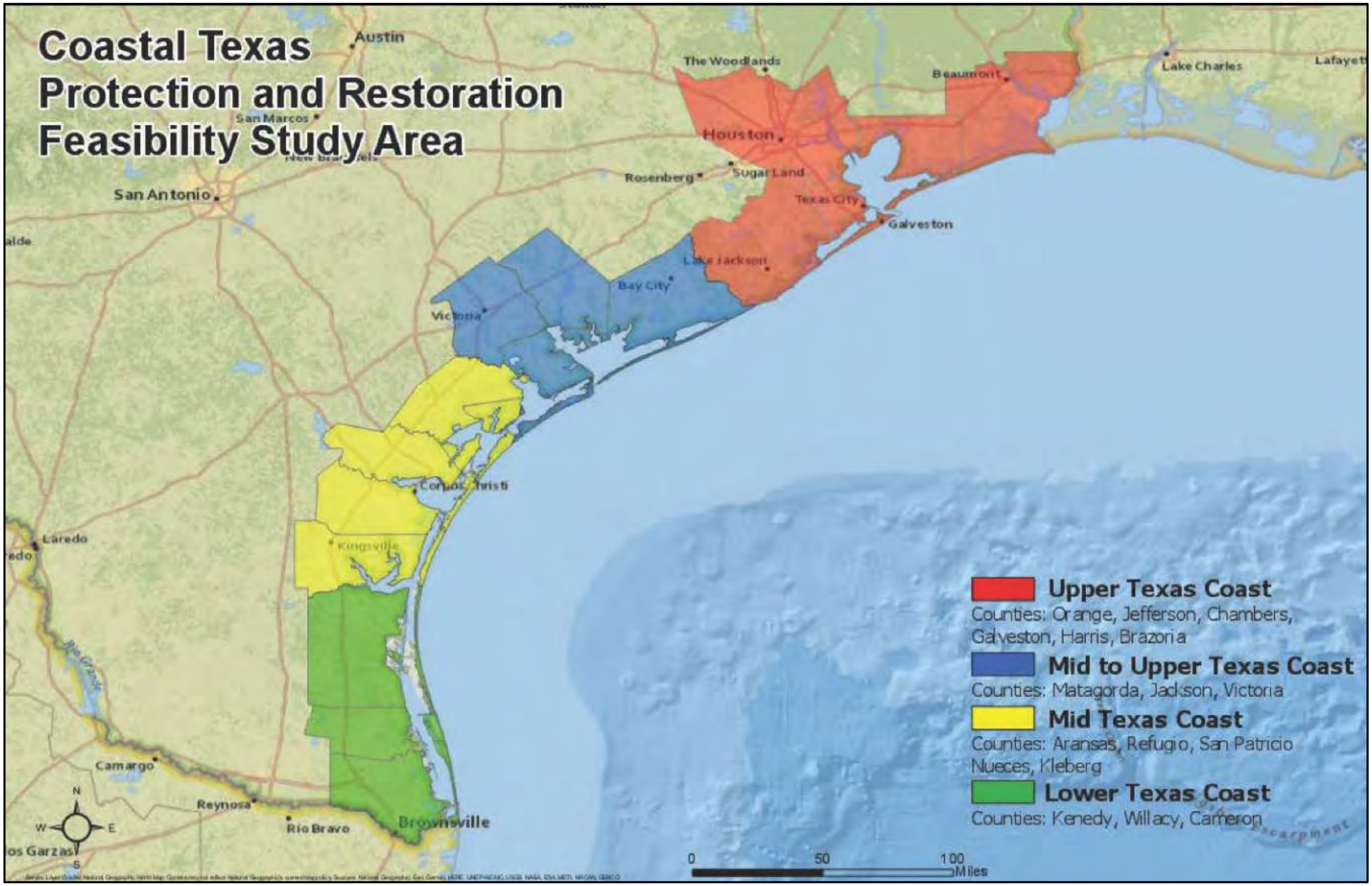


Figure 1-3: Coastal Texas Study Area

Table 1-1
Prior Studies, Reports, Programs, and Water Projects

Prior Studies, Reports, Programs, and Water Projects	Potential Data Source	Consistency	Source of Measures
Planning Studies:			
Texas Coastal Hurricane Study, 1979	✓	✓	✓
Sabine Pass to Galveston Bay CSRM and ER Feasibility Study	✓	✓	✓
Jefferson County ER Feasibility Study (ongoing)	✓	✓	✓
Houston Ship Channel Feasibility Study (ongoing)	✓	✓	✓
Coastal Texas Protection and Restoration Study Final Reconnaissance 905(b) Report	✓	✓	✓
Federal Laws and Programs:			
Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA 1990)	✓	✓	✓
Water Resources Development Act (WRDA) Section 204/1135 Projects			
RESTORE Act (including National Fish and Wildlife Foundation)	✓	✓	✓
Natural Resource Damage Assessment (NRDA)	✓	✓	✓
Gulf of Mexico Energy Security Act (GOMESA)	✓	✓	✓
U.S. Army Corps of Engineers (USACE) Continuing Authorities Program (WRDA Sec. 204), 1996		✓	✓
Coastal Impact Assistance Program (CIAP, 2001 and 2005)	✓	✓	✓
State Laws and Programs:			
Ecosystem Restoration Projects by Funding Source			
CWPPRA Projects	✓	✓	
CIAP Projects	✓	✓	✓
Coastal Erosion Planning and Response Act (CEPRA)	✓	✓	✓
State Projects	✓	✓	✓
Federal Emergency Management Grant Projects	✓	✓	
Federal CSRM Projects			
Port Arthur Hurricane Flood Protection System (HFPS), Texas	✓	✓	✓
Texas City HFPS, Texas	✓	✓	✓
Freeport HFPS	✓	✓	✓
Matagorda Hurricane Flood Protection	✓	✓	✓
Federal Navigation Projects			
Gulf Intracoastal Waterway (GIWW)	✓	✓	
Galveston Harbor Channel (including entrance channel)	✓	✓	
Sabine-Neches Waterway	✓	✓	
Houston Ship Channel	✓	✓	
Texas City Ship Channel	✓	✓	
Freeport Ship Channel	✓	✓	
Matagorda Ship Channel	✓	✓	
Corpus Christi Ship Channel	✓	✓	

RESTORE = Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States

Texas has some of the highest erosion rates in the Nation. Shores are retreating an average of 4 feet per year, with some areas experiencing losses greater than 30 feet per year. With 6.1 million (2010 census data) people living in the 18 Texas coastal counties, nearly one-quarter of the State's population, coastal erosion is quickly placing communities, business, and infrastructure at an increased risk from coastal storm surges. Disrupted sediment supply, coastal development, and relative sea level rise (RSLR) also amplify shoreline retreat (Bureau of Economic Geology [BEG], n.d.).

Systemwide problems were first used to identify overall problems and opportunities. The specific coastwide problems identified for the Coastal Texas Study include problems related to:

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

The specific coastwide opportunities identified for the Coastal Texas Study include the opportunity to:

- Provide CSRM alternatives to reduce the risks to public, commercial, and residential property, real estate, infrastructure, and human life;
- Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induced storm damages;
- Increase the reliability of the Nation's energy supply by providing alternatives that will potentially lessen damages to refinery infrastructure caused by coastal storm events;
- Enhance public education and awareness to coastal storm risk;
- Restore the long-term sustainability of coastal and forested wetlands that support important fish and wildlife resources within the study area;
- Restore the barrier island environments to promote long-term sustainability of the fish and wildlife resources that rely upon those ecosystems;
- Improve the water quality in coastal waters through marsh and oyster reef restoration;
- Use available sediment within the system beneficially;

- Support programs that promote long-term erosion reduction of the Gulf coast and bay shorelines and limit erosion potential during future coastal storm events;
- Protect threatened and endangered species habitat; and
- Enhance ecotourism and recreational opportunities.

1.3.2 Need

Along the Texas coast, vital resources critical to the economic and environmental welfare of the Nation are at risk from coastal storm damage. Forty percent of the Nation's petrochemical industry, 25 percent of national petroleum-refining capacity, eight deep-draft ports, and 750 miles of shallow-draft channels (including 400 miles of the GIWW) are present in the study area. Critical transportation infrastructure will continue to be at risk from coastal storm damages. Without a comprehensive plan to protect, restore, and maintain a robust coastal ecosystem and reduce the risks of storm damage to industries and businesses critical to the Nation's economy and security, the area will continue to be at risk from coastal storms. The health and safety of Texas coastal communities will also continue to suffer without a comprehensive plan. The U.S. Congress recognized the need for comprehensive water resources management for the Texas Gulf coast to ensure public safety and benefit to the Nation when they authorized the study under Section 4091, WRDA of 2007 Public Law (PL) 110-114, which states:

> "Sec. 4091. Coastal Texas Ecosystem Protection and Restoration, Texas.
>
> (a) In General. The Secretary shall develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ER in the coastal areas of the State of Texas.
>
> (b) Scope. The comprehensive plan shall provide for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.
>
> (c) Definition. For purposes of this section, the term 'coastal areas in the State of Texas' means the coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, marshes, coastal wetlands, rivers and streams, and adjacent areas."

The Coastal Texas Study was funded in 2014 and a Reconnaissance effort initiated. A Feasibility Cost Sharing Agreement was signed in November 2015 with the GLO. The Texas Legislature signed House Concurrency Resolution 106 in May 2017 stating its support for the "development and construction of a coastal barrier to protect the Gulf Coast Region of Texas from storm surges" and identified the role of the GLO moving forward and the need for an Operations and Maintenance sponsor.

The GLO submitted a letter of intent to be the implementing sponsor for both the CSRM and ER portions of the project. Additional sponsors and partners will be sought during future stages of the project study.

An Operations and Maintenance sponsor will be identified in the 2019 Texas Legislative session.

Based on the study authority, on March 31, 2016, the USACE Galveston District published a Notice of Intent in the *Federal Register* (Volume 81, Number 62, 18601) declaring its intent to prepare a DIFR-EIS to determine the feasibility of implementing the Coastal Texas Study.

1.3.3 Purpose

The study will investigate two areas of purpose, CSRM and ER:

1. Develop and evaluate coastal storm damage risk reduction measures for Texas residents, industries, and businesses, which are critical to the Nation's economy (CSRM).
2. Increase the net quantity and quality of coastal ecosystem resources by maintaining and restoring coastal Texas ecosystems and fish and wildlife habitat (ER).

The impacts of Hurricane Harvey in 2017 highlight an important distinction between risk mechanisms throughout the study area and the specific study objectives that guided plan formulation and evaluation. In the upper coast, Hurricane Harvey was primarily a rainfall event while the mid coast experienced storm surges, wind, and rainfall. Initially the study team discussed formulating for both flood risk management (rainfall impacts) and CSRM to address both rainfall and storm surges; however, the study team determined that adequate authorities exist to address flood risk management in the study area outside of the Coastal Texas Study, and specific legislation will revisit the opportunities to address those vulnerabilities to precipitation. The study team recognizes that there could be incidental benefits from CSRM measures, such as improved watershed run-off capacity under certain storm scenarios, when including both CSRM and flood risk management (rainfall impacts) together. However, the study team determined that by focusing and formulating flood risk management (rainfall impacts) measures in other study efforts under individual drainage basins, the teams could better address the individual risk mechanisms in those basins.

The modeling and comparison of water surface elevations as a result of coastal storms within this study assumed a more typical rainfall event in combination with storm surge. The refinement of the Tentatively Selected Plan (TSP or Preferred Alternative) will consider various scenarios to assess the performance and adaptability of the plan under high rainfall events and will assess pumping station capacities and locations to improve effectiveness.

1.3.4 Planning Goals and Objectives

The CSRM planning goals promote a sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the Nation's economy. The CSRM measures and alternatives were formulated to achieve National Economic Development (NED) principles and objectives.

The planning goals for ER sustainably reduce coastal erosion; restore fish and wildlife habitat, such as coastal wetlands, oyster reefs, beaches, and dunes; and evaluate a range of coastal restoration components to address a multitude of ecosystem problems. ER measures and alternatives were formulated to achieve National Ecosystem Restoration (NER) principles and objectives. Contributions to NER are increases in the net quantity and/or quality of desired ecosystem resources and are measured in the study area and nationwide.

The PDT developed planning objectives to apply to the entire study area over the 50-year planning horizon (2035–2085) (Table 1-2). Seven overall CSRM and five ER objectives were identified for meeting those planning goals.

Table 1-2
Overall Coastal Texas Study Goals and Objectives

Goals	Objectives
COASTAL STORM DAMAGE RISK REDUCTION Promote a sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the Nation's economy	1. Reduce economic damage from coastal storm surge to business, residents, and infrastructure along coastal Texas; 2. Reduce risk to human life from storm surge impacts along coastal Texas; 3. Enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts; 4. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact; 5. Manage regional sediment, including beneficial use of dredged material from navigation and other operations so it contributes to storm surge attenuation where feasible; 6. Increase the resilience of existing hurricane risk reduction systems from sea level rise (SLR) and storm surge impacts; and 7. Enhance and restore coastal geomorphic landforms that contribute to storm surge attenuation where feasible.
ECOSYSTEM RESTORATION Promote a sustainable coastal ecosystem by minimizing future land loss, enhancing wetland productivity, and providing and sustaining diverse fish and wildlife habitats	1. Restore size and quality of fish and wildlife habitats such as coastal wetlands, forested wetlands, rookery, oyster reefs, and beaches and dunes; 2. Improve hydrologic connectivity into sensitive estuarine systems; 3. Reduce erosion to barrier island, mainland, interior bay, and channel shorelines; 4. Create, restore, and nourish oyster reefs to benefit coastal and marine resources; and 5. Manage regional sediment so it contributes to improving and sustaining diverse fish and wildlife habitat.

1.3.5 Planning Constraints

Planning constraints limit plan formulation. Planning constraints in this project pertain to causing negative impacts to existing ecosystem resources and existing Federal projects. The planning constraints in this study are:

1. Avoid or minimize negative impacts to threatened and endangered species and protected species.

2. Induce no impact to authorized navigation projects. Avoid actions that negatively affect the ability of authorized navigation projects to continue to fulfill their purpose.
3. No loss of risk reduction from existing coastal storm damage risk reduction projects.
4. Avoid or minimize impacts to critical habitat, e.g., essential fish habitat (EFH).
5. Minimize impacts to commercial fisheries.
6. Avoid or minimize contributions to poor water quality.
7. Minimize impacts to local hydrology. Hydrology regimes in the study area are sensitive to changes in flows and drainage patterns. The measures and alternatives will consider local hydrology impacts. Careful consideration should also be given to actions that could induce flooding inside and outside of systems.
8. Avoid induced development, to the maximum extent practicable, that contributes to increased life safety risk. Public comments in scoping meetings reflected a concern that potential enclosed wetland areas would be opened in the future to urban development.

The TSP must consider the guidelines of the Coastal Barrier Resources System Act.

1.4 USACE CIVIL WORKS GUIDANCE AND INITIATIVES

The USACE planning process is grounded in the 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies (hereafter Principles and Guidelines). The Principles and Guidelines provide for the formulation of reasonable plans responsive to national, State, and local concerns. Within this framework, the USACE seeks to balance economic development and environmental needs as it addresses water resources problems. The Federal objective of water and related land resources planning is to contribute to NED consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable Executive Orders (EOs), and other Federal planning requirements. The objective of ER is NER to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition.

The Planning Guidance Notebook provides the overall direction to formulate, evaluate, and select projects for implementation. The study was conducted under the USACE's Civil Works Planning modernization process by utilizing the Specific, Measurable, Attainable, Risk Informed, and Timely (SMART) planning to effectively execute and deliver the study in a timely manner. The study also meets the USACE Campaign Plan goals and the USACE Environmental Operating Principles by undertaking a proactive public involvement campaign, including a project website, and targeted stakeholder meetings. Active and responsive public involvement has informed the development of solutions to the problems this study seeks to address and has facilitated the sharing and distribution of data and knowledge. The relationships that the study team have developed with non-governmental organizations (NGOs), local officials, community, special interest groups, the academic community, and agency partners have facilitated the consensus-building process to create a mutually supportable economic and environmentally sustainable solution for the Nation.

1.5 NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE AND REPORT STRUCTURE

This report integrates an EIS into the feasibility report, resulting in a Draft Integrated Feasibility and Environmental Impact Statement (DIFR-EIS). Report sections required for compliance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 United States .Code [USC] 4321 et seq). NEPA required sections are indicated with an asterisk following the section heading. Currently this report is a draft format.

This DIFR-EIS will undergo public review, policy review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR). The PDT will consider comments and present the TSP at an Agency Decision Milestone Meeting before developing a Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS).

The USACE serves as the lead agency for the preparation of the DIFR-EIS. This DIFR-EIS has been prepared to analyze and disclose the potential impacts of the proposed Coastal Texas Study and reasonable alternatives on the natural and human environment. It is intended to be sufficient in scope to address Federal, State, and local requirements with respect to the proposed activities. Cooperating agencies for the Coastal Texas Study include the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), U.S. Environmental Protection Agency (EPA), and Bureau of Ocean Energy Management (BOEM). Agency and tribal coordination are included in Appendix B.

This report integrates an EIS into the feasibility report. Report sections required for compliance with NEPA are indicated with an asterisk following the section heading. Currently this report is in a draft format. This DIFR-EIS will undergo public review, policy review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR). The PDT will respond to review comments, then present a TSP and develop a Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS).

Table 1-3 lists the required DEIS information and its location in this document. The list also provides a general overview of the content in all of the sections in the DIFR-EIS.

Table 1-3
Required DEIS Information and Report Structure

EIS Requirement	Location in Document	General Content
Cover Sheet	Cover Page	Cover Page
Summary	Executive Summary	Overall summary of the planning process and draft TSP.
Table of Contents	Table of Contents	Table of Contents
Introduction and Purpose	Section 1.0	Documentation of the initial steps of the Plan Formulation Process.
Existing Conditions	Section 2.0	Documentation of the existing conditions. Due to the large study area, the section focused on the entire Texas Gulf coast.
No-Action/Future Without-Project Conditions	Section 3.0	Documentation of the FWOP under no Federal action. Due to the large study area the section focused on the entire Texas Gulf coast.
Formulation and Evaluation of Alternative Plans	Section 4.0	Documentation of the formulation and evaluation of alternative plans to date. In this section, the study area was further refined to investigate discrete areas where CSRM measures and ER measures could be implemented to develop a comprehensive plan to protect, restore, and maintain a robust coastal ecosystem and reduce the risks of storm damage to industries and businesses critical to the Nation's economy.
Environmental Consequences	Section 5.0	Documentation of the environmental consequences associated with the final array of alternatives. The section covers the resources described in Section 2.0 but focuses only on the discrete areas where CSRM and ER plans would be implemented.
Tentatively Selected Plan	Section 6.0	Documentation of the TSP. This section will provide the details of the TSP. Once the report has undergone public review, policy review, ATR, and IEPR, the details of the TSP could be refined in the final report.
Consistency with Other State and Federal Plans and Regulations	Section 7.0	Documentation of consistency with other State and Federal plans and regulations. This section provides the status of the environmental compliance at the time of the TSP. Once the report has undergone public review, policy review, ATR, and IEPR, the final recommendation will be updated in the final report.
Implementation Requirements	Section 8.0	Documentation of the implementation requirements associated with the TSP. This section provides the estimated Federal and non-Federal cost for the TSP. Once the report has undergone public review, policy review, ATR, and IEPR, the final recommendation will be updated in the final report.
Public Involvement, Review, and Consultation	Section 9.0	Documentation of the public involvement, review, and consultation conducted to the time of the release of the draft report. Once the report has undergone public review, policy review, ATR, and IEPR, this section of the report will be updated in the final report.
Recommendations	Section 10.0	Documentation of the TSP. This section provides a general summary of the TSP.
List of Preparers	Section 11.0	Documentation of the list of preparers involved in writing and developing the Coastal Texas Study.

EIS Requirement	Location in Document	General Content
Literature Cited	Section 12.0	List of all reference materials used to compile the draft report.
Index	Section 13.0	To be included in the FIFR-EIS.
Appendices	Listed in the Table of Contents	

1.6 NON-FEDERAL SPONSOR AND CONGRESSIONAL REPRESENTATION

The GLO is the non-Federal Sponsor (NFS) for the Coastal Texas Study and has actively participated in the development of the scope of the Feasibility Study and the Project Management Plan resulting in the execution of a Feasibility Cost Sharing Agreement in November 2015. The GLO has been intricately involved in the feasibility study. The State of Texas is a possible construction sponsor; however, the GLO is working to identify construction sponsors on the local level. Local construction sponsors could include local governments such as counties, cities, levee improvement districts, drainage districts, municipal utility districts, or other special taxing entities that could be created for this specific project.

The study area is represented by U.S. Senators Cornyn and Cruz (Texas) and includes the following Texas Congressional Districts:

- TX-02 (Poe)
- TX-14 (Weber)
- TX-22 (Olson)
- TX-29 (G. Green)
- TX-36 (Babin)
- TX-37 (Cloud)
- TX-34 (Vela)

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2.0 EXISTING CONDITIONS (*NEPA REQUIRED)

The purpose of the Existing Conditions section of this DIFR-EIS is to provide a description of the existing environment in areas likely to be affected by the proposed Coastal Texas Study in a manner that allows alternatives' effects to be better understood. The following summarizes existing environmental conditions. More detail is contained in Appendix C-1, Environmental Supporting Documentation.

2.1 GENERAL SETTING

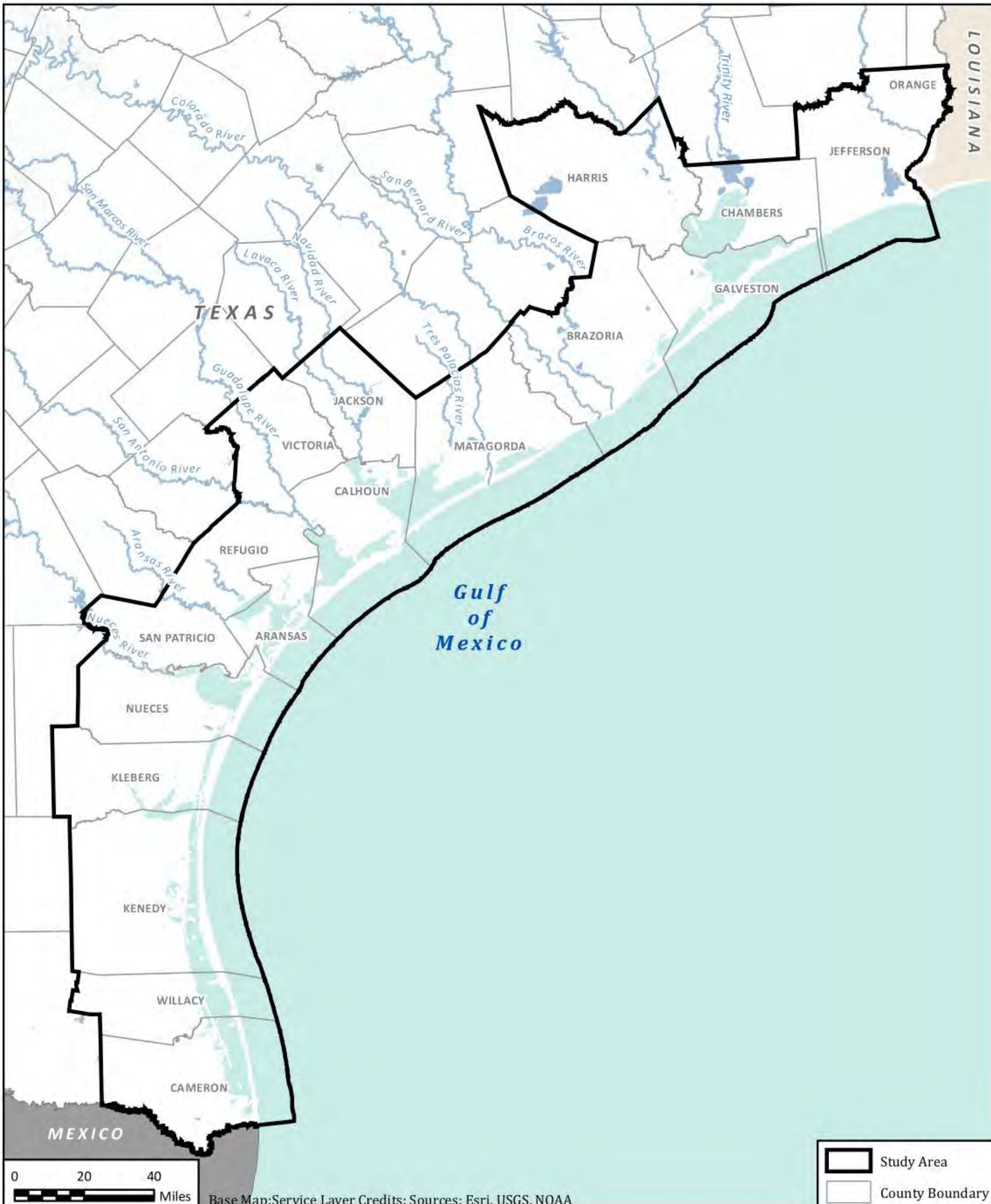
The study area consists of the entire Texas Gulf Coast from the mouth of the Sabine River to the mouth of the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystems along the Texas coast (Figure 2-1). The project area is defined as those areas that will be directly affected by construction or operation activities as a result of potential alternative plans of the Coastal Texas Study.

2.2 CLIMATE CHANGE

Rainfall is the main form of precipitation along the coast and is most frequent in the spring and late summer/early fall. Rainfall rates decrease, and temperatures increase moving southward along the coast. For example, average annual rainfall in Beaumont is approximately 60 inches and average temperature is 69 degrees Fahrenheit (°F) whereas average annual rainfall on South Padre Island is approximately 26 inches and average temperature is 74°F. Coastal relative humidity averages slightly more than 60 percent over the year (NOAA, 2016a; Nielsen-Gammon, 2016).

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

Climate change encompasses the difference in the Earth's global climate or in regional climates over time. It creates stressors such as SLR, temperature changes, salinity changes, and wind and water circulation changes that would continue to influence coastal climates in Texas over the 50-year period of analysis and longer. Average surface temperatures are expected to rise, more-frequent hot and fewer cold temperature extremes are expected, more severe and frequent flooding and droughts might occur (International Panel on Climate Change, 2014; Shafer et al., 2014; Texas Water Development Board [TWDB], 2012). Eustatic SLR is likely to exceed 0.07 to 0.09 inch per year and may reach 0.31 to 0.63 inch per year by the end of this century (International Panel on Climate Change, 2014).



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Study Area

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DATE	8/21/2017
SCALE	1:2,377,085
DESIGNED	SSJ
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2-1

FIGURE

NAD 1983 Texas Centric Mapping System Albers

2.3 PHYSICAL RESOURCES

2.3.1 Regional Geologic Setting

2.3.1.1 Geology

The geological setting of the Texas coast and the major geomorphological features have been developed through a combination of fluvial, coastal, and marine processes occurring over the last 125,000 years (Anderson et al., 2016). The Beaumont Formation, or Beaumont clays, is a Pleistocene formation present across the Texas coast composed of the oldest coastal deposits. Bernard et al. (1970) and Fisher et al. (1972) originally defined the Beaumont Formation as a fluvial delta with shallow marine deposits and barrier-strand plain-Chenier units that formed 35,000 to 400,000 years ago.

According to Anderson et al. (2016), with the slowing of SLR in the last 2,000 to 9,000 years, the current coastline became a mix of sandy barrier islands, marsh-swamps, bay-estuary-lagoons, inlets and offshore shorefaces, and fluvial-deltaic systems that covered the Beaumont Formation. These new depositional environments consist of a wide range of sands, silts, and clays in different geomorphological environments. The post-Beaumont Formation coastal deposits correspond to reworked deposits from these alluvial, fluviatile, and aeolian processes placed in the newly created coastal environments. Following the slowdown of SLR, the coastal environment has consisted of sandy low lands that are subject to severe shoreline retreat and limited sediment supply (Anderson et al., 2016).

2.3.1.2 Sediment Transport

Local and regional natural geomorphic and hydrodynamic processes (including river processes, tides, storm surges, circulation eddies, and longshore drift transporting sand from river deltas to other locations along the coast), catastrophic or episodic storm events, and anthropogenic developments (navigation infrastructure or the presence of engineered structures or shorelines) act upon coastal sediment transport along Gulf shorelines to form and erode beaches, barrier islands, and peninsulas (Freese and Nichols, Inc., 2016).

Due to a range of natural processes and anthropogenic modifications of the State’s rivers and estuaries, the Gulf shore is eroding due to reduced fluvial sediment supply. Typically, sediments that are deposited at the coast are carried in a southwesterly direction from Port Arthur to south of Corpus Christi via longshore drift (Dunn and Raines, 2001). An opposing current creates a zone of convergence and transports material in a northerly direction from the Mexico coastline toward Corpus Christi (Freese and Nichols, Inc., 2016). However, hard structures, such as groins, jetties, and breakwaters, interfere with longshore drift and induce either shoreline erosion or accretion adjacent to these artificial structures (Morton et al., 2004; Freese and Nichols, Inc., 2016). The fluvial sediment supply that nourishes the Gulf has been highly altered due to extensive reservoir construction, changes in land use, and instream sand and gravel mining (Dunn and Raines, 2001). The removed sediment from bay shorelines results in regional sediment sinks, and this loss results in or causes the disintegration of marsh systems, deltas, inlets, bird island habitat, oyster reefs, and other eco-geomorphologic systems (Moya et al., 2012).

2.3.1.3 Shoreline Change

Shoreline erosion threatens coastal habitats, recreation opportunities and qualities, and residential, transportation, and industrial infrastructure. Gulf shoreline erosion rates between the 1930s and 2012 averaged 4.1 feet per year of retreat. Rates of shoreline change are generally greater on the upper Texas coast (from the mouth of the Colorado River to Sabine Pass) than those in the mid to lower Gulf Coast. The upper Texas coast retreat was calculated at 5.5 feet per year, and the mid to lower coast retreated an average of 3.2 feet per year (Paine et al., 2014). Table 2-1 and Figure 2-2 show the net shoreline and land area change from the 1930s to 2012 for geomorphic areas and counties along the Texas Gulf shoreline.

2.3.2 Physical Oceanography

2.3.2.1 Tides

Tidal range (the difference in height between the highs and the lows) along the Texas coast averages less than 2 feet. The Texas coast experiences week-long periods of diurnal tides (once-per-day high and low) followed by a week of semidiurnal tides (twice-per-day high and low) making them more unpredictable than other areas in the United States. In Texas, diurnal tides have a much greater range than semidiurnal tides (Amos, 2014). Mean tides in Sabine Pass are 1.1 feet; Galveston Bay, 1.0 foot; Matagorda Bay Entrance Channel, 1.1 feet; Port Aransas, 0.9 foot; and South Padre Island, 1.1 feet (NOAA, 2016b). Additional information related to tides is included in the Engineering Appendix (Appendix D).

2.3.2.2 Currents and Circulation

The gently sloping nature of the Gulf continental shelf and low wave action cause local winds to play a more active role in shaping shoreline dynamics, such as tides and surface currents (King, 2007). Waves, which propagate across an ocean or bay expanse, obtain energy from the wind, delivering and transferring wave energy to nearshore coastal environments. Along Texas's Gulf coast, wind-generated waves induce longshore and cross-shore currents, which transport sediments. Wind direction, angle of wave approach, and the geographic orientation of the shoreline can influence the current direction and amount of sediment transportation from the beachhead (Grand Valley State University, 2016; NOAA, 2016c).

2.3.2.3 Salinity

Salinity which is related to differing rainfall rates and tidal exchange, varies broadly among Texas estuaries. The estuaries on the upper Texas coast generally have the lowest salinity and the estuaries along the lower Texas coast have the highest salinity. For example, Sabine Lake salinity averages approximately 5 parts per thousand (ppt), Matagorda Bay averages 24 ppt, and the Upper Laguna Madre averages 38 ppt (Lester and Gonzales, 2011; Lower Colorado River Authority-San Antonio Water System, 2008; Rio Grande, Rio Grande Estuary, and Lower Laguna Madre Bays Basin and Bay Expert Science Team, 2012).

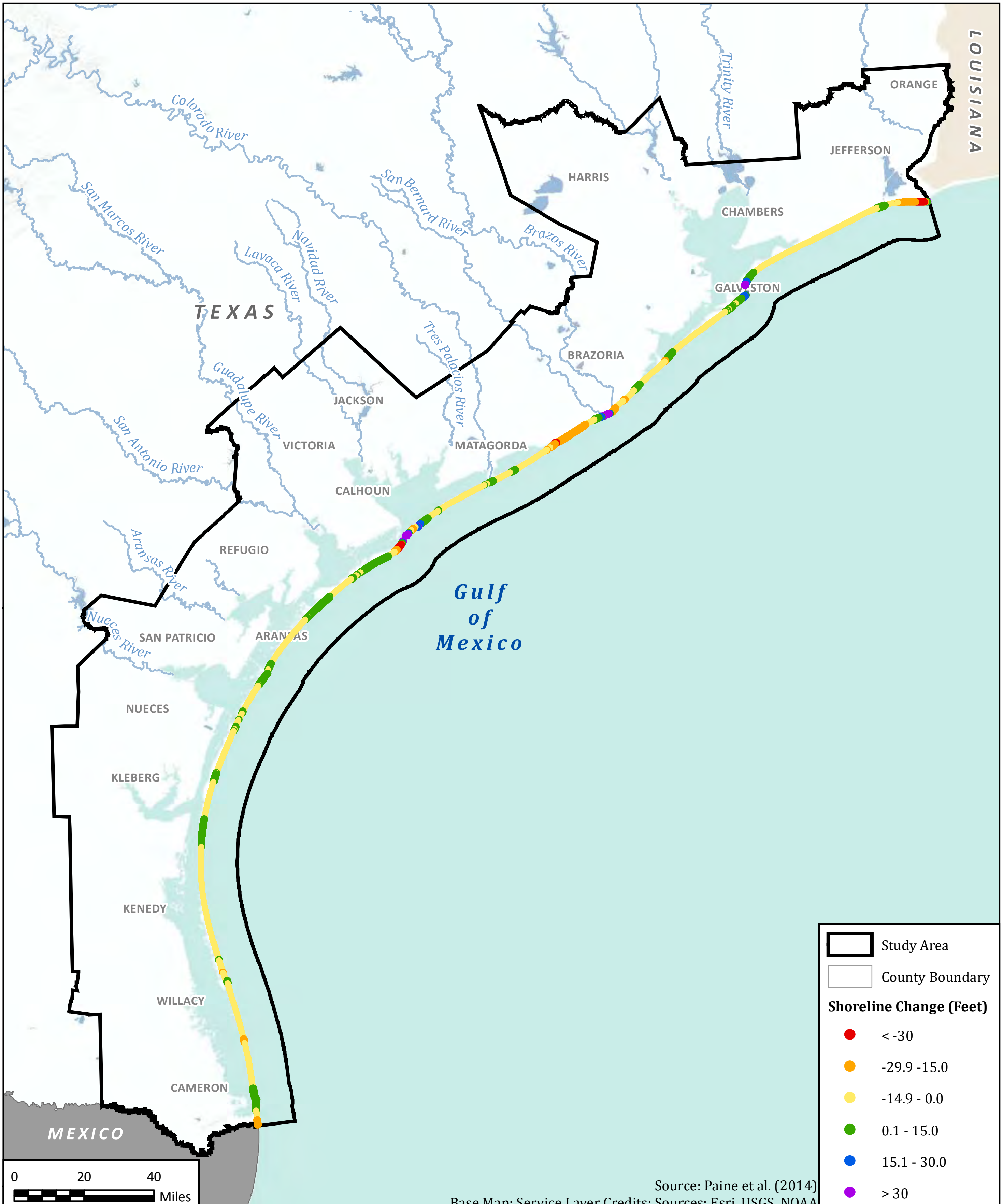
Table 2-1
Net Shoreline Change for the Texas Gulf Shoreline, 1930s to 2012*

Area	Number of Sample Sites	Net Rate of Retreat (feet/year)	Range of Retreat (acres/year)	Area Change Rate (acres/year)	Area Change (acres)
All Texas Sites	11,749	–4.1	–41.5 to 50.6	–177.8	–14,590
Geomorphic Areas:					
Sabine Pass to Rollover Pass	1,345	–9.7	–28.9 to 23.0	–48.9	–4,009
Bolivar Peninsula	543	1.4**	–4.4 to 36.1	+2.7	+227
Galveston Island	930	–0.9	–6.7 to 16.1	–3.2	–257
Brazos/Colorado Headland	1,258	–6.8	–32.1 to 50.6	–32.4	–2,648
Matagorda Peninsula	1,591	–3.3	–25.4 to 49.6	–19.5	–1,610
Matagorda Island	1,120	–2.4	–41.5 to 39.8	–10.1	–840
San José Island	620	–2.4	–4.0 to 1.0	–5.7	–467
Mustang Island	575	–1.1	–4.7 to 7.9	–2.5	–200
North Padre Island	2,404	–2.7	–11.1 to 2.7	–24.5	–1,996
South Padre Island	1,359	–7.5	–18.5 to 8.4	–38.0	–3,120
Counties:					
Jefferson	1,042	–10.9	–28.9 to 23.0	–43.0	–3,522
Chambers	36	–7.4	–6.2 to –4.7	–1.0	–82
Galveston	1,740	–0.8	–6.7 to 36.1	–5.2	–435
Brazoria	924	–1.4	–17.5 to 50.6	–4.9	–405
Matagorda	1,926	–6.5	–32.1 to 49.6	–47.2	–3,866
Calhoun	1,134	–2.4	–41.5 to 39.8	–10.1	–840
Aransas	609	–2.5	–4.0 to 1.0	–5.7	–467
Nueces	667	–1.2	–4.7 to 7.9	–3.0	–252
Kleberg	707	–1.71	–4.2 to 0.7	–4.4	–373
Kenedy	1,522	–2.62	–11.1 to 2.2	–15.1	–1,235
Willacy	428	–8.60	–11.1 to 9.1	–13.8	–1,136
Cameron	1,014	–7.42	–18.5 to 7.9	–28.4	–2,322

Source: BEG (2016a); Paine et al. (2014).

* Data calculated using coastwide LiDAR data collected in February 2012. Rates include effects (erosion, deposition, and recovery) associated with Hurricane Ike (September 2008).

** Most of the Gulf shoreline along Bolivar Peninsula has been eroding at rates up to 6.4 feet per year. Four miles of shore from the Bolivar Roads north jetty to the east has accreted sediment impounded behind the jetty. Sediment added in this area results in a net positive rate of retreat even though most of the peninsula's shore is eroding.



N W E S

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Shoreline Change 1930s to 2012

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DATE	10/9/2018
SCALE	1:2,377,085
DESIGNED	SSJ
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2-2

FIGURE

NAD 1983 Texas Centric Mapping System Albers

2.3.3 Coastal Processes

2.3.3.1 Relative Sea Level Change

The USACE policy in Engineer Regulation 1100-2-8162 and Engineering Technical Letter 1100-2-1, Sea Level Change Considerations for Civil Works Programs, requires all studies to consider impacts from sea level change (USACE, 2013, 2014). Changes in local or RSLR reflect the integrated changes in global or eustatic sea level plus changes due to vertical land movement of subsidence. Sea level has risen more than 0.17 inch per year (inch/year) along the upper and middle Texas coast from 1957 to 2011 (NOAA, 2016d). The highest rate of RSLR, 0.26 inch/year, was measured at the Galveston Pleasure Pier (tide gauge 8771510) and the lowest was at Port Mansfield at 0.08 inch/year (tide gauge 8778490). Sea level has also been increasing along the lower Texas coast at a lower rate, less than 0.16 inch/year. Higher rates of RSLR along the upper coast are generally attributed to higher rates of subsidence. Localized subsidence, ranging up to 10 feet from 1906 to 2000, has been highest in the Houston-Galveston area. Through increased groundwater regulation, reduced rates of groundwater withdrawal have considerably reduced the rate of subsidence in the area (NOAA, 2016d).

2.3.3.2 History of Severe Storms and Hurricanes

The probability of hurricane landfall on the Texas coast is about one every 6 years (Roth, 2010). The most active area for hurricanes over the past 160 years is the upper Texas coast with 28 landfalls, followed by the mid Texas coast with 26 landfalls, and lastly the lower Texas coast with 15 landfalls. As of the end of the 2017 hurricane season, Hurricane Harvey (2017) was the costliest storm in Texas history and tied with Hurricane Katrina as the Nation's costliest storm at $125 billion (Table 2-2). Hurricane Ike in 2008 was the second-costliest storm in Texas causing over $29.5 billion worth of damage. The top four costliest for Texas have all occurred since 2000, one of which (Allison) only reached tropical storm status (Blake et al., 2011; NOAA, 2018a).

Table 2-2
Costliest Texas Storms, 1900 to 2017*

Name	Year	Category	Landfall	Cost of Damage
Harvey	2017	3	Rockport	$125.0 billion
Ike	2008	2	Galveston	$29.5 billion
Rita	2005	3	Sabine Pass	$12.0 billion
Allison	2001	Tropical Storm	Freeport	$9.0 billion
Alicia	1983	3	Galveston	$2.0 billion
Dolly	2008	1	South Padre Island	$1.1 billion
Celia	1970	3	Corpus Christi	$930 million
Allen	1980	5	South Padre Island	$700 million
Carla	1961	5	Port O'Conner	$300 million

Source: Blake et al. (2011), Handbook of Texas Online (2017), NOAA (2018a).

* Not adjusted for inflation and include adjusted National Flood Insurance Program flood damage amounts beginning in 1995.

2.3.3.3 Storm Surge Effects

Many of the more extreme and damaging hurricane events have occurred along the U.S. Gulf Coast (Needham and Keim, 2012). The hurricane that struck Galveston Island in 1900 and Hurricane Harvey that struck Rockport in 2017 are examples of costly extreme hurricane events. The 1900 Galveston Hurricane claimed more than 6,000 lives, while Hurricane Harvey caused approximately $125 billion in damage (Rappaport and Fernandez-Partagas, 1995; NOAA, 2018a). Extremely high-water levels associated with storm surges at coastal locations are an important public concern and a factor in coastal hazard assessment, navigational safety, and ecosystem management. Figure 2-3 shows storm surge magnitudes in the study area (SURGEDAT, 2016).

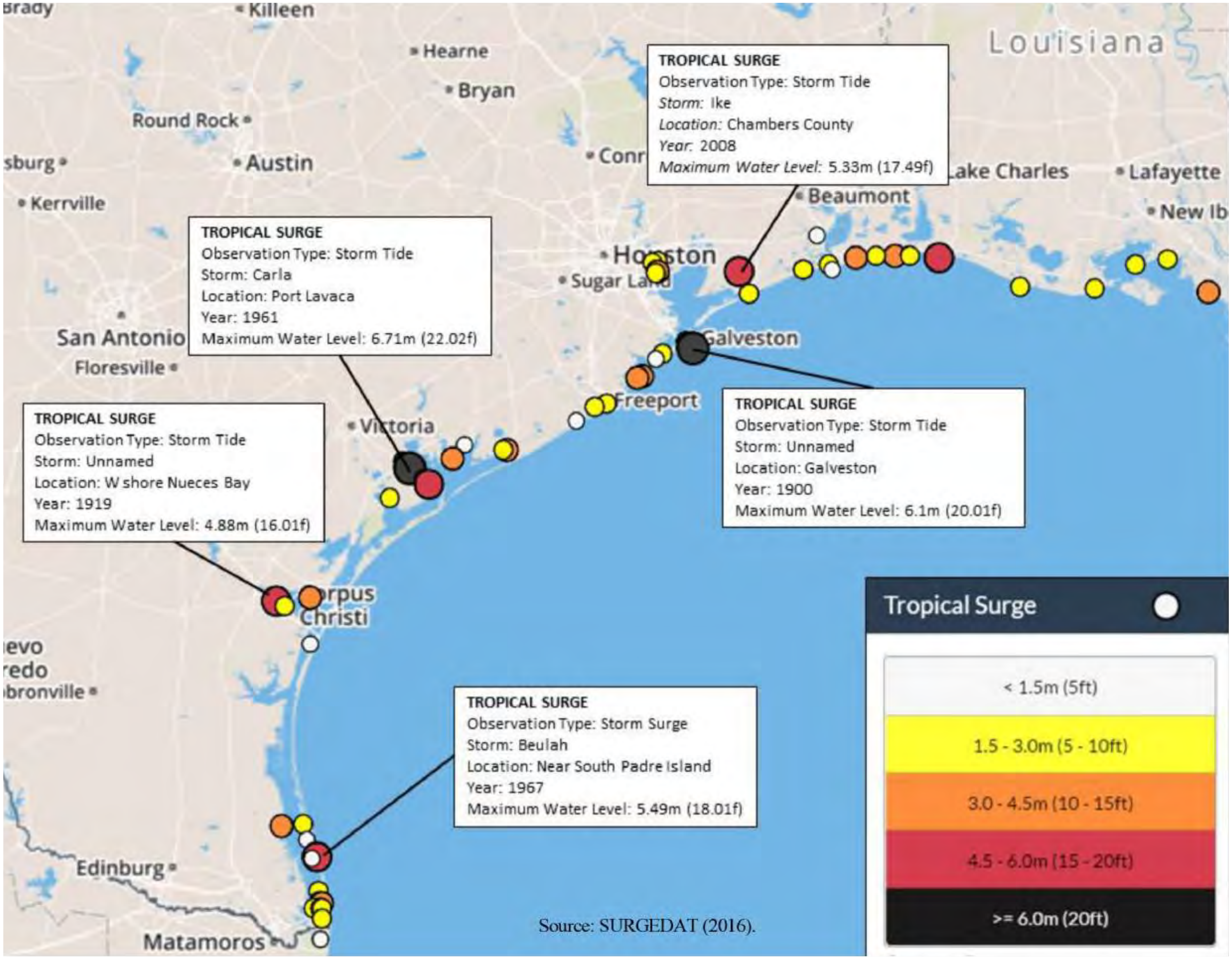
2.3.3.4 Attenuation of Storm Surge Impacts by Coastal Wetlands and Barrier Islands

It is generally believed that coastal wetlands provide critical risk reduction against incoming hurricane storm surges and that restoration of lost wetlands should be a key component of any strategy to protect vulnerable regions, such as the Texas coast. Storm surges can both benefit and impact these ecosystems (e.g., sediment deposition, erosion, saltwater stress, loss of vegetation, change in vegetation, creation of habitat through disturbance, loss of habitat through disturbance, etc.). Coastal wetlands can help attenuate storm surges by reducing the height of an incoming storm surge; however, the effect of wetlands in attenuating storm surge is situationally dependent (USACE, 2015a). The effect of specific marsh restoration or preservation measures cannot be determined without studies and modeling based on fundamental underlying physics, forcing and dissipation mechanisms, adequate specification of the system geometry, and the evaluation of a wide array of storms, varying in direction, speed, and size (Resio and Westerink, 2008).

2.3.4 Water and Sediment Quality

Water and sediment quality along the Texas coast are measured by various agencies and organizations. Along the upper Texas coast, water quality criteria, desired uses, and nutrient and chlorophyll *a* screening criteria are generally met in water and sediment samples. In some areas, bacteria levels exceeded criteria. Galveston Bay has a variety of water quality issues, including elevated bacteria, chlorophyll *a*, nutrients, bacteria above suitable levels for oyster-harvest waters, and depressed oxygen levels (Texas Commission on Environmental Quality [TCEQ], 2015a). Two widespread fish consumption advisories have been issued for the Galveston Bay system because of dioxins and polychlorinated biphenyl (PCBs) (Texas Department of State Health Services [TDSHS], 2013a).

Along the middle to upper coast in the Matagorda/Lavaca Bay system, some areas had elevated bacteria and oxygen levels below criteria (TCEQ, 2015a). A fish and crab consumption advisory is in effect for portions of Lavaca Bay due to mercury contamination (TDSHS, 2000).



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Texas Coast Storm Surge Locations and Magnitudes

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DATE	10/9/2018
SCALE	Not to Scale
DESIGNED	SSJ
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2-3

FIGURE

NAD 1983 Texas Centric Mapping System Albers

In the middle coast, San Antonio Bay to the Aransas Bay system had occasional bacteria above suitable levels for oyster-harvest waters, depressed oxygen levels, elevated chlorophyll *a*, nitrates, ammonia, and total phosphorous (TCEQ, 2015a).

Along the lower coast, the Arroyo Colorado has more water-quality issues than other estuarine waters in this region, including elevated bacteria, nitrates, and chlorophyll *a* contributing to low-oxygen levels. The Laguna Madre occasionally has had low oxygen and chlorophyll *a* above screening criteria. The Baffin Bay system has had high levels of chlorophyll *a*, and the Brownsville Ship Channel occasionally has had low-oxygen levels and elevated bacteria (TCEQ, 2015a).

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

2.3.5 Freshwater Inflow

Freshwater inflow to Texas estuaries reflects the pattern of decreasing rainfall rates from east to west across the State (Table 2-3). Sabine Lake receives more freshwater inflow than any other estuary in the State. The Laguna Madre in south Texas is one of a handful of hypersaline lagoons in the world where evaporation rates frequently exceed freshwater inflow (Tunnell and Judd, 2002).

Dramatic swings in freshwater inflow and sediment and nutrient loading occur in Texas estuaries. Extended droughts with reduced freshwater inflow are punctuated by episodic severe flooding typically from tropical storms and hurricanes, which tend to occur in late summer and early fall. Since that time, the State of Texas has studied freshwater inflows and has estimated how much fresh water is delivered to each estuary (see Table 2-3).

2.3.6 Hydrology

The study area encompasses several major Texas river basins and eight coastal basins, with each coastal basin named according to the major river basins that border them. Figures 2-4 and 2-5 present the major Texas rivers, river basins, coastal basins, and non-contributing and contributing water basins within the study area and Texas. Table 2-4 summarizes a few key hydrologic parameters of the major river basins connected to the Texas coastal zone. Each basin is described in detail in Section 2.3.6 in Appendix C-1 (Environmental Supporting Documentation).

Table 2-3
Freshwater Inflow to Texas Estuaries*

Estuary/Period of Record	Lowest Annual Inflow	Highest Annual Inflow	Median Annual Inflow
Sabine Lake (Sabine and Neches rivers) (1941–2010)	3.2	29.0	14.0
Galveston Bay (1941–2011)	1.5	22.0	11.1
Brazos Estuary (1977–2009)	1.2	19.6	5.6
San Bernard Estuary (1977–2009)	0.2	1.5	0.6
Matagorda Bay (including Lavaca and coastal basins) (1941–2009)	0.4	14.9	3.1
East Matagorda Bay (1977–2009)	0.06	1.2	0.5
Lavaca Bay (1941–2003)	0.3	0.02	1.4
San Antonio Bay (1941–1987)	0.3	7.7	2.1
Mission-Aransas Bay (1941–2009)	0.007	1.6	0.4
Nueces Estuary (1941–2009)	0.04	2.7	0.3
Upper Laguna Madre (1977–2010)	0.04	1.0	0.3
Lower Laguna Madre (1977–2010)	0.2	2.7	0.5
Rio Grande (1934–2006)	0.03	2.6	1.5 (average)

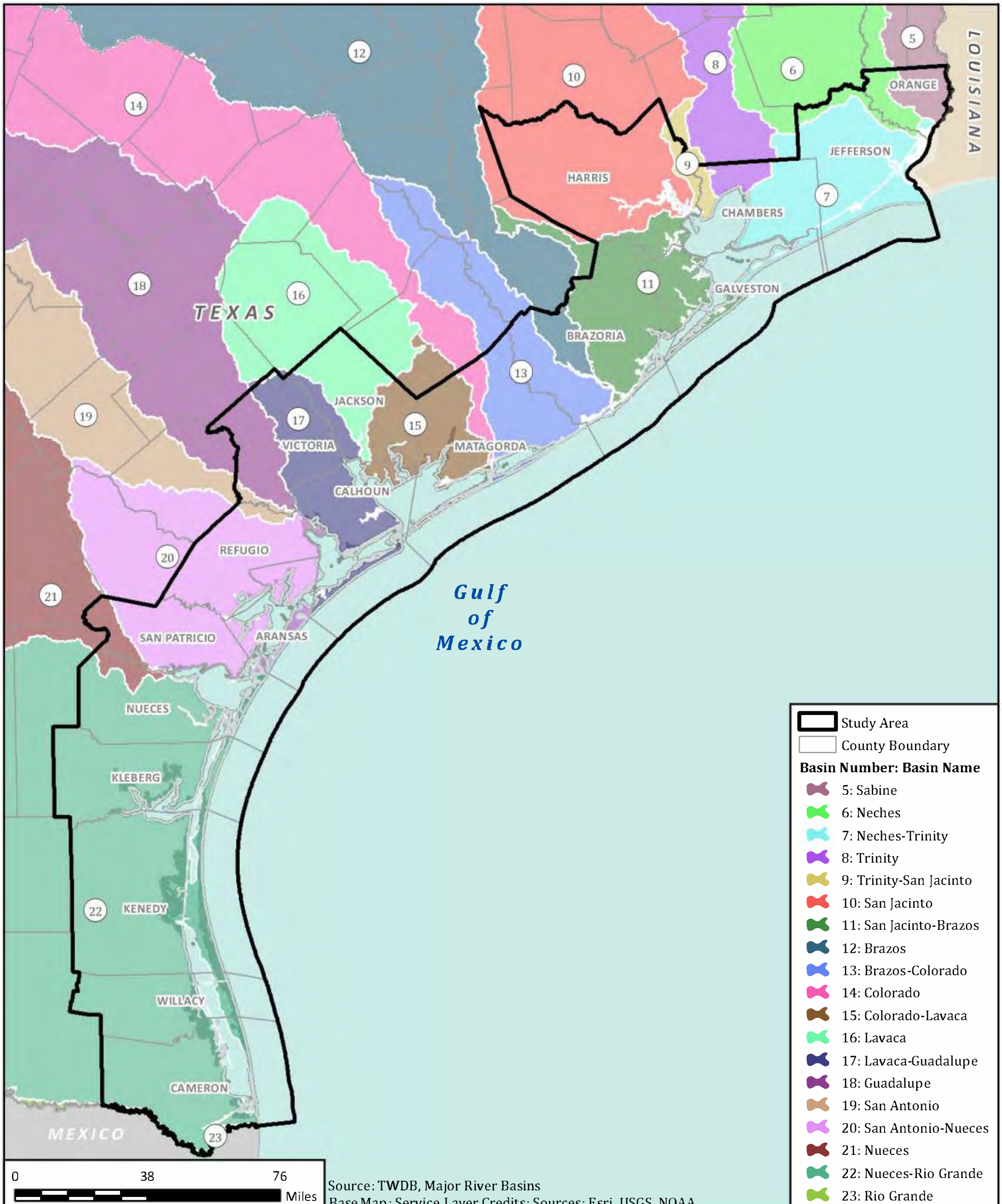
Source: Guthrie (2010), International Boundary and Water Commission (2006), Lower Colorado River Authority (2006), TWDB (2016a), Schoenbaechler and Guthrie (2011a–f).

* Units are in millions of acre-feet

Table 2-4
Texas River Basin Average Flows and Average Annual Precipitation

River Basin	Basin Area (square miles)	River Length (miles)	Average Flow (acre-feet per year)	Average Annual Precipitation (inches per year)
Sabine	9,756	360	5,864,000	60 at coast, range of 40–61
Neches	9,937	416	4,323,000	60 at coast, range of 41–60
Trinity	17,913	550	5,727,000	55 at coast, range of 29–60
San Jacinto	3,936	85	1,365,000	55 at coast, range of 44–56
Brazos	45,573	840	6,074,000	50 at coast, range of 17–54
Colorado	42,318	865	1,904,000	45 at coast, range of 13–41
Lavaca	2,309	117	277,000	45 at coast, range of 36–46
Guadalupe	5,953	409	1,422,000	35 at coast, range of 27–39
San Antonio	4,180	238	562,700	40 at coast, range of 27–39
Nueces	16,700	315	539,700	30 at coast, range of 22–31
Rio Grande	182,215	1,896	645,500	25 at coast, range of 8–21

Source: TWDB (2016a, 2016b).



Source: TWDB, Major River Basins
Base Map: Service Layer Credits: Sources: Esri, USGS, NOAA

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Major Water Basins

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SCALE	1:2,377,085
DESIGNED	SSJ
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2-4

FIGURE

NAD 1983 Texas Centric Mapping System Albers

Major Water Basins of Texas
Contributing Water Basins
Rivers of Texas
Existing Reservoirs

Non-Contributing Water Basins

1. Canadian
2. Red
3. Sulphur
4. Cypress

Contributing Water Basins

5. Sabine
6. Neches
7. Neches-Trinity
8. Trinity
9. Trinity-San Jacinto
10. San Jacinto
11. San Jacinto-Brazos
12. Brazos
13. Brazos-Colorado
14. Colorado
15. Colorado-Lavaca
16. Lavaca
17. Lavaca-Guadalupe
18. Guadalupe
19. San Antonio
20. San Antonio-Nueces
21. Nueces
22. Nueces-Rio Grande
23. Rio Grande

USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Contributing and Non-Contributing Water Basins

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FIGURE 2-5

NAD 1983 Texas Centric Mapping System Albers

2.3.7 Soils (Prime and Other Important Unique Farmland)

Soils on the upper coast are associated with the western plain and flatwoods soil types (Natural Resources Conservation Service [NRCS], 2008). Most of the prime farmlands in this area are found in historic alluvial terraces, flatwoods, wet plains, and woodlands (NRCS, 2006). The middle to upper coast consists of floodplains, Gulf coast prairie, and Gulf coast saline marshes (NRCS, 2008). Agricultural crops include corn, cotton, grain, rice, and sorghum. Pastures and hayfields include adapted bahiagrass and bermudagrass (Soil Conservation Service [SCS, now the NRCS], 1976).

The middle coast is associated with saline prairies on low coastal terraces and plains along the barrier islands (NRCS, 2008). The middle coast is predominantly open grassland and used for rangelands and wildlife habitat. Most of the prime farmlands in this area reside on historic open grassland areas with scattered trees and shrubs (SCS, 1979, 1988). The lower coast consists of dry plains to the west and saline prairie to the east with deltas and coastal prairies (NRCS, 2008; SCS, 1977). Prime farmlands in this area include irrigated lands used to grow cotton, sorghum, corn, grapefruit, oranges, sugarcane, onions, potatoes, cabbage, lettuce, and beets (SCS, 1977).

2.3.8 Energy and Mineral Resources

Texas leads the United States in overall energy production, including oil and gas exploration and production, power generation, and renewable and sustainable energy generation. The presence of energy production activities along the Texas coast, including oil and gas exploration and production facilities, has resulted in a large pipeline network within the coastal zone. While intricate pipeline networks are associated with each oil or natural gas field, several large-diameter transmission pipelines cross the coastal bays and GIWW. The upper and mid Texas coast contain the densest network of oil and gas pipelines beginning in Orange County and ending in Nueces County. Oil and gas pipelines in south Texas are generally located in or near Brownsville, Texas, in Cameron County (American Petroleum Institute, 2014; U.S. Energy Information Administration, 2016).

Widespread mineral mining is present along the entire Texas Gulf Coast; however, it is more prevalent in the upper coast around the cities of Beaumont, Port Arthur, Houston, and Freeport. Mining activities are distributed sparsely throughout the mid and southern coast. Most mineral mining in these areas is within the areas of Port Lavaca, Corpus Christi, and Brownsville. Mining activities are near more-developed cities and ports along the Texas coast (BEG, 2016b).

2.3.9 Hazardous, Toxic, and Radioactive Waste Concerns

A desktop Hazardous, Toxic, and Radioactive Waste (HTRW) assessment was conducted to identify the existence of, and potential for, HTRW contamination that could impact or be impacted by the TSP (see Section 5.3.7, Appendix C-1).

The upper Texas coast is a highly urbanized region with major industrial and commercial development along the coastal zone with HTRW concerns centered around the coastal cities and ports. Counties in the middle to upper coast are less densely developed, with HTRW concerns most prominent in the cities located throughout Matagorda and Calhoun counties with Port Lavaca and Palacios containing the highest volume of regulated sites. Industrial and commercial development increases in the middle Texas coast with HTRW concerns most prominent along the coast between Rockport and Corpus Christi, which contain the highest volume of regulated sites. HTRW concerns along the lower Texas coast are most prominent in Port Isabel and the Port of Brownsville; fewer regulated facilities are present near Harlingen and Port Mansfield in Cameron and Willacy counties, respectively (TCEQ, 2007a, 2015b, 2016a, 2016b; EPA, 2016a, 2016b).

2.3.10 Air Quality

Individual regions or counties are categorized by the EPA into two levels of compliance with the National Ambient Air Quality Standards (NAAQS) for criteria pollutants: “attainment areas” and “non-attainment areas.” Attainment areas are districts or areas that meet NAAQS; non-attainment areas exceed the NAAQS and must have and implement a plan to meet the NAAQS (EPA, 2017a). There are currently 18 counties in Texas that exceed the ozone standard (Table 2-5; TCEQ, 2016c). Of these non-attainment counties, Chambers, Galveston, Brazoria, and Harris counties are within the study area.

Table 2-5
TCEQ’s Current Designation for Counties Within the Study Area

Designation	Counties	
Nonattainment	Brazoria	Galveston
	Chambers	Harris
Attainment/ Special Inventory	Jefferson	Kleberg
	Orange	Nueces
	Calhoun	Refugio
	Jackson	San Patricio
	Matagorda	Cameron
	Victoria	Kenedy
	Aransas	Willacy

Source: TCEQ (2016c).

Under the Clean Air Act (CAA), the General Conformity Rule (40 CFR Part 51, subpart 54) ensures that Federal actions conform to the appropriate State Implementation Plans (SIP). Counties in the study area currently in non-attainment will require a General Conformity Determination (TCEQ, 2016c). Coordination with TCEQ and the EPA is ongoing.

2.3.11 Noise

There are many different sources of noise that contribute to the ambient noise environment throughout the study area. Waterborne transportation activities that contribute to the ambient noise environment include ship traffic, barges, commercial fishing/shrimping vessels, sport and recreation boats, and dredging vessels. Other forms of transportation that contribute to the ambient noise environment include automobiles, trucks, recreational vehicles, and airplanes. Noise sources related to recreation and commercial enterprises include public beaches, restaurants and nightclubs, retail stores, marinas, and hotels. Multiple types of industry also contribute to the existing noise environment, including heavy industry, such as petroleum refineries; light industry, such as manufacturers of consumer electronics and clothing; and port activities like importing and exporting cargo.

Noise-sensitive receptors are facilities or areas where excessive noise may disrupt normal human or wildlife activities, cause annoyance, or loss of business. Land uses such as residential, religious, educational, passive recreational, and medical facilities are more sensitive to increased noise levels than are commercial and industrial land uses. Common examples of noise-sensitive receptors in the study area include residential communities, schools, motels and hotels, parks and other outdoor recreation areas, and coastal wildlife areas such as habitat for colonial nesting birds.

2.4 ECOLOGICAL AND BIOLOGICAL RESOURCES

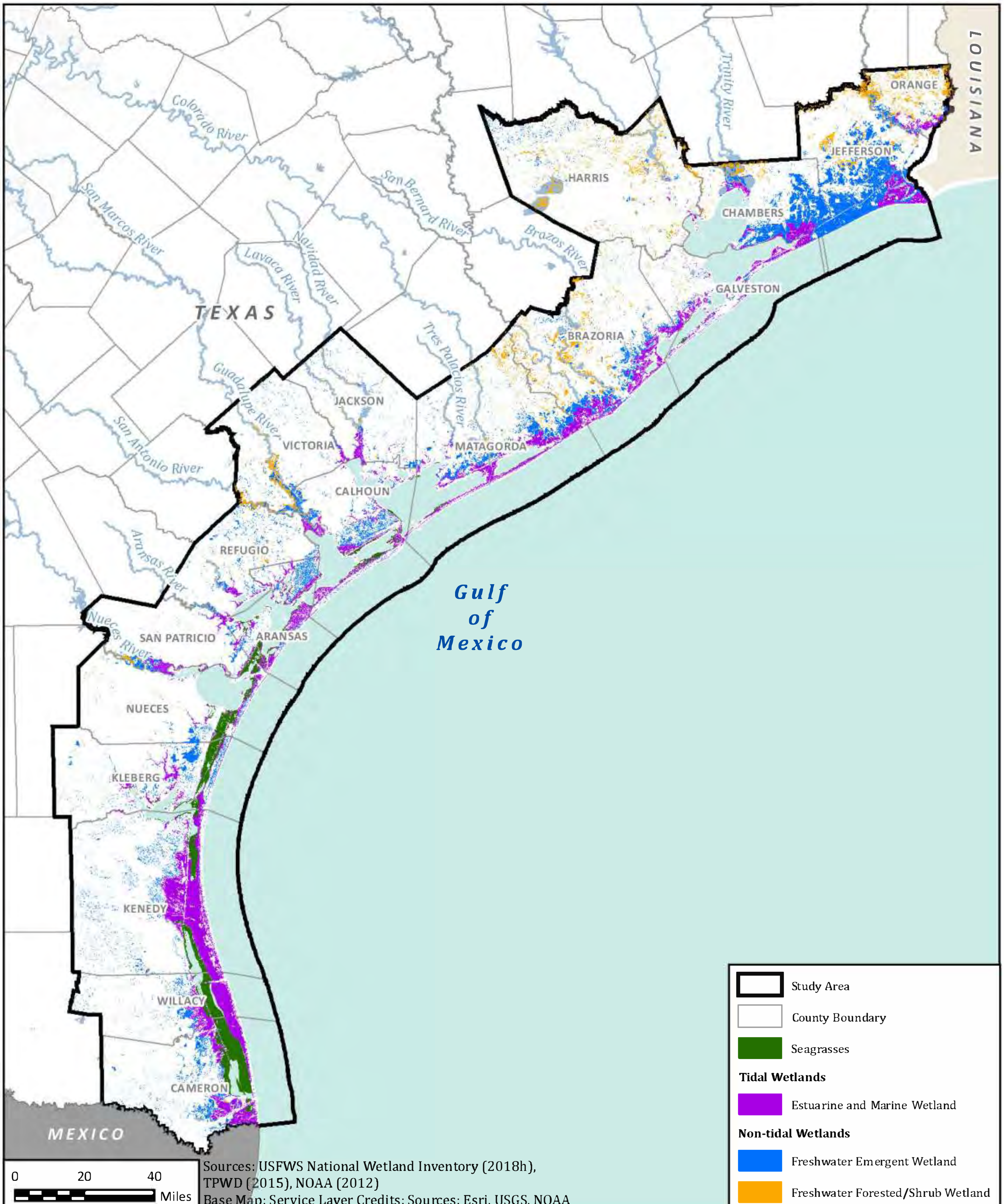
2.4.1 Ecoregions

The study area is located entirely within the Western Gulf coastal plain, which is a low-elevation area adjacent to the Gulf (EPA, 2011). Due to its nutrient-rich soils and abundance of rain, much of the land has been converted to cropland and pastures for livestock. About a third of the state's population resides within 100 miles of the coast along with a large part of the state's industry. The large expanses of intact wetlands and coastal marshes along the coast are also important rest stops and wintering habitats for waterfowl and migrating birds. The warm Gulf waters are home to a variety of fish and shellfish, while the marshes and wetlands provide an abundance of habitat for birds and migrating waterfowl (Griffith et al., 2007).

The Western Gulf coastal plain can be categorized further into nine distinct level IV ecoregions (Griffith et al., 2007). These ecoregions are divided based on similarities of soils, vegetation, climate, geology, wildlife, and human factors; a detailed description is included in Section 2.4.1 in Appendix C-1.

2.4.2 Wetlands

Wetlands within the study area encompass the full range of conditions in the upper, mid, and lower Texas coast, both tidal and non-tidal (Figure 2-6). Non-tidal (fresh water) wetlands include riverine forested, prairie potholes and marshes, and Texas coastal sand sheet. Tidal wetlands include estuarine or tidal fringe and barrier island interior.



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Texas Coastal Wetlands

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FIGURE

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NAD 1983 Texas Centric Mapping System Albers

Riverine Forested Wetlands. These wetlands are found on the floodplains of rivers and large streams, with overtopped riverbanks and flooding as the main source for water. Within the upper Texas coast, swamps are the wettest type of forested wetlands and are typically persistently inundated, located from east Houston to Louisiana (Mitsch and Gosselink, 2007). Coastal flatwood wetlands are unique forested wetlands found between the Louisiana border and the Houston area (Texas A&M AgriLife Extension, 2017a). The lower coast riparian wetlands are unique forested wetlands associated with riverine areas from the San Antonio River to southern Texas. These freshwater, depressional wetlands are maintained by river runoff and regular flooding events (Texas A&M AgriLife Extension, 2017b).

Prairie Potholes and Marshes. Prairie potholes and marshes occur on the prairie from just west of Beaumont to the Rio Grande. These wetlands once covered vast expanses of prairie before urbanization and agriculture destroyed most of them. The difference between a pothole and a marsh is mainly size; marshes occur in larger and generally less-well-defined depressions than potholes. Potholes and marshes maintain their hydrology through direct precipitation, runoff from adjacent flats, and occasionally local groundwater (Texas A&M AgriLife Extension, 2017c).

Texas Coastal Sand Sheet Wetlands. The coastal sand sheet that covers parts of Kleberg, Kenedy, and Willacy counties was formed from sand blown in from the Gulf Coast and shaped by the wind. Because of the dry climate, most of the water supplied to the wetlands is from groundwater percolating through the sandy soils (Texas A&M AgriLife Extension, 2017d).

Estuarine Wetlands. Estuarine wetlands are tidally influenced wetlands that occur throughout the Texas Gulf Coast (Mitsch and Gosselink, 2007; Moulton et al., 1997). Estuarine emergent wetlands are mostly concentrated at the upper and mid Texas coast; estuarine shrub-scrub wetlands were most abundant in the mid Texas coast in Espiritu Santo Bay and at the southern end of South Padre Island (Moulton et al., 1997).

Barrier Island Interior Wetlands. Island interior wetlands provide an important source of fresh water for wildlife. Although these wetlands are primarily fresh water; storm events and extreme tides occasionally introduce salt into these barrier island wetlands. Wetland plants are similar to those found in other freshwater marshes but may include some brackish-water species due to elevated soil salinity and occasional tidal inundation in some areas (Texas A&M AgriLife Extension, 2017e).

Seagrass. Seagrass can be found along the Texas Gulf Coast between the coastal barrier islands and mainland. There is approximately 235,000 acres of seagrass in Texas (TPWD, 1999). Although seagrasses occur throughout the entire coast, about 75 percent of seagrasses occur within the Laguna Madre in the lower Texas coast (Handley et al., 2007). More-detailed information on wetlands can be found in Appendix C-1, Section 2.4.2.

2.4.3 Aquatic Resources

2.4.3.1 Freshwater and Estuarine Habitats and Fauna

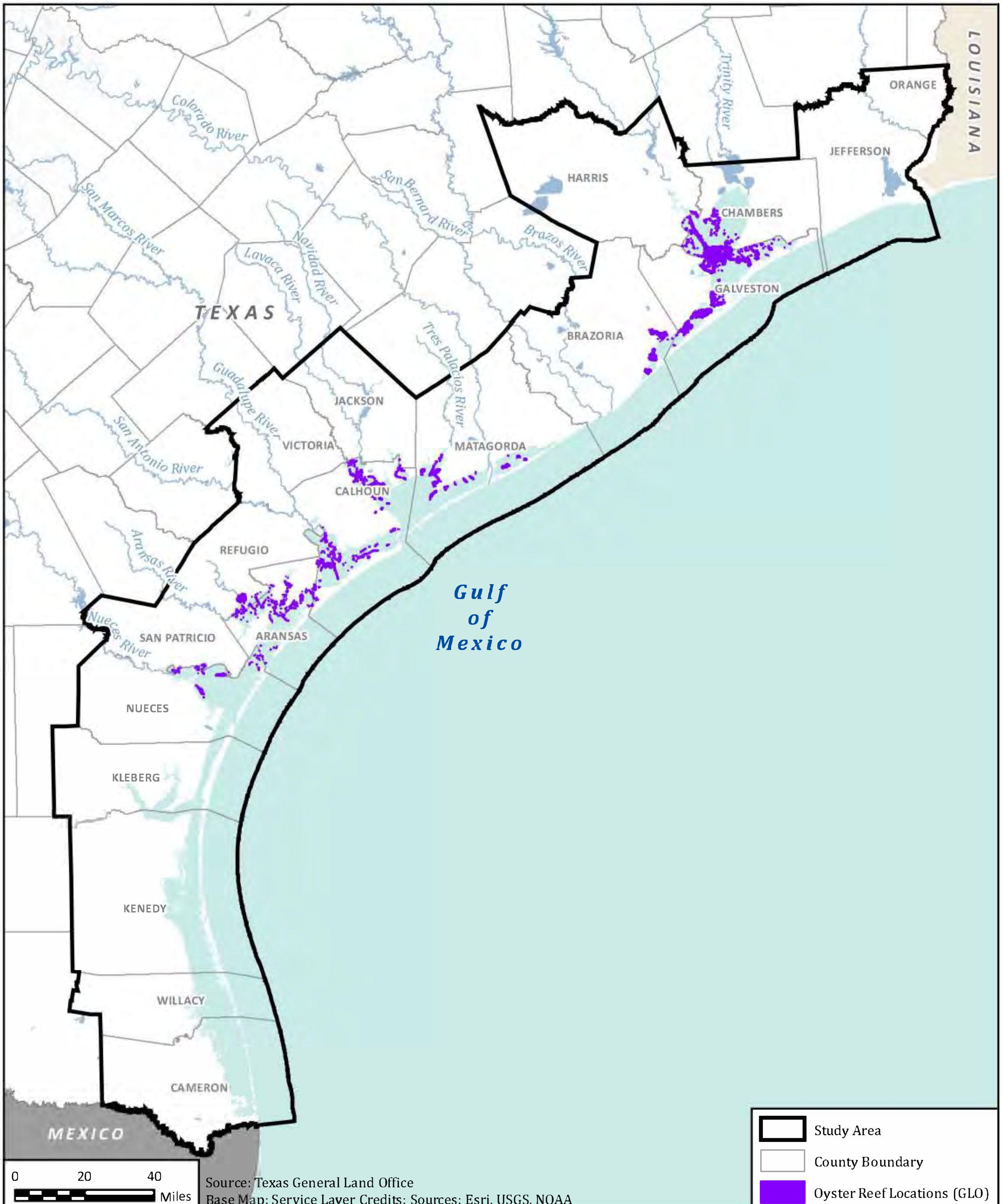
Fluctuations between prolonged low-salinity/freshwater-dominated conditions and higher salinity/drought-dominated conditions depend on rainfall patterns, reservoir releases, and discharges of treated municipal wastewater. Freshwater fish use estuarine systems, particularly when salinities are less than 5 ppt. Conversely, some estuarine and marine fish live in freshwater systems. Because many estuaries extend miles upstream into tidal rivers, there can be overlap between freshwater and estuarine nekton communities. Common species found in tidal streams include bay anchovy (*Anchoa mitchelli*), western mosquitofish (*Gambusia affinis*), Gulf menhaden (*Brevoortia patronus*), grass shrimp (*Palaemonetes* sp.), silversides (*Menidia* sp.), and blue catfish (*Ictalurus furcatus*) (Hendrickson and Cohen, 2015).

Open Bay. The open bay is comprised of phytoplankton and nekton. Phytoplankton (microscopic algae) are the major primary producers (plant life) in the open bay, taking up carbon through photosynthesis and nutrients for growth. Phytoplankton are fed upon by zooplankton (small crustaceans), fish, and benthic consumers. Nekton assemblages (organisms that swim freely in the water column) consist mainly of secondary consumers, which feed on zooplankton and smaller nekton (Armstrong et al., 1987; Britton and Morton, 1989). Plankton assemblages for each major estuary along the Texas coast are described in detail in Appendix C-1, Section 2.4.3.2.

Texas bay systems support a diverse nekton population, including fish, shrimp, and crabs (Armstrong et al., 1987). Dominant nekton species include blue crab (*Callinectes sapidus*), white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), Atlantic croaker (*Micropogonias undulatus*), bay anchovy, code goby (*Gobiosoma robustum*), black drum (*Pogonias cromis*), Gulf menhaden, hardhead catfish (*Arius felis*), pinfish (*Lagodon rhomboides*), sheepshead (*Archosargus probatocephalus*), silversides, southern flounder (*Paralichthys lethostigma*), spot (*Leiostomus xanthurus*), and spotted seatrout (*Cynoscion nebulosus*) (Nelson et al., 1992; Pattillo et al., 1997).

Open-Bay Bottom. The open-bay bottoms in the Texas bay systems include all unvegetated subtidal areas with various sediment types. They are open systems that greatly interact with the overlying waters and adjacent habitats (Armstrong et al., 1987; Tunnell and Judd, 2002). Dominant substrate types are mud and sandy mud bottoms. The primary benthic macroinvertebrates found in all Texas bays include polychaetes, bivalves, gastropods, and crustaceans (White et al., 1987; White et al., 1985; White et al., 1988; White et al., 1989a; White et al., 1983; White et al., 1989b; White et al., 1986).

Oyster Reef. Eastern oysters (*Crassostrea virginica*) are present in all bay systems from Sabine Lake to Corpus Christi Bay, and South Bay and provide ecologically important functions (Figure 2-7). Few oysters are present in the Upper Laguna Madre, Baffin Bay, or Lower Laguna Madre (Lester and Gonzalez, 2011; Powell et al., 1992). While oysters can survive in salinities ranging from 5 to over 40 ppt, they thrive from 10 to 25 ppt, which is the



USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Oyster Reef Locations

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DATE	8/18/2017
SCALE	1:2,377,085
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FIGURE 2-7

NAD 1983 Texas Centric Mapping System Albers

level where pathogens and predators are limited (Cake, 1983). Oyster reef habitat has been in a decline from most bay systems in Texas, with Matagorda Bay showing the greatest loss (Baggett et al., 2014).

Offshore Sands. There are few seagrasses or attached algae found in the offshore sands due to the strong currents and unstable sediments. Most of the bottom surface is populated with macroinfauna, such as hermit crab (Paguroidea), portunid crab (Portunidae), and ray (Batoidea). Phytoplankton are abundant, including microscopic diatoms, dinoflagellates, and other algae (Britton and Morton, 1989).

2.4.3.2 Commercial and Recreational Fisheries

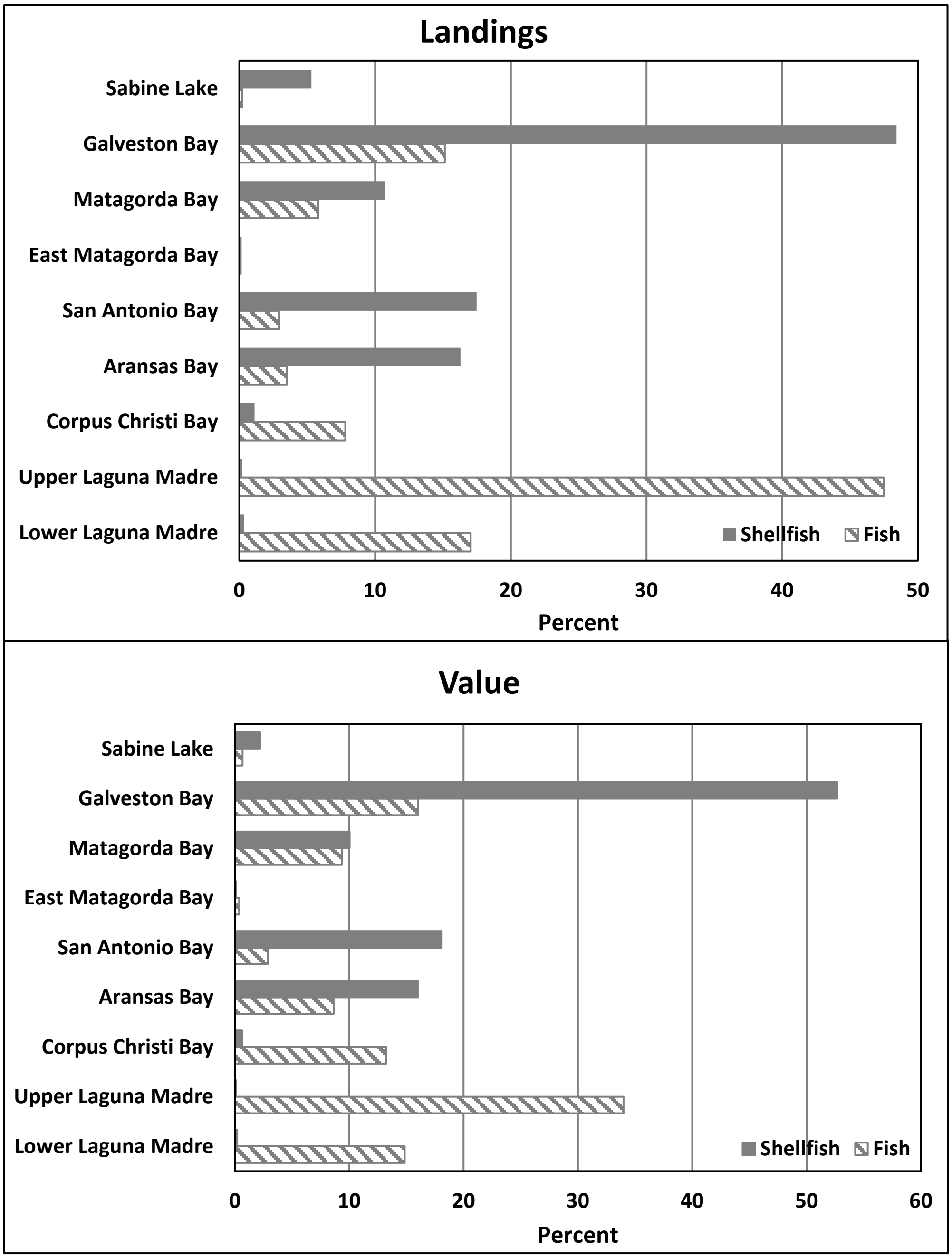
Commercial and recreational fisheries data along the Texas coast were obtained from Darin Topping and Mark Fisher at the Rockport TPWD Marine Laboratory. Species included in the commercial fisheries data are black drum, flounder, sheepshead, mullet, and other. Shellfish include blue crab, eastern oyster, brown and pink shrimp, white shrimp, and other. Species included in the recreational fisheries data are spotted seatrout, red drum, southern flounder, red snapper (*Lutjanus campechanus*), and king mackerel (*Scomberomorus cavalla*).

From 2006 to 2015, the Upper Laguna Madre, Lower Laguna Madre, and Galveston Bay produced the highest commercial finfish harvest from all Texas bay systems, while East Matagorda Bay and Sabine Lake produce the least (Table 2-6 and Figure 2-8). The highest commercial shellfish harvest came from Galveston, San Antonio, Aransas, and Matagorda bays. Almost half the eastern oysters and almost half the shrimp harvest comes from Galveston Bay. Most black drum are collected from the Upper Laguna Madre, flounder from East Matagorda Bay and Aransas Bay. Sheepshead are harvested mainly from Galveston, Matagorda, and East Matagorda bays and mullet from the Lower Laguna Madre and Galveston Bay (pers. com. D. Topping [TPWD], 2016).

Table 2-6
Commercial Landings and Values by Texas Bay System, 2006 to 2015

	Fish		Shellfish		Total Combined	
Bay System	Pounds	Value	Pounds	Value	Pounds	Value
Sabine Lake	45,272	$188,038	5,064,516	$5,143,620	5,109,788	$5,331,658
Galveston Bay	3,106,632	$4,488,176	46,268,367	$122,359,116	49,374,999	$126,847,292
Matagorda Bay	1,188,943	$2,619,944	10,230,949	$23,301,144	11,419,892	$25,921,088
East Matagorda Bay	19,786	$104,550	154,525	$252,068	174,311	$356,618
San Antonio Bay	598,265	$800,409	16,703,598	$42,022,980	17,301,863	$42,823,389
Aransas Bay	718,988	$2,418,969	15,560,727	$37,154,255	16,279,715	$39,573,224
Corpus Christi Bay	1,601,657	$3,712,742	1,067,999	$1,462,062	2,669,656	$5,174,804
Upper Laguna Madre	9,746,031	$9,521,444	175,014	$215,833	9,921,045	$9,737,277
Lower Laguna Madre	3,558,791	$4,158,333	322,126	$468,619	3,880,917	$4,626,952

Source: Personal communication with Darin Topping (October 19, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.



Source: Personal communication with Darin Topping (October 19, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.

Figure 2-8. Percent of Commercial Landings and Value of Fish and Shellfish by Texas Bay System, 2006–2015

Recreational anglers in all Texas bay systems primarily sought spotted seatrout, red drum, southern flounder, a combination of spotted seatrout and red drum, or a combination of spotted seatrout, red drum, and southern flounder. From 2006 to 2015, annual private boat and party-boat fishing pressure was greatest from Galveston Bay, Aransas Bay, and the Upper Laguna Madre (Table 2-7) (Green and Campbell, 2010; pers. com. M. Fisher [TPWD], 2016).

Table 2-7
Percent of Angler Effort for Texas Bays and Gulf, 2006 to 2015

System	Private Boat	Party-Boat
Bay:		
Sabine Lake	8.1	2.1
Galveston Bay	29.4	28
Matagorda Bay	10.9	8.6
San Antonio Bay	8.8	4.7
Aransas Bay	12.8	23.1
Corpus Christi Bay	6.9	10.3
Upper Laguna Madre	12.7	17.5
Lower Laguna Madre	10.4	5.7
Gulf:		
Gulf off Sabine Lake	5.6	0
Gulf off Galveston	26.8	26.9
Gulf off Port O'Connor	21.7	32.5
Gulf off Port Aransas	36.6	30.9
Gulf off Port Isabel	9.5	9.6

Source: Personal communication with Mark Fisher (October 26, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.

2.4.4 Wildlife Resources

Blair (1950) categorizes Texas into seven biotic provinces: the Austroriparian, Texan, Tamaulipan, Chihuahuan, Navahonian, Kansan, and Balconian. The study area is located within the Austroriparian (upper Texas coast), Texan (upper to mid Texas coast), and Tamaulipan (lower Texas coast) biotic provinces. More-detailed information on amphibian, reptile, mammal, bird, and insect species can be found in Appendix C-1, Section 2.4.4.

The Austroriparian Biotic Province is situated in the eastern border of Texas and extends southward to Galveston County on the Gulf Coast. According to Blair (1950), at least 47 mammal species, 29 snake species, 10 lizard species, 2 land turtle species, 17 anuran (frogs and toads) species, and 18 urodele (salamanders and newts) species occur within the region.

The Texan Biotic Province stretches from Galveston Bay to western Calhoun County (Blair, 1950). Wildlife habitats include beach, shell ramp-barrier flats, dredged material, saltwater marsh, brackish to freshwater marsh, fresh to brackish lakes, inland freshwater marsh, grassland, and riparian forest (McGowen et al., 1976). The Texan Biotic Province supports a diverse fauna composed of a mixture of species common to neighboring provinces. At least 49 species of mammals are known to have occurred in the Texan province in recent times, in addition to over 300 avian species, 39 snake species, 16 lizard species, 2 land turtle species, 18 anuran species, and 5 urodele species (Blair, 1950).

The vertebrate fauna of the Tamaulipan Biotic Province is typified by neotropical and plains species. Wildlife habitats include upland prairies, salt marshes, tidally influenced lowlands, barrier islands, saline lagoons, and coastal prairies. According to Blair (1950), there are 61 mammalian species, over 300 avian species, 38 species of snakes, 19 species of lizards, and at least 5 species of amphibians.

2.4.5 Protected Resources

2.4.5.1 Protected Lands

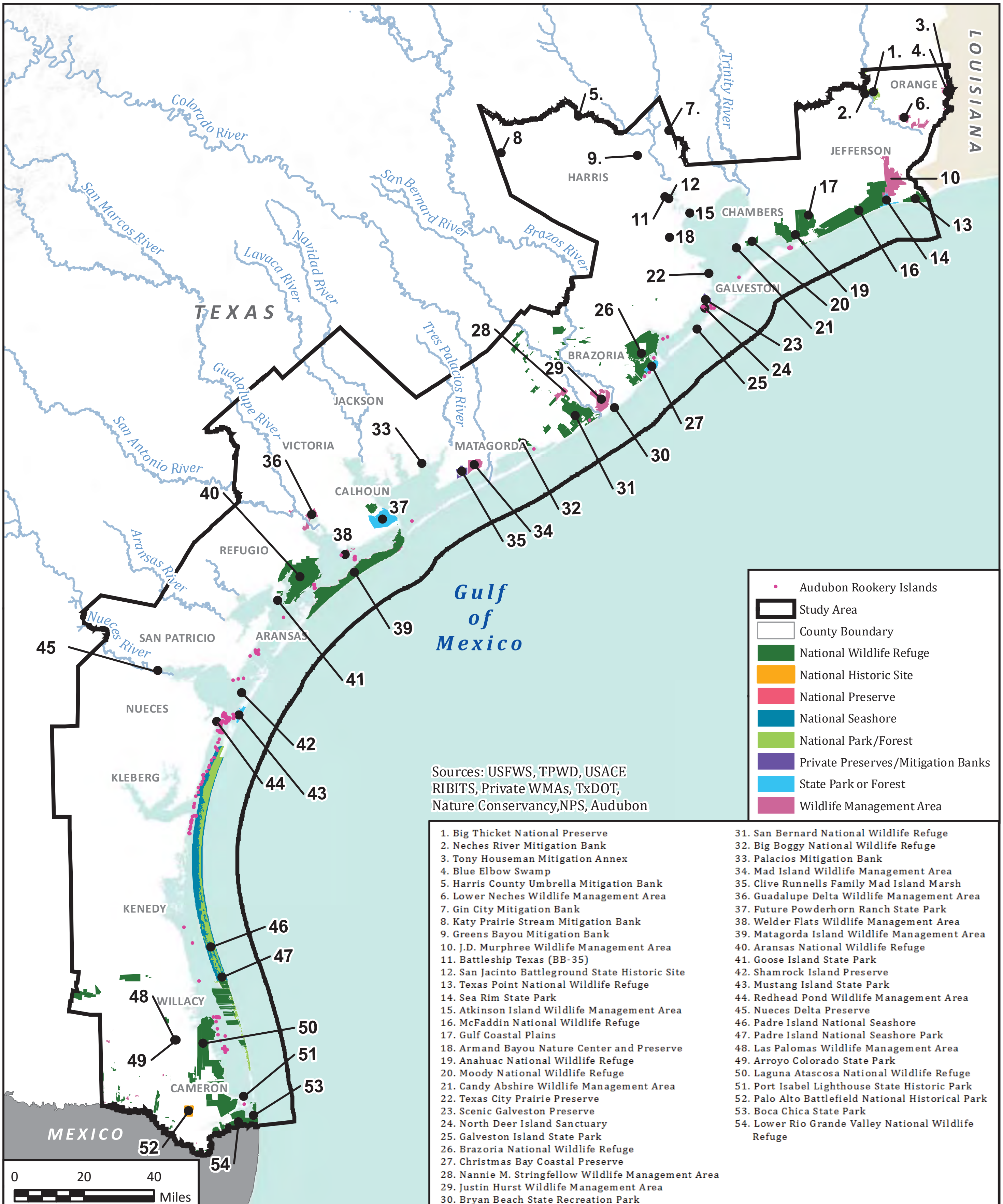
Numerous protected lands have been established along the Texas Gulf Coast and within the study area that demonstrate the ecological, cultural, and recreational diversity of Texas (Figure 2-9). Some of these areas were created to provide opportunities for hunting, fishing, wildlife viewing, and environmental education. Administration of these areas is provided under Federal and State governance or by private organizations. Table 2-8 provides a brief description of the protected areas as well as the managing group.

2.4.5.2 Threatened and Endangered Species

The U.S. Fish and Wildlife Service (USFWS) and NMFS have identified 31 Federally listed threatened and endangered species as potentially occurring in the study area (Table 2-9). Species are listed in Table 2-9 and discussed briefly in Appendix C-1, Section 2.4.5.2. Inclusion in the list does not imply that a species occurs in the study area, but only acknowledges the potential for its occurrence in those counties.

Threatened or endangered species in which one or more project features or construction thereof are likely to adversely affect include green sea turtle (*Chelonia mydas*), Kemp's ridley sea turtle (*Lepidochelys kempii*), loggerhead sea turtle (*Caretta caretta*), piping plover (*Charadrius melodus*), and rufa red knot (*Calidris canutus rufa*). Other species that might be found in the area, but not likely to be adversely affected include West Indian manatee (*Trichechus manatus*), interior least tern (*Sterna antillarum*), northern aplomado falcon (*Falco femoralis*), whooping crane (*Grus americana*), hawksbill sea turtle (*Eretmochelys imbricata*), leatherback sea turtle (*Dermochelys coriacea*), and Texas prairie dawn flower (*Hymenoxys texana*).

A Biological Assessment (BA) of the study area describing the Federally listed threatened and endangered species likely to occur and the potential impact associated with the proposed Federal action has been prepared and is attached as Appendix C-3.



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Protected Lands

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NAD 1983 Texas Centric Mapping System Albers

Table 2-8
Protected Lands Within the Study Area

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Upper Texas Coast					
Goose Island State Park	State (TPWD)	321	Aransas	estuarine marsh; oak mottes; tidal flats	This park boasts fishing, camping and boating. The “Big Tree” at the park is more than 1,000 years old and one of the largest live oak trees in the Nation.
Brazoria National Wildlife Refuge (NWR)	National (USFWS)	44,413	Brazoria	wetlands; prairies; woody thickets; salt and mud flats; lakes and streams	This refuge boasts 400 species of birds, 95 species of reptiles and amphibians, and 130 species of butterflies and dragonflies.
Bryan Beach State Recreation Park	State (TPWD)	885	Brazoria	coastal prairie	The park is regularly maintained by the City of Freeport. Recreation activities include sunbathing, camping, birding, and fishing.
Christmas Bay Coastal Preserve	State (GLO/TPWD)	4,831	Brazoria	prairies; salt marshes; oyster reefs	The preserve contains about 250 acres of seagrass beds and has minimal man-made alterations to the landscape.
Justin Hurst Wildlife Management Area (WMA)	State (TPWD)	15,612	Brazoria	coastal dunes; Gulf shoreline; bay	The WMA is part of the Central Coast Wetlands Ecosystem Project, which provides research on biological conservation, outdoor demonstrations, and public hunting.
Nannie M. Stringfellow WMA	State (TPWD)	3,664	Brazoria	coastal bottomland; hardwood forest	The WMA is part of the Coastal Bottomlands Mitigation Bank to improve the forest and grasslands as wildlife habitat.
San Bernard NWR	National (USFWS)	57,698	Brazoria, Matagorda	salt and freshwater marshes; ponds; coastal prairies; bottomland forests	The Columbia bottomland forest contains some of the largest live oak stands in Texas and provides habitat for wintering and nesting birds. The refuge was designated an “Internationally Significant Shorebird Site” and is popular for waterfowl hunting and fishing.
Guadalupe Delta WMA	State (TPWD)	7,410	Calhoun, Victoria, Refugio	coastal marsh; man-made wetlands; riparian forest	The freshwater discharge of the Guadalupe River contributes to the low salinity of the bay system. The wetland habitat provides food and forage for wildlife such as white-faced ibis, herons, white-tailed hawk, and peregrine falcons.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Boca Chica State Park	State (TPWD)	1,055	Cameron	sandy beaches and dunes	The TPWD signed a 50-year lease agreement with the USFWS; the park is now a part of the Lower Rio Grande Valley NWR. SpaceX is currently in the process of building a private spaceport adjacent to the state park.
Anahuac NWR	National (USFWS)	34,400	Chambers	brackish and saline marshes; coastal prairie and woodlands; Chenier plains	This refuge is used as a stopover along the Central Flyway for millions of migrating birds. The refuge contains one of the last remnants of native coastal tallgrass prairie in the United States and is known for its abundance of large American alligators.
Candy Abshier WMA	State (TPWD)	207	Chambers	live oak woodlots; freshwater ponds; bay shoreline	This WMA was recently rewarded with a grant from the National Fish and Wildlife Foundation to construct 2,660 feet of breakwater barriers to stabilize the eroding shoreline. The observation platform on site is used from August to November to count and observe migrating hawks along the coast.
Gulf Coastal Plains	(Private)	1,850	Chambers	coastal plains; prairies	Not available
Moody NWR	National (USFWS), perpetual non-development conservation easement	3,517	Chambers	estuarine marsh; bay shoreline	The tract is under a conservation easement under private ownership and has no public access. The NWR contains numerous shell middens and archeological sites.
Trinity River NWR	National (USFWS)	25,000	Chambers, Liberty	cypress-tupelo swamp; bottomland hardwood forest; wet pastures; lakes; rivers	The refuge is home to one of the largest maternal colonies of Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) in the world. The refuge contains more than 650 different species of plants and 400 types of butterflies and moths.
Galveston Island State Park	State (TPWD)	2,000	Galveston	coastal prairie; wetlands	One of the last undeveloped public lands on Galveston Island, this park is popular for swimming, fishing, camping, and hiking. The state park is still in the process of recovering from damages from Hurricane Ike in 2008.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
North Deer Island Sanctuary	National Audubon Society, Houston Audubon Society	144	Galveston	upland salt marsh	This island is one of the most productive waterbird colonies in Galveston Bay with up to 40,000 breeding pairs during the season. It was recently a part of a shoreline restoration project where 6,450 feet of breakwater was installed to prevent shoreline erosion from natural wave action and barge traffic.
Scenic Galveston Preserve	Scenic Galveston (private)	3,200	Galveston	restored marsh	This tract is part of a conservation easement. The marshes are currently under clean-up restoration by volunteer groups.
Texas City Prairie Preserve	The Nature Conservancy (TNC) (Private)	2,303	Galveston	coastal prairie; marsh	Donated by ExxonMobil, this preserve is partnered with the GLO, USFWS, and the Galveston Bay Estuaries Program to implement a series of living shoreline projects to protect and provide resiliency.
Armand Bayou Nature Center and Preserve	Armand Bayou Nature Center (Private)	2,800	Harris	brackish water bayou; riparian hardwood forest; remnant coastal prairie	Located outside of Houston, the center specializes in outdoor education, community outreach programs, canoeing, and hiking.
Atkinson Island WMA	State (TPWD)	150	Harris	brackish marsh; woodlot	Donated by Conoco Inc., this wildlife preserve is mainly used for wetland restoration research on dredged materials.
Battleship Texas State Historic Site	State (TPWD)	1	Harris	historic ship	This decommissioned World War I and World War II battleship now serves as a floating museum and war memorial. The battleship is located along the Houston Ship Channel and adjacent to the San Jacinto Battleground site.
Gin City Mitigation Bank	Gin City Restoration (Private)	500	Harris	freshwater wetlands	Restored rice fields include 300,000 trees and locally collected plants. The site provides 1,170 wetland credits.
Greens Bayou Mitigation Bank	County (Harris County Flood Control District [HCFCD])	961	Harris	ponds; marshes; forests	One of the largest mitigation banks in the Texas Gulf Coast region. The mitigation bank provides habitat, naturally filters urban runoff, and stores stormwater during rain events.
Harris County Umbrella Mitigation Bank	County (HCFCD)	66	Harris	wetland; stream channel	Restored sand and gravel mining pit now include 25 acres of wetland and 2,000 linear feet of stream channel.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Katy Prairie Stream Mitigation Bank	Warren Family, Katy Prairie Conservancy, Restoration Systems LLC (Private)	500	Harris	wetland; stream channel; prairie	Houston's first and the largest permitted stream mitigation bank in the United States (12,000+ linear feet).
San Jacinto Battleground State Historical Site	State (TPWD)	1,109	Harris	coastal prairie; tidal marsh; bottomland forest	This park sits on the site of one of the most important battles of the Texas Revolution. The park now contains the San Jacinto monument, a reflecting pool, and hosts annual battle reenactments.
JD Murphree WMA	State (TPWD)	24,250	Jefferson	fresh, intermediate and brackish marsh; Chenier plain	This site has a been a waterfowl-banding location since the 1960s and provides valuable information on the population of mottled ducks, geese, and other birds. There are several continuous studies conducted by university staff and students related to the wetlands and other wildlife.
McFaddin NWR	National (USFWS)	58,861	Jefferson	fresh water and intermediate marsh; Gulf shoreline dune system	The refuge is home to the largest concentration of American alligators in Texas. The refuge serves as an important stopover for migrating songbirds and wintering grounds for geese and other waterfowl.
Neches River	Wetlands Mitigation Replacement of Southeast Texas (private)	541	Jefferson	cypress-tupelo swamp; emergent marsh mitigation bank	The area is a privately owned mitigation bank.
Sea Rim State Park	State (TPWD)	4,141	Jefferson	gulf prairie and marsh	This park was damaged after Hurricanes Rita and Ike and recently reopened. The park is a popular destination for birdwatching, beach recreation and kayaking.
Texas Point NWR	National (USFWS)	8,952	Jefferson	coastal wetlands	A primitive refuge with no paved trail or vehicle access. Designated by the American Bird Conservancy as a “Globally Important Bird Area of the United States.”
Blue Elbow Swamp Mitigation Bank	State (Texas Department of Transportation [TxDOT])	2,737	Orange	cypress-tupelo swamp	The tract is located right behind the Texas Travel information center along State Highway (SH) 10 and provides visitors with a quick look at a marsh ecosystem.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Big Thicket National Preserve	National (National Park Service)	112,501	Orange, Hardin, Jefferson	cypress-tupelo swamp; bottomland hardwood forest; freshwater marsh	This preserve boasts an incredible amount of biodiversity and has been designated a United Nations Educational, Scientific and Cultural Organization Biosphere Reserve. The preserve is home to 4 species of carnivorous plants, more than 1,000 different species of flowering plants, ferns, and orchids.
Mid to Upper Texas Coast					
Aransas NWR/ Matagorda Island WMA	National (USFWS), State (TPWD)	114,657	Calhoun, Aransas, Refugio	salt, brackish, and freshwater marsh; coastal woodlots; tidal flats; Gulf beaches	This refuge is the winter migration stop of the endangered whooping cranes. The Matagorda island unit of the refuge is a nesting ground for Kemp's ridley sea turtles and piping plovers. The portion of Matagorda Island is jointly shared with USFWS and TPWD where the refuge has the lead responsibility for wildlife and habitat management, and TPWD is responsible for public use management.
Big Boggy NWR	National (USFWS)	4,526	Matagorda	brush and flat coastal prairie; freshwater and saltwater marsh; uplands	Only opened to the public during waterfowl hunting season, this refuge serves as a stop along the Central Flyway and as a breeding colony for herons, pelicans, spoonbills, and many other birds.
Clive Runnells Family Mad Island Marsh	TNC (Private)	7,063	Matagorda	coastal marsh; wetlands; upland prairie; barrier island	The preserve is ranked within the top 5 annual Christmas Bird Counts in the nation and is home to nearly 250 different species of birds. Efforts are currently underway to restore freshwater inflows, freshwater wetlands, and upland prairies.
Mad Island WMA	State (TPWD)	7,281	Matagorda	fresh to brackish marsh land; coastal prairie	The WMA is well known for duck hunting in the fall and winter.
Palacios Mitigation Bank	Private	2,564	Matagorda	wetlands	The largest environmental bank in Texas. The area was previously corn and sorghum fields. The bank is important habitat for migratory birds and wildlife.
Mustang Island State Park	State (TPWD)	3,954	Nueces	coastal barrier island; sand dune	The park is used as nesting grounds for the Atlantic green and Kemp's ridley sea turtles. There has also been reintroduction efforts for the endangered Aplomado falcon inside of the park.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Lower Neches WMA	State (TPWD)	7,998	Orange	open-water marsh	Donated by philanthropist Nelda Childers Stark, this area was used by the Atakapan Indians for centuries. Hunting, wildlife viewing, and fishing activities are offered.
Mid Texas Coast					
Redhead Pond WMA	State (TPWD)	37	Nueces	freshwater wetland	A freshwater pond in downtown Corpus Christi provides winter habitat for waterfowl.
Shamrock Island Preserve	TNC (Private)	110	Nueces	island	The island is utilized by 19 different species of birds as a nesting site and for roosting. The TNC has developed a long-term habitat restoration program for the island.
Nueces Delta Preserve	Coastal Bend Bays and Estuaries Program (Private)	10,500	Nueces	grasslands; thornscrub; wetlands; marsh delta	The preserve contains limited trails and a learning and visitor center for outdoor classrooms. Land management programs include re-establishing a prairie wetland, invasive species control, prescribed burns, and tree plantings.
Tony Houseman WMA	State (TPWD)	3,313	Orange	cypress-tupelo swamp	The site has a 600-foot boardwalk running through the center of the swamp. The WMA offers public hunting, hiking, canoeing and fishing.
Lower Texas Coast					
Powderhorn Ranch State Park	State (TPWD)	17,351	Calhoun	shrubland; pasture; grassland; wetlands; open water	The newest Texas state park features 6 different types of plant species, including wetlands and shoreline for migratory birds. There are also plenty of recreational opportunities such as paddling, hiking, birdwatching, and hunting. The park is not yet open to the public.
Welder Flats WMA	State (GLO/TPWD)	1,480	Calhoun	Submerged coastal wetlands	The shallow seagrass shoreline provides a foraging area for waterfowl and whooping cranes. The San Antonio Bay shoreline is used by bay hatcheries to stock the area with red drum and spotted sea trout.
Lower Rio Grande Valley NWR	National (USFWS)	90,788	Cameron	riparian woodlands; saline flats; resacas and mesquite savannahs	The refuge contains several historical landmarks. The NWR provides habitat for 17 Federally listed threatened and endangered species such as ocelots, Kemp's ridley sea turtles, and Aplomado falcons.
Palo Alto Battlefield National Historical Park	National (National Park Service)	3,364	Cameron	resacas; grassland prairie; scrub woodlands	The historic park contains many landmarks and battle sites from the Mexican War. The site remains an important place for Texas tortoise conservation.

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Port Isabel Lighthouse State Historical Site	State (TPWD)	2	Cameron	historic building	This lighthouse is the only lighthouse in Texas open to the public. The site also features a small museum and visitor center.
Laguna Atascosa NWR	National (USFWS)	97,007	Cameron, Willacy	tidally affected lagoon system; wetlands; sandy beaches; dunes; tidal mud flats; brackish marsh; freshwater ponds	One of the few places in the United States where ocelots and jaguarundis are found. The refuge also has the most recorded species of birds (417) than any other in the national refuge system.
Padre Island National Seashore	National Parks Service	130,434	Kleberg, Kenedy, Willacy	coastal prairie; dune system; tidal flats; hypersaline lagoon	North Padre Island is the longest undeveloped barrier island in the world. The seashore is an important nesting site for the endangered Kemp's ridley sea turtle and migratory bird species.
Arroyo Colorado State Park	State (TPWD)	1,005	Willacy, Cameron	freshwater stream	The unit is part of the coastal birding trail and an important fishery area.
Las Palomas WMA	State (TPWD)	754	Willacy, Cameron	restored grasslands; wetlands	This WMA lies along the U.S.-Mexican border. Some of the units were formerly farm fields that have not been restored for white-winged dove breeding habitat.

Source: Armand Bayou Nature Center (2016), Brazosport (2017), Coastal Bend Bays and Estuaries Program (2009), Dotzour and Manning (2002),HCFCD (2017), Houston Audubon (2016), Mitigation Solutions (2017), National Park Service (2016, 2017a, 2017b), Restoration Systems LLC (2017), Scenic Galveston (2016), TxDOT (1995), TNC (2016a, 2016b, 2017), TPWD (2014, 2016a–o, 2017a–g), USACE et al. (1999), USFWS (2013a–f, 2018a–f).

Table 2-9
Federally Endangered, Threatened, or Candidate for Listing
Species of Potential Occurrence in the Study Area

Common Name	Scientific Name	Federal Status
PLANTS		
Black lace cactus	*Echinocereus reichenbachii* var. *albertii*	E
Slender rush-pea	*Hoffmannseggia tenella*	E
South Texas ambrosia	*Ambrosia cheiranthifolia*	E
Texas ayenia	*Ayenia limitaris*	E
Texas prairie dawn-flower	*Hymenoxys texana*	E
BIRDS		
Attwater’s prairie chicken	*Tympanuchus cupido attwateri*	E
Interior least tern	*Sterna antillarum*	E
Northern aplomado falcon	*Falco femoralis septentrionalis*	E
Piping plover	*Charadrius melodus*	T
Rufa red knot	*Calidris canutus rufa*	T
Red-cockaded woodpecker	*Picoides borealis*	E
Red-crowned parrot	*Amazona virdigenalis*	C
Whooping crane	*Grus americana*	E
MAMMALS		
Gulf coast jaguarundi	*Herpailurus yagouaroundi cacomitli*	E
Ocelot	*Leopardus pardalis*	E
Blue whale	*Balaenoptera musculus*	E
Fin whale	*Balaenoptera physalus*	E
Humpback whale	*Megaptera novaeangliae*	T
Sei whale	*Balaenoptera borealis*	E
Sperm whale	*Physeter macrocephalus*	E
West Indian manatee	*Trichechus manatus*	T
REPTILES		
Atlantic hawksbill sea turtle	*Eretmochelys imbricata*	E
Kemp’s ridley sea turtle	*Lepidochelys kempii*	E
Leatherback sea turtle	*Dermochelys coriacea*	E
Loggerhead sea turtle	*Caretta caretta*	T
FISHES		
Largetooth sawfish	*Pristis pristis*	E
AMPHIBIAN		
Houston toad	*Bufo houstonensis*	E
MOLLUSKS		
Golden orb	*Quadrula aurea*	C
Smooth pimpleback	*Quadrula houstensis*	C
Texas fawnsfoot	*Truncilla macrodon*	C
Texas pimpleback	*Quadrula petrina*	C

Source: NMFS (2016a), USFWS (2017a, 2018g).

E – Endangered; T – Threatened; C – Candidate for Federal listing

2.4.5.3 Essential Fish Habitat

This DIFR-EIS will serve to initiate EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Rules published by the NMFS (50 CFR sections 600.805–600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identified consultation requirements.

EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” EFH is separated into estuarine and marine components. The estuarine component is defined as “all estuarine waters and substrates (mud, sand, shell, rock, and associated biological communities); subtidal vegetation (seagrasses and algae); and adjacent intertidal vegetation (marshes and mangroves).” The marine component is defined as “all marine waters and substrates (mud, sand, shell, rock, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone” (200 nautical miles from the coast) (Gulf of Mexico Fisheries Management Council, 2004). Adverse effect to EFH is defined as, “any impact, which reduces quality and/or quantity of EFH…” and may include direct, indirect, site-specific or habitat impacts, including individual, cumulative, or synergistic consequences of actions.

Table 2-10 lists 34 species that NMFS and the Gulf of Mexico Fisheries Management Council identify in the study area as EFH and tables 2-11 through 2-13 describe the relative abundance and adult and juvenile presence of each EFH managed species occurring in the study area. The categories of EFH that occur within the study area are described ins Appendix C-1, Section 2.4.5.3. An EFH Assessment has been prepared and is included as Appendix C-4.

2.4.5.4 Migratory Birds

The Migratory Bird Treaty Act (MBTA) of 1918 makes it illegal to kill, possess, transport, buy, sell, or trade any migratory bird parts, nest, or eggs unless a valid Federal permit is issued (USFWS, 2017b). There are several NWRs, WMAs, parks, protected areas, and dredge islands areas along the Texas Gulf Coast that provide nesting habitat and support rookeries for migratory birds. The USFWS lists 59 migratory species that may use or have the potential to use the islands and other land areas near the project area (Table 2-14; USFWS, 2018g).

Table 2-10
Species Identified as Essential Fish Habitat in the Study Area

Common Name*	Species Name*	Coastal Region		
		Upper	Mid	Lower
Brown shrimp	*Farfantepenaeus aztecus*	X	X	X
Pink shrimp	*Farfantepenaeus duorarum*	X	X	X
White shrimp	*Litopenaeus setiferus*	X	X	X
Blacknose shark	*Carcharhinus acronotus*	X	X	X
Atlantic angel shark	*Squatina dumeril*			X
Spinner shark	*Carcharhinus brevipinna*	X	X	X
Silky shark	*Carcharhinus falciformis*		X	X
Finetooth shark	*Carcharhinus isodon*		X	X
Bull shark	*Carcharhinus leucas*	X	X	X
Blacktip shark	*Carcharhinus limbatus*	X	X	X
Dusky shark	*Carcharhinus obscurus*		X	
Tiger shark	*Galeocerdo cuvier*	X	X	X
Lemon shark	*Negaprion brevirostris*	X	X	X
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	X	X	X
Scalloped hammerhead shark	*Sphyrna lewini*	X	X	X
Great hammerhead shark	*Sphyrna mokarran*	X	X	X
Bonnethead shark	*Sphyrna tiburo*	X	X	X
Red grouper	*Epinephelus morio*	X	X	X
Gag grouper	*Mycteroperca microlepis*	X	X	X
Scamp	*Mycteroperca phenax*	X	X	X
Cobia	*Rachycentron canadum*	X	X	X
Dolphin	*Coryphaena hippurus*		X	X
Greater amberjack	*Seriola dumerili*	X	X	X
Lesser amberjack	*Seriola fasciata*	X	X	X
Red snapper	*Lutjanus campechanus*	X	X	X
Gray snapper	*Lutjanus griseus*	X	X	X
Lane snapper	*Lutjanus synagris*	X	X	X
Vermilion snapper	*Rhomboplites aurorubens*	X	X	X
Red drum	*Sciaenops ocellatus*	X	X	X
Little tunny	*Euthynnus alletteratus*	X	X	X
King mackerel	*Scomberomorus cavalla*	X	X	X
Spanish mackerel	*Scomberomorus maculatus*	X	X	X
Sailfish	*Istiophorus platypterus*		X	X
Blue marlin	*Makaira nigricans*			X

Source: NMFS (2009); NOAA (2013, 2016e).
* Species according to Page et al. (2013).

Table 2-11
Species Adult and Juvenile Presence in the Upper Texas Coast for Identified Essential Fish Habitat

Common/Scientific Name*	Estuarine								Marine	
	Sabine Lake		Galveston Bay		Brazos River		Matagorda Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Brown shrimp (*Farfantepenaeus aztecus*)	abundant July–Oct common Nov–Mar major nursery area	common Apr–Oct	abundant year-round major nursery area	common Apr–Oct	abundant year-round major nursery area	not present	common to highly abundant year-round major nursery area	common to highly abundant Apr–July	spawning area year-round	major adult area spring, summer, fall
Pink shrimp (*Farfantepenaeus duorarum*)	nursery area summer and fall	not present	nursery area summer and fall	not present to rare	common Nov–June	not present	nursery area summer and fall	common Feb–May	nursery area summer and fall	present year-round spawning area in summer
White shrimp (*Litopenaeus setiferus*)	highly abundant Apr–Dec nursery area	highly abundant Aug–Mar common Apr–July	highly abundant Apr–Dec common Jan–Mar nursery area	rare to common year-round	highly abundant July–Oct abundant Nov–June nursery area	common Apr–June	highly abundant Feb–Nov rare to not present Dec-Jan nursery area	abundant March common Apr–June, Aug–Nov	not present	present year-round spawning Mar–Oct
Blacknose shark (*Carcharhinus acronotus*)	not present		not present		not present		not present		not present	present
Spinner shark (*Carcharhinus brevipinna*)	not present		present	not present	not present		present	not present	present	not present
Finetooth shark (*Carcharhinus isodon*)	not present		not present		not present		not present		present	
Bull shark (*Carcharhinus leucas*)	rare Mar–Oct	not present	common Mar–Nov	not present	present		present	not present	present	
Blacktip shark (*Carcharhinus limbatus*)	not present		present	not present	not present		present	not present	present	

Common/Scientific Name*	Estuarine								Marine	
	Sabine Lake		Galveston Bay		Brazos River		Matagorda Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Tiger Shark (*Galeocerdo cuvier*)	not present		not present		not present				present	
Lemon shark (*Negaprion brevirostris*)	not present		not present	present	not present		present		present	
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)	not present		present		not present		present		present	
Scalloped hammerhead shark (*Sphyrna lewini*)	not present		present	not present	not present		present	not present	present	not present
Great hammerhead shark (*Sphyrna mokarran*)	not present		not present		not present		not present		present	
Bonnethead shark (*Sphyrna tiburo*)	not present		present	not present	not present		present		present	
Red grouper (*Epinephelus morio*)	not present		not present		not present		not present		nursery area year-round	adult occurrence
Gag grouper (*Mycteroperca microlepis*)	not present		not present		not present		not present		not present	adult occurrence
Scamp (*Mycteroperca phenax*)	not present		not present		not present		not present		not present	adult occurrence
Cobia (*Rachycentron canadum*)	not present		nursery area year-round	adult area summer	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	present summer
Greater amberjack (*Seriola dumerili*)	not present		not present		not present		not present		present year-round	adult and spawning area year-round
Lesser amberjack (*Seriola fasciata*)	not present		not present		not present		not present		not present	present

Common/Scientific Name*	Estuarine								Marine	
	Sabine Lake		Galveston Bay		Brazos River		Matagorda Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Red snapper (*Lutjanus campechanus*)	not present		nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	not present
Gray snapper (*Lutjanus griseus*)	not present		nursery area	major adult area year-round	not present		nursery area	major adult area year-round	not present	major adult area year-round spawn June-August
Lane snapper (*Lutjanus synagris*)	nursery area	not present	nursery area	not present	nursery area	not present	nursery area	not present	nursery area	not present
Vermilion snapper (*Rhomboplites aurorubens*)	not present		not present		not present		not present		nursery area	not present
Red drum (*Sciaenops ocellatus*)	common year-round nursery area	present year-round	common year-round nursery area	present year-round	common year-round nursery area	common year-round	nursery area year-round	common year-round	not present	present year-round spawning area fall and winter
Little tunny (*Euthynnus alletteratus*)	not present		not present		not present		not present		present	
King mackerel (*Scomberomorus cavalla*)	not present		nursery area year-round	present year-round	nursery area year-round	present year-round	not present		nursery area year-round	present year-round spawning area May–Nov
Spanish mackerel (*Scomberomorus maculatus*)	rare to not present	common Apr–June	common May–Oct nursery area	not present	rare to not present	present year-round	nursery area year-round	common July–Oct rare Nov-June	nursery area year-round	present year-round spawning area summer and fall

Source: Nelson et al. (1992); NMFS (2009); NOAA (2013, 2016e); Pers. com. R. Swafford (NMFS, 2018).
* Species according to Page et al. (2013).

Table 2-12
Species Adult and Juvenile Presence in the Mid Texas Coast for Identified Essential Fish Habitat

Common/Scientific Name*	Estuarine								Marine	
	San Antonio Bay		Aransas Bay		Corpus Christi/ Upper Laguna Madre		Baffin Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Brown shrimp (*Farfantepenaeus aztecus*)	common to highly abundant year-round major nursery area	abundant May-June common April, July–Sept	abundant July–Mar abundant to highly abundant Apr–June major nursery area	not present	common July–Mar common to highly abundant Apr–June major nursery area	present Mar–May	highly abundant May–July abundant Aug–May major nursery area	not present	spawning area year-round	major adult area spring, summer, fall
Pink shrimp (*Farfantepenaeus duorarum*)	common Feb-Apr	common Mar–June	common Aug–Apr	common Mar–Apr	common Aug–June	not present	common Nov–Mar abundant Apr-June	present spring	nursery area summer and fall	present year-round spawning area in summer
White shrimp (*Litopenaeus setiferus*)	highly abundant May–July common to abundant Aug–May nursery area	highly abundant Sept common to abundant May–Aug, Oct–Dec	abundant June–Nov common Dec	common Sept-Nov, Apr-May	abundant July–Oct common Nov–June nursery area	abundant Aug–Mar common Apr–June	common Nov–Jul abundant Aug–Oct nursery area	present summer	not present	present year-round Aransas and Corpus Christi bays present summer Upper Laguna Madre and Baffin Bay present year-round spawning Mar–Oct
Blacknose shark (*Carcharhinus acronotus*)	not present		present	not present	present	not present	present	not present	present	
Spinner shark (*Carcharhinus brevipinna*)	present	not present	not present		not present		not present		present	
Finetooth shark (*Carcharhinus isodon*)	not present		not present		not present		not present		present	

Common/Scientific Name*	Estuarine								Marine	
	San Antonio Bay		Aransas Bay		Corpus Christi/ Upper Laguna Madre		Baffin Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Bull shark (*Carcharhinus leucas*)	common Mar-Nov	not present	common Mar-Nov	not present	common Mar-Oct	not present	present		present	
Blacktip shark (*Carcharhinus limbatus*)	present		present		present		present		present	
Dusky shark (*Carcharhinus obscurus*)	not present		not present		not present		not present		present	
Tiger shark (*Galeocerdo cuvier*)	not present		present		present		not present		present	
Lemon shark (*Negaprion brevirostris*)	present		not present	present	not present	present	not present		present	
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)	present		present		present		not present		present	
Scalloped hammerhead shark (*Sphyrna lewini*)	present	not present	present	not present	present	not present	present	not present	present	
Great hammerhead shark (*Sphyrna mokarran*)	not present		not present		present		not present		present	
Bonnethead shark (*Sphyrna tiburo*)	present		present		present		present		present	
Red grouper (*Epinephelus morio*)	not present		not present		not present		not present		nursery area year-round	adult occurrence
Gag grouper (*Mycteroperca microlepis*)	not present		not present		not present		not present		not present	adult occurrence

Common/Scientific Name*	Estuarine								Marine	
	San Antonio Bay		Aransas Bay		Corpus Christi/ Upper Laguna Madre		Baffin Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Scamp (*Mycteroperca phenax*)	not present		not present		not present		not present		not present	adult occurrence
Cobia (*Rachycentron canadum*)	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	present summer
Dolphin (*Coryphaena hippurus*)	not present		not present		not present		not present		present year-round	
Greater amberjack (*Seriola dumerili*)	not present		not present		not present		not present		present year-round	adult and spawning area year-round
Lesser amberjack (*Seriola fasciata*)	not present		not present		not present		not present		not present	present
Red snapper (*Lutjanus campechanus*)	nursery area year-round	not present	nursery area year-round	not present	nursery area year-round	not present	not present		nursery area year-round	not present
Gray snapper (*Lutjanus griseus*)	nursery area	major adult area year-round	nursery area	major adult area year-round	nursery area	major adult area year-round	nursery area	major adult area year-round	not present	major adult area year-round spawn June–Aug
Lane snapper (*Lutjanus synagris*)	nursery area	not present	nursery area	not present	nursery area	not present	nursery area	not present	nursery area	not present
Vermilion snapper (*Rhomboplites aurorubens*)	not present		not present		not present		not present		nursery area	not present
Red drum (*Sciaenops ocellatus*)	common year-round nursery area	present year-round	common year-round nursery area	present year-round	common year-round nursery area	present year-round	common year-round nursery area	present year-round	not present	present year-round spawning area fall and winter
Little tunny (*Euthynnus alletteratus*)	not present		not present		not present		not present		present	

Common/Scientific Name*	Estuarine								Marine	
	San Antonio Bay		Aransas Bay		Corpus Christi/ Upper Laguna Madre		Baffin Bay			
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
King mackerel (*Scomberomorus cavalla*)	not present		not present		not present		not present		nursery area year-round	present year-round spawning area May–Nov
Spanish mackerel (*Scomberomorus maculatus*)	nursery area year-round	present year-round	nursery area year-round	present year-round	nursery area year-round	present year-round	nursery area year-round	present year-round	nursery area year-round	present year-round spawning area summer and fall
Sailfish (*Istiophorus platypterus*)	not present		not present		not present		not present		not present	present

Source: Nelson et al. (1992); NMFS (2009); NOAA (2013, 2016e); Pers. com. R. Swafford (NMFS, 2018).
* Species according to Page et al. (2013).

Table 2-13
Species Adult and Juvenile Presence in the Lower Texas Coast for Identified Essential Fish Habitat

Common/ Scientific Name*	Estuarine – Lower Laguna Madre		Marine	
	Juvenile	Adult	Juvenile	Adult
Brown shrimp (*Farfantepenaeus aztecus*)	common June–July abundant Aug–Nov major nursery area	common Mar–May	spawning area year-round	major adult and spawning area year-round
Pink shrimp (*Farfantepenaeus duorarum*)	common to abundant Sept–April nursery area year-round	common Mar–April adult and spawning area year-round	nursery area summer and fall	present year-round spawning area in summer
White shrimp (*Litopenaeus setiferus*)	common to abundant May–Nov nursery area	common Mar–May spawn Mar–Oct	not present	present year-round spawning area Mar–Oct
Blacknose shark (*Carcharhinus acronotus*)	not present		present	not present
Atlantic angel shark (*Squatina dumeril*)	not present		present	
Spinner shark (*Carcharhinus brevipinna*)	present	not present	present	
Silky shark *Carcharhinus falciformis*)	present		present	
Finetooth shark (*Carcharhinus isodon*)	not present		present	
Bull shark (*Carcharhinus leucas*)	present		present	
Blacktip shark (*Carcharhinus limbatus*)	present		present	
Tiger shark (*Galeocerdo cuvier*)	not present	present	not present	present
Lemon shark (*Negaprion brevirostris*)	present	not present	present	not present
Atlantic sharpnose shark (*Rhizoprionodon terraenovae*)	present		present	

Common/ Scientific Name*	Estuarine – Lower Laguna Madre		Marine	
	Juvenile	Adult	Juvenile	Adult
Scalloped hammerhead shark (*Sphyrna lewini*)	present	not present	present	
Great hammerhead shark (*Sphyrna mokarran*)	not present		present	
Bonnethead shark (*Sphyrna tiburo*)	present		present	
Red grouper (*Epinephelus morio*)	not present		nursery area year-round	adult occurrence
Gag grouper (*Mycteroperca microlepis*)	not present		not present	adult occurrence
Scamp (*Mycteroperca phenax*)	not present		not present	adult occurrence
Cobia (*Rachycentron canadum*)	nursery area spring-fall	not present	nursery area spring-fall	present spring-fall
Dolphin (*Coryphaena hippurus*)	not present		present year-round	
Greater amberjack (*Seriola dumerili*)	not present		present year-round	adult and spawning area year-round
Lesser amberjack (*Seriola fasciata*)	not present		not present	present
Red snapper (*Lutjanus campechanus*)	nursery area year-round	not present	nursery area year-round	not present
Gray snapper (*Lutjanus griseus*)	nursery area	major adult area year-round	not present	major adult area year-round spawning area June-August
Lane snapper (*Lutjanus synagris*)	nursery area	not present	nursery area	adult and spawning area year-round
Vermilion snapper (*Rhomboplites aurorubens*)	not present		nursery area	not present

Common/ Scientific Name*	Estuarine Lower Laguna Madre		Marine	
	Juvenile	Adult	Juvenile	Adult
Red drum (*Sciaenops ocellatus*)	common year-round nursery area	present year-round	not present	present year-round spawning area fall and winter
Little tunny (*Euthynnus alletteratus*)	not present		present	
King mackerel (*Scomberomorus cavalla*)	not present		nursery area year-round	present year-round spawning area May–Nov
Spanish mackerel (*Scomberomorus maculatus*)	nursery area year-round	present year-round	nursery area year-round	present year-round spawning area summer and fall
Sailfish (*Istiophorus platypterus*)	not present		present	not present
Blue marlin (*Makaira nigricans*)	present	not present	not present	

Source: Nelson et al. (1992); NMFS (2009); NOAA (2013, 2016e); Pers. com. R. Swafford (NMFS, 2018).
* Species according to Page et al. (2013).

Table 2-14
Migratory Birds Listed by the USFWS That May Be Found within the Study Area

Common Name	Scientific Name	Season(s)
Altamira Oriole	*Icterus gularis*	Year-round
American Golden Plover	*Pluvialis dominica*	Migrant
American Kestrel	*Falco sparverius paulus*	Year-round
American Oystercatcher	*Haematopus palliatus*	Year-round
Audubon's Oriole	*Icterus graduacauda audubonii*	Year-round
Audubon's Shearwater	*Puffinus Iherminieri*	Migrant
Band-rumped Storm-petrel	*Oceanodroma castro*	Migrant
Bewick's Wren	*Thryomanes bewickii*	Year-round
Black Rail	*Laterallus jamaicensis*	Year-round
Black Skimmer	*Rynchops niger*	Year-round
Botteri's Sparrow	*Aimophila botterii*	Breeding
Bridled Tern	*Onychoprion anaethetus recongnitus*	Migrant
Buff-breasted Sandpiper	*Tryngites subruficollis*	Migrant
Burrowing Owl	*Athene cunicularia*	Year-round
Cassin's Sparrow	*Aimophila cassinii*	Year-round
Cerulean Warbler	*Dendroica cerulea*	Migrant
Chestnut-collared Longspur	*Calcarius ornatus*	Migrant
Clapper Rail	*Rallus longirostris*	Year-round
Curve-billed Thrasher	*Toxostoma curvirostre*	Year-round
Dunlin	*Calidris alpina hudsonia*	Wintering
Eastern Whip-poor-will	*Antrostomus vociferus*	Breeding
Elf Owl	*Micrathene whitneyi*	Breeding
Gull-billed Tern	*Gelochelidon nilotica*	Year-round
Harris's Hawk	*Parabuteo unicinctus*	Year-round
Harris's Sparrow	*Zonotrichia querula*	Wintering
Henslow's Sparrow	*Ammodramus henslowii*	Breeding
Hooded Oriole	*Icterus cucullatus*	Breeding
Hudsonian Godwit	*Limosa haemastica*	Migrant
Kentucky Warbler	*Oporornis formosus*	Breeding
King Rail	*Rallus elegans*	Year-round
Lark Bunting	*Calamospiza melanocorys*	Wintering
Le Conte's Sparrow	*Ammodramus leconteii*	Wintering
Least Tern	*Sterna antillarum*	Year-round
Lesser Yellowlegs	*Tringa flavipes*	Wintering
Long-billed Curlew	*Numenius americanus*	Wintering
Magnificent Frigatebird	*Fregata magnificens*	Migrant
Marbled Godwit	*Limosa fedoa*	Wintering

Common Name	Scientific Name	Season(s)
Mountain Plover	*Charadrius montanus*	Wintering
Nelson's Sparrow	*Ammodramus nelsoni*	Wintering
Prairie Warbler	*Dendroica discolor*	Breeding
Prothonotary Warbler	*Protonotaria citrea*	Breeding
Red Knot	*Calidris canutus*	Wintering
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Year-round
Reddish Egret	*Egretta rufescens*	Year-round
Ruddy Turnstone	*Arenaria interpres morinella*	Wintering
Rufous-crowned Sparrow	*Aimophila ruficeps*	Year-round
Seaside Sparrow	*Ammodramus maritimus*	Year-round
Semipalmated Sandpiper	*Calidris pusilla*	Wintering
Short-billed Dowitcher	*Limnodromus griseus*	Wintering
Smith's Longspur	*Calcarius pictus*	Wintering
Snowy Plover	*Charadrius alexandrinus*	Year-round
Sprague's Pipit	*Anthus spragueii*	Wintering
Swallow-tailed Kite	*Elanoides forficatus*	Breeding
Varied Bunting	*Passerina versicolor*	Breeding
Whimbrel	*Numenius phaeopus*	Wintering
Willet	*Tringa semipalmata*	Year-round
Wilson's Plover	*Charadrius wilsonia*	Breeding
Wood Thrush	*Hylocichla mustelina*	Breeding
Yellow Rail	*Coturnicops noveboracensis*	Wintering

Source: Audubon (2017), USFWS (2018g).

2.4.5.5 Marine Mammals

The Marine Mammal Protection Act of 1972 was established to prevent the decline of marine mammal species and populations. It prohibits the taking (harassment, injury, killing) and importing of marine mammals and products into the United States. As cooperating agencies, NMFS and USFWS were consulted during preparation of the DIFR-EIS to solicit information on marine mammals inhabiting the proposed project area and identify data gaps and potential risks regarding possible project alternatives.

The two species of concern primarily discussed in the DIFR-EIS are the common bottlenose dolphin (*Tursiops truncatus*) and the Federally threatened West Indian manatee (*Trichechus manatus*). The West Indian manatee occurs as an occasional vagrant within estuarine habitats, though historically they were considered common in south Texas, with 66 records in Texas dating back to 1912. Manatee in Texas may stray from populations in either Florida or Mexico as an extension of their natural seasonal migration in warm weather or possibly in response to Gulf conditions during notably active hurricane seasons (Würsig, Jefferson et al., 2000).

Common bottlenose dolphins are known to inhabit bays, estuaries, and nearshore waters of Texas. Currently, there are six bay, sound, and estuary (BSE) stocks found in Texas, and a seventh stock located near the Texas/Louisiana border and a nearshore coastal stock, all of which are considered "strategic" (Hayes et al., 2018; Waring et al., 2013). The "Galveston Bay, East Bay, Trinity Bay" stock is thought to contain the largest population of common bottlenose dolphins of the six BSE stocks found in Texas. While it is thought that the BSE stocks are relatively discrete, research using genetic data suggests there may be some overlapping of adjacent stocks as evidenced by documented clinal variation along the Gulf coast. Hayes et al. (2018) state that marine mammals are vulnerable to many stressors and threats including disease, biotoxin, pollution, habitat alteration, vessel collisions, human feeding of and activities causing harassment, interactions with commercial and recreational fishing gear, energy exploration activities and oil spills, and other types of human disturbance, such as underwater noise. Other stressors thought to be specific to Galveston Bay include hypoxia, adverse weather, and freshwater inflows. Although dolphins in Galveston Bay are often associated with areas of human impact and anthropogenic activities, these risks when combined with limited and outdated information on population structure, abundance, or mortality led NOAA to assign Galveston Bay a "high priority" ranking for stock assessment research and the highest risk score for the Texas coast in the assessment (Phillips and Rosel, 2014). A more-detailed discussion is included in Appendix C-1, Section 2.4.5 of this DIFR-EIS.

2.5 CULTURAL RESOURCES

There are over 5,200 cultural resources recorded within the study area. Many of these resources have national and regional significance and are either listed on or are eligible for inclusion in the National Register of Historic Places. Additionally, almost all cultural resources within the study area are at risk from hurricane storm damage to varying degrees. Those resources at highest risk are archeological sites along coastal and bay shorelines where storm surge wave action and flooding can cause severe erosion, historic buildings and structures that can be destabilized or destroyed by wave action and flooding, and submerged resources, such as shipwrecks, which can be exposed and dispersed by shifting sea floor and bay bottom during violent storm events. Indirectly, cultural resources whose owners lack sufficient money or resources to rehabilitate damaged properties could be lost entirely. See Section 2.5, Appendix C-1 for a more detailed discussion.

2.6 SOCIOECONOMIC CONSIDERATIONS

More than one-quarter of the Texas population has lived within the coastal counties. More than 6.4 million residents live in the study area, and more than 80 percent of those reside along the upper Texas coast (Wilson and Fischetti, 2010; U.S. Census Bureau, 2018). Within the study area, numerous coastal communities are at risk from storm surge, where approximately 673,346 structures are located. Over 3,500 critical infrastructures are at risk, including electricity, gas distribution, water supply, transportation, education, and community services (e.g., police, fire department, etc.). Severe storm surge events threaten the health and safety of residents living within the study area. Loss of life, injury, and post-flood health hazards may occur in the event of catastrophic flooding. There are 140 medical care facilities, 364 police stations/sheriff's offices, and 672 fire stations located within the study area (NOAA, 2018b). Within the study area, 14.8 percent of the population fall below the poverty level;

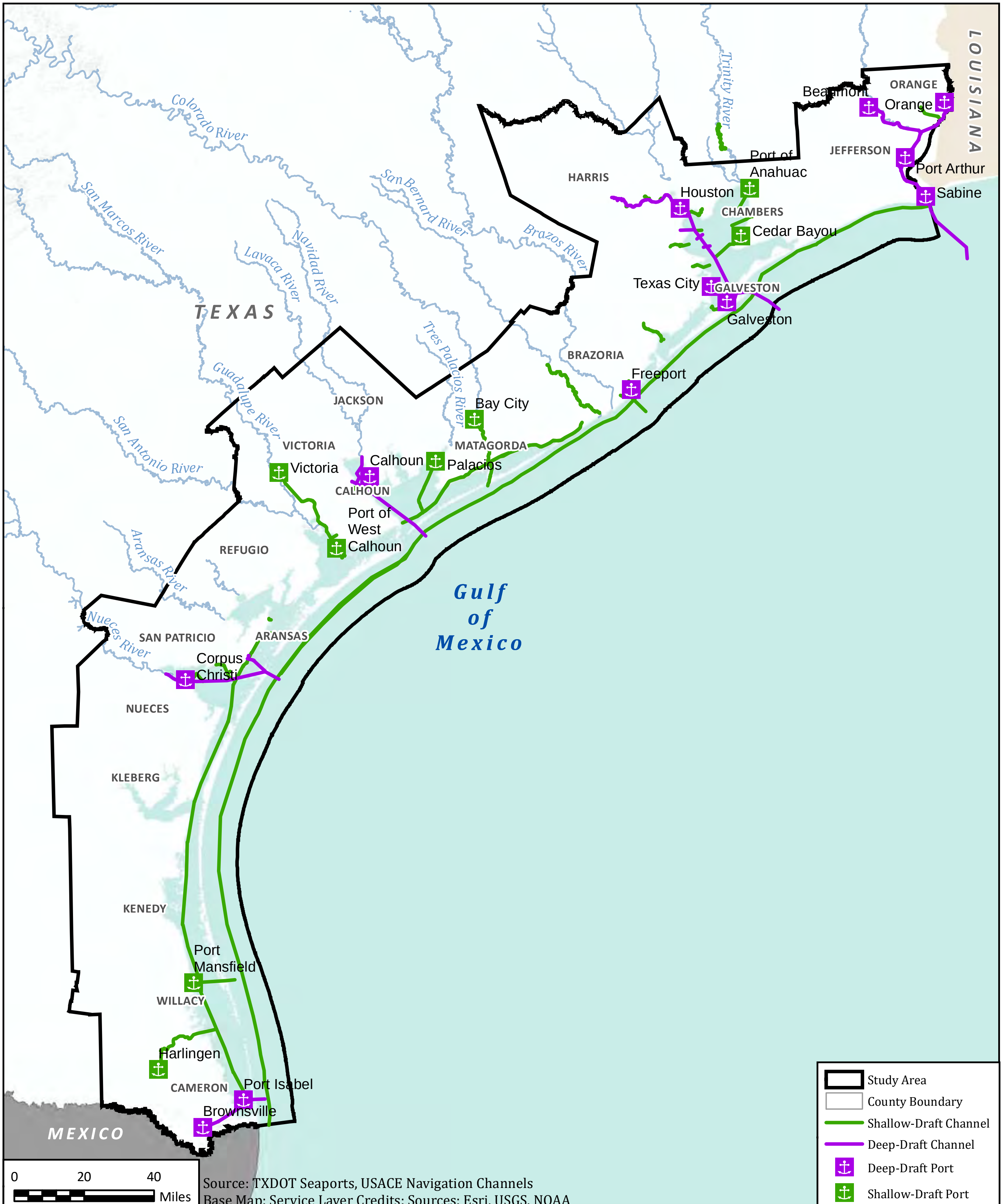
much of those populations are found in the lower coastal counties. Minority residents make up 16 percent of the population in the study area (U.S. Census Bureau, 2018). Recreation and tourism play a large role in the study area, with over 50 NWRs, WMAs, State Parks, preserves, etc.; outstanding fishing, birding, and waterfowl-hunting opportunities; and nature tourism opportunities.

2.7 NAVIGATION

Texas ports and waterways consist of a mix of deep-draft and shallow-draft commercial ports, fishing and recreational ports, and the GIWW, with roughly 270 miles of deep-draft channels (greater than 15 feet deep) and 750 miles of shallow-draft channels (less than 15 feet deep) (Figure 2-10) (Demirbilek and Sargent, 1999; USACE, 2012a). These ports and waterways are major contributors to the economy and security of the State of Texas and the Nation, and additionally serve as key gateways for domestic and international freight movement (Texas Ports Association, 2017; TxDOT, 2016a). Texas ports accommodate comprehensive ports, which handle multiple cargo types, specialized ports that handle large volumes of one cargo type, and niche ports, which provide nontraditional services or cargo that is very specific (TxDOT, 2016b).

2.7.1 Commercial Waterborne Commerce

Commercial waterborne commerce in Texas is supported by ports with 11 major deep-draft channels (25 feet or deeper) and six ports with shallow-draft channels, all of which are linked by the GIWW and connected to the Gulf, one of the world's most important oil and gas production and refining regions, to statewide, national, and international markets (tables 2-15 and 2-16; TxDOT, 2014). The Port of Houston is the largest port in Texas handling 248 million tons of cargo (USACE, 2016). The GIWW is a man-made and protected waterway that links Texas's ports, moving 73 million tons of cargo per year and over $31 million annually in wholesale seafood products (NMFS, 2016b; TxDOT, 2014, 2016a, 2017). The USACE, in partnership with its NFSes, is responsible for maintenance of these channels to their authorized dimensions dependent upon Congressional appropriations (Gulf of Mexico Alliance, 2010). On average, the USACE dredges between 30 and 40 million cubic yards (mcy) of maintenance dredged material on an annual basis (Table 2-17; USACE, 2012a).



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USACE COASTAL TEXAS
PROTECTION AND RESTORATION STUDY

Texas Ports and Navigation Channels

FN JOB NO	COH16388
FILE NAME	2-10TXPorts_Nav_Chan.mxd
DATE	10/9/2018
SCALE	1:2,377,085
DESIGNED	SSJ
DRAFTED	SSJ

2-10

FIGURE

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NAD 1983 Texas Centric Mapping System Albers

Table 2-15
Texas Deep-Draft Port Dimensions, Statistics, and Rankings

Ports	Official Name	Classification	Channel Depth (feet)	Channel Width (feet)	Length (miles)	Port Ranking	Cargo (million tons)
Port of Orange	Orange County Navigation and Port District	Niche	30	200	30	150	0.8
Port of Beaumont	Port of Beaumont Navigation District of Jefferson County	Comprehensive	40	400	40	5	84.5
Port of Port Arthur	Port of Port Arthur Navigation District	Specialized	40	450	19	20	35.2
Port of Houston	Port of Houston Authority	Comprehensive	45	530	61	2	248
Port of Texas City	Texas City Terminal Railway Company	Specialized	40–45	1,200	27	15	41.3
Port of Galveston	Board of Trustees of the Galveston Wharves	Comprehensive	45	1,200	9	52	9.9
Port Freeport	Port Freeport	Comprehensive	45	400	8	33	19.6
Calhoun Port Authority	Calhoun Port Authority	Specialized	36	200	24	76	4.9
Port of Corpus Christi	Port of Corpus Christi Authority of Nueces County, Texas	Comprehensive	45	300	35	6	82
Port Isabel	Port Isabel-San Benito Navigation District	Niche	36	200	21	N/A	N/A
Port of Brownsville	Brownsville Navigation District	Specialized	42	250	21	66	7.3

Source: TxDOT (2016a); USACE (2016).

Table 2-16
Texas Shallow-Draft Port Dimensions, Statistics, and Rankings

Ports	Official Name	Classification	Channel Depth (feet)	Channel Width (feet)	Length (miles)	Port Ranking	Cargo (million tons)
Cedar Bayou	Cedar Bayou Navigation District, Chambers-Liberty Counties Navigation District	Niche	11	N/A	N/A	N/A	N/A
Port of Bay City	Port of Bay City Authority Matagorda County, Texas	Niche	12	200	12+	N/A	N/A
Port of Palacios	Matagorda County Navigation District No. 1	Niche	12	125	4	N/A	N/A
Port of Victoria	Victoria County Navigation District	Specialized	12	125	35+	74	5.1
Port of West Calhoun	West Side Calhoun County Navigation District	Niche	12	N/A	N/A	N/A	N/A
Port of Harlingen	Port of Harlingen Authority	Niche	12	125	25+	N/A	N/A

Source: TxDOT (2016a); USACE (2015b, 2016).

Table 2-17
USACE Average Annual Maintenance Dredging Volumes in Coastal Texas

Navigation Channel	Total Quantity Sediment Dredged Annually (cubic yards)
Sabine-Neches Waterway Port Arthur Canal, Turning Basin, Junction Area, and Taylors Bayou	3,000,000
Sabine Neches Waterway Outer Bar and Bank Channel	2,500,000
Texas City Channel Main Channel and Turning Basin	1,500,000
Galveston Harbor Channel	2,000,000
Houston Ship Channel Morgan's Point to Exxon and Barbour's Cut Channel	2,500,000
Houston Ship Channel-Bayport Flare and Redfish Reef to Morgan's Point	3,500,000
Galveston Harbor-Galveston Entrance Channel and Houston Ship Channel – Bolivar Roads to Redfish	2,500,000
Freeport Harbor – Entrance Channel	2,600,000
Matagorda Ship Channel Matagorda Peninsula to Point Comfort	3,000,000
Corpus Christi Ship Channel Entrance Channel	1,000,000
Corpus Christi Ship Channel Inner Basin to Viola Turning Basin/ La Quinta Channel	2,500,000
Brazos Island Harbor Brownsville Jetty Channel	400,000
GIWW, Corpus Christi to Port Isabel	1,500,000
GIWW, Galveston Causeway to Bastrop Bayou	1,000,000
GIWW, Rollover to Causeway	800,000
GIWW, Turnstake to Live Oak	600,000
GIWW, High Island to Rollover and Bolivar Flare	800,000
GIWW, Channel to Victoria Lower and Middle Reach	1,500,000

Source: USACE (2015c).

2.7.2 Recreational

According to Stokes and Lowe (2013), 7.8 million state residents and non-residents participated in some form of fishing, hunting, and wildlife-watching-related recreation, and the combined economic impact of these recreational activities totaled over $5 billion in annual spending and $181 million in State and local annual tax revenue generated. Fishing alone accounted for approximately $1.85 billion in economic activity, and hunting and wildlife viewing across the State accounted for over $43.5 billion in annual economic value. The economic significance of recreational boating for the combined Texas Congressional Districts in which the proposed ER and CSRM alternative plans are proposed, totaled $416 million in 2008 (Table 2-18).

Table 2-18
Critical Infrastructure in the Study Area

Coastal Area	County	Schools	Law Enforcement	Fire/EMS	Hospital/ Medical	Percent in FEMA Floodplain
Upper	Brazoria	116	34	50	3	14
	Chambers	14	10	8	2	--
	Galveston	115	34	48	5	26
	Harris	1,434	132	340	80	9
	Jefferson	109	22	40	12	4
	Orange	29	15	15	2	25
	Subtotal	1,817	247	501	104	
Mid	Aransas	7	3	9	--	--
	Calhoun	11	5	9	1	4
	Jackson	10	7	7	1	12
	Kleberg	26	6	7	1	4
	Matagorda	26	11	15	2	7
	Nueces	153	18	41	13	12
	Refugio	7	7	6	1	--
	San Patricio	37	13	17	2	--
	Victoria	44	4	22	4	3
	Subtotal	321	74	133	25	
Lower	Cameron	182	31	32	11	9
	Kenedy	1	2	--	--	--
	Willacy	16	10	6	--	50
	Subtotal	199	43	38	11	
Total		2,337	364	672	140	

Source: NOAA (2018b).

2.8 FLOOD RISK REDUCTION

Flood risk reduction projects in the study area include the Texas City Hurricane Flood Protection Project (HFPP), the Lynchburg Pump Station, and the Colorado River Flood Protection at Matagorda. All these projects are Federally authorized and locally operated and maintained. The Texas City HFPP has had performance issues during storm events, and mitigation and repair efforts are currently being developed. The Lynchburg Pump Station currently performs as intended with no issues. The Colorado River Flood Protection at Matagorda continues to perform as intended.

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3.0 NO-ACTION/FUTURE WITHOUT-PROJECT CONDITIONS (*NEPA REQUIRED)

The USACE is required to consider the FWOP alternative (called the “No-Action” Alternative) during the planning process and assessment of impacts to comply with USACE regulation and guidance for planning as well as consideration of NEPA. With the FWOP, it is assumed that no project would be implemented by the Federal government or by local interests to achieve the planning objective. The FWOP forms the basis against which all other alternative plans are measured.

The FWOP condition assumes the continuation of existing conditions for the resources listed above; no improvement of existing hurricane flood risk reduction projects; no intervention to reduce the impacts of storm surge on the vulnerable populations and infrastructure of the study area; and no large-scale ER efforts to improve the sustainability of fragile coastal systems and attenuate storm surge. The FWOP condition does consider those projects that have been completed (existing), are under construction, or have been authorized for construction. For the projects that are under construction or authorized for construction, their footprints and actions are included in this analysis as if they existed. Any proposed projects, which are not yet authorized for construction, are not considered part of the FWOP conditions for analysis.

The following summarizes the No-Action Alternative, a more detailed discussion can be found in Section 3.0 of Appendix C-1.

3.1 CLIMATE CHANGE

Climate change would continue to influence coastal climates in Texas over the 50-year period of analysis and longer. Average surface temperatures are expected to rise, more-frequent hot and fewer cold temperature extremes are expected, more severe and frequent flooding and droughts might occur (International Panel on Climate Change, 2014; Shafer et al., 2014; TWDB, 2012). Eustatic SLR is likely to exceed 0.07 to 0.09 inch per year and may reach 0.31 to 0.63 inch per year by the end of this century (International Panel on Climate Change, 2014).

3.2 PHYSICAL RESOURCES

3.2.1 Physical Oceanography

There would be no direct impacts to physical oceanography under the No-Action Alternative. Changes in physical oceanography are expected to occur in the future. Salinity regimes in estuaries would be expected to change. Rising sea levels are expected to increase tidal exchange through existing passes with the Gulf and may increase the frequency of washovers and size of washover areas on barrier islands along with erosion of barrier island shorelines (BEG, n.d.). Increasing tidal exchange with the Gulf from widening and deepening ship channels, combined with breaches in barrier islands, increased frequency, and some amount of barrier island washover and increased bay shore perimeter from RSLR would likely increase tidal range, tidal prisms, storm surge heights, and bay shore erosion (Holleman and Stacey, 2014; Passeri et al., 2015; Passeri et al., 2016).

3.2.2 Coastal Processes

There would be no direct impacts to coastal processes by implementing the No-Action Alternative. Indirect impacts include barrier islands and coastal wetlands, which have historically protected coastal Texas from tropical and hurricane storm surges and are prone to future erosion, fragmentation, and loss resulting from continued coastal development and reduced sediment delivery affecting the natural processes to sustain these features as natural buffers against surges. Climate change could increase hurricane development and intensity, and RSLR could magnify frequency and duration of coastal flooding.

3.2.3 Water and Sediment Quality

Water and sediment quality trends would not change with the No-Action Alternative and would continue as described in Section 2.3.4, Appendix C-1. Increased flooding from storms may mobilize nutrients, metals, and synthetic organic hydrocarbons and transport them into estuarine waters and wetlands. Climate change and RSLR may raise water temperatures and salinities in estuaries. Increased tidal flushing with Gulf waters may decrease nutrient and plankton concentrations and increase transparency; however, increased human population growth and coastal development may increase nutrient loading, cause algal blooms, and decrease transparency in estuaries. Saltwater intrusion and inundation of marshes may kill plants and release sediments into the water column as plants die. Estuaries may increase in clarity in one area from increased seawater intrusion, and turbidity may increase in other areas due to marsh inundation.

3.2.4 Hydrology

Under the No-Action Alternative, there would be no direct impacts to watershed and river basin hydrology. However, climate change is expected to increase drought severity, which may increase agriculture, municipal, industrial, and commercial freshwater demand and diminish reservoir storage and freshwater inflows to bays and estuaries. Without sufficient freshwater flows and saltwater barriers, salinity levels in estuaries would transition from a brackish to saltwater ecosystem. Rising sea level and saltwater intrusion into bays and tributaries can modify habitat. Increase groundwater withdrawals among aquifers, such as the Gulf Coast Aquifer, could lead to further subsidence and flooding in low-lying areas.

3.2.5 Soils (Prime and Other Important Unique Farmland)

Under the No-Action Alternative, there would be no direct impacts to soil and prime farmlands. However, there would be the continued degradation and loss of soil resources as well as prime and unique farmlands due to saltwater intrusion from RSLR and conversion for development.

3.2.6 Energy and Mineral Resources

The No-Action Alternative would result in no direct impacts on energy and mineral resources. Trends that are presently occurring would continue, including shoreline recession, land loss, subsidence, and increased storm intensity. The loss of coastal island barriers and marshes would reduce the natural protection for energy and mineral resources, including oil and gas pipelines and infrastructure, increasing their susceptibility to damage.

3.2.7 Hazardous, Toxic, and Radioactive Waste Concerns

The No-Action Alternative would result in no direct impacts on hazardous materials associated with regulated facilities and shipping traffic. As industrial activity continues to increase to accommodate future anticipated demands for petroleum products, additional indirect impacts would occur. Continued RSLR and hurricane storm surges would increase degradation of natural and man-made seawalls, levees, and barrier islands leaving industrial facilities more susceptible to damage, increasing the potential for the release of waste materials into the environment. Due to climate change, storm intensity could increase, potentially causing increased damage to industrial facilities.

3.2.8 Air Quality

The No-Action Alternative would have no direct impacts on air quality. Trends would include continued degradation of air quality along coastal areas due primarily to increasing populations, commercialization, industrialization, increased use of motor vehicles, continued oil and gas exploration, and refinement operations.

3.2.9 Noise

Existing noise conditions would continue as described in Section 2.3.11 under the No-Action Alternative. Noise generated by existing noise sources (e.g., waterborne transportation, automobile and train transportation, recreation and commercial enterprises, industrial operations, port activities) would continue into the future.

3.3 ECOLOGICAL AND BIOLOGICAL RESOURCES

3.3.1 Wetlands

Under the No-Action Alternative, there would be no direct impacts to non-tidal or tidal wetlands. The trends of wetland loss would continue due to development, population growth, increased water demand, potentially decreased water quality, and RSLR. In response to RSLR, in some areas where coastal elevations are low and slopes inland are gradual, tidal wetlands could potentially migrate inland and increase in area or extent.

There would be no direct impacts to seagrass resources by implementing the No-Action Alternative. Some areas along the Texas coast are expanding in area (i.e., mid and lower Texas coast), while some are declining (i.e., Galveston Bay). These changes in seagrass are due to RSLR, water quality, and population growth.

3.3.2 Aquatic Resources

There would be no direct impacts to aquatic resources by implementing the No-Action Alternative. However, shoreline erosion, subsidence, and land loss would continue, converting marsh to marine and open-water habitats.

Freshwater habitats have been impacted by modification or loss due to coastal development, including channelization and development for residential and industrial purposes, major navigation projects, saltwater intrusion, subsidence, water demands due to population increases, and RSLR. These processes and activities would decrease freshwater habitats in the study area.

Impacts to estuarine communities are due to climate change stressors (RSLR, temperature increases, salinity changes, and wind and water circulation changes), storm severity and frequency, and USACE dredging and maintenance-dredging operations. As sea level rises, it is predicted that there will be decreases in existing marsh areas and tidal flats and increases in open water and marsh fragmentation (Kearney and Rogers, 2010). As this occurs, nursery production might be negatively affected initially, but ultimately producing positive changes in production due to the increase in marsh-edge habitat that results from fragmentation (Chesney et al., 2000; Fulford et al., 2014; Minello et al., 2003). The general consensus among the scientific community is that as long as there is sufficient habitat, the biological community could adapt to RSLR (pers. comm. Jim Tolan [TPWD], 2017).

3.3.3 Wildlife Resources

There would be no direct impacts to wildlife resources by implementing the No-Action Alternative. However, continued human development and encroachment into wildlife habitat could decrease species diversity and abundance. RSLR would likely inundate low-lying marshes, beaches, and islands, which provide valuable stopover habitats for nesting and migrating avian species. With the loss of suitable habitat, wildlife could be forced to relocate to alternative areas causing loss of biodiversity, tourism, and recreational income for the Texas coast.

3.3.4 Protected Lands

3.3.4.1 Protected Lands

There would be no direct impacts to protected lands by implementing the No-Action Alternative. Indirect impacts could occur if shoreline stabilization or nourishment projects do not occur on State and Federal lands. Wildlife habitat on protected lands could be lost, forcing wildlife to use suboptimal habitats or relocate.

3.3.4.2 Threatened and Endangered Species

There would be no direct impacts to threatened and endangered species by implementing the No-Action Alternative. Impacts would likely occur to sea turtle, piping plover, and rufa red knot habitat due to rising sea level and shoreline erosion. Increased saltwater intrusion, stronger storm surges, and human development could impact the Texas prairie dawn-flower (*Hymenoxys texana*) and Attwater's prairie chicken (*Tympanuchus cupido* *attwateri*) due to coastal prairie loss. Conversely, increasing open water and marsh fragmentation could potentially benefit the largetooth sawfish (*Pristis pristis*) and West Indian manatee.

3.3.4.3 Essential Fish Habitat

Under the No-Action Alternative, there would be no direct impacts to EFH resources. Impacts due to climate change stressors, severe storms, and USACE dredging and maintenance-dredging operations would continue to have an impact to EFH managed species; however, no long-term effects are anticipated. It is anticipated that open water and marsh habitat would increase because of RSLR, benefiting larval stages of some fish and shellfish species (Guannel et al., 2014; Kearney and Rogers, 2010). As salt marsh fragments, marsh edge increases, which increases nursery habitat and could potentially benefit EFH managed species (Chesney et al., 2000; Minello et al., 2003).

3.3.4.4 Migratory Birds

There would be no direct impacts to migratory birds by implementing the No-Action Alternative. Indirect impacts associated with habitat loss resulting from RSLR, urban development, and increased storm intensity are expected to continue.

3.3.4.5 Marine Mammals

Texas marine mammals are subject to many stressors, and with outdated population assessments, Texas BSE estuary common bottlenose dolphin stocks are considered "strategic" within Galveston Bay, and West Bay stocks have received a "high priority" ranking. Under the No-Action Alternative, coastal and BSE stocks would likely continue to be exposed to the current environmental conditions, habitat, resources, and stressors as modified by increased human populations, urbanization, and different climatic conditions. The major additional factors that may influence dolphin stocks are climate change, projected water demand that would reduce freshwater inflows, and planned projects outside the scope of this project.

As described in Section 2.4.5.5, Texas marine mammals are subject to many stressors, and with outdated population assessments, Texas BSE stocks are considered "strategic" with the Galveston Bay and West Bay stocks receiving a "high priority" ranking (Waring et al., 2016). Based on current stock assessment data, future risks and stock status as described in Section 2.4.5.5 would likely remain under the No-Action Alternative.

3.4 CULTURAL RESOURCES

There are an estimated 247 cultural resources located within the CSRM measures and 97 cultural resources within the ER measures. The formation processes that currently affect these sites would continue into a FWOP. Submerged cultural resources could be at risk from future dredging activities, shifting bars, and wave damage for shallow sites. Submerged resources are also at risk from high-energy storms that can dislodge wrecks from the seafloor or impact wrecks on beaches or in shallow water. Upland historic and prehistoric sites would continue to be at risk from shoreline erosion and commercial, industrial, and residential development. Shoreline sites are also at risk from RSLR and storm surge. These formation processes may result in partial or total loss of historic properties.

3.5 SOCIOECONOMIC CONDITIONS

The overall population is projected to increase coastwide; however, in the upper coast, the population is expected to increase under the No-Action Alternative due to the robust economics of the area. Coastal structures would continue to be impacted by storm surges and increased potential for damage due to RSLR. Public facilities, community services, and community cohesion would continue to be impacted by hurricane storm surge events. The area's social vulnerability is expected to increase over time as subsidence and SLR continues to increase, which in turn would increase the area of influence of storm surges.

3.6 NAVIGATION

Under the No-Action Alternative, and as reported by TxDOT (2016a), it is anticipated the economy of the State and Nation would continue to grow, placing greater demands on port infrastructure and efficiency of transport. Along Texas's inland waterway system, wave action from barge traffic within the GIWW has and would continue to induce shoreline erosion and wetland loss. Additionally, an increasing population in Texas would increase shoreline development along navigable waterways, including marinas, residential developments, docks, piers, and other shoreline modifications, resulting in further safety concerns. These anthropogenic waterborne activities coupled with RSLR and future storm events threaten the stability and integrity of existing coastal wetlands and marshes that serve as a natural barrier to protect the GIWW's barge traffic from storm-induced winds and waves and from excessive channel shoaling. Continued degradation of these natural coastal resources features will increase the risk to navigation safety and increase the frequency and expense of maintenance dredging (GLO, 2016).

The expanded Panama Canal complex would increase in cargo throughput at some Texas ports, although the throughput volumes would most likely not be dramatic and future trade patterns for Texas ports would be governed more by population increases and economic growth (TxDOT, 2016b). Economic growth in Texas is also supported by improvements to deep-draft navigation channels and continued maintenance of existing and authorized deep-draft and shallow-draft navigation channels.

3.7 FLOOD RISK REDUCTION

Under the No-Action Alternative, the Texas City HFPP is currently reducing flood risks to the Texas City and La Marque areas. Identified deficiencies and replacement items are currently being provided by the NFS, Galveston County. The Lynchburg Pump Station levee system risk is considered low. Identified deficiencies and replacement items are currently being provided by the NFS, Coastal Water Authority. The Colorado River Flood Protection at Matagorda risk is considered moderate. Identified deficiencies and replacement items are currently being provided by the NFS, Port of Bay City Authority.

The current level of risk reduction of these features could be affected by population growth, RSLC, and storm intensity. However, local communities could make improvements to the system to offset these impacts.

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4.0 FORMULATION AND EVALUATION OF ALTERNATIVE PLANS

Plan formulation supports the USACE water resources development mission. A systematic and repeatable planning approach is used to ensure that sound decisions are made. The Principles and Guidelines describe the process for Federal water resource studies and requires formulating alternative plans that contribute to Federal objectives. The sections below describe the plan formulation process used to identify the TSP. This section of the DIFR-EIS will be used to inform decisionmakers, stakeholders, and the public of the tradeoffs that should be considered. Future decisions that are required to maintain existing coastal storm risk levels and/or reduce coastal storm risk and future decisions required to maintain, protect, and restore Texas coastal ecosystems and fish and wildlife habitat along the Texas Gulf coast are discussed in this section. See Section 5.0 (Tentatively Selected Plan) for complete details of the finalized plan and recommendations.

> ***Note***: Once the report has undergone a public review, policy review, ATR, IEPR, and once the TSP has undergone further development under future planning and design phases, additional sections in the final report will be added to describe any additional planning efforts undertaken to account for comments received on the DIFR-EIS.

4.1 FOCUSING THE STUDY EFFORTS

As discussed in Section 1.0, the initial plan formulation process focused on four areas of the Texas coast within the study area. As the planning process progressed, the planning criteria and goals were further refined to reduce the complexity of the scope of the problems and opportunities. By focusing in on these four areas, specific planning objectives were developed to guide the development and screening of management measures. The PDT still continued to refer back to the overall problems, opportunities, and objectives listed in Section 1.0 to ensure that a comprehensive plan was being developed for the entire Texas coast. Figure 4-1 and the sections below explain this process and the rationale for this step of the planning process.

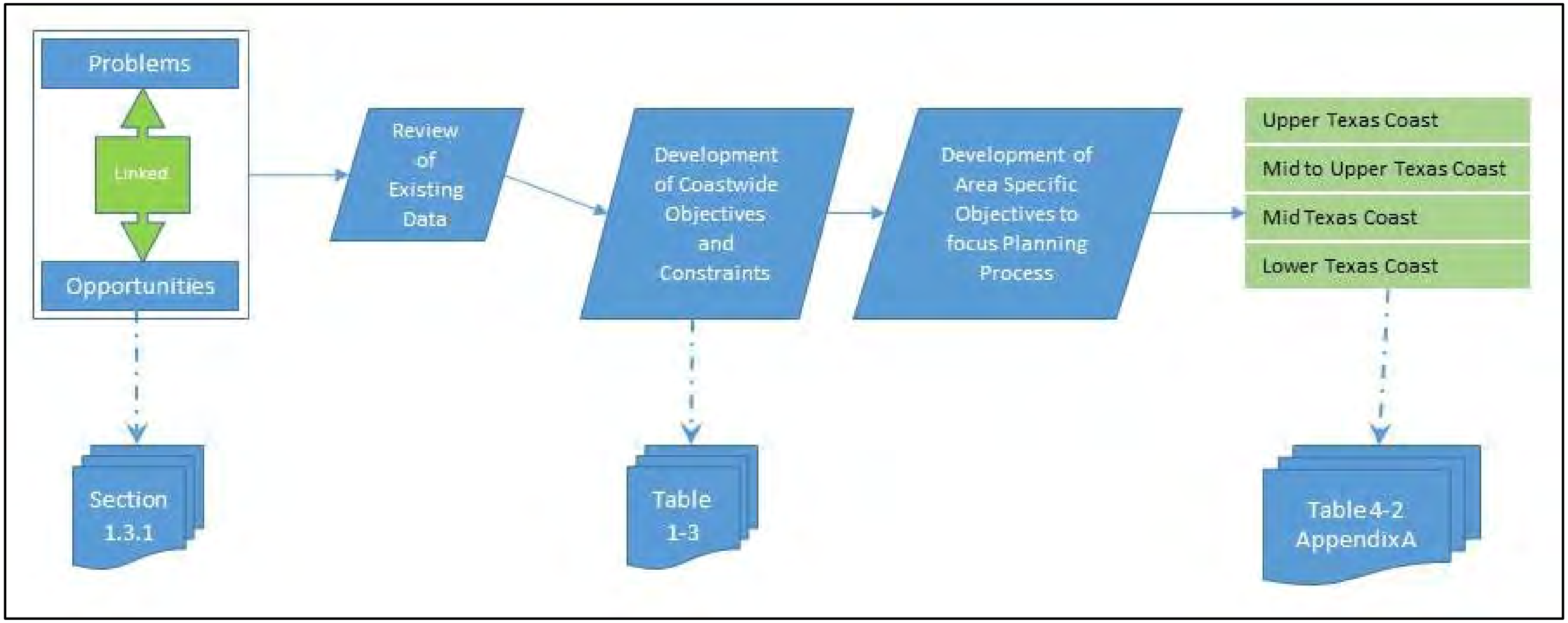

Figure 4-1: Focusing the Coastal Texas Study Efforts

4.1.1 Expanded Problems and Opportunities with Linked Specific Objectives

The problems and opportunities definition provided in Section 1.0 provided a general assertion of the basic problems the Texas coast is facing. Using the four sections of the coast, the team considered the existing conditions and the FWOP conditions presented in sections 2.0 and 3.0 while expanding the problems and opportunities to identify the nature, cause, location, dimensions, origin, timeframe, and importance of the problem. For example, in the Upper Texas Coast the problems and opportunities were expanded to highlight the CSRM and ER issues in the Galveston Bay region (Table 4-1). The PDT also recognized that without well-defined planning objectives the team would not be able to clearly lay out the purpose of the study in the four very different sections of the coast. In order to facilitate the plan formulation, specific objectives and durations were also developed for the four areas to further refine the investigations across the Texas coastline. Table 4-2 shows the specific objectives developed for the upper Texas coast. The Plan Formulation Supporting Information (Appendix A) provides a detailed overview of the expanded problem and opportunities while linking objectives throughout all four geographic areas of the Texas coast.

These problems, opportunities, and specific objectives (tables 4-1 and 4-2) helped the team focus its planning efforts. For example, when reviewing the description of life, health, and welfare (Facilities), the objective focuses the study on reducing risk on specific critical infrastructure (e.g., SH 87 and SH 146 access routes) in the upper Texas coast. This process was continued throughout the remaining areas of the Texas coast. In some areas this led to refinements of the expected problems, opportunities, and linked objectives.

Another example of focused planning was an initial problem identified with coastal storm damages in the area of Corpus Christi in the mid Texas coast. A detailed review of the structure inventory showed that many of the structures were outside the areas of high risk from surges or that these structures are elevated above these surge impacts (Figure 4-2).

The PDT also reviewed the current 100- and 500-year Federal Emergency Management Agency (FEMA) floodplains (Figure 4-3). The data showed some of the same results as the NOAA Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Models. Many of the structures in areas of Corpus Christi had limited risk from coastal storm surges due to their location in the coastal landscape or they had already been elevated above the frequent surge elevations. More-frequent surges historically have impacted the densely populated areas along the upper and lower Texas coast that are at lower elevations.

Also, when reviewing the historical shoreline erosion rates, there were mainly three areas with high erosion rates (figures 4-4 and 4-5). Many of the other areas are stable. This led the PDT to refine some of the specific objectives related to ER for the four areas of the Texas coast.

Table 4-1
Expanded Problems and Opportunities for the Upper Texas Coast

Problems	Opportunities
CSRM:	
• Populations are vulnerable to life safety from flooding due to their close proximity to the coast. This includes the fourth largest U.S. city (Houston) and other key metropolitan areas such as Beaumont/Port Arthur/Orange, Galveston/Texas City, and Freeport/ Surfside; • Flood risk increase in the industrial section of the upper Galveston Bay system due to coastal storm surges. The area at risk includes nine of the largest oil refineries in the world, 40 percent of the Nation's petrochemical industry, 25 percent of the Nation's petroleum-refining capacity, 60 percent of the U.S. jet fuel production, and includes two of the Nation's strategic petroleum reserves; • Local existing hurricane risk reduction systems are increasingly at risk from coastal storms due to RSLR. Majority do not meet current design standards for resiliency and redundancy; • Infrastructure associated with nationally important deep-draft seaport and shallow-draft channels is susceptible to flood and hurricane storm damages, particularly the Port of Houston which is number one in importing fuel, and the Port of Beaumont which is the number one military outload port in the world; • Critical infrastructure throughout the region, including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools are at risk of damage due to storm events. Also, there is the potential for release of HTRW to the sensitive environmental areas due to storm surge impacts on refineries and tank farms.	• Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induced storm damages along Galveston Island, Bolivar Peninsula, and along the interior of the Galveston Bay system; • Improve flood warnings for preparation and/or evacuation; • Improve emergency response vehicle access during and following hurricane and tropical storm events; • Reduce region's population vulnerable to life safety issues from storm surge flooding.
ER:	
• Loss of fish and shellfish habitat in the Galveston Bay system due to navigation impacts and increased salinities; • Gulf shoreline erosion along the Texas-Louisiana coastal marshes due to loss of longshore sediment transportation, particularly in areas near the Texas Point NWR and from the Clam Lake Road area to High Island in the McFaddin NWR area; • Gulf shoreline erosion along the mid-coast barrier islands and coastal marshes near the Brazos River due to the redirection of riverine flows; • Saltwater intrusion in the Galveston Bay estuary due to breaches in the barrier islands system resulting from coastal storms reduces the long-term sustainability of coastal wetland systems; • Loss of coastal wetlands along the GIWW due to wind and barge traffic wave impacts.	• Improve fish and shellfish habitat along the GIWW damaged by salinity intrusion and barge wake erosion; • Increase resiliency of barrier island systems and improve longshore sediment transportation; • Benefit coastal and marine resources in the Galveston Bay system; • Maintain sediment within the Galveston Bay system; • Reduce saltwater intrusion associated with tropical systems within sensitive estuarine systems; • Assist in the restoration and long-term sustainability of coastal wetlands that support important fish and wildlife resources within areas of national significance; • Restore and protect endangered species habitat.

Table 4-2
Example: Upper Texas Coast Specific Objectives Through 2085

Title	Description
Objectives for CSRM (NED)	
Reduce Flood Damages	Reduce economic damage from coastal storm surge flooding to business, residents, and infrastructure in the areas of the Galveston Bay system, Galveston Island, and in the area of Chocolate Bayou
Life, Health, and Welfare (Facilities)	Reduce risk to critical infrastructure (e.g., medical centers, government facilities, universities, and schools) from coastal storm surge flooding in the areas of Galveston Bay, Galveston Island, and in the area of Chocolate Bayou, to the maximum extent practical and also reduce emergency costs associated with the occurrence of storm-related events, specifically the Blue Water Highway; Interstate (I)-45; SH 87, and SH 146 access routes
Life, Health, and Welfare (Population)	Reduce risk to public health and safety from storm surge impacts in the areas of the Galveston Bay system, Galveston Island, and in the area of Chocolate Bayou
Industrial Impacts	In the areas of the Galveston Bay system, Galveston Island, and in the area of Chocolate Bayou, enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to coastal storm surge impacts
Existing CSRM	In the areas of the Galveston Bay system and Galveston Island, increase the resilience of existing coastal storm risk reduction management systems from SLR and coast storm surge impacts
Coastal Landforms	Enhance and restore coastal landforms along Galveston Island and Bolivar Peninsula that contribute to reducing the risk of coastal storm surge damages
Objectives for ER (NER)	
Marsh Improvements (Navigation Impacts)	Along the GIWW, reduce the magnitude of shoreline erosion to marshes and also reduce the magnitude of tidal flow entering interior marshes to prevent continuing wetland loss
Hydrologic Connectivity	Improve hydrologic connectivity of area wetlands in the Texas-Louisiana coastal marshes, mid-coast barrier islands, and coastal marshes
Beaches and Dunes	Restore size and quality of beaches and dunes focusing on areas with existing high erosion rates
Oyster Reefs	Create, restore, and nourish oyster reefs to benefit coastal and marine resources
Back Bay Systems	Improve sustain of coastal marshes and bay shorelines on barrier island system and estuarine systems
Rookeries	In area of Galveston Bay, improve migratory bird habitat and threatened and endangered species

Table 4-3 provides an example of how information collected under the inventory and forecasting phase of the planning process was used to update the specific objectives for the different areas of the coast. For example, many of the CSRM objectives were removed from the mid Texas coast at this point due to the investigation related to the structure inventory and surge mapping mentioned above. Also, based on the shoreline change rates, many of the beaches and dunes restoration goals were focused on areas of high loss rates.

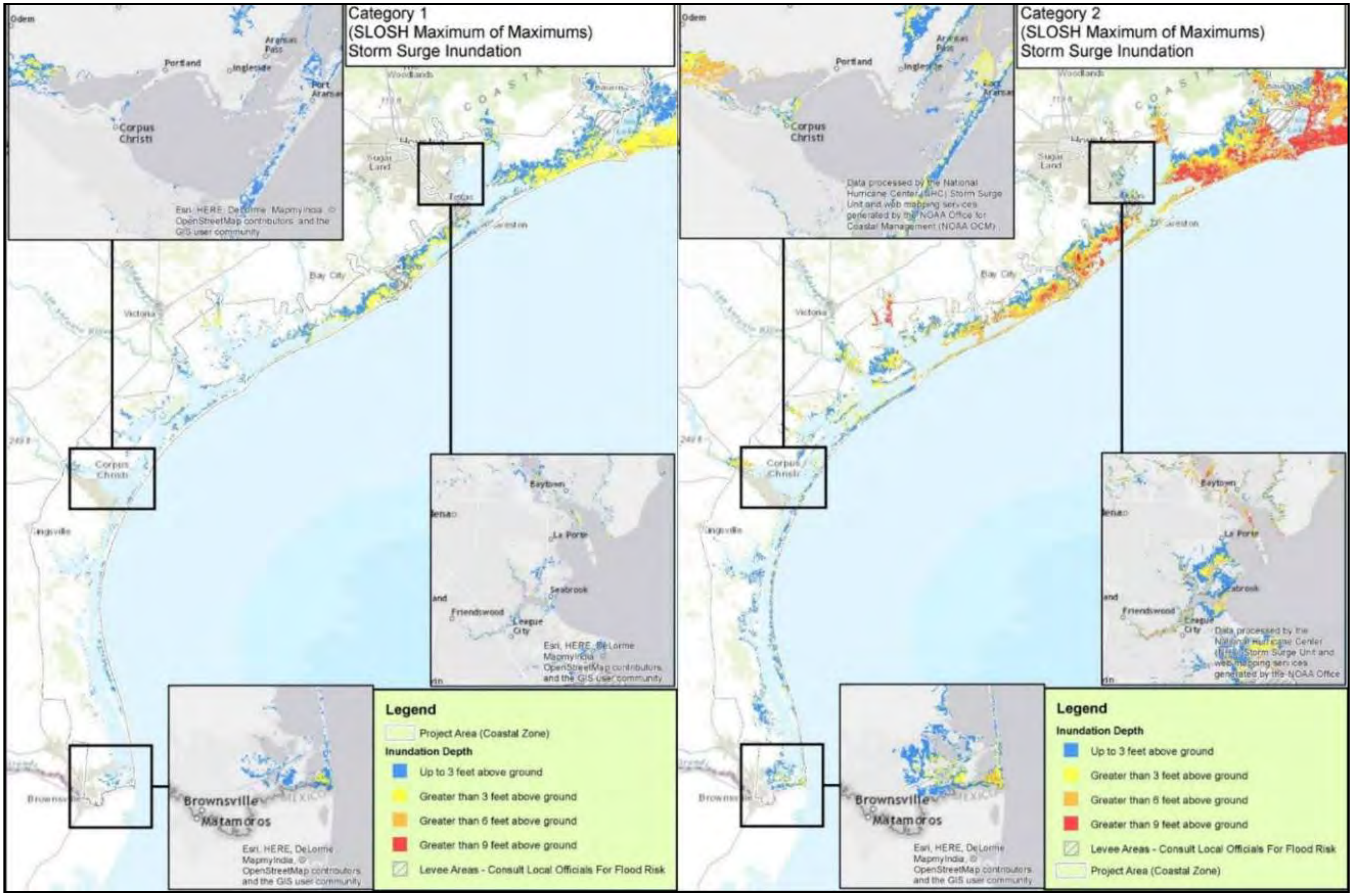

Figure 4-2: Coastal Texas SLOSH Model Results

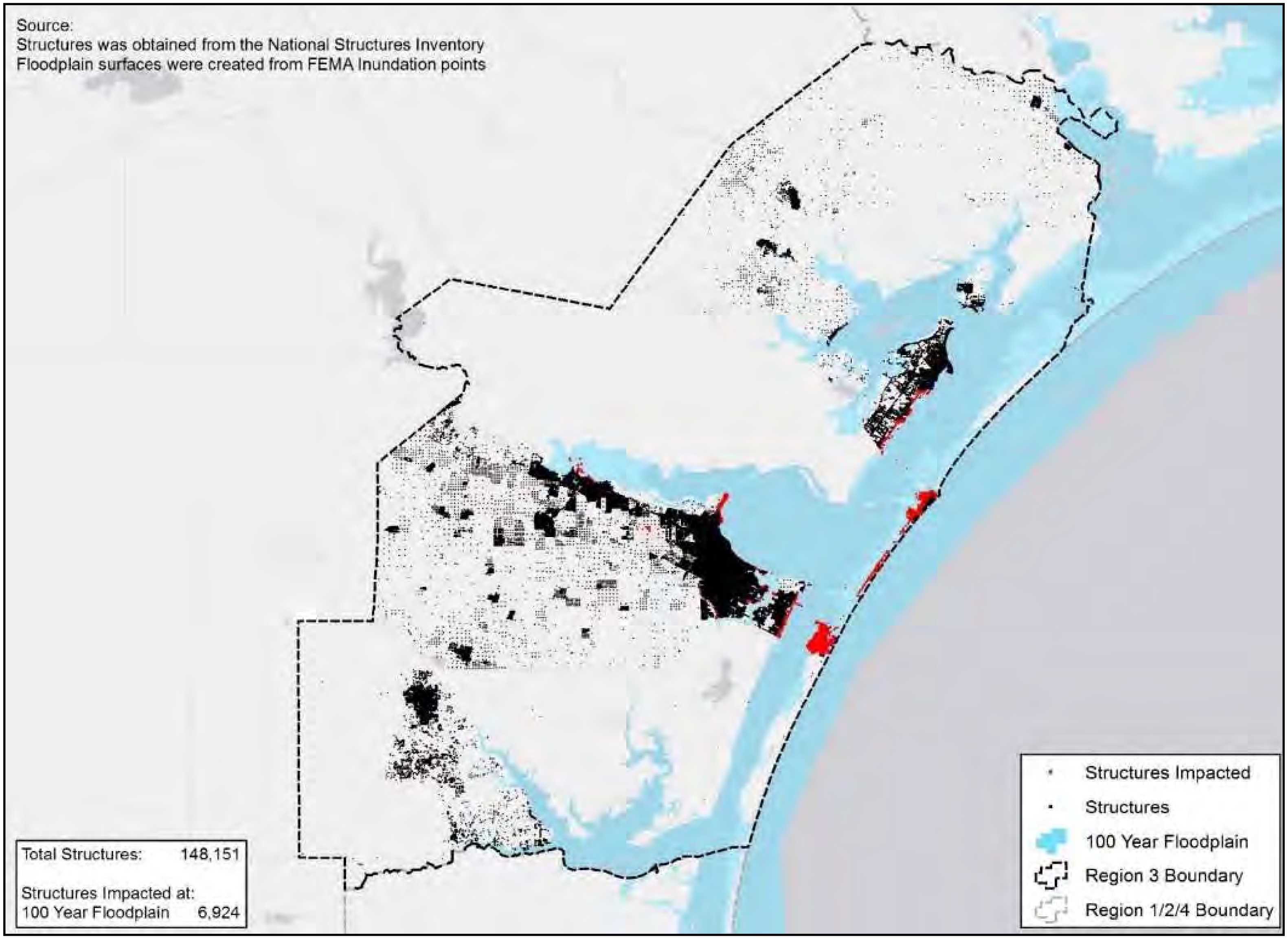

Figure 4-3: Mid Texas Coast Structures and FEMA 100-year Floodplain

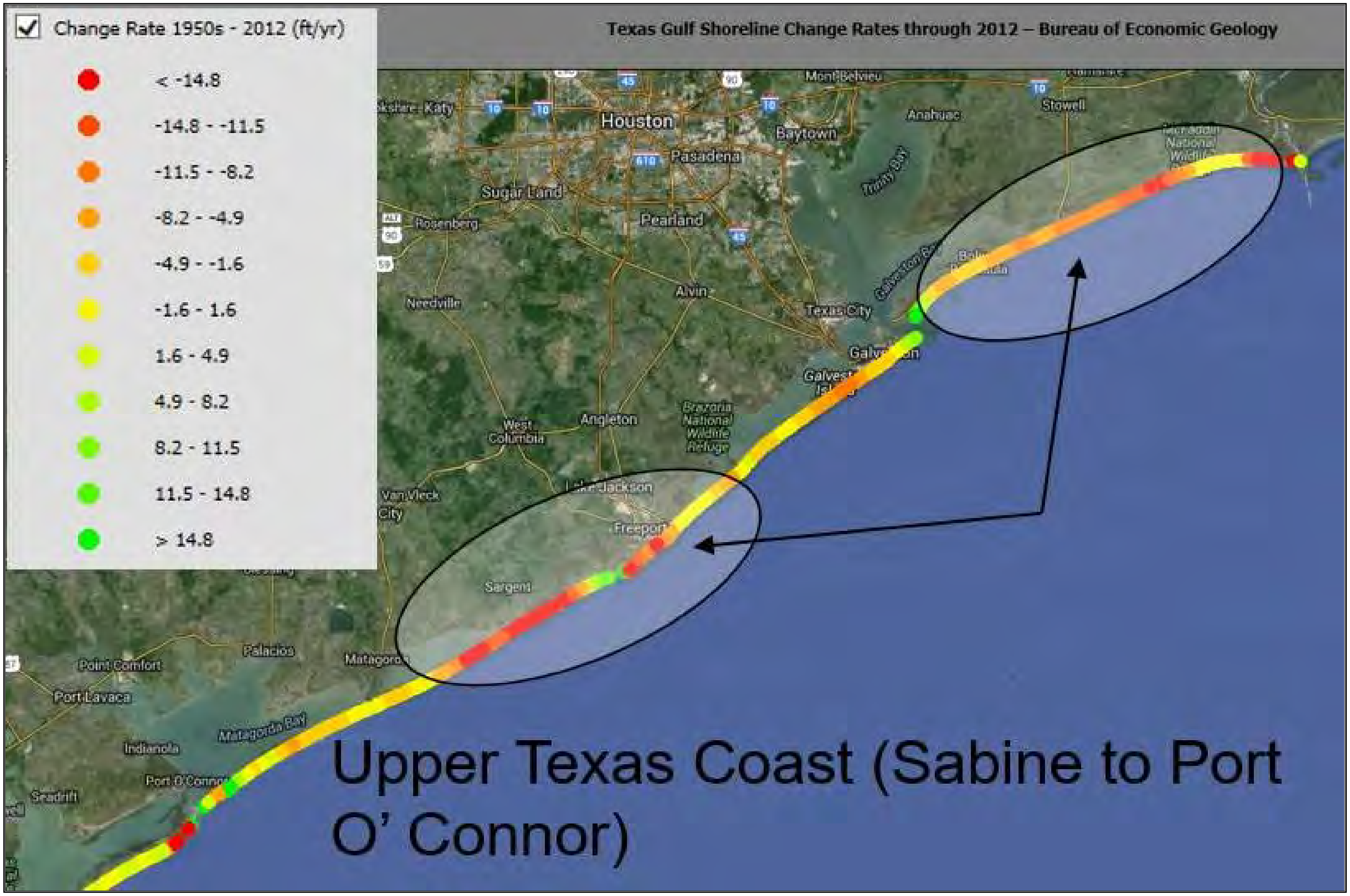

Figure 4-4: Upper Texas Coast Shoreline Change Rates

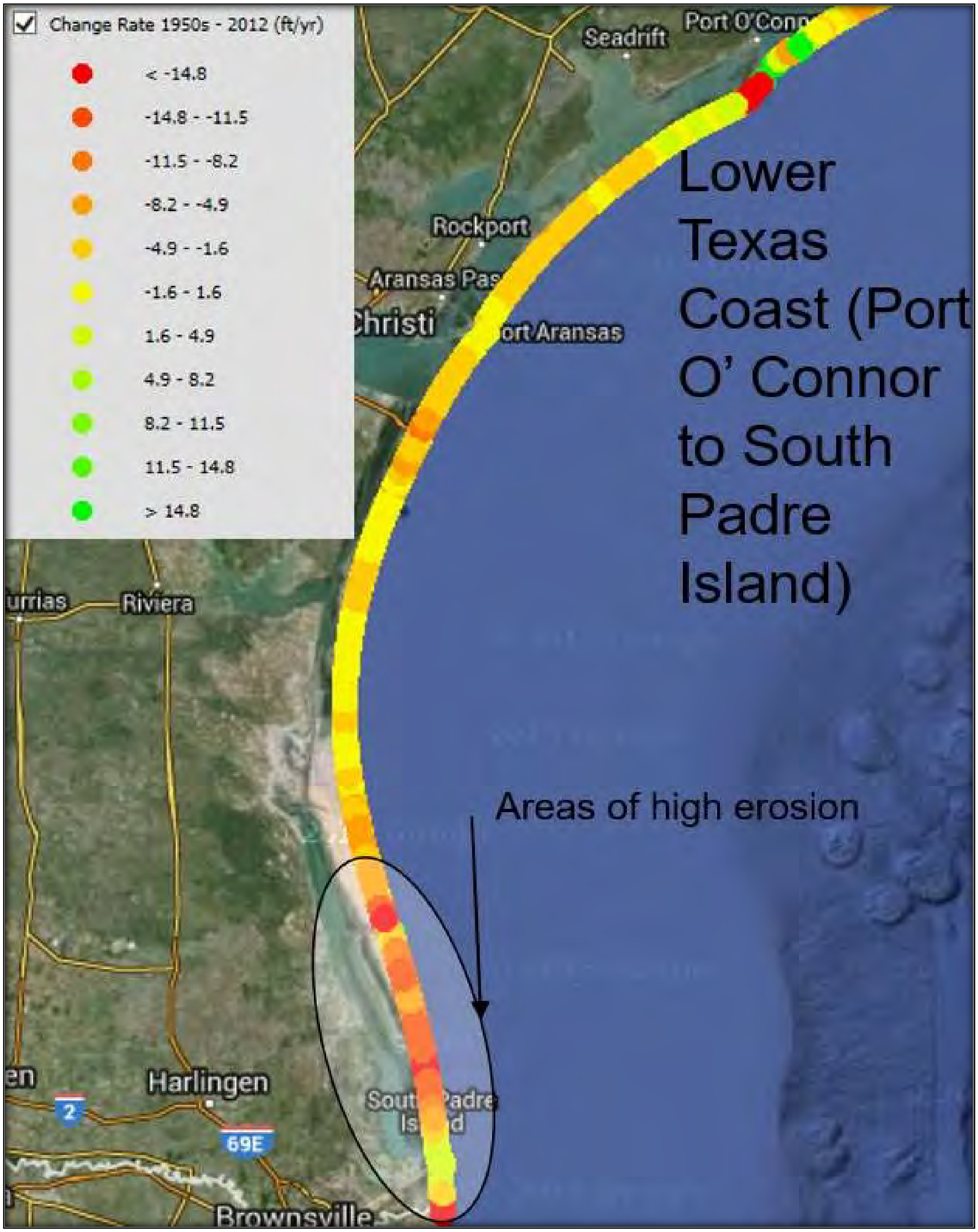

Figure 4-5: Lower Texas Coast Shoreline Change Rates

Table 4-3
Mid Texas Coast Specific Objectives

Title	Description	Screening	Refinements
Objectives for CSRM (NED):			
Reduce Flood Damages	Reduce economic damage from storm surge flooding to business, residents and infrastructure in the area of Rockport/Fulton and surrounding area	~~Reduce economic damage from storm surge flooding to business, residents and infrastructure in the area of Rockport/Fulton and surrounding area~~	Limited Risk. Areas not included in final considerations
Life, Health, and Welfare (Facilities)	Reduce risk to critical infrastructure and evacuation routes (e.g., I-37, SH 35, and US 361) from storm surge flooding Corpus Christi; Rockport/Fulton and surrounding areas	~~Reduce risk to critical infrastructure and evacuation routes (e.g. I-37, SH 35, and US 361) from storm surge flooding Corpus Christi; Rockport/Fulton and surrounding areas~~	
Life, Health, and Welfare (Population)	Reduce risk to public health and safety from storm surge impacts in the area of Rockport/ Fulton and surrounding area	~~Reduce risk to public health and safety from storm surge impacts in the area of Rockport/ Fulton and surrounding area~~	
Life, Health, and Welfare (Population/Facilities)	In the surrounding areas of Corpus Christi, enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts	~~In the surrounding areas of Corpus Christi, enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts~~	
Coastal Geomorphology	Enhance and restore coastal landforms along Mustang and North Padre islands that contribute to reducing the risk of storm surge damages	Enhance and restore coastal landforms along Mustang and North Padre islands that contribute to reducing the risk of storm surge damages	
Objectives for ER (NER):			
Hydraulic Connectivity	Restore hydrologic connectivity in the Nueces Delta, Aransas Delta, and in the Mesquite Bay system	Restore hydrologic connectivity in the Nueces Delta, Aransas Delta, and in the Mesquite Bay system	
Migratory Birds/Rookery	Regionwide improvement to migratory bird habitat, and critical T&E* habitat	Regionwide improvement to migratory bird habitat, and critical T&E habitat	

Title	Description	Screening	Refinements
Estuary and Bay Habitat	Improve habitat quality in coastal bays and estuaries with restoration of marshes and oyster reefs	Improve habitat quality in coastal bays and estuaries with restoration of marshes and oyster reefs	
Beaches and Dunes	Restore size and quality of beaches and dunes focusing on areas with existing high erosion rates	~~Restore size and quality of beaches and dunes focusing on areas with existing high erosion rates~~	Limited Areas of High Erosion
Sustainability of Barrier Islands and Estuaries	Improve/sustain sustainability of coastal marshes and bay shorelines on barrier island system and estuarine systems	Improve/sustain sustainability of coastal marshes and bay shorelines on barrier island system and estuarine systems	
Marshes	Along the GIWW, reduce the magnitude of shoreline erosion to marshes and also reduce the magnitude of tidal flow entering interior marshes to prevent continuing wetland loss	Along the GIWW, reduce the magnitude of shoreline erosion to marshes and also reduce the magnitude of tidal flow entering interior marshes to prevent continuing wetland loss	

*T&E = threatened and endangered

4.2 INITIAL ALTERNATIVE PLAN FORMULATION ITERATION

The refined problems, opportunities, and specific planning objectives were used for the formulation and evaluation of alternatives. Many of the objectives were directly related to the problems and opportunities identified for the study. As shown on Figure 4-6, the development and screening of management measures and alternatives were directly related to the refined problems, opportunities, and specific planning objectives.

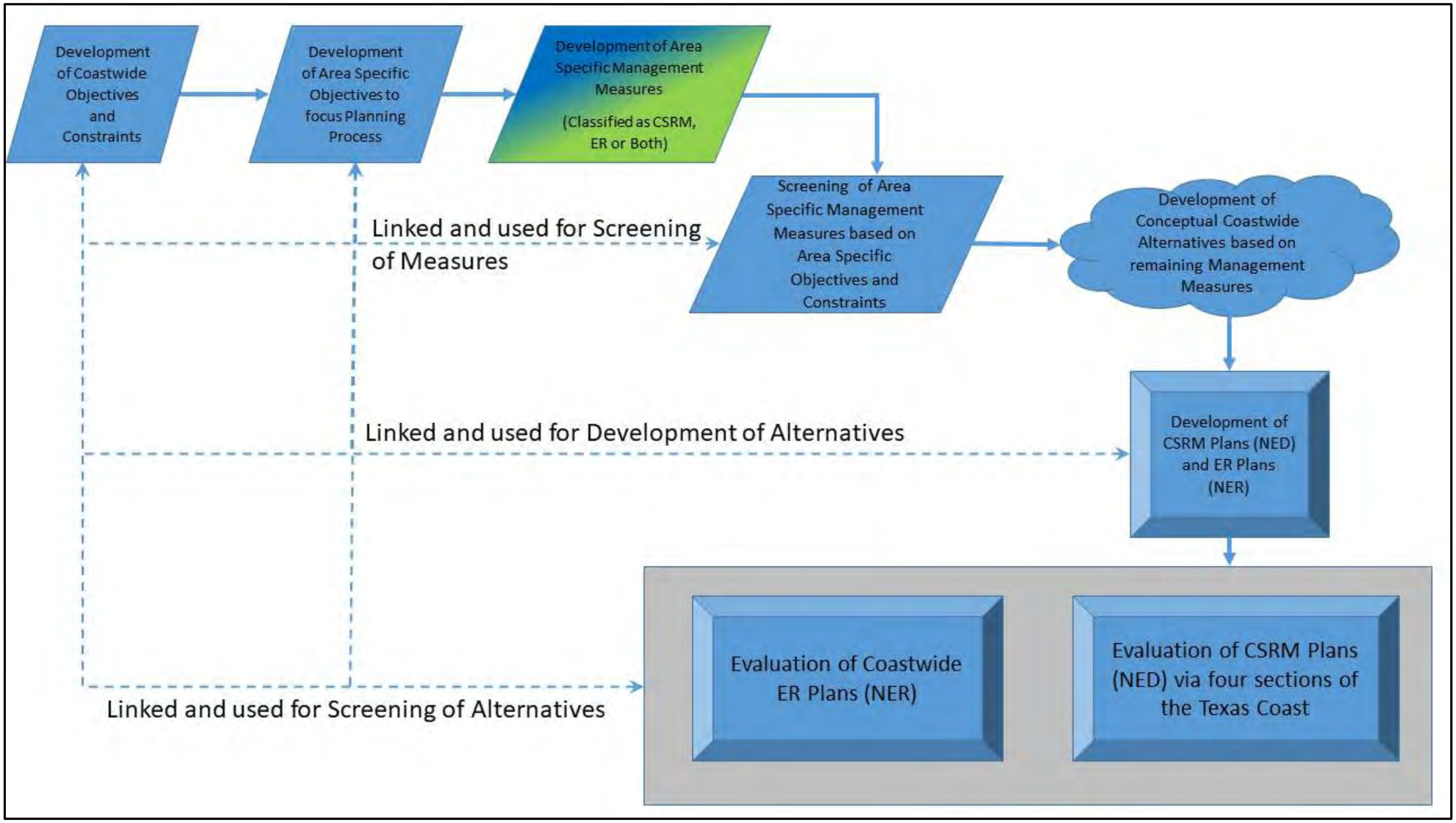

Figure 4-6: Development and Screening of Management Measures and Alternatives

4.2.1 Measure Development and Initial Phase

A **management measure** is a feature or an activity that can be implemented at a specific geographic site to address one or more planning objective. They can be used individually or combined with other management measures to form alternative plans. Measures were developed to address problems and to capitalize upon opportunities. The objective of ER measures was to restore degraded ecosystem structure, function, and dynamic processes to a less-degraded, more-natural condition, while CSRM measures were to reduce flood damages to property and infrastructure, and to increase the resilience of coastal populations from storm surges. Measures were derived from a variety of sources including prior studies, the public scoping process held in 2012 and 2014, and input from the PDT. In order to ensure that the PDT was developing a comprehensive risk reduction and restoration plan for the entire Texas coast, the team developed a comprehensive list of CSRM and ER measures based on the overall problems and opportunities listed in Section 1.0, the expanded problems and opportunities in Table 4-1 above, and the Plan Formulation Supporting Information (Appendix A). The PDT initially included an extensive range of measures (Table 4-4); 92 different measures were developed across all four areas of the Texas coast. Measures came from various sources and included measures that may be constructed under other authorizations (e.g., Continuing Authorities Programs [CAP], CIAP, RESTORE Act, CEPRA, NRDA, etc.). The list included measures that currently are being investigated under other study efforts to inform the comprehensive planning efforts. For example, measures investigated under the Sabine Pass to Galveston Bay Feasibility Study (S2G) were initially included in the measures list.

Table 4-4
Initial Measure List

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
			Upper Texas Coast		
1	B-1	CSRM (NED)	Ring Bayou, Chocolate Bayou Plants (S2G Measure 3-10.6), Brazoria County	Brazoria County and Local Industry	
2	B-2	ER (NER)	Gulf Beach and Dune Restoration – Follets Island (S2G Measure 5-11), Brazoria County	✓	✓
3	B-3	NED with NER (Qualitative impacts)	Gulf Beach and Dune B22 Restoration – Surfside Island (S2G Measure 5-12)	CEPRA and GOMESA	
4	B-4	ER (NER)	Gulf Beach and Dune Restoration – Quintana (S2G Measure 5-13)	CEPRA and GOMESA	
5	B-5	ER (NER)	Bastrop Bay Shoreline Protection (S2G Measure 7-2), Brazoria County	✓	✓
6	B-6	ER (NER)	GIWW Breakwaters (S2G Measure 6-6.1), Brazoria County	✓	✓

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
7	B-7	ER (NER)	GIWW Island Restoration (S2G Measure 6-6.2), Brazoria County	O&M	
8	B-8	NED with NER (Qualitative impacts)	Follets Island Road Raising (S2G Measure 4-2.3), Brazoria County	TXDOT and FHWA	
9	B-9	ER (NER)	Galveston Bay Estuary Program	RESTORE, NRDA	
10	B-10	ER (NER)	Oyster Reef Restoration, Galveston County	RESTORE, NRDA	
11	C-1 East Galveston	ER (NER)	Bay Shoreline Restoration (S2G Measure 7-1), Chambers County	CEPRA, GOMESA, and RESTORE	
12	G-1	NER with NED (Qualitative impacts)	Closure of Rollover Pass (S2G Measure 5-10), Galveston County	Specific State appropriations	
13	G-2	CSRM (NED)	Galveston Ring Levee (S2G Measure 3-9), Galveston County	✓	✓
14	G-3	CSRM (NED)	Risk Reduction Measure for West Galveston Bay Area (S2G Measure 4-1), Galveston and Harris counties	✓	✓
15	G-3-SSPEED*	CSRM (NED)	Risk Reduction Measure for West Galveston Bay Area SSPEED Center H-GAPS* proposal Galveston and Harris counties		
16	G-4	CSRM (NED)	Texas City Hurricane Flood Protection (HFP) System (S2G Measure 3-2), Galveston County	✓	✓
17	G-5 East	NER with NED (Qualitative impacts)	Galveston County Gulf Beach and Dune Restoration (S2G Measures 5-6 and 5-8), Galveston County	✓	✓
18	G-5 West	NER with NED (Qualitative impacts)	Galveston County Gulf Beach and Dune Restoration (S2G Measures 5-6 and 5-8), Galveston County	✓	✓
19	G-6	NER with NED (Qualitative impacts)	Galveston Seawall Dune-Beach Restoration (S2G Measure 5-7), Galveston County	✓	✓
20	G-7	CSRM (NED)	Galveston Bay Coastal Barrier (S2G Measure 1), Galveston County	✓	✓
21	G-7-1979-USACE-1-B	CSRM (NED)	Galveston Bay Coastal Barrier (S2G Measure 1), Galveston County	✓	✓
22	G-8	CSRM (NED)	Surge Gate and Barrier at Fred Hartman Bridge (S2G Measure 2), Harris County (part of a greater Galveston Bay/Galveston County risk reduction system)	✓	✓
23	G-9	ER (NER)	Bolivar Island Marsh Restoration (S2G Measures 8-4.1 and 8-4.2), Galveston County	ER grants, O&M, CAP	

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
24	G-10	ER (NER)	Galveston Island Marsh Restoration (S2G Measures 8-7.1, 8-7.2, 8-7.3, 8-7.4, 8-7.5, 8-7.6, 8-7.7), Galveston County	RESTORE, NRDA	
25	G-11	ER (NER)	West Bay Marsh Restoration (S2G Measures 8-6.1, 8-6.2, 8-6.3), Galveston County	RESTORE, NRDA	
26	G-12 East	ER (NER)	GIWW Breakwaters (S2G Measures 6-4.1, 6-5.1), Galveston County	✓	✓
27	G-12 West	ER (NER)	GIWW Breakwaters (S2G Measures 6-4.1, 6-5.1), Galveston County	✓	✓
28	G-13 East	ER (NER)	GIWW Island Restoration (S2G Measures 6-4.2, 6-5.2, 6-5.3), Galveston County	RESTORE, NRDA, CEPRA	
29	G-13 West	ER (NER)	GIWW Island Restoration (S2G Measures 6-4.2, 6-5.2, 6-5.3), Galveston County	RESTORE, NRDA, CEPRA	
30	G-14	ER (NER)	Oyster Reef Restoration, Galveston County	RESTORE, NRDA	
31	G-15	CSRM (NED)	Texas City Nonstructural Improvements	✓	✓
32	G-16	CSRM (NED)	Galveston Island (Developed Area) Nonstructural Improvements	✓	✓
33	G-17	CSRM (NED)	Galveston Island (Rural Area) Nonstructural Improvements		
34	G-18	CSRM (NED)	Bolivar Peninsula (Rural Area) Nonstructural Improvements		
35	G-19	CSRM (NED)	San Leon Nonstructural Improvements	✓	✓
36	G-20	CSRM (NED)	Bacliff/Bayview Nonstructural Improvements	✓	✓
37	G-20	CSRM (NED)	Kemah Nonstructural Improvements	✓	✓
38	G-22	CSRM (NED)	Seabrook Nonstructural Improvements	✓	✓
39	G-22	CSRM (NED)	La Porte Nonstructural Improvements	✓	✓
40	O-1	ER (NER)	GIWW Breakwaters (S2G Measure 6-1.1), Orange County	✓	✓
41	O-2	ER (NER)	GIWW Island Restoration (S2G Measure 6-1.2), Orange County	✓	✓
42	O-3	ER (NER)	Neches River Marsh Restoration (S2G Measures 8-1, 8-2, and 8-3), Orange County	RESTORE, NRDA	
43	J-1	ER (NER)	Gulf Shoreline Ridge Restoration (S2G Measure 5-3), Jefferson County	✓	✓
44	J-2	ER (NER)	Marsh Restoration, Jefferson County, Jefferson County	RESTORE, NRDA	
45	J-3	ER (NER)	GIWW Siphons (S2G Measure 9.2), Jefferson County	RESTORE, NRDA, Jefferson Co.	
46	RI-1	ER (NER)	Smith Point Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
47	RI-2	ER (NER)	Vingt-et-un Islands Rookery Island Restoration	RESTORE, NRDA, CEPRA	
48	RI-3	ER (NER)	Rollover Pass Rookery Island Restoration	RESTORE, NRDA, CEPRA	
49	RI-4	ER (NER)	Alligator Point Rookery Island Restoration	RESTORE, NRDA, CEPRA	
50	RI-5	ER (NER)	West Bay Bird Island Old Rookery Island Restoration	RESTORE, NRDA, CEPRA	
51	RI-6	ER (NER)	Syndey Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
52	RI-7	ER (NER)	Dooms Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
53	RI-8	ER (NER)	Jigsaw Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
54	RI-9	ER (NER)	Dooms Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
55	RI-10	ER (NER)	North Deer Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
56	RI-11	ER (NER)	Point Hunt Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
57	RI-12	ER (NER)	Evia Island Rookery Island Restoration	RESTORE, NRDA, CEPRA	
			Mid to Upper Texas Coast		
58	CA-1	CSRM (NED)	Beach/Dune Restoration at Indianola Beach	CEPRA, GOMESA	
59	CA-2	CSRM (NED)	Beach/Dune Restoration at Port O'Connor	SWG-O&M	
60	CA-3	ER (NER)	Matagorda Island Hydrologic Restoration (Texas Advisory Committee Workbook Region 2, #R2-44, GLO 2012)	RESTORE, NRDA, CEPRA	
61	CA-4	ER (NER)	Redfish Lake Restoration (Texas Advisory Committee Workbook Region 2, #R2-23, GLO 2012)	✓	✓
62	CA-5	ER (NER)	Keller Bay Restoration	✓	✓
63	CA-6	NER with NED (Qualitative impacts)	Indianola/Magnolia/Powderhorn Lake Shoreline Protection	✓	✓
64	CA-7	ER (NER)	Guadalupe River Delta Hydrologic Restoration/Breakwaters (Texas Advisory Committee Workbook Region 2, #R2-37 and R2-39; 2012).	✓	✓
65	M-1	ER (NER)	Dune/Beach Restoration Sargent Beach	✓	✓
66	M-2	ER (NER)	Mouth of Colorado to 3-Mile Cut Beach/ Dune Restoration	Matagorda Co.	

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
67	M-3	ER (NER)	Additional Restoration at Half Moon Bay Oyster Reef	RESTORE, NRDA, CEPRA	
68	M-4	ER (NER)	Dressing Point Island Rookery Restoration	NRDA	
69	M-5 (A)	ER (NER)	East Matagorda Bay Hydrologic Restoration	RESTORE, NRDA, CEPRA	
70	M-5 (B)	ER (NER)	Matagorda Bay – Small Scale Hydrologic Restoration	RESTORE, NRDA, CEPRA	
71	M-6	ER (NER)	Oliver Point Reef/Coon Island Bay Restoration	RESTORE, NRDA, CEPRA	
72	M-7	ER (NER)	Chester (formerly Sundown) Island Restoration	RESTORE, NRDA, CEPRA	
73	M-8	NER with NED (Qualitative impacts)	GIWW Mainland Breakwaters at Chinquapin Beneficial Use Site	✓	✓
74	M-9	CSRM (NED)	Matagorda HFPS	✓	✓
75	VA-1	NER with NED (Qualitative impacts)	Log-jam Removal, Lower Guadalupe and San Antonio rivers	Local priority	
			Mid Texas Coast		
76	A-1	ER (NER)	Oyster Reef Restoration in Copano Bay (Texas Advisory Committee Workbook Region 3, #R3-15, GLO 2012)	RESTORE, NRDA, CEPRA	
77	A-2	CSRM (NED)	Rockport/Fulton Beach Road Protection (Texas Advisory Committee Workbook Region 3, #R3-3, 4, 5, 6 and 7, GLO 2012)	CEPRA, GOMESA	
78	A-3	ER (NER)	Cedar Bayou and Vinson Slough Hydrologic Restoration	GOMESA, Aransas Co.	
79	N-1	CSRM (NED)	North Padre Island Beach and Dune Restoration (Texas Advisory Committee Workbook Region 3, #R3-34 and 36, GLO 2012)	CEPRA, GOMESA	
80	N-2	ER (NER)	North Beach Restoration (Texas Advisory Committee Workbook Region 3, #R3-19, GLO 2012)	CEPRA, GOMESA	
81	N-3	ER (NER)	Nueces Delta Restoration-Breakwaters	✓	✓
82	N-4	ER (NER)	Shamrock Island Rookery Breakwaters	CEPRA, GOMESA	
83	N-5	ER (NER)	Nueces Delta Hydrological Restoration	✓	✓
84	R-1	ER (NER)	Aransas River Delta Marsh Restoration (Texas Advisory Committee Workbook Region 3, #R3-16, GLO 2012)	RESTORE, NRDA, CEPRA	
85	R-2	CSRM (NED)	Copano Bay Shoreline Restoration (Texas Advisory Committee Workbook Region 3, #R3-17, GLO 2012)	CEPRA, GOMESA	

Count	Measure ID	Type		Screened or Deferred for Alternative Vehicle*	Carried Forward for Plan Develop-ment
86	SP-1	ER (NER)	Dagger and Ransom Islands Breakwaters	✓	✓
			Lower Texas Coast		
87	CM-1	CSRM (NED)	Adolph Thomae, Jr. Park Shoreline Protection (Texas Advisory Committee Workbook Region 4, #R4-1, GLO 2012)	CEPRA, GOMESA	
88	CM-2	ER (NER)	Bahia Grande Hydrologic Restoration	RESTORE, NRDA, CEPRA	
89	CM-3	ER (NER)	Bird and Heron Islands Shoreline Stabilization (Texas Advisory Committee Workbook Region 4, #R4-7, GLO 2012)	RESTORE, NRDA, CEPRA	
90	CM-4	ER (NER)	Three Islands Rookery Restoration (Texas Advisory Committee Workbook Region 4, #R4-11, GLO 2012)	RESTORE, NRDA, CEPRA	
91	CM-5	CSRM (NED)	South Padre Island Beach Nourishment	✓	✓
92	W-1	ER (NER)	Mansfield Island Rookery Restoration (Texas Advisory Committee Workbook Region 4, #R4-12, GLO 2012)	✓	✓

* Operation and maintenance (O&M), Federal Highway Administration (FHWA), Severe Storm Prediction, Education, and Evacuation for Disasters (SSPEED), Houston-Galveston Area Protection System (H-GAPS), USACE Galveston District (SWG).

4.2.2 Screening of Measures

Using the list above, individual measures were qualitatively screened for their capability to meet objectives while avoiding or minimizing the study constraints. In order to develop a comprehensive plan for the coast and ensure that the study supported, rather than duplicated, efforts from other Federal, State, and local agencies, CSRM and ER efforts were included for their layered contributions to risk reduction and restoration in the study area. The team used a three-step process as shown on Figure 4-7.

- **STEP 1 –** All measures were evaluated and qualitatively screened for capability to meet objectives.

For example, in the mid Texas coast, measures were ranked based on ability to exceed or meet the study's objectives. If the measures provided no change to, conflicted, or decreased the objectives of the study, it was noted (Table 4-5).

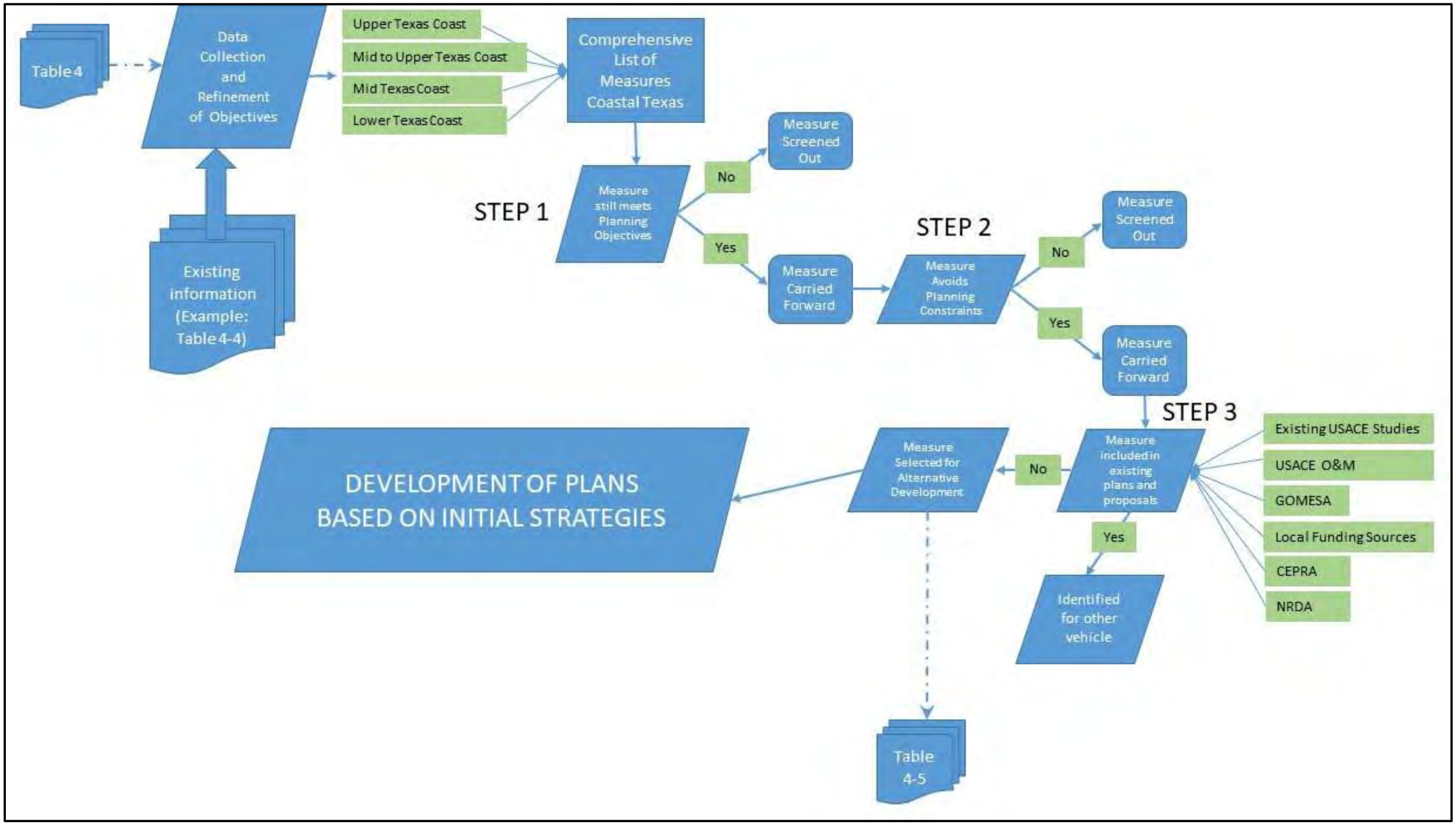

Figure 4-7: Screening of Measures – Three Step Process

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Table 4-5
Measures Linked to Objectives

			Mid Texas Coast Measures Linked to Objectives					
			NER_Reg_3_Obj1	NER_Reg_3_Obj2	NER_Reg_3_Obj3	NER_Reg_3_Obj4	NER_Reg_3_Obj5	NER_Reg_3_Obj6
Map ID	Type		Hydrologic Connectivity	Migratory Birds/ Rookery	Estuary and Bay Habitat	Beaches and Dunes	Sustainability for Barrier Islands and Estuaries	Marshes
A-1	ER (NER)	Oyster Reef Restoration in Copano Bay (Texas Advisory Committee Workbook Region 3, #R3-15, GLO 2012)	n	n	++	n	n	n
A-3	ER (NER)	Cedar Bayou and Vinson Slough Hydrologic Restoration	++	+	++	n	n	n
N-2	ER (NER)	North Beach Restoration (Texas Advisory Committee Workbook Region 3, #R3-19, GLO 2012)	n	n	n	++	n	n
N-3	ER (NER)	Nueces Delta Restoration-Breakwaters	+	++	++	n	++	++
N-4	ER (NER)	Shamrock Island Rookery Breakwaters	n	++	n	n	++	n
N-5	ER (NER)	Nueces Delta Hydrological Restoration	++	++	++	n	+	+
R-1	ER (NER)	Aransas River Delta Marsh Restoration (Texas Advisory Committee Workbook Region 3, #R3-16, GLO 2012)	++	++	++	n	n	++
SP-1	ER (NER)	Dagger and Ransom Islands Breakwaters	n	+	++	n	++	n
			NER_Reg_3_Obj1	NER_Reg_3_Obj2	NER_Reg_3_Obj3	NER_Reg_3_Obj4	NER_Reg_3_Obj5	
			Reduce Flood Damages	Life, Health, and Welfare (Facilities)	Life, Health, and Welfare (Population)	Life, Health, and Welfare (Population/ Facilities)	Coastal Geomorphology	
A-2	CSRM (NED)	Rockport/Fulton Beach Road Protection (Texas Advisory Committee Workbook Region 3, #R3-3, 4, 5, 6 and 7, GLO 2012)	+	++	++	++	n	
N-1	CSRM (NED)	North Padre Island Beach and Dune Restoration (Texas Advisory Committee Workbook Region 3, #R3-34 and 36, GLO 2012)	++	++	n	n	n	
R-2	CSRM (NED)	Copano Bay Shoreline Restoration (Texas Advisory Committee Workbook Region 3, #R3-17, GLO 2012)	n	n	n	n	n	

Exceeds (++), Meets (+), No Change (n), or Decreases (–) the Objective
N/A was used for measures that were strictly NER

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- **STEP 2** – Remaining measures were evaluated and qualitatively screened for capability to avoid study constraints.
- **STEP 3 –** Measures currently being covered under other study efforts or other authorities were removed from the Coastal Texas Study alternative array.

All three steps were used to determine which measures would be carried forward and used for developing alternatives. Several measures that did not outperform others but warranted further action in another context were screened out and referred to the appropriate interagency investigations or considered under other USACE authorities. Continued participation with the revision of the GLO's Resiliency Master Plan will provide an opportunity to ensure that all measures to restore, enhance, and protect the Texas coast are considered for further development under the appropriate authority. Table 4-6 indicates which measures were carried forward after the screening. The ER screening process is described in greater detail and is included in the Plan Formulation Supporting Information (Appendix A). It provides a detailed list of the screening and the rationale used for the final screening.

In the end, the three-step process screening of measures left the team with a total of 36 measures to develop into alternative plans (Table 4-6).

4.2.3 Development of Conceptual Array of Alternative Plans

The PDT developed formulation strategies using a process similar to the North Atlantic Coast Comprehensive Study Coastal Storm Risk Management Framework where the primary strategy was to increase coastal resilience and reduce vulnerability. This can be achieved by 1) instituting land-use changes over time to adapt to impacts that increase risks; 2) accommodating potential changes such as climate variability, sea-level change, etc. to preserve the natural and built environment over time; and 3) employing risk reduction measures to reduce flood damages to property and infrastructure. The development of alternative plans used the overall coastwide strategies to address the Texas coastal problems; however, due to the scale of Coastal Texas Study and differences along the coast, not all of the strategies worked in all of the area of the Texas coast. Table 4-7 describes how the different strategies were used in different sections to begin to formulate plans based on the remaining measures listed in Table 4-6.

The PDT combined the remaining management measures to develop a range of alternative plans based on the updated planning objectives, constraints, and ability to solve opportunities and problems. The following conceptual tiered approach shown on Figure 4-8 was used to combine measures into plans.

Table 4-6
Remaining Coastal Texas Measures after Screening

Count	Map ID	Type	Description
Upper Texas Coast			
1	B-2	ER (NER)	Gulf Beach and Dune Restoration – Follets Island (S2G Measure 5-11), Brazoria County
2	B-5	ER (NER)	Bastrop Bay Shoreline Protection (S2G Measure 7-2), Brazoria County
3	B-6	ER (NER)	GIWW Breakwaters (S2G Measure 6-6.1), Brazoria County
4	G-2	CSRM (NED)	Galveston Ring Levee (S2G Measure 3-9), Galveston County
5	G-3	CSRM (NED)	Risk Reduction Measure for West Galveston Bay Area (S2G Measure 4-1), Galveston and Harris counties
6	G-4	CSRM (NED)	Texas City Hurricane Flood Protection (HFP) System (S2G Measure 3-2), Galveston County
7	G-5 East	NER with NED (Qualitative impacts)	Galveston County Gulf Beach and Dune Restoration (S2G Measures 5-6 and 5-8), Galveston County
8	G-5 West	NER with NED (Qualitative impacts)	Galveston County Gulf Beach and Dune Restoration (S2G Measures 5-6 and 5-8), Galveston County
9	G-6	NER with NED (Qualitative impacts)	Galveston Seawall Dune-Beach Restoration (S2G Measure 5-7), Galveston County
10	G-7	CSRM (NED)	Galveston Bay Coastal Barrier (S2G Measure 1), Galveston County
11	G-7 – 1979 - USACE-1-B	CSRM (NED)	Galveston Bay Coastal Barrier (S2G Measure 1), Galveston County
12	G-8	CSRM (NED)	Surge Gate and Barrier at Fred Hartman Bridge (S2G Measure 2), Harris County (part of a greater Galveston Bay/Galveston County risk reduction system)
13	G-12 East	ER (NER)	GIWW Breakwaters (S2G Measures 6-4.1, 6-5.1), Galveston County
14	G-12 West	ER (NER)	GIWW Breakwaters (S2G Measures 6-4.1, 6-5.1), Galveston County
15	G-15	CSRM (NED)	Texas City Nonstructural Improvements
16	G-16	CSRM (NED)	Galveston Island (Developed Area) Nonstructural Improvements
17	G-19	CSRM (NED)	San Leon Nonstructural Improvements
18	G-20	CSRM (NED)	Bacliff/Bayview Nonstructural Improvements
19	G-20	CSRM (NED)	Kemah Nonstructural Improvements
20	G-22	CSRM (NED)	Seabrook Nonstructural Improvements
21	G-22	CSRM (NED)	La Porte Nonstructural Improvements
22	O-1	ER (NER)	GIWW Breakwaters (S2G Measure 6-1.1), Orange County
23	O-2	ER (NER)	GIWW Island Restoration (S2G Measure 6-1.2), Orange County
24	J-1	ER (NER)	Gulf Shoreline Ridge Restoration (S2G Measure 5-3), Jefferson County

Count	Map ID	Type	Description
			Mid to Upper Texas Coast
25	CA-4	ER (NER)	Redfish Lake Restoration (Texas Advisory Committee Workbook Region 2, #R2-23, GLO 2012)
26	CA-5	ER (NER)	Keller Bay Restoration
27	CA-6	NER with NED (Qualitative impacts)	Indianola/Magnolia/Powderhorn Lake Shoreline Protection
28	CA-7	ER (NER)	Guadalupe River Delta Hydrologic Restoration/Breakwaters (Texas Advisory Committee Workbook Region 2, #R2-37 and R2-39; 2012).
29	M-1	ER (NER)	Dune/Beach Restoration Sargent Beach
30	M-8	NER with NED (Qualitative impacts)	GIWW Mainland Breakwaters at Chinquapin Beneficial Use Site
31	M-9	CSRM (NED)	Matagorda HFPS
			Mid Texas Coast
32	N-3	ER (NER)	Nueces Delta Restoration-Breakwaters
33	N-5	ER (NER)	Nueces Delta Hydrological Restoration
34	SP-1	ER (NER)	Dagger and Ransom Islands Breakwaters
			Lower Texas Coast
35	CM-5	CSRM (NED)	South Padre Island Beach Nourishment
36	W-1	ER (NER)	Mansfield Island Rookery Restoration (Texas Advisory Committee Workbook Region 4, #R4-12, GLO 2012)

Table 4-7
General Overview Formulation Strategies

Formulation Strategy Developed	Methodology for Strategy	Proposed Sections to Focus on
Multiple Lines of Defense	The strategy works on the well-founded premise that the Texas coast must be protected from hurricane surge by both man-made features, such as levees, and by the natural coastal wetland buffer along the Texas coast. Levees alone will not work. Together, a healthy coastal estuary and appropriately designed levees system can sustain Texas's ecology and economy of the coast.	Upper Texas Coast Mid Texas coast
Navigation Impacts	The strategy works by focusing ER measures on repairing or preventing future damages to the Texas coastal ecosystems from navigation impacts. The strategy focuses on areas of high land loss to wetlands, where breaches in the bank-line allow boat wakes to push turbid, higher salinity waters into interior wetlands, causing marsh loss and decreasing submerged aquatic vegetation (SAV) coverage.	All Sections Focus on GIWW
Resiliency	The strategy works by focusing ER measures that would provide resiliency to existing CSRM features or proposed CSRM features. The strategy also focuses on including nonstructural measures that would increase the resiliency of coastal communities.	All Sections Galveston Island Galveston Bay
Limited Impacts to Navigation	The strategy works by focusing on CSRM measures that would have limited impacts to existing navigation features.	Galveston Bay
Focus on Significant Resources	The strategy works by focusing on ER measures where they would restore and protect key nationally significant migratory bird habitat, critical threatened and endangered species habitat, and critical EFH areas.	All Sections

In discussions with the USACE Vertical Team (USACE decisionmakers and reviewers), the PDT was encouraged to identify a conceptual array of comprehensive, coastwide plans that would reduce risks of flooding caused by storm surge and coastline degradation while considering a full range of risks to people, environment, property, and economy as well as infrastructure, construction, operations, and maintenance costs.

The conceptual formulation strategy explored whether three different geographic strategies (Gulf Shoreline Focus, Back/Mid Bays Focus, Upper Bay Focus) could achieve project goals. Restoration and structural measures were combined to achieve project goals. Measures that conflicted with other measures were not combined (e.g., coastal barrier versus inland barrier systems).

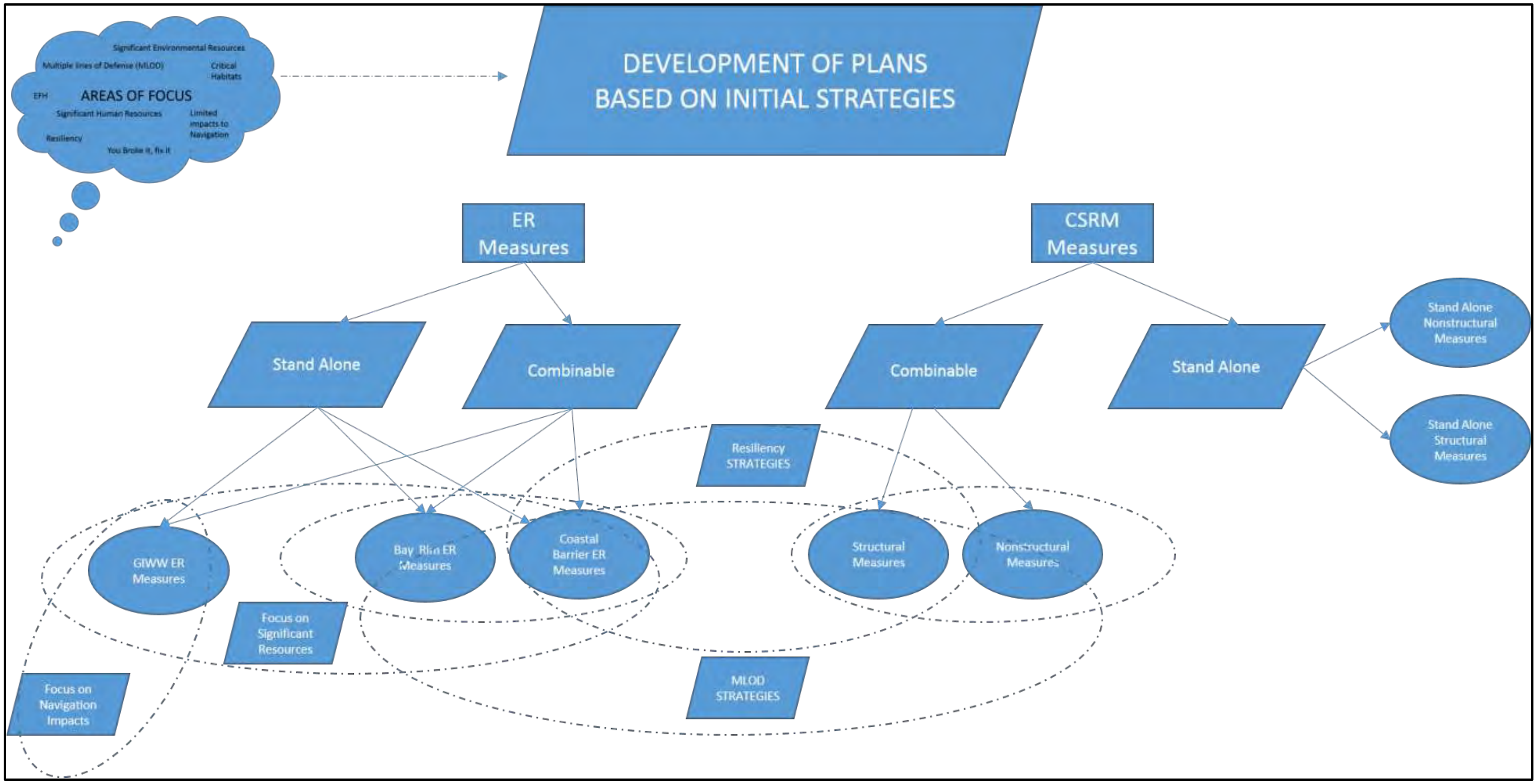

Figure 4-8: Conceptual Approach for Developing Plans

The conceptual plans demonstrated that a combined approach to habitat restoration and CSRM features could achieve complementary risk reduction benefits. Below is a quick overview of the conceptual plans the team initially developed.

Conceptual Alternative A – Coastal Barrier/Nonstructural System and Maximize ER Benefits: A conceptual strategy was developed to focus on preventing storm surge from entering Galveston Bay with a barrier system across Bolivar Peninsula, a closure at Bolivar Roads, a levee system or nonstructural measures on Galveston Island, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. This plan addressed storm surge damages near South Padre Island, the city of Matagorda, and included all ER measures across the four areas of the Texas coast to maximize ER benefits, regardless of cost.

Conceptual Alternative B – Coastal Barrier and Maximize ER Benefits: For this conceptual alternative, a similar strategy was used as with Alternative A, but this plan only avoided the barrier islands and used existing landscape features such as the GIWW disposal dikes and the Texas City Dike as the coastal barrier. Flooding on Galveston Island is addressed with a levee system or nonstructural measures and storm surge damages near South Padre Island and the city of Matagorda. All ER measures across the four areas of the Texas coast to maximize ER benefits, regardless of cost, are also included.

Conceptual Alternative C – Mid Bay Barrier and Maximize ER Benefits: This conceptual strategy was developed to avoid 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. This plan also addressed flooding on Galveston Island with a levee system. This plan still focused on including all ER measures across the areas of the Texas coast to maximize ER benefits, regardless of cost.

Conceptual Alternative D – Upper Bay (SH 146)/Nonstructural System and Maximize ER Benefits: This conceptual strategy was developed to potentially avoid all navigation impacts by focusing on a levee system on the west side of Galveston Bay along SH 146 from Texas City to the Fred Hartman Bridge. The levee system would be located such that there would be structures east of the levee outside of the system. Nonstructural measures were formulated to address existing surges and any surges induced into the area by the levee system. The plan also addressed flooding on Galveston Island with a levee system, which rings the island. The plan still focused on including all ER measures across the area to maximize ER benefits, regardless of cost.

Conceptual Alternative E – Gulf Shoreline ER Focus: This conceptual plan focuses on maintaining the barrier island systems in the upper Texas coast, mid to upper Texas coast, and lower Texas coast. This plan focused on a Beach and Dune Restoration measure to increase resiliency of barrier island systems and included the CSRM feature in the lower Texas coast associated with the incidental benefits for the South Padre Island CSRM measure.

Conceptual Alternative F – GIWW (Navigation Impacts) ER Focus: This conceptual plan focused on addressing some of the historical navigation impacts across the Texas coast, particularly along the GIWW. The plan only included measures along the GIWW to reduce the magnitude of shoreline erosion to marshes and tidal flow entering interior marshes.

Conceptual Alternative G – Upper Bays ER Focus: This conceptual plan focused on addressing freshwater flows into the upper bay systems of the coast. The plan intended to improve hydrologic connectivity into sensitive estuarine systems around the upper bays. Galveston Bay and Coastal Bend Bays and Estuary are part of the EPA's National Estuary Program that are designated as Estuaries of National Significance. Of all Texas bays, the Nueces Bay/Delta region is listed as "an unsound ecological environment" due to substantial alterations in freshwater reaching the bay and delta (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011).

4.3 DEVELOPMENT OF ALTERNATIVE PLANS AND SELECTION OF TSP COMPONENTS

In discussions with the USACE Vertical Team, it was determined during an Alternatives Milestone Meeting that further refinement of the conceptual plans was necessary to confirm cost effectiveness and performance of each one of the measures. This analysis required separate evaluation and comparison of the project features and the conceptual alternative plans presented in the sections above. Although the plans included different scales, and were formed using coastwide strategies, the more-detailed qualitative and quantitative comparison of the individual plan components required separate comparisons of CSRM Plans (NED) and ER Plans (NER). Also due to the hydrologic separability of the CSRM features in the Galveston region, the city of Matagorda and South Padre Island were evaluated independently.

Nonstructural measures were also included in the evaluation. USACE policy requires that nonstructural measures be considered with other structural measures to create a comprehensive systems approach to risk reduction. Both a stand-alone nonstructural plan, as well as nonstructural measures, that could function in combination with other risk-reducing structural measures to provide multiple lines of defense for the region were considered. While structural components of the system are intended to provide a reduction in damages from storm surges, a complementary system of nonstructural measures can also facilitate post-storm recovery in the event that the structural components are exceeded. Nonstructural measures could reduce the adverse consequences when storm flooding occurs. As a redundant feature, nonstructural measures contribute to management of the risk of interior flooding, whether from rainfall or from hurricane surge exceeding the channel capacity, levees, and floodwalls. An added benefit of this redundant system is found in the timing of implementation. Because nonstructural measures can typically be implemented in less time, they would reduce flood risk prior to completion of the structural measures. Upon completion of the structural measures, the combined measures would provide redundancy to the risk reduction system.

Due to the scale of the originally proposed ER measures, additional steps were taken to refine ER measures to address specific problems and opportunities and quantify the benefit stream through ecological modeling. Following this analysis, ER measures were formulated into strategic plans, consistent with the conceptual plans listed in the section above; however, these plans were assembled with specific habitat strategies. A cost effectiveness and incremental cost analysis (CE/ICA) of the plans requires uniform benefit outputs. Since CSRM benefits are measured in dollars, and ER benefits are assessed in Average Annual Habitat Units (AAHUs), subsequent plan formulation required ER assessment without combination with CSRM measures. Table 4-8 provides an overview for the process that took place to transition from conceptual plans to individual CSRM and ER plans.

Table 4-8
Overview of Evaluation Procedures for Alternative Plans

ID under Initial Formulation Process	Transformed Into	Carried Forward into Final Array* (NEPA)
No-Action Federal Action	No-Action Federal Action	✓
	Upper Texas Coast: Stand-alone Nonstructural Plan	
Conceptual Alternative A	Upper Texas Coast: Coastal Barrier with complementary system of nonstructural measures (Alternative A)	✓
	Mid to Upper Texas Coast: City of Matagorda CSRM	
	Lower Texas Coast: South Padre Island CSRM	✓
Conceptual Alternative B	Upper Texas Coast: Coastal Barrier behind GIWW complementary system of nonstructural measures (Alternative B)	
Conceptual Alternative C	Upper Texas Coast: Mid-bay Barrier Concept (Alternative C)	
Conceptual Alternative D	Upper Texas Coast: SH 146 Barrier Alignment (Alternative D1)	
	Upper Texas Coast: Bay Rim Barrier Alignment (Alternative D2)	✓
Conceptual Alternatives E, F, and G	ER Measures evaluated under ecological modeling and analysis followed by CE/ICA. This process led to 6 alternatives listed below:	
	Alternative 1: Coastwide All-Inclusive Restoration	✓
	Alternative 2: Coastwide Restoration of Critical Geomorphic Features	
	Alternative 3: Coastwide Barrier System Restoration	
	Alternative 4: Coastwide Bay System Restoration	
	Alternative 5: Coastwide ER Contributing to Infrastructure Risk Reduction	
	Alternative 6: Top Performers	

The sections below provide a detailed account of evaluation and comparison of alternative plans and explain the process to get to a final array of plans for evaluation and comparison. Due to the increasing complexities of plan formulation with the coastwide ER plans and upper coastal CSRM plans, the separable city of Matagorda and South Padre Island CSRM evaluations have been presented first in the sections below.

4.3.1 Development and Evaluation of Mid to Upper Texas Alternative Plans – City of Matagorda CSRM

The Matagorda HFPP is a Federally authorized, non-Federally operated and maintained project located in Matagorda County. It is designed to protect the city of Matagorda from flooding along the Colorado River occurring concurrent with a minor hurricane approaching Matagorda from the Gulf. The system is 7.31 miles of levee embankment with nine drainage structures and two irrigation canal structures encircling the city of Matagorda, with its western portion of the levee system located along the Colorado River. Each drainage structure is equipped with a hand-operated slide gate located in the channel and a flap gate located on the unprotected end of the culvert. The irrigation structures are equipped with hand-operated slide gates located on the unprotected side of the culvert. The levee has a crest elevation of 17.3 feet North American Vertical Datum of 1988 (NAVD 88) through the southern portion of the alignment and slightly higher elevations along the northern portion. The Matagorda HFPP is designed to provide risk reduction up to a water surface elevation of 12.0 feet mean sea level (msl) at the Colorado River Locks and was the basis of design of the overall levee system. The design water surface elevation along the river side of the levee ranges from 12.0 feet above msl at the Colorado River Locks to 15.8 feet above msl at the upstream end of the levee. Along the northern portion of the levee, the design water surface varies from 15.8 feet at the Colorado River to 15.0 feet above msl at the northeast corner. The eastern and southern portions of the system are designed to prevent damage from hurricane storm tides.

A series of periodic inspections gave the system an unacceptable rating due to the amount of damage recorded along the system's culvert and drainage system. This led to the installation of stability berms to increase the level of risk reduction against failure due to long- and short-term loading, the placement of bedding and erosion protection around existing and repaired culvert and drainage systems, and placement of erosion protection along the slopes of the levee that are affected by river conditions. In 2015, an annual inspection noted that the majority of the concerns in the previous periodic inspection were addressed and repaired.

The PDT reviewed potential improvements to the system by reviewing external water surface elevations derived from a coastwide ADvanced CIRCulation (ADCIRC) modeling effort using a suite of synthetic storms. Tables 4-9 through 4-11 show water surface elevations at the points identified on Figure 4-9 using water levels from 2017, 2035, and 2085, respectively. At 2017 water levels, the system provides risk reduction up to a 500-year exceedance event. With future RSLR, the system provides risk reduction greater than a 100-year exceedance event.

Table 4-9
Water Surface Elevations as a Function of Return Period Given 2017 Water Levels

Station ID	Elevation (feet)	Water Surface Elevations (feet NAVD 88)									
		1-year	2-year	5-year	10-year	20-year	50-year	100-year	200-year	500-year	1,000-year
10146	–4.98	1.11	1.77	2.48	3.31	4.57	6.88	9.71	12.47	15.10	16.75
13411	–0.54	--	--	--	--	4.38	6.95	9.97	12.90	15.57	17.22
13894	–14.00	1.09	1.77	2.53	3.39	4.63	6.59	8.60	10.32	12.31	13.54
17568	5.71	--	--	--	--	--	--	8.36	10.07	12.46	13.99
17569	–16.43	1.12	1.78	2.56	3.47	4.72	6.53	8.49	10.25	12.71	14.30
17576	8.37	--	--	--	--	--	--	--	9.81	12.49	14.04

Table 4-10
Water Surface Elevations as a Function of Return Period Given 2035 Water Levels

Station ID	Elevation (feet)	Water Surface Elevations (feet NAVD 88)									
		1-year	2-year	5-year	10-year	20-year	50-year	100-year	200-year	500-year	1,000-year
10146	–4.98	1.74	2.46	3.26	4.13	5.40	7.82	10.54	13.17	15.71	17.31
13411	–0.54	0.77	0.91	1.09	1.25	5.26	7.91	10.81	13.59	16.17	17.77
13894	–14.00	1.71	2.44	3.26	4.13	5.36	7.33	9.29	10.98	12.97	14.22
17568	5.71	--	0.88	1.03	1.16	1.29	1.52	9.05	10.77	13.15	14.68
17569	–16.43	1.74	2.44	3.27	4.19	5.43	7.24	9.19	10.95	13.41	14.99
17576	8.37	--	--	--	1.14	1.29	1.52	1.74	10.54	13.18	14.73

Table 4-11
Water Surface Elevations as a Function of Return Period Given 2085 Water Levels

Station ID	Elevation (feet)	Water Surface Elevations (feet NAVD 88)									
		1-year	2-year	5-year	10-year	20-year	50-year	100-year	200-year	500-year	1,000-year
10146	–4.98	3.62	4.51	5.58	6.58	7.89	10.63	13.04	15.26	17.53	18.97
13411	–0.54	3.07	3.64	4.38	4.99	7.91	10.81	13.33	15.65	17.96	19.42
13894	–14.00	3.59	4.44	5.44	6.36	7.53	9.55	11.35	12.95	14.95	16.26
17568	5.71	--	3.54	4.12	4.62	5.16	6.08	11.14	12.85	15.22	16.75
17569	–16.43	3.61	4.43	5.40	6.37	7.56	9.38	11.28	13.05	15.49	17.06
17576	8.37	--	--	--	4.58	5.16	6.07	6.96	12.73	15.26	16.80

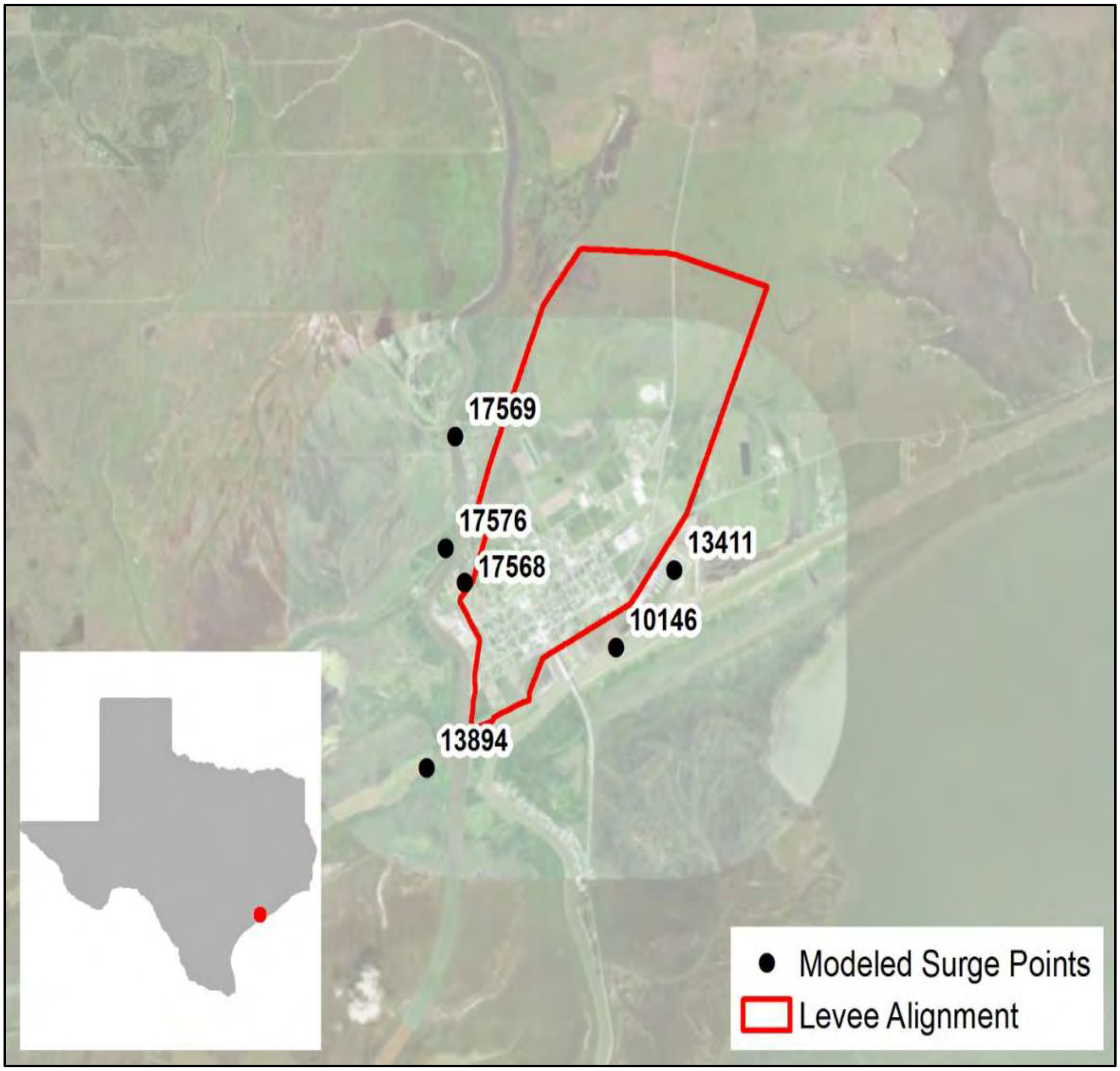

Figure 4-9: Locations of Reported Storm Surge Modeling – City of Matagorda CSRM

Due to the recent levee inspections and after reviewing the external water surface elevations, the PDT determined that the Matagorda HFPP already meets many of the goals and objectives of the Coastal Texas Study. Under most storm conditions, the existing levee system performs well above a 100-year exceedance event. Many of the problems in the system are related to interior drainage issues. There is a specific need in the area for an enhancement of the culvert and drainage components of the levee system, focusing on the use of a medium-sized pumping station and the installation of lift stations to address internal flooding; however, the PDT determined such an effort is more appropriate for a shorter duration study and authority, rather than the scale of the Coastal Texas Study.

4.3.2 Development and Evaluation of the Lower Texas Coast Alternative Plans – South Padre Island CSRM

This portion of the study area was included in the CSRM features for evaluation because of the city of South Padre Island's dense concentration of structures and risk from coastal storms. This section of the coast experienced an overall period of erosion that varied from 2 to 25 feet per year from 1800 to 1935. Jetty construction in 1935 led to erosion immediately north of the jetty. Erosion since the 1980s has been between 5 and 25 feet per year in the northern portion.

A history of beneficial use (BU) placements since 1988, conducted in conjunction with the GLO and the city of South Padre Island under a cooperative agreement with the USACE, has maintained sediment within the coastal zone along this heavily used stretch of coast. The periodic projects have beneficially used material from Brazos Santiago Pass to nourish the Gulf beach to counter the ongoing erosion along the city's Gulf-facing beach. However, when timing and funding are limited, the structures and population remain at risk along the study area between storm events.

The planning evaluation focused only on beach and dune measures due to the fact that other structural measures (revetments, seawalls, rock groins, or offshore breakwaters) would have detrimental impacts to the longshore and cross-shore sediment transport processes. Also, nonstructural measures were initially considered but not carried forward due to the many nonstructural measures (flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land-use regulations, development restrictions within the greatest flood hazard areas, and elevated development) already being implemented by the community.

In order to determine the value of the long-term construction and renourishment of beach and dune measures, life-cycle costs and benefits of varying scales of dune and berm features were estimated with the Beach-fx model. The area was divided into seven reaches (Figure 4-10).

The initial model results show that the benefits exceeded the annual project costs within reaches 3 and 4 of beachfill, since these 2 miles are the most erosive reaches. Based on the nourishment volumes and intervals (Table 4-12), the most cost-effective scale within these reaches was shown to be a 12.5-foot dune and 100-foot-wide beach berm with a 10-year renourishment cycle. Table 4-13 presents the range of potential benefits based on varying levels of cost estimate details.

Figure 4-10: South Padre Island CSRM Measure Reaches

Table 4-12
Nourishment Volumes and Intervals for the South Padre Island CSRM Feature

Cycle	Reach 3 (cy)	Reach 4 (cy)	Total (cy)*	Cost ($ FY18)
	Reach			
Initial	15,627	7,931	23,558	$5,988,500
Year 10	44,537	66,877	111,414	7,265,500
Year 20	52,660	253,267	305,927	15,794,000
Year 30	75,815	394,608	470,422	22,977,500
Year 40	99,872	423,699	523,572	25,301,500
Total**	288,511	1,146,381	1,434,893	$77,347,000

cy = cubic yards; FY = fiscal year
*volumes developed for TSP
** Total includes real estate costs

Table 4-13
Costs and Benefits of South Padre Island CSRM Measure*

Cost Estimate Level	Initial Construction and Out-Year Nourishment Including Real Estate	Average Annual Initial Construction	Average Annual Nourishment	Average Annual Cost	Average Annual Benefits	Recreation Benefits	Net Benefits	BCR
Low	71,576,000	212,299	1,137,728	1,350,027	1,285,428	202,491	137,892	1.10
Average	77,327,000	222,070	1,232,531	1,454,601	1,285,428	202,491	33,318	1.02
High	83,078,000	231,842	1,327,335	1,559,177	1,285,428	202,491	–71,258	0.95

*FY 18 PL
BCR = benefit to cost ratio

The measure was evaluated for CSRM purposes, but recreational benefits would accrue across all scales of the alternative and across multiple reaches. Following consultation with the Vertical Team, the PDT decided to defer the in-depth computation of recreation benefits through the willingness to pay method and applied a placeholder value of recreation benefits from the unit day value procedure. The team capped visitation at 750,000 per year and estimated a range of an applicable unit day value to demonstrate the economic viability of the TSP in reaches 3 and 4. The GLO has indicated that they are interested in exploring a larger extent of beachfill along South Padre Island; however, that determination will require completion of the in-depth computation of recreation benefits in future planning and design phases. In order to document the full NEPA impacts of any beach and dune measures on any of the reaches evaluated, Section 6.0 discusses the impacts of both the TSP and the potential larger extent of the project area. Table 4-12 presents the volumes for the TSP.

4.3.3 Development and Evaluation of Coastwide ER Alternative Plans

ER measures presented in tables 4-4 and 4-6 were assembled into conceptual plans for the Alternatives Milestone Meeting, but the list from Table 4-6 was replaced by a broader range of restoration opportunities once an interagency team was created to refine the measures with consideration of regional issues of concern and to complement a layered approach to coastal restoration. The ER measure screening, which evolved over many interagency meetings and workshops is presented in greater detail in the Plan Formulation Supporting Information (Appendix A). The screening process narrowed the initial array through an interagency effort to assess performance of each measure against eight specific project criteria that considered hydrological connections, sediment transport, wetland sustainability, and ecosystem influence. Final ER measure review and refinement, presented in Appendix A, identified 9 measures, which are large and varied in scale, and crafted to restore critical coastal habitats.

4.3.3.1 Adaptability in Response to Relative Sea Level Change

The final refinement of ER measures included an assessment of current and future conditions of wetland inundation images under the relative sea level change (RSLC) curves for each proposed footprint and surrounding area.

The PDT identified vulnerable areas at different points in time for the low, intermediate, and high rates of RSLC to evaluate the performance and cost effectiveness across different sea level change scenarios. The comparison confirmed that RSLC threatens critical geomorphic ecosystem features and habitats along the Texas coast under all RSLC scenarios, with variation across the curves only in how quickly the water level reaches that height. A “tipping point”/break point, where the rate at which estuarine environments in Texas evolve into open water or unconsolidated shoreline, is evident when the water level increases by 2.7 feet. Due to the uncertainty in SLR rates (low, intermediate, and high curves) and the variations in subsidence in different geographic areas, the adaptability in out years could vary anywhere between 2065 and 2112.

Given the coast-wide scale of the intervention necessary to restore marsh and estuarine environments in Texas, the PDT considered it more conservative to plan with higher impacts than lower impacts (i.e., worst-case scenario). Underestimating the quantities, time of intervention, or cost of the measures could negate the value of the effort. The GLO expressed concern that the planning effort and budget decisions should not underestimate the scale and budget implications of a meaningful action to restore the coastal environment. As a result, several measures were formulated to include an out-year nourishment or “continuing construction” component to adapt the measure over changing physical conditions in the study area.

The plan recognizes that the out-year nourishment can be implemented only when necessary. Under lower rates of RSLC, the tipping point will occur later, and the out-year nourishment may not be necessary or may occur later. An Adaptive Management Plan will address the data collection and thresholds that will trigger the implementation of out-year nourishments and will be included as an Appendix in the FIFR-EIS.

A description of the final array of ER measures, their anticipated benefits, and the expected FWOP conditions for each are described below.

Measure G-5 – Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration

Project Description. Restore, create, and/or enhance approximately 26 miles of Gulf shoreline from High Island on Bolivar Peninsula to the Galveston East Jetty. In addition, the project would restore, protect, and/or enhance about 18 miles of Galveston Island Gulf shoreline west of the Galveston seawall.

Project Benefits. The project would decrease the likelihood of erosion and breaches to beaches, dunes, wetlands, and transportation routes. It would protect the wildlife in these habitats, in addition to protecting SH 87 and Farm-to-Market Road (FM) 3005, both of which are the only evacuation routes for Bolivar Peninsula and the west end of Galveston Island, respectively. Several coastal communities, including but not limited to Pirate's Beach, Jamaica Beach, the Silverleaf Seaside Resort, Vista Del Mar, Terramar, and Baywater, would gain the benefits of the project.

FWOP. The Gulf shoreline is eroding at a rate of up to 5.7 feet per year along this area of Bolivar Peninsula and at 8.2 feet per year on the identified section of Galveston Island (BEG, 2016a). If this project does not occur, much of the existing 5,000 acres of Gulf beach, dunes, and wetlands in this area will be lost in 50 years. Loss of these ecosystems will increase susceptibility of inland habitat and infrastructure to damage during storms.

Measure G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

Project Description. Install breakwaters and restore marsh habitat to protect 27 miles of marsh habitat along the GIWW on Bolivar Peninsula and 9 miles of shoreline along the north shore of West Bay. Use sediment to restore, create, and/or enhance islands adjacent to the GIWW to protect 5 miles of shoreline habitat along the north shore of West Bay, which is eroding. Subsequently in the future, based on RSLR, renourish 6,891 acres of marsh identified as "unconsolidated shore" using the NOAA (2017a) marsh migration layer. G-12 East and G-12 West were combined with G-13 East and G-13 West to create measure G-28.

Project Benefits. Breakwaters are a proven method to greatly reduce, and sometimes reverse, the loss of marsh habitat that erodes along the GIWW due to barge wakes. The shoreline and marshes in these areas would be restored and protected from storm surge and erosion. Beyond the ecological lift just described, this project also could reduce maintenance dredging of the GIWW.

FWOP If the habitat along the shoreline is not protected, approximately 18,000 acres of existing intertidal to high marsh along the south shore of the GIWW through Bolivar Peninsula and the north shore of West Bay would be inundated at a RSLR of 3 feet (NOAA, 2017a). This marsh habitat also serves as a buffer from some storm impacts to area infrastructure.

Ancillary benefits can be expected when the ecological habitat is restored in this way. Aside from the ecological loss when sediment is lost from the marsh, the accumulation in the GIWW increases shoaling and maintenance dredging frequency. The increased width of open water in the GIWW due to the loss of marsh and the erosion of the islands adjacent to the GIWW can change the waves and currents and accelerate erosion. These factors can negatively impact navigation.

Protecting the bay shoreline of Bolivar Peninsula reduces the likelihood it will breach to the Gulf since, at 3 feet of RSLR, portions of the peninsula may narrow to less than 2,000 feet wide. Breaching can increase salinities in East Bay, which impact bay habitat.

Measure B-2 – Follets Island Gulf Beach and Dune Restoration

Project Description. Restore, protect, and/or enhance beach and dune complex on approximately 10 miles of Gulf shoreline on Follets Island in Brazoria County.

Project Benefits. A restored shoreline on Follets Island will guard against beach and dune breaches caused by erosion, storm surge, and RSLR. This will protect inland wetlands, seagrass meadows, and other habitats, all of which shield SH 257 from the effects of storm surge; it is the only road accessing and providing evacuation capability to the east towards Galveston Island and to the west towards Freeport.

The beach, dune, wetland, and seagrass meadow ecosystems along Follets Island are the first line of defense for Bastrop, Christmas, and Drum bays, the Brazoria NWR, and various residential developments on the mainland. Christmas Bay is a designated Gulf Ecological Management Site because of its relatively undeveloped shorelines, high water quality, and unique mix of seagrass meadows, oyster reefs, and smooth cordgrass marsh; it is also a TPWD Coastal Preserve.

FWOP. The Gulf shoreline in this area is eroding at a rate of 13 feet per year (BEG, 2016a). Over the next 50 years, more than 200 acres of existing beaches and dunes that protect homes, infrastructure, and habitat may be washed away due to erosion and severe storms. The critical evacuation route of SH 257 would be threatened because of its proximity to the shoreline. Currently, some sections of the highway are within 180 feet of the shoreline. Also, a Gulf-water breach of Follets Island into Christmas Bay could negatively affect its unique ecological features.

Measure B-12 – West Bay and Brazoria GIWW Shoreline Protection

Project Description. Restore, create, and/or enhance critical areas of shoreline in the bay complex of Bastrop Bay, Oyster Lake, Cow Trap Lake, and the western side of West Bay. This would be accomplished through several methods. Use breakwaters along the GIWW and along the land that separates Oyster Lake from West Bay. In Oyster Lake, add 0.7 mile of oyster cultch near the shoreline that is expected to breach into West Bay. To maintain and protect the GIWW shoreline that is identified as an "unconsolidated shore" using the NOAA (2017a) marsh migration layer at 2.5-foot RSLR, a one-time marsh nourishment of 19,794 acres would occur in year 2065. Measure B-5 (Bastrop Bay, Oyster Lake, and West Bay Shoreline Protection) was combined with measure B-6 (Brazoria County GIWW Shoreline Protection), because they are not considered separable elements and cannot stand alone; these combined measures were renamed to B-12.

Project Benefits. This restoration would protect this bay complex from being breached by West Bay. This would safeguard the critical shoreline in this bay complex from erosion, and the effects of storm events, vessel wakes, and RSLR. This also will preserve the marsh, oysters, enhance oyster populations, colonial waterbird rookeries, and other habitats in this bay complex.

FWOP. If this project does not occur, 10 miles of shoreline in this bay complex and more than 6,000 acres of intertidal marsh and freshwater wetland along the north side of the GIWW will be inundated with 3 feet of RSLR. The Brazoria NWR will lose valuable wetland habitat. Patterns of sedimentation flow will change, which will negatively affect the oyster reefs in Bastrop Bay and Oyster Lake. The conversion of large expanses of wetlands to open water also will adversely affect navigation in the GIWW.

Measure CA-5 – Keller Bay Restoration

Project Description. Use breakwaters and/or living shorelines to restore, protect, create, and/or enhance approximately 5 miles of shore along Matagorda Bay between Matagorda and Keller bays. Add oyster reef balls to protect, enhance, and create oyster habitat of about 2.3 miles of western shoreline along Sand Point, which separates the two bays. In the future, nourish 623 acres of marsh along the back side of the initial restoration to maintain and protect areas identified by NOAA (2017a) as “unconsolidated shore” with a 2.5-foot RSLR.

Project Benefits. This project would prevent the breaching of the Matagorda and Keller bays shoreline into Keller Bay. This would reduce erosion to preserve and enhance the intertidal marsh and oysters in Keller Bay and increase oyster populations.

FWOP. If a breach into Keller Bay occurs, erosion will accelerate, and currents will be modified. This will lead to the degradation and loss of oysters and over 250 acres of intertidal marsh in Keller Bay along the Matagorda and Keller bays shoreline.

Measure CA-6 – Powderhorn Shoreline Protection and Wetland Restoration

Project Description. Restore and reduce erosion to approximately 6.7 miles of Matagorda Bay shoreline with breakwaters and marsh restoration. This area fronts the communities of Indianola, Magnolia Beach, and Alamo Beach, and the Powderhorn Lake estuary.

Project Benefits. This shoreline is primarily used for recreation. The restoration would enhance the economic value of this area and protect the intertidal marsh and ecological integrity of Powderhorn Lake estuary.

FWOP. More than 300 acres of intertidal marsh/open water complex will erode and submerge at a 3-foot RSLR if the shoreline breaches. Another effect of not implementing this project is the continued widening of the mouth of Powderhorn Lake. This type of transformation would change the lake’s salinity regime and increase wave generated erosion and lead to a decline or loss of marsh.

Measure M-8 – East Matagorda Bay Shoreline Protection

Project Description. This project would use living shorelines and/or breakwaters to restore, protect, create, and/or enhance approximately 12 miles of shoreline and associated marsh along the Big Boggy NWR shoreline and eastward to the end of East Matagorda Bay. About 3.5 miles of shoreline directly in front of Big Boggy NWR also will be enhanced by adding a breakwater on the south side of the GIWW. In addition, the islands adjacent to the GIWW and the oyster reefs behind the adjacent islands on the bayside will be restored. Subsequently, in the future, a one-time marsh nourishment of 6,034 acres would occur in the areas designated by NOAA (2017a) as "unconsolidated shore" at 2.5-foot RSLR.

Project Benefits. This project would mitigate the effects of breaches, erosion, RSLR, storm events, and vessel wakes to protect the GIWW marshes, shoreline, and oyster populations in this area.

FWOP. If this project does not occur, the following areas may convert to open water at 3-foot RSLR: 1) more than 2,000 acres of intertidal marsh and wetlands around the Pelton, Kilbride and Boggy lakes complex in the Big Boggy NWR along the north shore of the GIWW and west of the Chinquapin community; and 2) over 7,000 acres of intertidal marsh and wetlands to the east of Big Boggy NWR towards Bay City at the east end of Matagorda Bay. This will increase wave erosion along the north shore and on marsh, reefs, and islands in East Matagorda Bay and south of the GIWW.

Measure SP-1 – Redfish Bay Protection and Enhancement

Project Description. Use breakwaters and/or living shorelines, BU material, and oyster reef balls to restore, create, and/or enhance the island complex of Dagger, Ransom, and Stedman islands in Redfish Bay. Breakwaters and islands would protect SAV within Redfish Bay and it is assumed about 200 acres of additional SAV will form between the breakwaters and islands.

Project Benefits. This project would prevent loss of islands to protect extensive seagrass meadows and support coastal waterbirds, fisheries, and oysters.

FWOP. Not restoring this island complex would result in continued erosion and will expose the area to greater wave action from the deep-draft navigation in the Corpus Christi Ship Channel. This could threaten approximately 2,000 acres of seagrass meadows and damage the habitat for coastal waterbirds and fisheries.

Measure W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

Project Description. This project would restore the Port Mansfield Channel area by implementing the following: 1) use beach and dune restoration to improve and maintain the geomorphic function of the Gulf shoreline north of the Port Mansfield Channel through the barrier island; 2) protect and restore Mansfield Island Bird Rookery with 3,696 feet of rock breakwater and beneficial use for island restoration; and 3) restore and maintain the hydrologic connection between the Laguna Madre and the Gulf with dedicated dredging of a portion of the Port Mansfield Channel. W-1 and W-2 were combined to create one measure, W-3, in which the material dredged from the channel would be used beneficially for beach nourishment and for additional restoration of Mansfield Island.

Project Benefits. Currently, jetties block the prevailing south to north longshore current. This project would restore sediment transport north of the Port Mansfield Channel jetties. This would prevent the eminent breach of the barrier island and maintain access to visitors and National Park Service staff. Restoration of sediment transport would support dune development and help control erosion along the Gulf shore. This would help protect the critical habitat for wintering piping plovers and the primary U.S. nesting beach for the Federally endangered Kemp's ridley sea turtles.

Restoring Mansfield Island would increase the size and elevation of the island to mitigate erosion due to RSLR, storms, and vessel wakes, allowing more birds to nest. Lastly, the hyper-salinity in the Laguna Madre would be reduced, improving the habitat.

FWOP. If this project does not occur, erosion on the north side of the pass would continue at a rate of 14 feet per year (BEG, 2016a). The beach and dune system would erode toward washovers, which can increase the likelihood of system breaches. Breaches would increase water exchange with the Gulf resulting in changes to salinity, circulation, and habitat in the Laguna Madre.

Without the project, the area would not be protected from the effects of RSLR. With an expected 2-foot RSLR by 2085, dune areas can transition to brackish intertidal wetlands on the back side of South Padre Island and increase the possibility of breaches in the barrier island. RSLR of 2 feet combined with ongoing erosion would completely convert the 3-acre Mansfield Island used by colonial waterbirds to unconsolidated tidal flats.

4.3.3.2 Construction Cost Estimates of ER Measures

Cost estimates were derived by applying unit costs from comparable restoration measures of adjacent projects in the district. The costs included real estate acquisition, mobilization and demobilization, and transportation costs from specific borrow areas to the feature locations.

The PDT identified multiple sediment sources for each measure to ensure adequate sediment is available to construct all measures (Table 4-14). In several instances, a portion of the necessary sediment would be available from closer sources; however, the cost estimate reflects the cost of dredging and transporting from the largest and possibly farthest source. This approach recognized that certain cost savings may be achieved at the time of construction by using closer sources but ensured that the cost estimate adequately reflected the highest cost source.

Table 4-14
Sediment Sources and Volumes by Measure

Measure	Volume Required (cy)		Primary Sediment Source Location*	Possible Sediment Sources
G-5 – Bolivar Peninsula/West Galveston Island Beach and Dune Restoration	Dune: Beach-low: Beach-high:	3,339,928 30,173,310 63,549,998	• Sabine Heald Banks	• Shoreface Sediments
G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (East and West)	Marsh Creation and Restoration (Initial): Marsh Creation and Restoration (Out-year): Island Creation and Restoration:	482,137 10,117,098 5,822,917	• GIWW Beneficial Use of Dredged Material and/or mining • Houston Ship Channel Bypass Channel from the Coastal Barrier CSRM	• Big Reef • GIWW Bolivar Flare Sediment Trap • Houston Ship Channel Beneficial Use of Dredged Material and/or mining • Sabine and Trinity River Paleo Channels
B-2 – Follets Island Gulf Beach and Dune Restoration	Beach/Dune (Initial): Beach/Dune (Renourishment):	8,782,000 11,639,000	• Sabine Heald Banks	• Shoreface sediments
B-12 - West Bay and Brazoria GIWW Shoreline Protection	Marsh Creation and Restoration (Initial): Marsh Creation and Restoration (Out-year):	399,863 29,060,231	• Freeport Beneficial Use of Dredged Material and/or mining • GIWW Beneficial Use of Dredged Material and/or mining • Paleo Colorado and Brazos Deltas	• Chocolate Bayou Beneficial Use of Dredged Material and/or mining • San Bernard River Beneficial Use of Dredged Material and/or mining
CA-5 – Keller Bay Restoration	Marsh Creation and Restoration:	914,647	• Matagorda Ship Channel Beneficial Use of Dredged Material and/or mining	
CA-6 – Powderhorn Shoreline Protection and Wetland Restoration	Marsh Creation and Restoration:	385,760	• Matagorda Ship Channel Beneficial Use of Dredged Material and/or mining	

Measure	Volume Required (cy)		Primary Sediment Source Location*	Possible Sediment Sources
M-8 – East Matagorda Bay Shoreline Protection	Marsh Creation and Restoration (Initial): Marsh Creation and Restoration (Out-year): Island Creation and Restoration:	173,696 8,858,717 1,195,299	• Colorado River Diversion Delta • GIWW Beneficial Use of Dredged Material and/or mining • Paleo Colorado and Brazos Deltas	
SP-1 – Redfish Bay Protection and Enhancement	Island Creation and Restoration:	6,685,556	• Corpus Christi Ship Channel Beneficial Use of Dredged Material and/or mining • La Quinta Beneficial Use of Dredged Material and/or mining	• Aransas Pass Channel Beneficial Use of Dredged Material and/or mining • Placement Areas 10 (east end) mining; 11 mining; 13 mining
W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration		To be determined	• Port Mansfield Channel	

* Coordination has begun with agencies for sediment sources. Agency coordination will continue as sediment sources are refined in future planning and design phases.

The costs were presented in high and low range by considering the highest and lowest acceptable contingencies for each action (Table 4-15). The costs were also estimated for each scale of the measure, with initial construction as a separate alternative, and as the initial and out-year construction undertaken at an assumed year in the future under an intermediate rate of RSLC.

Table 4-15
Construction Cost Estimates of ER Measures, FY 18

	Initial	Initial	Initial	Continuing	Continuing	Continuing	
Measure	Low Estimate	High Estimate	Average Estimate	Low Estimate	High Estimate	Average Estimate	Total of Average Initial and Continuing Construction Estimates
G-5	$2,974,454	$3,711,107	$3,342,781	$946,809	$1,325,533	$1,136,171	$4,478,952
G-28-1	757,074	989,345	873,210	0	0	0	873,210
G-28-2	757,074	989,345	873,210	474,513	664,318	569,416	1,442,626
B-2	433,386	600,155	516,771	517,313	724,238	620,776	1,137,547
B-12-1	517,262	717,713	617,488	0	0	0	617,488
B-12-2	517,262	717,713	617,488	2,925,131	4,095,183	3,510,157	4,127,645
CA-5-1	46,692	65,369	56,031	0	0	0	56,031
CA-5-2	46,692	65,369	56,031	15,685	21,959	18,822	74,853
CA-6	64,078	88,280	76,179	0	0	0	76,179
M-8-1	149,971	209,720	179,846	0	0	0	179,846
M-8-2	149,971	209,720	179,846	298,825	418,355	358,590	538,436
SP-1	274,405	384,164	329,285	0	0	0	329,285
W-3	36,098	50,039	43,069	433,173	606,442	519,808	562,877

* Measures with "-1" do not include the one-time out-year nourishment in 2065. Measures with "-2" include the one-time out-year nourishments in 2065.

4.3.3.3 ER Alternative Development Strategy

ER measures were assembled into alternatives with a systematic combination of management measures based upon specific planning objectives to narrow the universe of possible solutions to a concise group of initial alternatives.

4.3.3.3.1 Identify Lines of Defense Strategy for Ecosystem Restoration

The multiple lines of defense formulation strategy is based on the concept that natural landforms provide lines of defense against coastal storms. The concept of lines of defense is also related to risk reduction of coastal ecosystems and human infrastructure from storm damage caused by hurricanes and tropical storms coming ashore from the Gulf. The series of barriers provided first by the barrier islands, then by living shorelines, and finally coastal marshes can reduce the physical impacts of storm surges and winds that enter the bays. This combination of multiple lines of defense using natural features is intended to provide redundant levels of risk reduction and restoration for both humans and Texas coastal ecosystems.

1st Line of Defense and Ecosystem Restoration – Barrier Systems

Barrier islands, shorelines, and headlands, as well as tidal inlets, form the first line of defense for the nine major estuarine bays and the residential, industrial, and recreational structures therein. They are the boundary between the Gulf, estuarine, and terrestrial ecosystems. These features include barrier beach, dune, back marsh, and shallow open-water areas along the inland side of barrier islands. Coastal barriers also provide habitat for various marine, estuarine, and terrestrial organisms as well as stopover habitat for migrating neotropic birds. Coastal barrier systems provide protection to the wetlands, bays, and estuaries located behind the barrier systems. These features influence tidal prism, limit storm surge heights, retard saltwater intrusion, and limit mechanical erosion by reducing wave energy at the margins of coastal wetlands. Coastal barrier systems and other features of the coastal landscape (e.g., shoals, marshes, and forested wetlands) can provide a potentially sustainable buffer from wind-wave action and storm surge generated by tropical storms and hurricanes.

2nd Line of Defense and Ecosystem Restoration – Estuarine Bay System

Bay shorelines, inlets, and bordering estuarine marshes form the second line of defense for ER. As the barrier systems are eroded, fragmented, and lost, the tidal prism seeks to reestablish dynamic equilibrium between the higher-energy Gulf forces moving tidal waters faster and higher into the upper parts of the estuary thereby subjecting bay shorelines and estuarine wetlands to greater Gulf forces of wind and wave erosion and higher salinities. These cumulative changes can cause increased estuarine marsh loss and shoreline erosion. Estuaries provide habitat for ecologically, commercially and recreationally important fish and wildlife. Estuaries are particularly important nursery habitat for many organisms with early life stages depending on salinities below Gulf salinities. Estuarine shorelines also provide important habitat for migrating neotropic birds.

Associated with estuarine bay systems are adjacent bird rookery islands, oyster reefs, and SAV. Each of these habitat features are typically isolated and relatively small features, as in the case of bird rookery islands. Despite this, when considered from a cumulative perspective, the combination of these features within an estuarine bay system can have local, regional, and especially important to the NER requirements for the study, national importance. In addition, strategic placement and numbers of bird rookery islands, oyster reefs, submerged vegetation beds, and living shorelines can also function as terraces to slow down waves and sediments, reduce fetch, and create EFH.

3rd Line of Defense and Ecosystem Restoration – Bayhead Deltas

The third line of defense for ER involves conserving, restoring, and protecting bayhead deltas. Managing freshwater inflows to optimize salinity, sediment, and nutrient regimes helps sustain deltas and their associated habitats. Developing sediment management strategies would maximize delta accretion and sustain important wetland habitats provided by healthy deltas. Opportunities to manage hydrologic connectivity could also help benefit delta wetlands. The land and wetland habitat provided by deltas further protects human infrastructure and estuarine ecosystems.

Similar to barrier and estuarine bay systems there are adjacent bird rookery islands, oyster reefs, and SAV in the bayhead deltas, which provide benefits similar to those previously described for barrier systems and bay systems.

Six ER alternatives were developed using the formulation strategies. Also, two scales were developed for the measures to investigate the scale and the budget implications for addressing an unknown landscape in light of RSLR scenarios. Scale 1 alternatives do not include out-year nourishment for measures G-28, B-12, CA-5, and M-8. Scale 2 alternatives include out-year nourishment for those same measures, if they are included in the measure. Measures G-5, B-2, and W-3 will not have out-year marsh nourishment in any alternative where they are included. Table 4-16 provides a summary of the measures in the alternatives. Table 4-17 presents the list and title of the alternatives. Figures 4-11 through 4-16 illustrate the alternative, as a combination of the features.

Table 4-16
Crosswalk of ER Measures by Alternative

	Measures												
Alt.	G-5	G-28-1	G-28-2	B-2	B-12-1	B-12-2	CA-5-1	CA-5-2	CA-6	M-8-1	M-8-2	SP-1	W-3
1-1	•	•		•	•		•		•	•		•	•
1-2	•		•	•		•		•	•		•	•	•
2-1	•			•	•				•				•
2-2	•			•		•			•				•
3-1	•	•		•									•
3-2	•		•	•									•
4-1		•			•		•		•	•		•	
4-2			•			•		•	•		•	•	
5-1	•	•		•	•								
5-2	•		•	•		•							
6-1	•	•		•	•				•				
6-2	•		•	•		•			•				

Table 4-17
List of Fully Formed ER Alternatives

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

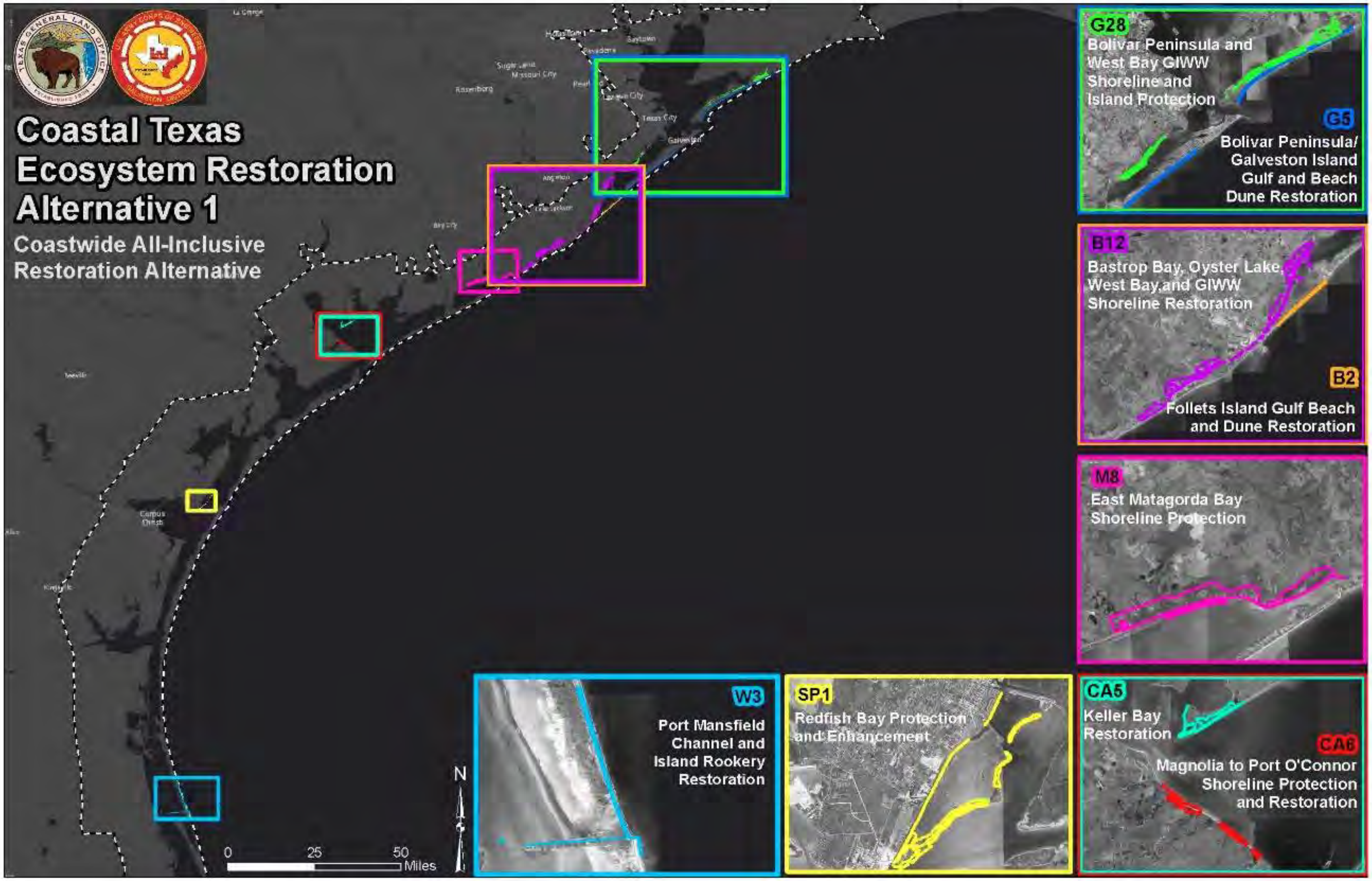

Figure 4-11: ER Alternative 1, Scale 2

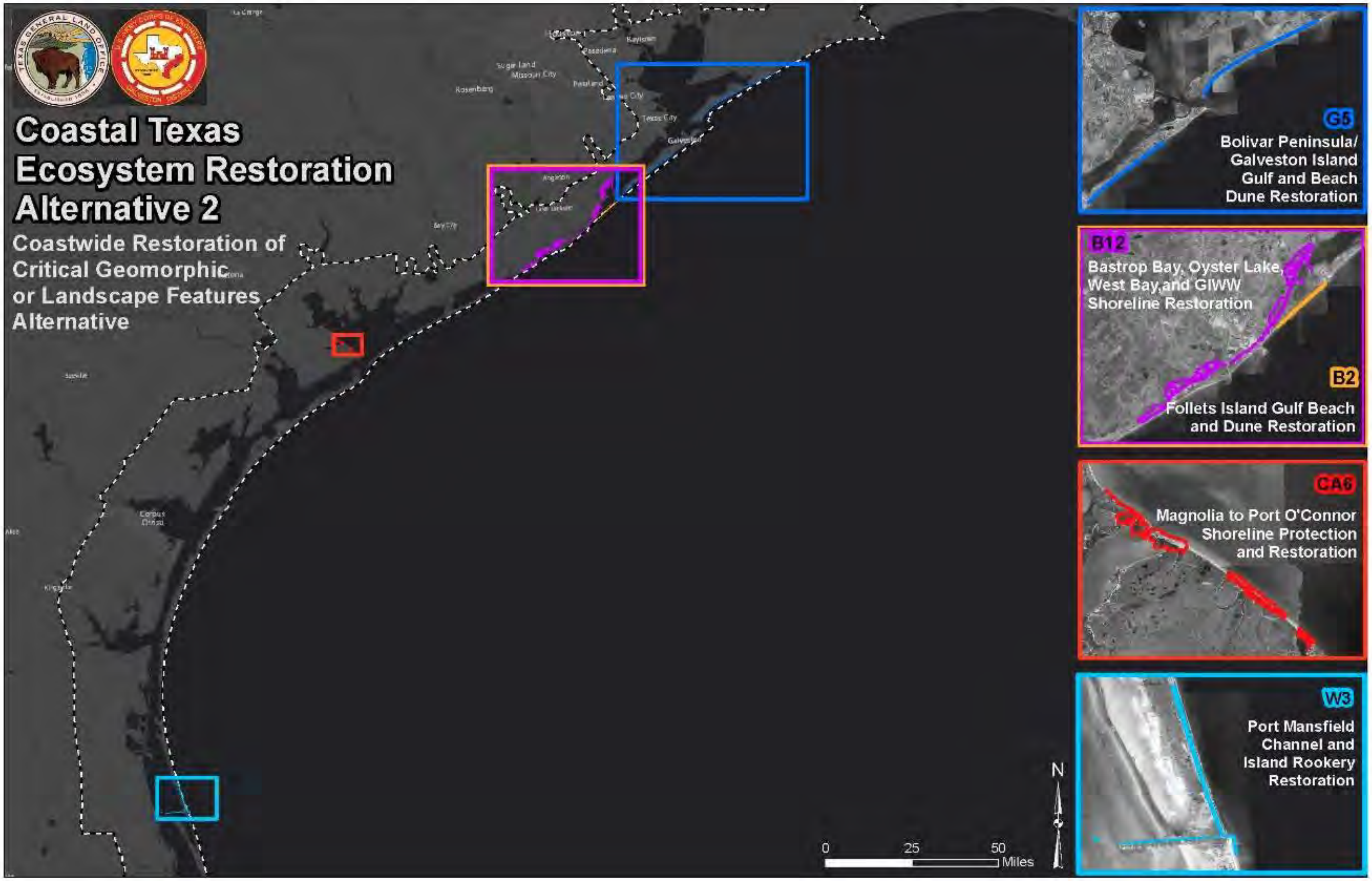

Figure 4-12: ER Alternative 2, Scale 2

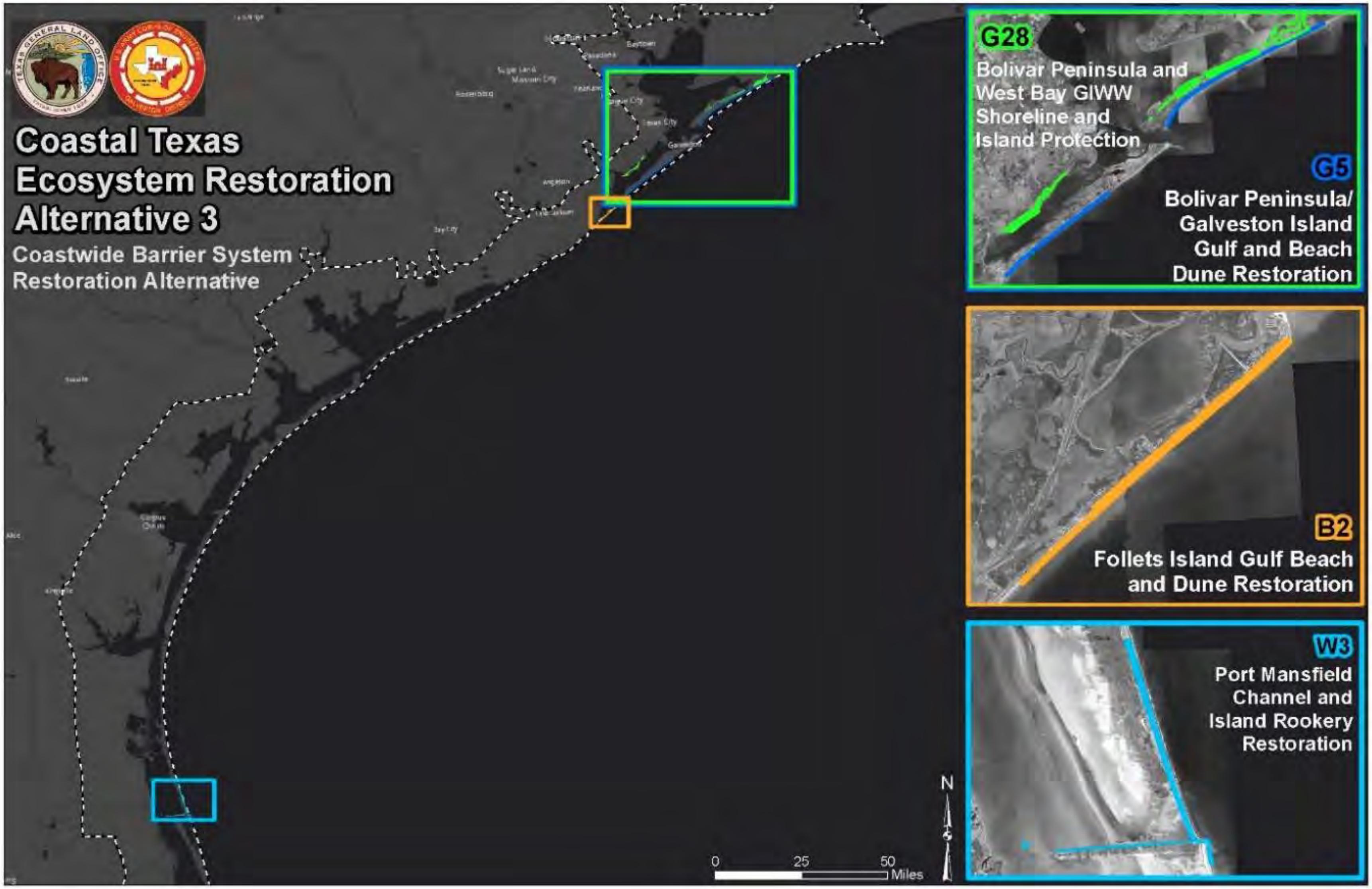

Figure 4-13: ER Alternative 3, Scale 2

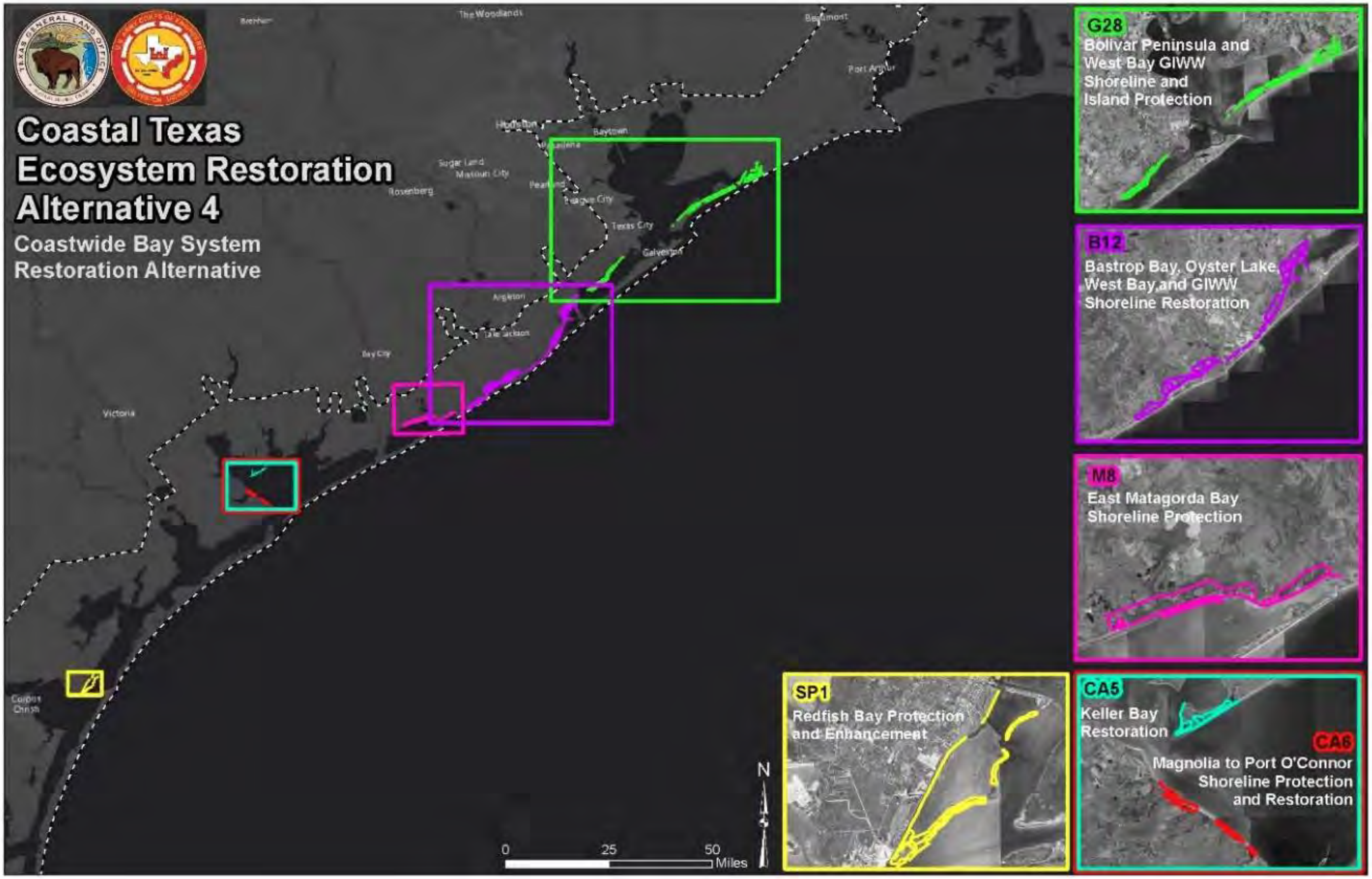

Figure 4-14: ER Alternative 4, Scale 2

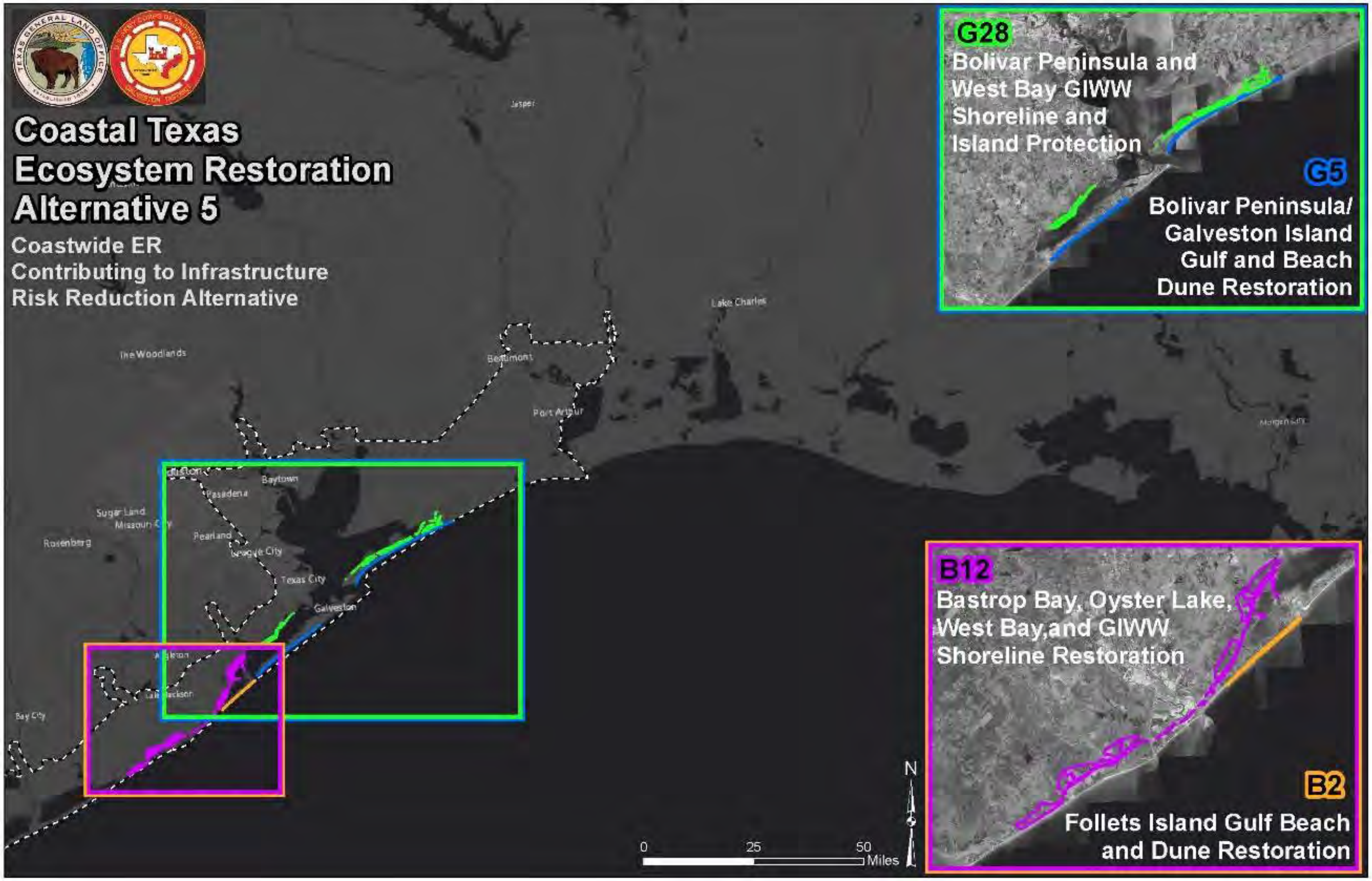

Figure 4-15: ER Alternative 5, Scale 2

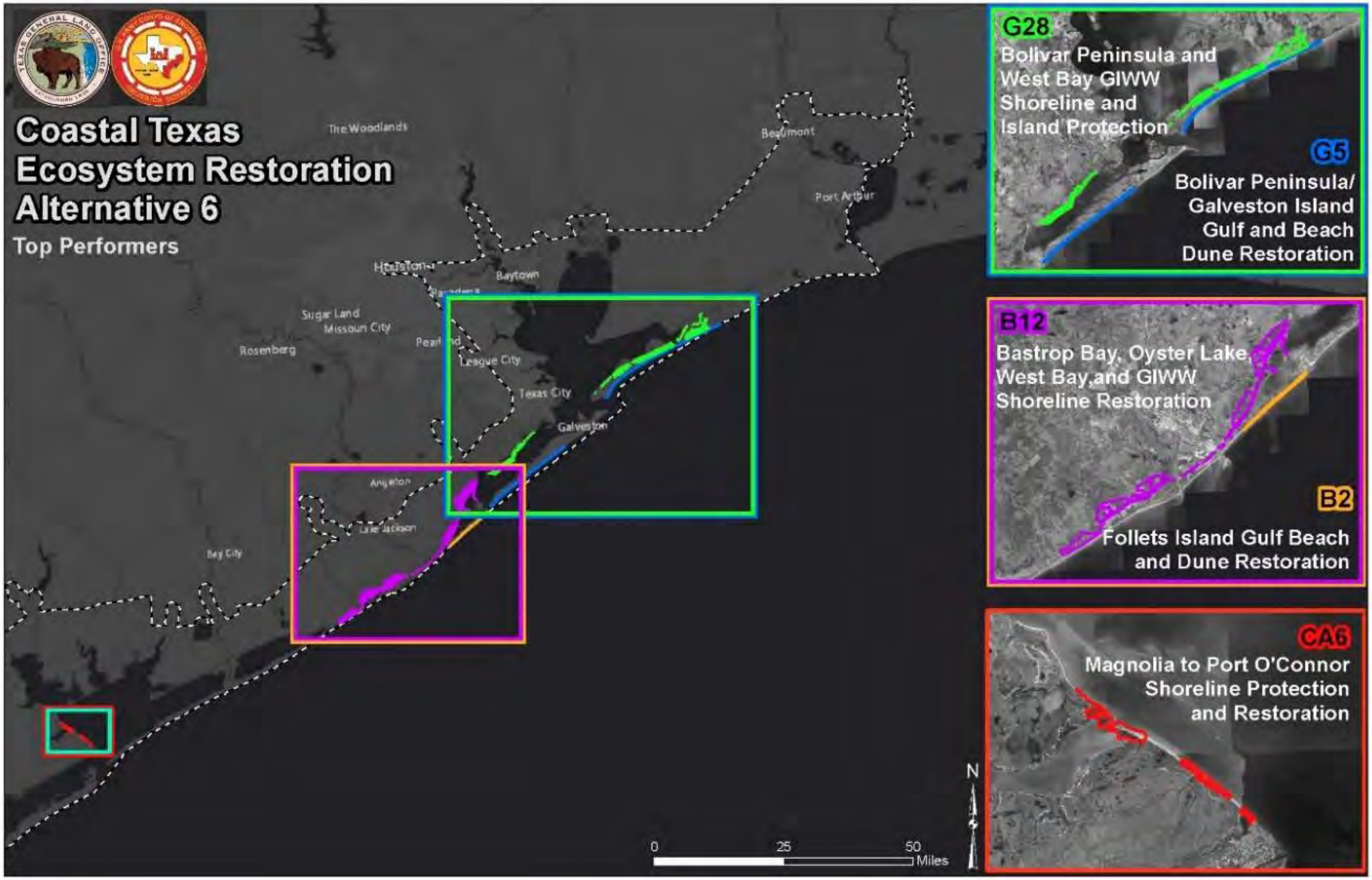

Figure 4-16: ER Alternative 6, Scale 2

4.3.3.4 ER Benefit Quantification

The final justification of ER alternatives requires quantification of ecological lift in the form of net AAHUs between the FWOP and future with-project (FWP) condition (Table 4-18). This comparison performance requires evaluation with the Habitat Evaluation Procedures (HEP) and Wetland Valuation Analysis (WVA) models to characterize the improvement in habitat suitability. HEP is a widely accepted approach for quantitative evaluation of measures or management activities that cause environmental changes and to predict ecological impact of measures. The WVA methodology, similarly, quantifies changes in habitat quality and quantity that are predicted to result from management activities. HEP uses a species-oriented approach and is based on approved Habitat Suitability Index (HSI) models, while WVA uses a community approach, for example, the barrier island WVA model used in this study.

Table 4-18
AAHUs by Measure and Scale

Measures	FWOP	FWP	Net AAHUs
G-5	804	2,624	1,820
G-28-1	20,327	21,414	1,087
G-28-2	20,327	29,537	9,210
B-2	222	613	391
B-12-1	30,357	31,618	1,261
B-12-2	30,357	47,591	17,234
CA-5-1	559	781	222
CA-5-2	559	890	331
CA-6	901	919	18
M-8-1	10,769	10,992	223
M-8-2	10,769	17,072	6,303
SP-1	20	3,521	3,501
W-3	8,279	38,815	30,536

Since 4 of the 9 management measures were developed with two scales, initial construction and out-year construction, the analysis considered this array to be 13 management measures in total, although Scales 1 and 2 for a single measure were not combinable (Table 4-19). Scale 1 assumes there are no out-year nourishment actions beyond the initial construction. Scale 2 assumes one or more out-year nourishment after initial construction and within the 50-year period of analysis, varying by measure. Environmental benefits and project first costs were developed separately for each measure and are fully additive when measures are combined to form alternatives.

Table 4-19
AAHUs and Acres by Alternative and Scale

ER Alternative	Net AAHUs	Target Year 51* Acres
Alternative 1 (9 measures)		
Scale 1	39,059	63,199
Scale 2	69,344	160,279
Alternative 2 (5 measures)		
Scale 1	34,026	54,669
Scale 2	49,999	105,119
Alternative 3 (4 measures)		
Scale 1	33,834	53,205
Scale 2	41,957	83,145
Alternative 4 (6 measures)		
Scale 1	6,312	11,142
Scale 2	36,597	108,222
Alternative 5 (4 measures)		
Scale 1	4,559	7,385
Scale 2	28,655	87,775
Alternative 6 (5 measures)		
Scale 1	4,577	8,005
Scale 2	28,673	88,395

* Target Year 51 is the end of the period of analysis.

4.3.3.5 Cost Effectiveness/Incremental Cost Analysis

Environmental restoration benefits can be measured in habitat units or some other physical unit, while costs are measured in dollars. Therefore, benefits and costs cannot be directly compared. Two analyses are conducted to help planners and decisionmakers identify plans for implementation, although the analyses themselves do not identify a single ideal plan. These two techniques are CE/ICA. Use of these techniques are described in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies* (U.S. Water Resources Council, 1983).

Cost effectiveness compares the annual costs and benefits of plans under consideration to identify the least cost plan alternative for each possible level of environmental output, and for any level of investment, the maximum level of output is also identified.

Incremental cost analysis of the cost-effective plans is conducted to reveal changes in costs as output levels are increased. Results from both analyses are presented graphically to help planners and decisionmakers select plans. For each of the plans identified through incremental cost analysis, an “is it worth it?” analysis is then conducted for each incremental measure or plan to justify the incremental cost per unit of output to arrive at a TSP.

For this study, the multiple CE/ICA runs were informative and supported reformulation of alternative plans to ensure the maximum ecological lift was achieved for incremental costs.

4.3.3.6 Best Buy Plans

The alternatives formulated according to the strategy were evaluated within the Institute for Water Resources Planning Suite to identify cost-effective alternative plans. A cost-effective plan alternative is defined as one where no other plan alternative can achieve the same level of output at a lower cost, or a greater level of output at the same or less cost. A subset of cost-effective plan alternatives is identified as "best buy plans." Best buy plans are cost-effective plan alternatives that provide the greatest increase in environmental output for the least increase in cost per unit of output. Two alternatives were identified as best buy plans: Alternative 1-Scale 2 and Alternative 4-Scale 2. The CE/ICA analysis was also run on the individual measures, which combined measures to produce alternatives, rather than only considering the formulated alternatives. This second analysis created an additional alternative, which was a best buy plan that was named Alternative Z.

4.3.3.7 Alternative Refinement to Improve Cost Effectiveness

After considering why Alternative Z performed better than Alternative 4 Scale 2, an alternative from the array developed according to the formulation strategy, the PDT realized that measure W-3 was a very cost-effective measure and was the only difference between Alternative 4 and Alternative Z. However, W-3 would be consistent with the formulation strategy of Coastwide Bay System Restoration, since it improves the hydrologic connection between Laguna Madre (a bay system) and the Gulf. Therefore, Alternative 4 Scale 2 was reformulated to include measure W-3 and renamed as Alternative 4 Revised-Scale 2. Interim CE/ICA analyses and results are available in the CE/ICA Appendix (Appendix E-3). The CE/ICA was then rerun with Alternative 4 Revised-Scale 2.

4.3.3.8 Comparison of Final Array of Coastwide ER Alternative Plans and Selection of TSP

The final array of ER plans includes Alternative 4 Revised-Scale 2 and Alternative 1-Scale 2.

Alternative 4 Revised-Scale 2 – Coastwide Bay System Restoration. This alternative includes seven measures: G-28, B-12, M-8, CA-5, CA-6, SP-1, and W-3; a combination that would restore habitats that offer ecological lift and protect bay shorelines, inlets, and estuarine marshes that can slow down waves and sediments and reduce wind-generated waves.

Alternative 1-Scale 2 – Coastwide All-Inclusive Restoration. This is the largest alternative and includes all nine ER measures: G-5, G-28, B-2, B-12, M-8, CA-5, CA-6, SP-1, and W-3. This alternative would restore natural features that provide diverse habitat within the coastal ecosystems and support natural conditions to withstand coastal storm conditions that cause land and habitat loss.

ER measures G-5 and B-2 are included in Alternative 1 but are not included in Alternative 4 Revised. These two measures create beach habitat, which provides an ecological lift in the study area greater than the AAHUs of the beach footprint. Beach habitat restoration also addresses an issue of concern of the State of Texas, Gulf beach erosion and dune degradation, as described within the GLO's Texas Coastal Resiliency Master Plan. The following describes the multiple routes through which beach habits generate lift to biodiversity:

- Threatened and endangered species rely upon beach environments. Beach nourishment adds nesting habitat for multiple species of sea turtles. The Kemp's ridley sea turtle, the most critically endangered sea turtle species in the world, uses the Texas coast beaches for nesting. Protecting Texas Gulf coast beaches is especially important for this species, as Texas is one of only two areas in the world where they are known to nest. Narrow, eroded beaches deter sea turtle nesting. Loss of beaches and barrier islands with RSLR presents threats to the long-term survival of the species. Additionally, warmer water temperatures are predicted to drive the species northward causing Kemp's ridley sea turtles to nest more frequently on the upper Texas coast similar to their current nesting frequency on South Padre Island.
- Piping plover and rufa red knot are specific threatened and endangered species who forage, flourish, and nest in and around the beach areas. Texas is estimated to winter more than 35 percent of the known population of piping plovers (Campbell, 2003). Generally, adult and young plovers return to the same areas each year. They feed on beaches and tidal flats at high tide. Loss of sandy beach is a primary threat for this species. Critical Habitat has been designated along the Texas coast, including on Bolivar Peninsula and Galveston Island, for wintering piping plovers. Building beach habitat to maintain barrier islands would also maintain plover habitat. The threatened rufa red knot uses similar habitat to the piping plover and also winters on the Texas coast. Habitat loss is a primary threat to this species. Like plovers, rufa red knots return to the same wintering areas each year during migration. Creation of beach habitat and maintaining that habitat in suitable areas, like in Texas, is key to protecting this species.
- Multiple bird species rely on coastal beach habitats for forage. Food sources include crabs, bivalves, and other invertebrates that themselves rely on healthy beaches.
- Beach restoration along the Texas coast reduces the risk of over proliferation of certain habitats at the expense of others, promoting biodiversity.
- Beach habitats also provide a physical barrier between ecologically significant habitats of the Gulf and bay. The salinity differences between estuarine and Gulf waters yield distinct ecosystems, which support multiple species. When saltwater enters freshwater marshes, there is a loss of freshwater vegetation. Loss of vegetation leads to more erosion as plants are not present to trap sediment to maintain a barrier, and fewer plants leads to fewer species of birds and fishes.
- Acres of estuarine environment are maintained in the face of short-term storm conditions and long-term RSLC. While the applicable model does not capture AAHUs as a result, a portion of the preserved estuarine environment is the result of beach restoration.

- Without a natural dune system on Bolivar Peninsula, saltwater will flood the marsh, resulting in the loss of marsh habitat at a rate of 15 to 45 feet per year. Beaches absorb high-impact waves and stop or delay intrusion of water inland.
- Protection of Christmas Bay (as mentioned in B-2 above).

The combination of recommended actions to restore and maintain the habitats along the Texas coast is unavoidably massive in scale in order to effectively address historic losses and impairments and to ensure impactful intervention. The scale of the effort necessitates phasing of the actions and adaptive efforts to ensure the effectiveness of the intervention in the life cycle of the plan. This phasing, in turn, assists the spreading of financial costs to aid in budgeting, both the Federal budget and the NFS's budget. Table 4-20 presents the cost per ER Alternative and scale by AAHUs, and Figure 4-17 shows the final array of Best Buy alternatives.

Table 4-20
Cost of AAHUs by ER Alternative and Scale (FY 18 PL)

Alternative	Output (AAHU)	Cost ($1,000)	Average Cost ($1,000/ AAHU)	Incremental Cost ($1,000)	Incremental Output	Incremental Cost per Output ($1,000)	Total Cost ($1,000)
No-Action	–	–	–	–	–	–	–
Alternative 4 Revised-Scale 2	67,133	$159,882	$2.38	$159,882	67,133	$2.38	$7,225,239
Alternative 1-Scale 2	69,344	$378,759	$5.46	$231,024	32,747	$98.99	$12,881,299

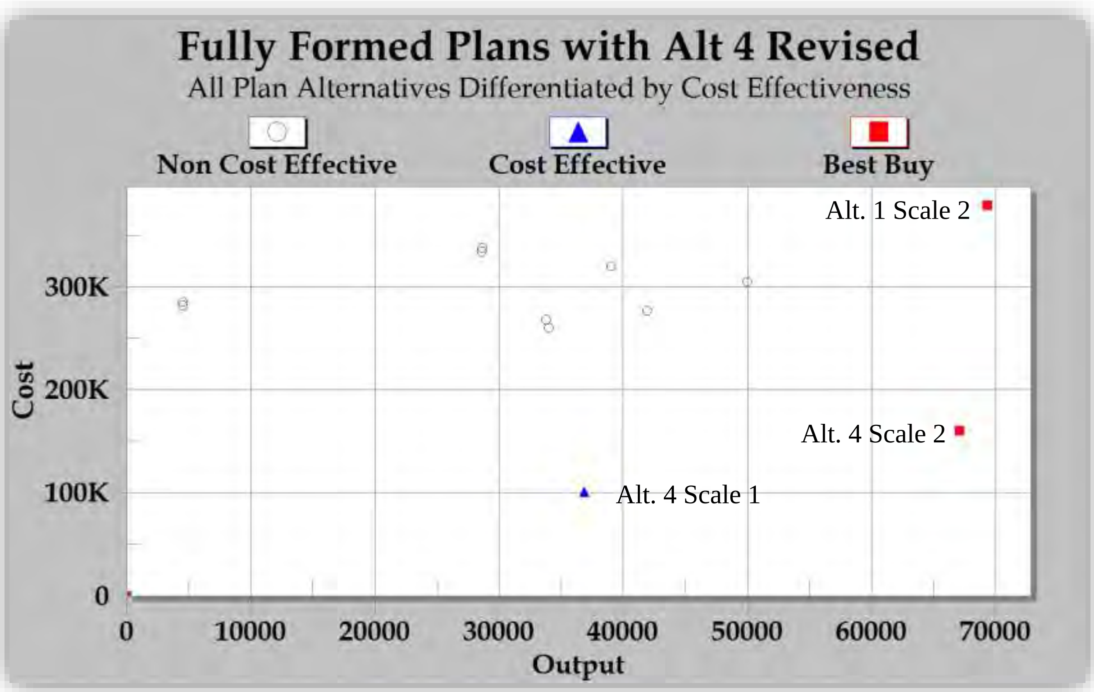

Figure 4-17: Final Array of ER Best Buy Alternatives

> The measures within Alternative 1-Scale 2 have been refined through multiple screenings of their effectiveness specific to the needs and opportunities within the study area and the diversity of the habitat they preserve. Therefore, Alternative 1 Scale 2 is recommended for inclusion in the TSP.

4.3.4 Development and Initial Screening of the Upper Texas Coast CSRM Alternative Plans

The remaining CSRM measures in Table 4-6 and the conceptual plans were reformulated into an array of six CSRM alternative plans for the upper Texas coast, in addition to the No-Action Alternative. As plans were developed, they were assumed to have similar level of risk reduction to some of the existing risk reduction systems in the upper Texas coast. For example, plans which had a levee system tying into the Galveston seawall were designed and evaluated based on similar heights of the existing seawall, an elevation of approximately 17 feet NAVD 88. The same assumption was used for plans tying into the Texas City HFPS. The PDT made this simplifying assumption to ensure that the analysis focused on an initial comparison of distinctly different plans rather than different scales of plans. This was consistent with the conceptual formulation strategy, which explored different strategies (Gulf Shoreline Focus, Back/Mid Bays Focus, Upper Bay Focus). Once a strategy for risk reduction has been selected, the study team will focus on the scale of the level of risk reduction for the TSP in future planning and design phases. Individual features such as levee heights, flood heights, pump station sizes, and nonstructural features will be optimized.

It is important to understand that plans were first evaluated on the effects of a comparison of the with-project and without-project conditions for each alternative. The evaluation was conducted by assessing or measuring the differences between each with- and without-project condition and by appraising or weighting those differences. This process led the team to screening the six CSRM alternative plans into two CSRM alternatives for the comparison of alternative plans phase. In this step, the two CSRM plans were compared against each other, with emphasis on the outputs and effects that had the most influence in the decision-making process. These two CSRM plans, including the No-Action Alternative, were also included in the NEPA evaluations discussed in Section 5.0.

4.3.4.1 Nonstructural Plans

Section 73 of the WRDA of 1974 requires consideration of nonstructural alternatives in flood damage reduction studies. They can be considered independently or in combination with structural measures. Nonstructural measures reduce flood damages without considerably altering the nature or extent of flooding. Damage reduction from nonstructural measures is accomplished by changing the development within floodplains or by accommodating existing uses to the flood hazard. Examples are flood proofing, relocation of structures, flood warning and preparedness systems (including associated emergency measures), and regulation of floodplain uses. The following describe potential nonstructural measures:

- **Dry Flood Proofing.** Dry Flood Proofing measures allow flood waters to reach the structure but diminish the flood threat by preventing the water from getting inside the structure walls. Dry Flood Proofing measures considered in this screening make the portion of a building that is below the flood level watertight through attaching watertight closures to the structure in doorway and window openings. Detached levees and floodwalls were not considered due to the density of structures in the floodplains.
- **Wet Flood Proofing.** Allowing flood water to enter lower, non-living space areas of the structure via vents and openings to reduce hydrostatic pressure and in turn reduce flood-related damages to the structure's foundation. This technique can be used along with the protection of utilities and other critical equipment, which can include permanently raising machinery, critical equipment, heating and cooling units, electrical outlets, switches, panels and merchandise/ stock above the estimated flood water height. It can also involve construction of interior or exterior floodwalls, utility rooms, or additional living space to compensate for space subject to flooding, and the use of flood-resistant materials.
- **Elevation.** Raising the lowest finished floor of a building to a height above the design flood level. This option was considered both as a stand-alone measure and in conjunction with additional construction. In some cases, the structure is lifted in place and foundation walls are extended up to the new level of the lowest floor. In other cases, the structure is elevated on piers, posts, or piles.
- **Acquisition.** Removal of the structure from the floodplain through demolition. Lands are then preserved for open space uses.
- **Relocation.** Moving the structure out of the floodplain, either within the existing property boundary (if sufficient space is available) or to another property.
- **Rebuild.** Demolishing a flood-prone structure and replacing it with a new structure built to comply with local regulations regarding new construction and improvements in a floodplain and therefore is at a lower risk. The rebuild option would be considered only where the costs were found to be less than those associated with an otherwise recommended treatment.

The team initially evaluated a nonstructural raising or a buyout program in the entire area of the upper Texas coast. The nonstructural assumption was based on a 100 percent participation rate and would have included removing or modifying over 64,000 residential and nonresidential structures receiving flood damage by the stage associated with the 0.01 (100-year) annual chance exceedance event in 2035 and 2085 under without-project conditions. The PDT determined that a nonstructural treatment as a stand-alone plan does not achieve the project goals and objectives for a variety of reasons. Based on initial stakeholder and NFS discussions, it is highly likely a voluntary program would receive very little participation due to the number of structures to be potentially removed from the community. Residents may not want to volunteer for buyouts because of the economic cost of relocation and the social costs of breaking up a community or uprooting a family. Also, it is important to note that, as seen with Hurricane Harvey impacts, relocating residents away from the coastal surge doesn't necessarily remove all flooding risk from residents.

There are also community cohesion and environmental justice concerns in minority and low-income populations in some of the communities along the west side of Galveston Bay. A large-scale nonstructural plan results in challenges since the final detailed evaluations for nonstructural raising or buyout proposals must undergo a Benefit-Cost Analysis showing that the estimated cost of future flood damage surpasses the cost of purchasing and demolishing a structure. Equity concerns have come up around the Benefit-Cost Analysis method when reviewing the Social Vulnerability Index for the communities of La Porte, Santa Fe, La Marque, and in portions of the city of Galveston (Figure 4-18).

For instance, because the cost of repeated flooding must be greater than the cost of acquisition and demolition to justify the effort, neighborhoods with low land values and cheaper homes may not qualify. Residents of these low-lying, affordable neighborhoods are more likely to be low-income, elderly, or people of color.

> The PDT recommended that smaller increments of nonstructural measures be carried forward to complement the structural measures where cost-effective risk reduction can be achieved.

Elevation is a common approach already being undertaken by residents and businesses in the study area. Specific assumptions related to managed retreat were applied in scenario analysis when developing the without-project conditions. Adjustments were made to the structure inventory to more accurately reflect the most-likely FWOP and FWP conditions. Under FWOP and FWP conditions, residential and nonresidential structures that were identified as severely flooded structures (greater than 50 percent damage to the structural components) from the 0.10 (10-year) annual chance exceedance event were set equal to the stage associated with 0.002 (500-year) plus 1 foot for the year 2085 under the high SLR scenario. This adjustment is consistent with the FEMA floodplain regulations, which require residents to rebuild above the base flood elevation after a structure receives greater than 50 percent damage to the structural components as a result of a flood and would simulate a managed retreat on a small scale. The first-floor elevations of 21 structures in 2017, 68 structures in 2035, and 542 structures in 2085 were adjusted for severe flooding. The severe damage adjustment lowered equivalent annual without-project damages from $2.1 billion to $1.75 billion under the high SLR scenario.

> Nonstructural measures that could function in combination with other risk-reducing structural measures to provide multiple lines of defense for the upper Texas coast are being recommended for further development in the feasibility stage.

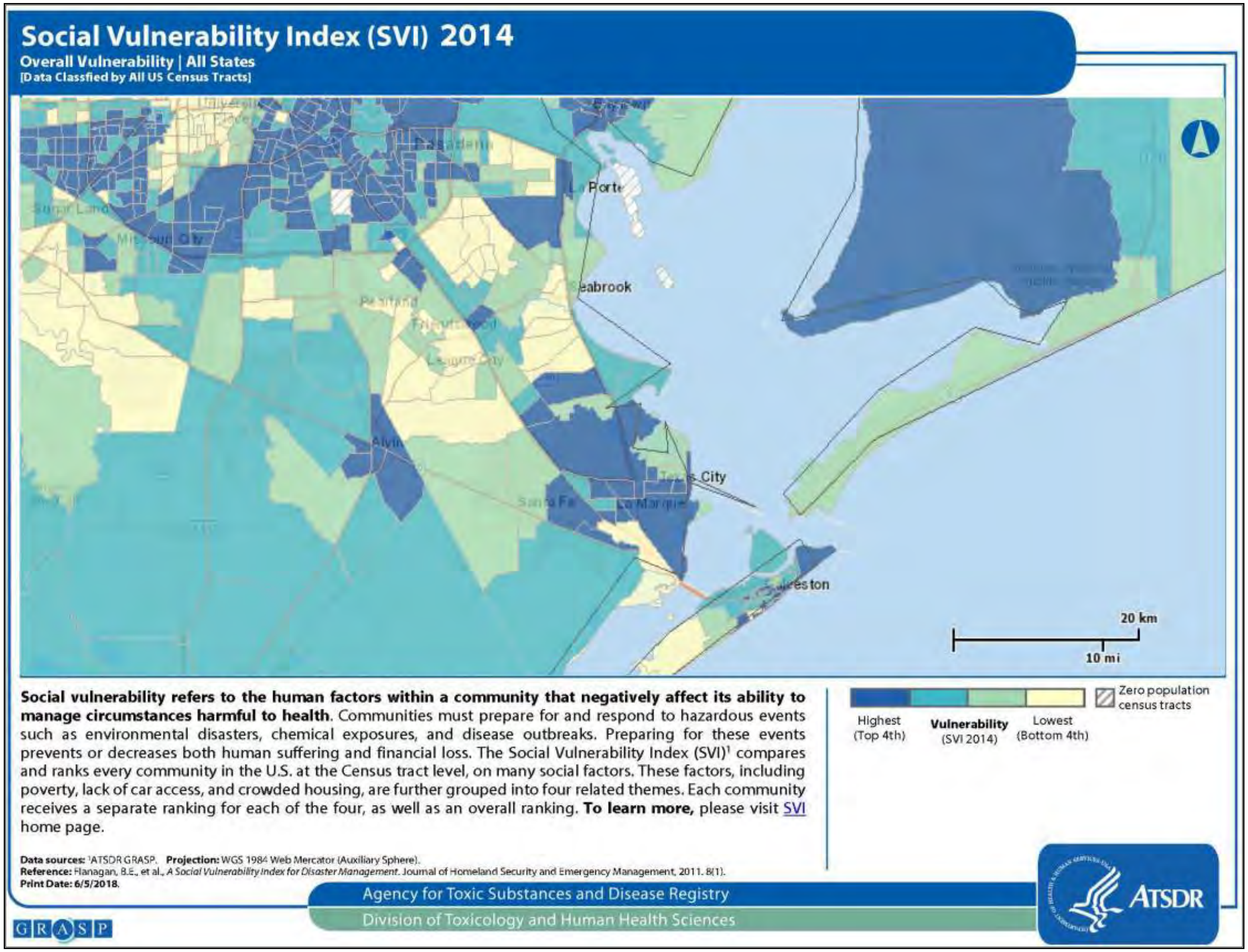

Figure 4-18: Galveston Bay Region Social Vulnerability Index
(Source: Agency for Toxic Substances and Disease Registry, 2018)

Due to the general uncertainty associated with structures' first-floor elevations and locations in the floodplain, in future planning and design phases of the study, the PDT will conduct additional structure inventory investigations. The focus will be on the west side of Galveston to reduce the risk from wind-driven surges in the upper bay. The full list of nonstructural measures discussed above will be considered, but due to the continued common approach of elevating structures already being undertaken by residents and businesses in the study area, this will be the common method recommended in the FIFR-EIS.

4.3.4.2 Coastal Barrier Behind the GIWW with Complementary System of Nonstructural Measures (Alternative B)

One of the first alternatives developed was a coastal barrier placed behind the GIWW. This alternative was developed to address storm surge flooding at the Gulf interface but also avoided some of the high and intense surges on the large surge barrier gates that would be needed to close off Galveston Bay to the elevated water level experienced ahead of storms. The alignment also avoided some of the critical habitat along Bolivar Peninsula, Galveston Island, and west Galveston Bay. The strategy included preventing storm surge from entering Galveston Bay by placing surge barrier gates across the Houston Ship Channel, north of the Bolivar Roads. The system includes a barrier across Bolivar Peninsula, but the barrier would be set back north of the GIWW and would connect some of the existing dredge disposal sites to avoid the habitat along Bolivar Peninsula. The closure north of the pass at Bolivar Roads would tie into the existing Texas City Dike. The dike would require substantial improvements to be able to address coastal storm surge. The system would then tie into the existing Texas City Levee System, with improvements to that system, and would include additional improvements farther west into the communities of Hitchcock and Santa Fe. Due to the uncertainties associated with induced stages on the city of Galveston, the alternative would include a ring levee around the city. Also, as explained in the sections above, to address wind-driven surges in the bay's upper reaches, nonstructural measures and closures on key waterways, Dickinson Bayou, and Clear Lake were included. Figure 4-19 provides an overview of the features included with a Coastal Barrier behind the GIWW.

When the alternative was compared to the FWOP conditions; it was determined that there were a few areas of concern that need to be reviewed in detail to determine if this alternative would be carried forward for further development. These concerns are discussed in the sections below.

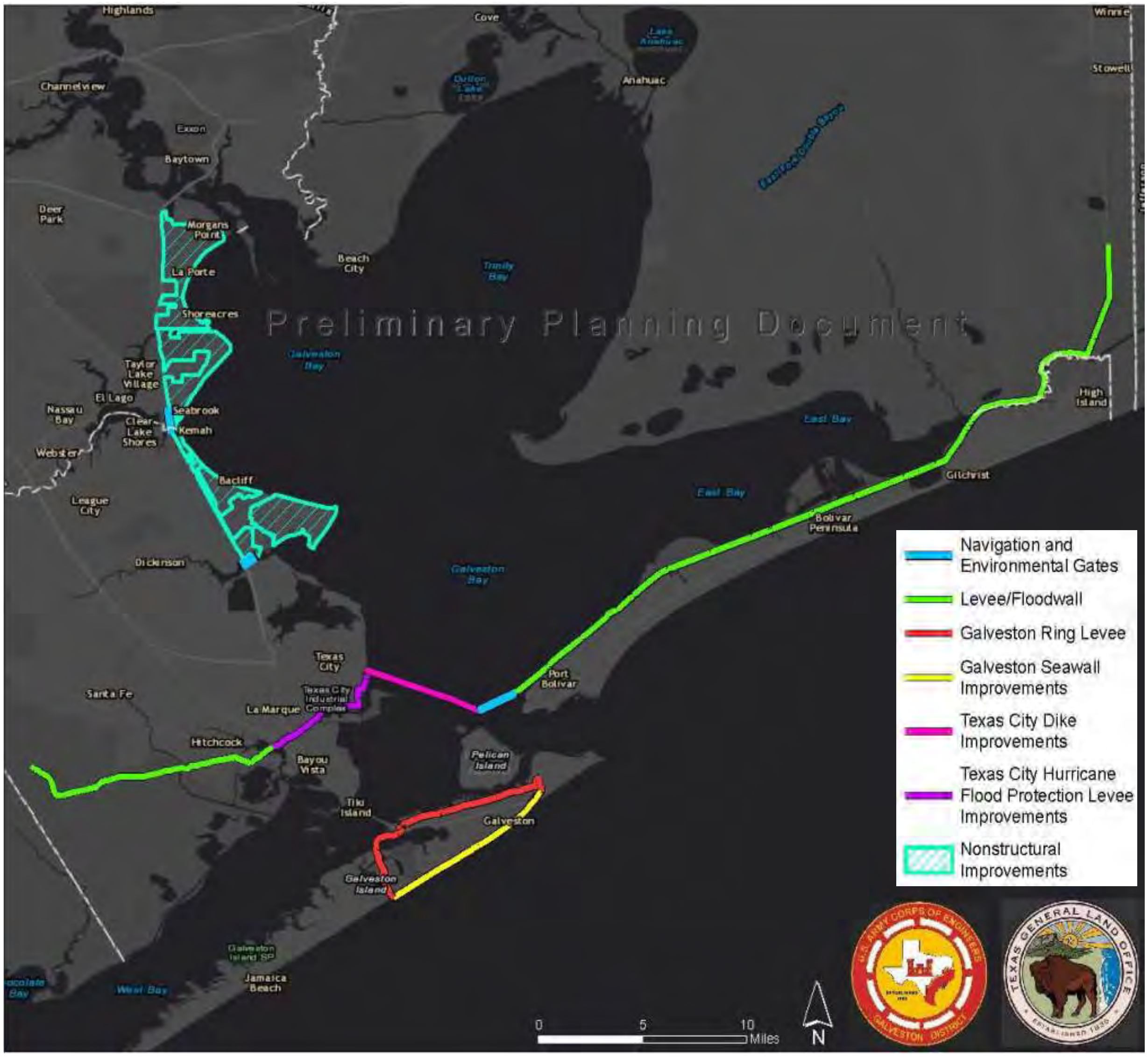

Figure 4-19: Coastal Barrier Behind the GIWW with Complementary System of Nonstructural Measures (Alternative B)

4.3.4.2.1 Navigation Concerns

One of the first areas of concern was navigation impacts, particularly surrounding navigation safety. The concern was related to the number of deep-draft ships and shallow-draft tugs and barges (domestic traffic) that would have to transition through the surge-barrier gates. Using data from the USACE's Waterborne Commerce Statistics Center, the team determined that over 300,000 shallow-draft tugs and barges would pass through the large surge barrier gate at this location (Figure 4-20).

The alternative would also have impacts on interactions between deep-draft ships and shallow-draft tugs and barges . The intersection with the Houston Ship Channel and the GIWW is very busy, and with additional traffic and larger vessels transiting every year, it is expected to become even more challenging. The Houston-Galveston Navigation Safety Advisory Committee has implemented an alternate route that allows mariners to avoid the Bolivar Roads/Houston Ship Channel intersection. Known as the Bolivar Roads Alternate Inbound Route (Figure 4-21), the passage acts much like a freeway on-ramp. Westbound traffic exiting Bolivar Roads may enter the ship channel via the Bolivar Roads Alternate Inbound Route and continue inbound, rather than navigating the difficult 105-degree turn at the intersection. The alternative would impact this route since barge traffic would be redirected to the surge barrier gates, or the system would require additional surge barrier gates.

4.3.4.2.2 Construction Concerns

Part of the construction activities for this alternative would be to raise the exiting Texas City Dike to provide risk reduction from Gulf storm surges. The dike's existing structure consists of a 28,200-foot-long (approximately 5.34 miles) pile dike paired with a rubble-mound dike that runs along the south edge of the pile dike (USACE, 2007). The Texas City Dike was built to protect the Texas City Channel from cross currents and excessive silting, but not necessarily storm surge. In discussions with the PDT, it was determined that the foundation of the existing structure would have to be improved to increase its existing height. This action would have major impacts on the current recreational use on the dike. The dike includes recreation features such as asphalt and crushed gravel parking areas, roughly three-quarter mile of beaches, four boat ramps (two with running water for fish cleaning stations), ten concrete picnic shelters, and one wheelchair accessible pier. The Dike's Samson-Yarbrough boat ramp was the busiest on Galveston Bay, and the dike as a whole was the second-busiest boat launch site in the state (Aulds, 2010). Many of the features would be impacted during construction or would have to be relocated after construction.

Due to both the navigation and construction concerns, the "Coastal Barrier behind the GIWW" alternative was removed from further consideration.

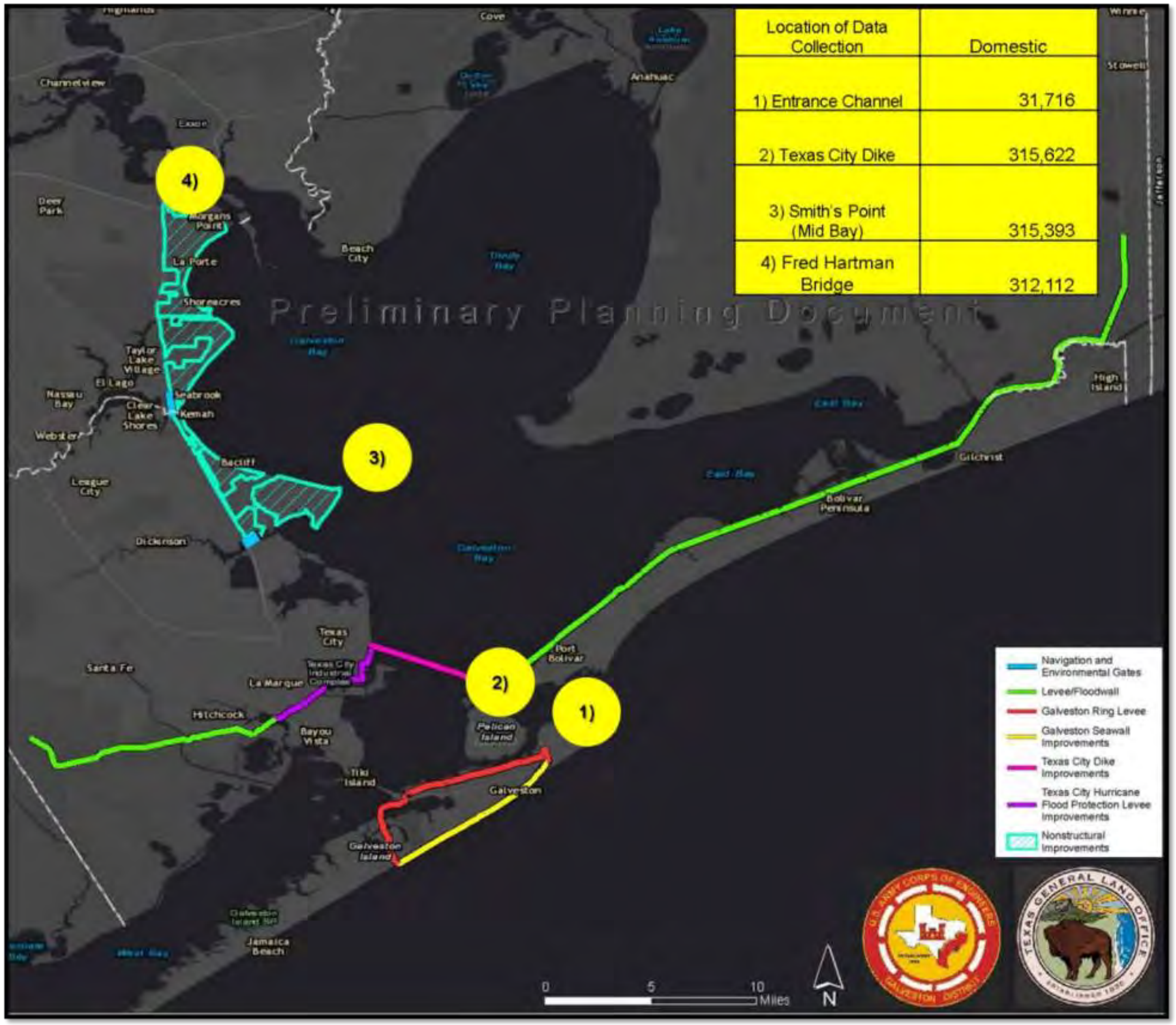

Figure 4-20: Navigation Impacts – Domestic Traffic
(Source: USACE, Waterborne Commerce Statistics Center)

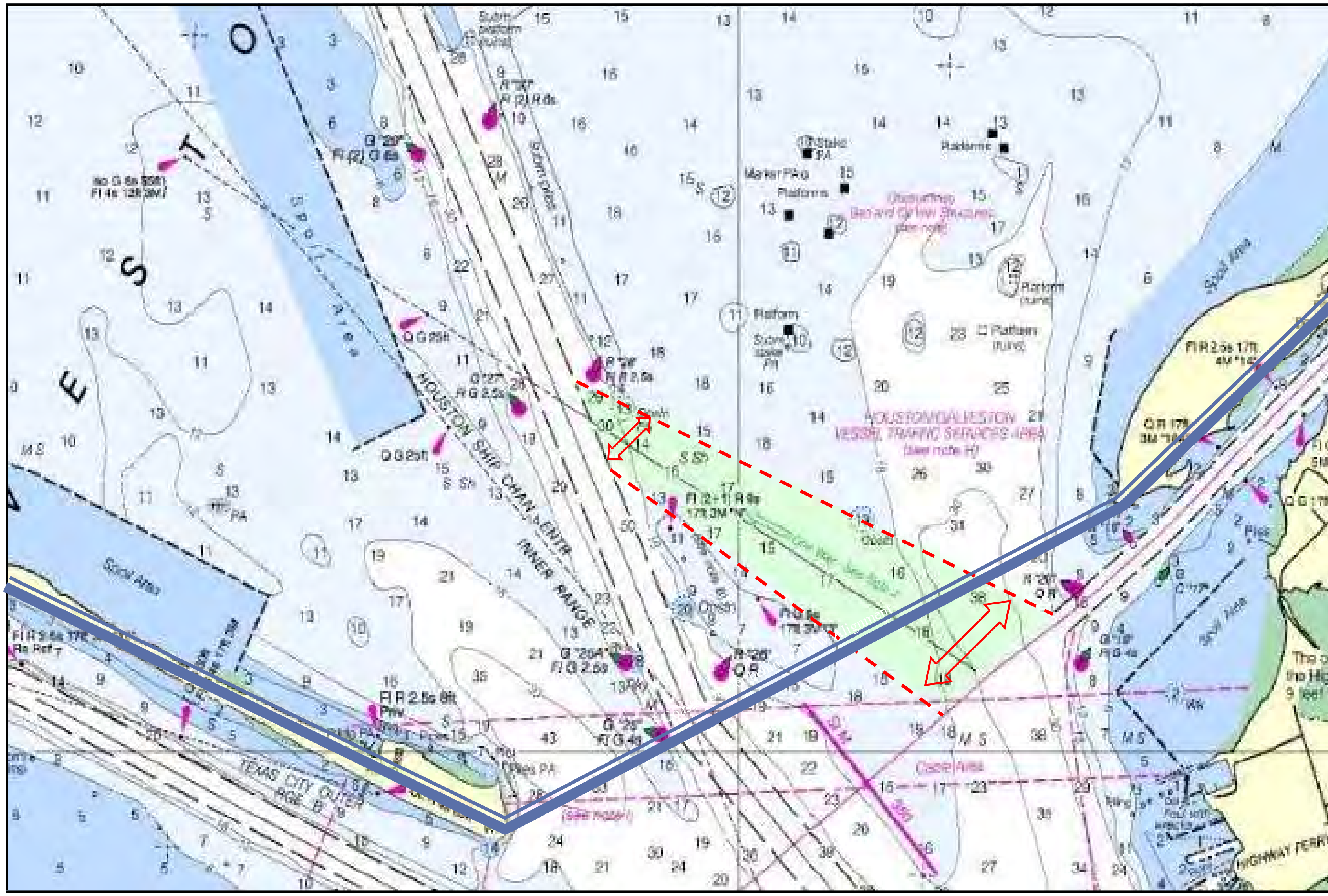

Figure 4-21: Bolivar Roads Alternate Inbound Route (shown in green) with Coastal Barrier GIWW Alignment (shown in blue)

4.3.4.3 Mid-Bay Barrier Concept (Alternative C)

This alternative was developed to avoid some of the navigation impacts at Bolivar Roads, by placing a surge barrier gate near the middle of Galveston Bay. This alignment is similar to the recommendation in a USACE Texas Coast Hurricane Study released in 1979. The system would start on the east side of Galveston Bay near Smith Point and continue across the bay, crossing the ship channel and connecting on the west side of the bay. The surge barrier gates across Galveston Bay include environmental control gates to maintain flows between upper and lower Galveston Bay and small gates to address small recreational vessels moving through the system as well as a large gate across the ship channel. The system would tie into the existing Texas City Levee System. Improvements to this existing levee system would be included and require additional improvements farther west into the communities of Hitchcock and Santa Fe (Figure 4-22). The plan also addresses flooding on Galveston Island with a levee system. Due to the limited open-water area north of the system, wind-driven surges in the bay's upper reaches are not expected to be a concern, which is why the nonstructural measures, ring levees, and closures on key waterways were dropped from consideration.

When the alternative was compared to the FWOP conditions, it was determined that there were a few areas of concern that needed to be reviewed in detail to determine if this alternative would be carried forward for further development.

4.3.4.3.1 Navigation Concerns

Similar to Alternative B, there was also a concern with navigation impacts, particularly surrounding navigation safety for recreational vessels. Deep-draft ships, shallow-draft tugs and barges, and large recreational vessels would all be forced to use one opening in the center of the bay. Small recreational vessels and small commercial vessels with limited draft, width, and vertical clearance could use some of the environmental gates and small sector gates similar to the gates used in the Greater New Orleans Hurricane and Storm Damage Risk Reduction System; however, Galveston Bay includes one of the Nation's largest recreation sailing fleet, including multiple yacht clubs along the east side of the bay. Vertical clearances and keel clearances may force some of the recreational vessels through the large gate near the center of the system, adding to vessel congestion and safety concerns.

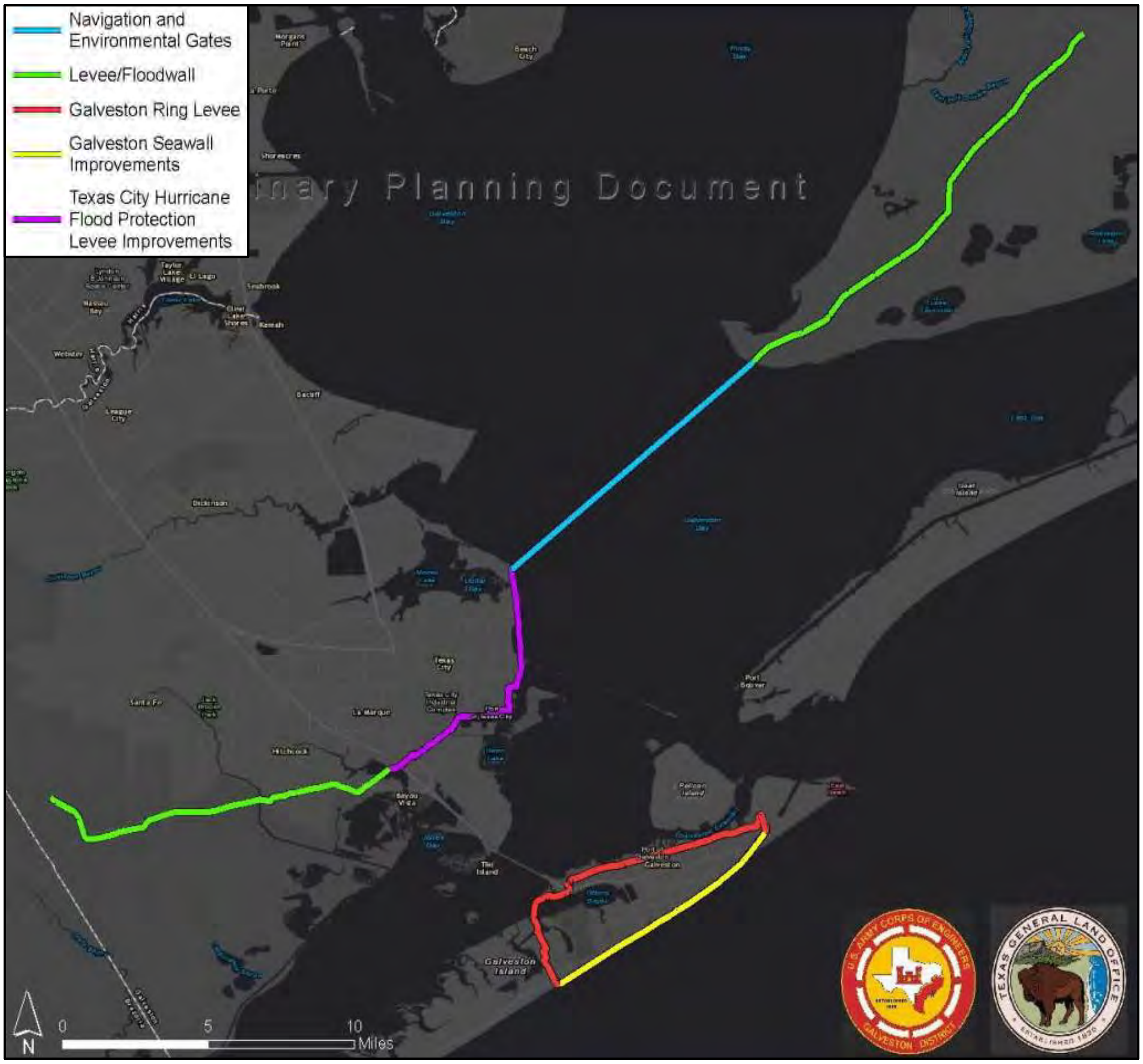

Figure 4-22: Mid-Bay Barrier Concept

4.3.4.3.2 Operation, Maintenance, Repair, Replacement, and Rehabilitation Concerns

In order to maintain flows between upper and lower Galveston Bay, the structure would include environmental gates to maintain the natural water circulation in the bay when the system is open. Current modeling estimates that over 100 environmental gates would be needed to maintain existing circulation in the bay. In addition to the cost for constructing these gates, there would be large operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs associated with these gates. OMRR&R with environmental gates typically include:

- Monthly startup of backup generators/systems;
- Yearly closure of surge barrier gates pre-hurricane season;
- Dive inspection;
- Gate adjustments/greasing;
- Gate rehabilitation; and
- Gate replacement.

4.3.4.3.3 Direct and Indirect Environmental Impacts

Due to the location and size of the required underwater footprint for the mid-bay closure, this alternative is likely to have negative impacts on Galveston Bay oyster reefs. Historically, the creation and widening of the Houston Ship Channel has increased the penetration of more saline water into the upper estuary and increased current velocities, thus extending the area of oyster productivity northward. Over 2,500 acres of reef have developed along this channel (Powell et al., 1994). The current alignment would have direct impacts to the historic “Redfish Oyster Reef” near the middle of Galveston Bay and the reefs along the Houston Ship Channel near the proposed surge barrier gates (Figure 4-23).

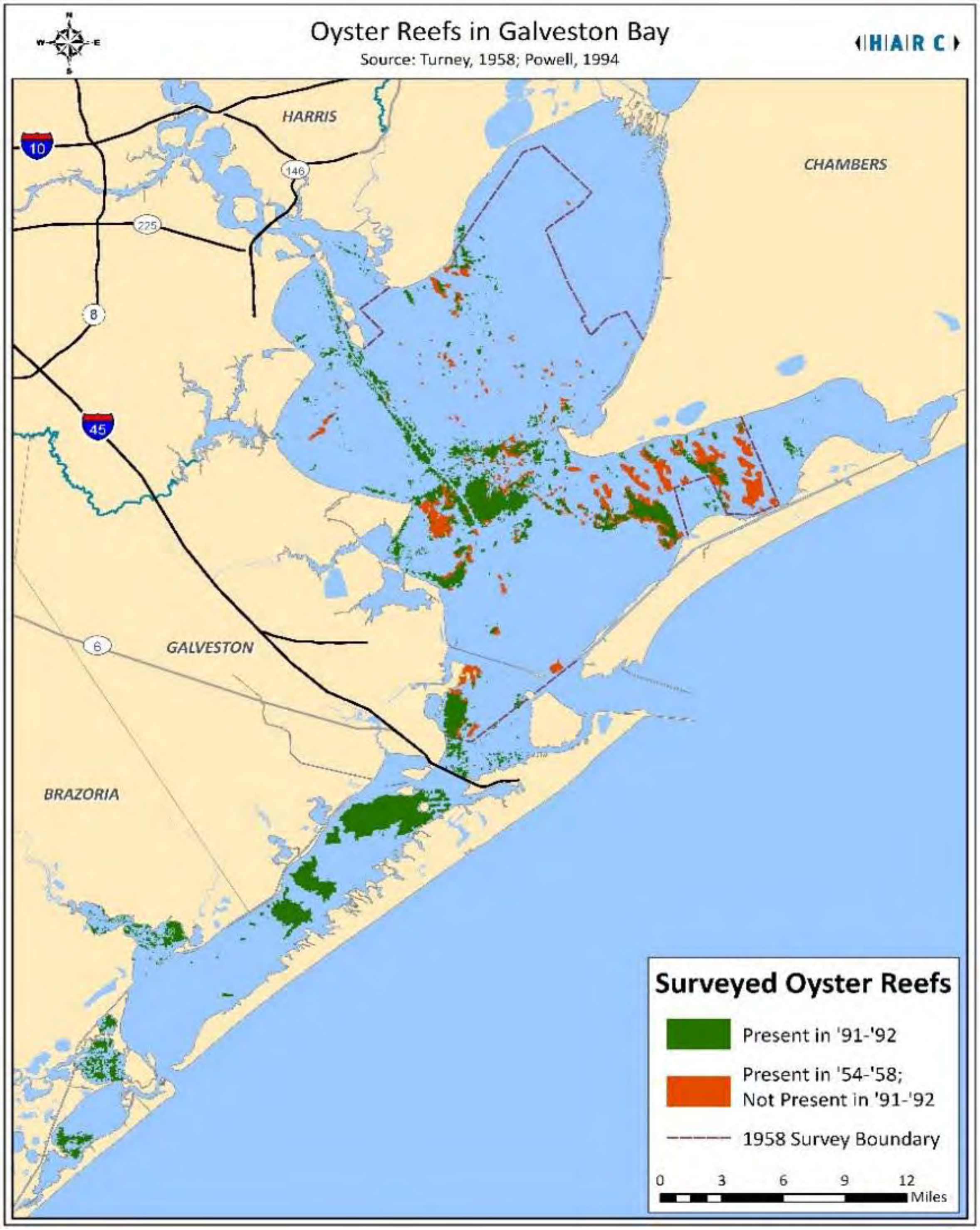

Figure 4-23: Galveston Bay Oyster Reef Locations

It was estimated that 240 acres of oyster reefs would be impacted with the Mid-Bay Barrier Concept. Indirect impacts were not evaluated, but the location of the structure places the environmental gates in a complex location in the bay for circulation. Today, the bulk of the Trinity River flow exits Trinity Bay along the southern shore and wraps around Smith Point, then flows across Mattie B. Reef and Tom Tom Reef, reaching nearly to Bolivar Peninsula before becoming entrained in the seaward-flowing water at Bolivar Roads. This circulation pattern has likely existed for many decades, but its intensity has dramatically increased as the Houston Ship Channel became deeper and Redfish Reef ceased to function as a circulation barrier (Lester and Gonzalez, 2011). Even with the environmental structures in the open position, the support structures for the surge barrier gates could function as a circulation barrier, changing the circulation pattern across local reefs.

Due to the concerns listed above the “Mid-Bay Barrier Concept” alternative was removed from further consideration.

Note: The following two CSRM alternatives were included in the final array for the Upper Texas Coast CSRM and underwent additional evaluations. The planning discussion below provides a general overview of the assumption that went into the development of the alternatives and results of the comparison of the alternatives. Additional details related to the two alternatives can be found in the Plan Formulation Supporting Information (Appendix A). It is important to note that the team focused on the general geographic location of the barriers and used the locations to make informed decisions on the environmental consequences of each system. The team used a conservative approach to document the widest possible impacts with each system.

4.3.4.4 Coastal Barrier with Complementary System of Nonstructural Measures (Alternative A)

This alternative was developed to address storm surge flooding at the Gulf interface and to also include the highest number of structures and critical facilities within the alignment. The alignment would provide risk reduction to the critical GIWW by maintaining the existing geomorphic features along Bolivar Peninsula and Galveston Island. The planning strategy included preventing storm surge from entering Galveston Bay with a barrier system across Bolivar Peninsula, a closure at the pass at Bolivar Roads, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. The barrier is similar to other proposals that have been released to the public, such as the Gulf Coast Community Protection and Recovery District’s (GCCPRD) Central Region Alternative (CR #1) – Coastal Spine or Texas A&M University at Galveston’s Ike Dike. For planning purposes, the team has evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island; however, the team recognizes that there are opportunities to optimize the design and alignment to minimize impacts to existing structures and the environment on the peninsula and island. Future design efforts would focus on where engineered dune systems may be appropriate versus levees and floodwalls.

To address wind-driven surges in the bay, which could impact both the back side of Galveston Island and the upper reaches of the bay, nonstructural measures, such as ring levees and closures on key waterways, have been included in the system. As discussed above, elevation is a common approach already being undertaken by residents and businesses in the study area. Due to the general uncertainty associated with structures' first-floor elevations and locations in the floodplain, additional structure inventory investigations will be conducted in future planning and design phases. The focus will be on the west side of Galveston, currently the area shown on Figure 4-24, include approximately 10,000 structures between SH 146 and the bay rim.

Although the ER and CSRM alternatives will be evaluated for separate benefits, the different alternatives provide some nexuses between the features. By linking into the beach and dune restoration features along Bolivar Peninsula and Galveston Island, the ER features should also increase the resiliency of the CSRM feature. Alternative A was carried forward for further consideration.

4.3.4.5 Upper Bay Barrier (Alternative D)

This alternative was developed to potentially avoid the majority of the navigation impacts by focusing on a levee system on the west side of Galveston from Texas City to the Fred Hartman Bridge. The alternative evolved into two options: SH 145 Alignment (Alternative D1) and Upper Bay Barrier-Bay Rim (Alternative D2).

4.3.4.5.1 SH 146 Alignment (Alternative D1)

The first option was named D1. This alignment was similar to GCCPRD's Reach 2, Texas City Extension North (SH 146) alignment, which included a levee system paralleling SH 146 from Texas City to the Fred Hartman Bridge (Figure 4-25). The levee system placed approximately 10,000 structures east of the levee outside of the system. In order to address this concern, nonstructural measures were initially included to address existing surges and any surges induced into the area by the levee system.

A detailed evaluation revealed other concerns with this option. The first issue was related to the overall project objective of reducing risk to critical infrastructure (e.g., medical centers, government facilities, universities, and schools) from coastal storm surge flooding. An evaluation of the FWOP condition surges and economic damages determined that the area surrounding the system is one of the highest reaches for economic damages. Once a levee is constructed near SH 146, modeling showed that it would induce stages and damages in the area outside of the levee system (Figure 4-26). Economic modeling estimated that over $175 million in average annual damages would be included in the area without addressing the inducements. Due to these issues, Alternative D1 was removed from further consideration.

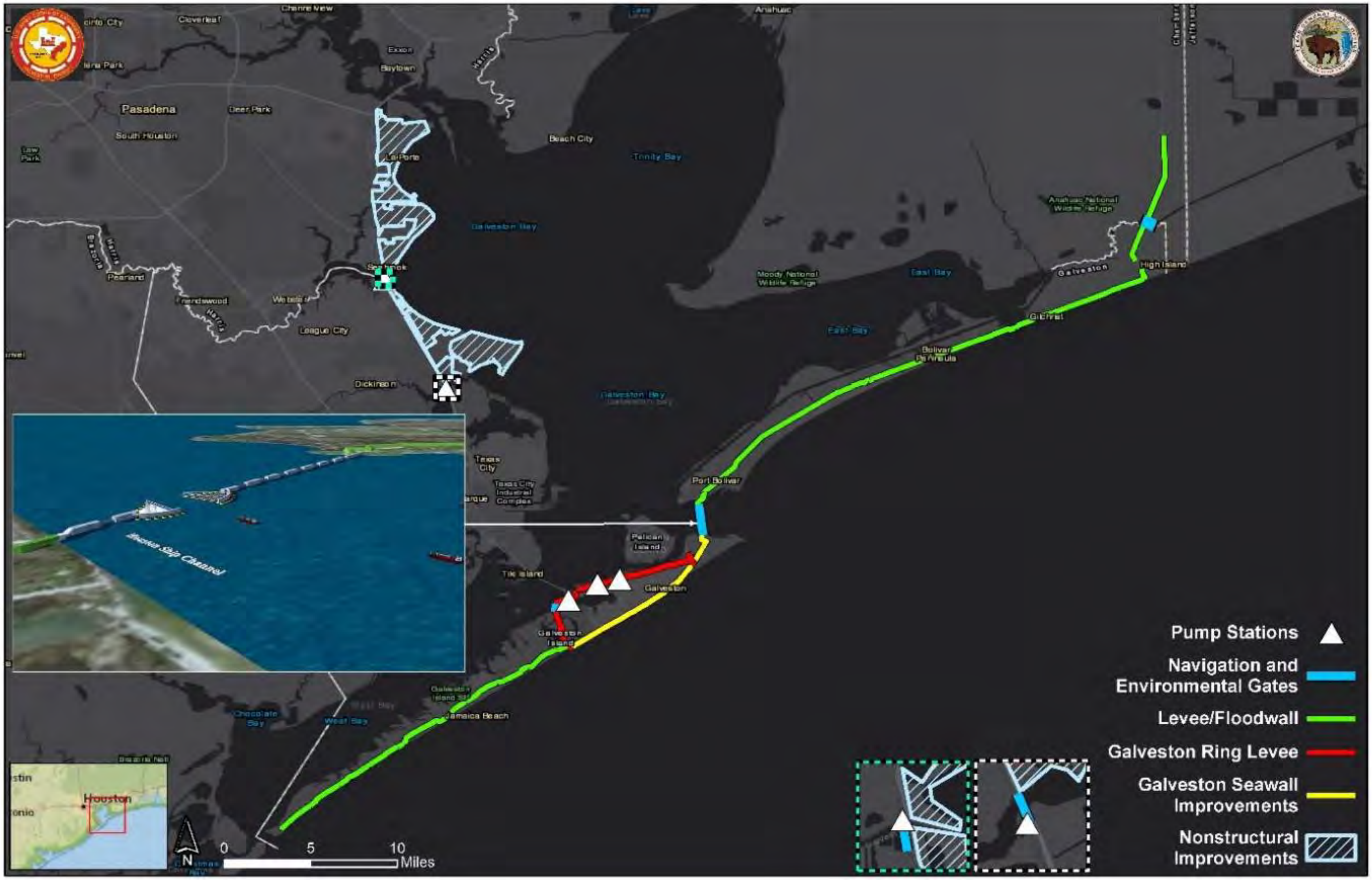

Figure 4-24: Coastal Barrier with Complementary System of Nonstructural Measures (Alternative A)

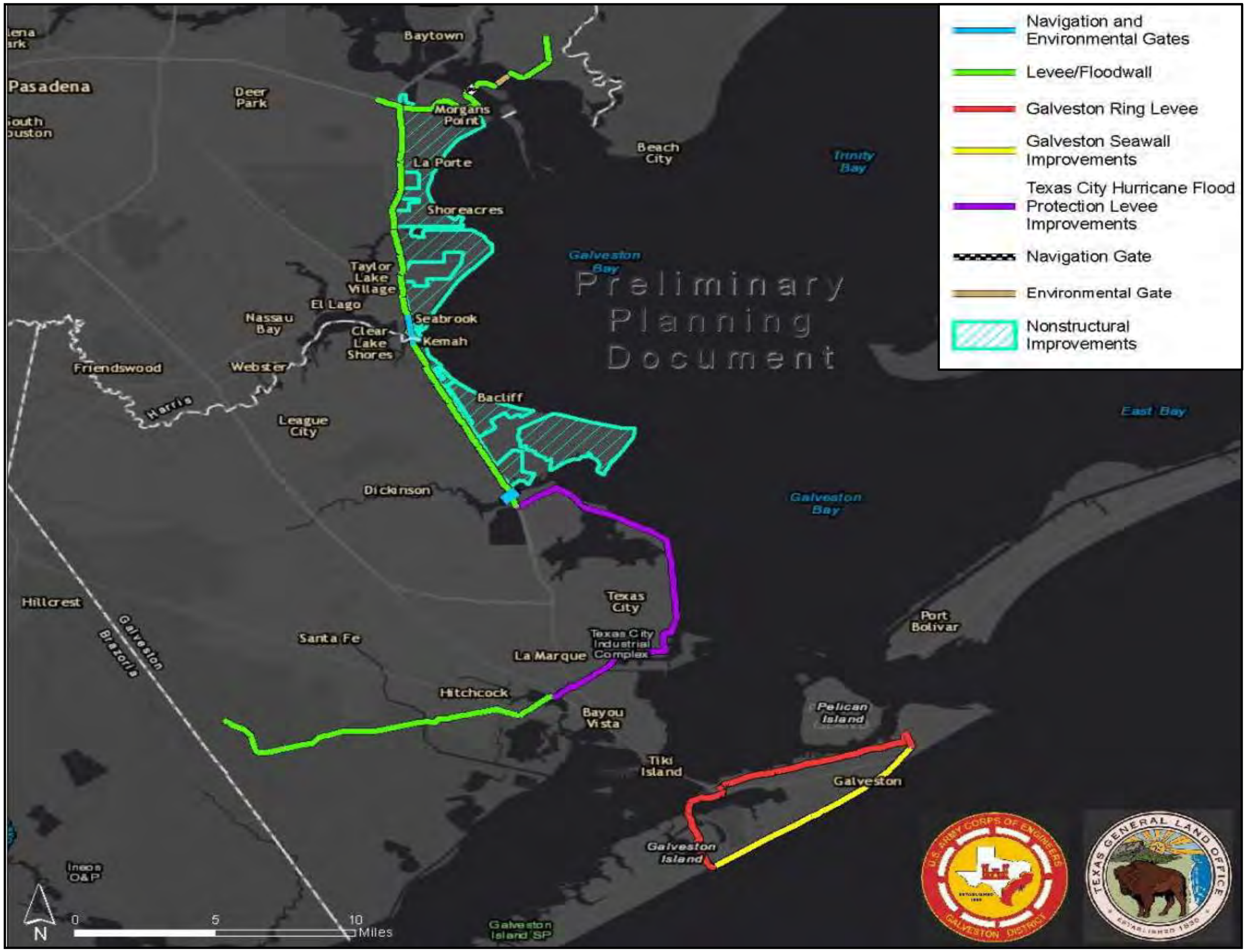

Figure 4-25: SH 146 Alignment (Alternative D1)

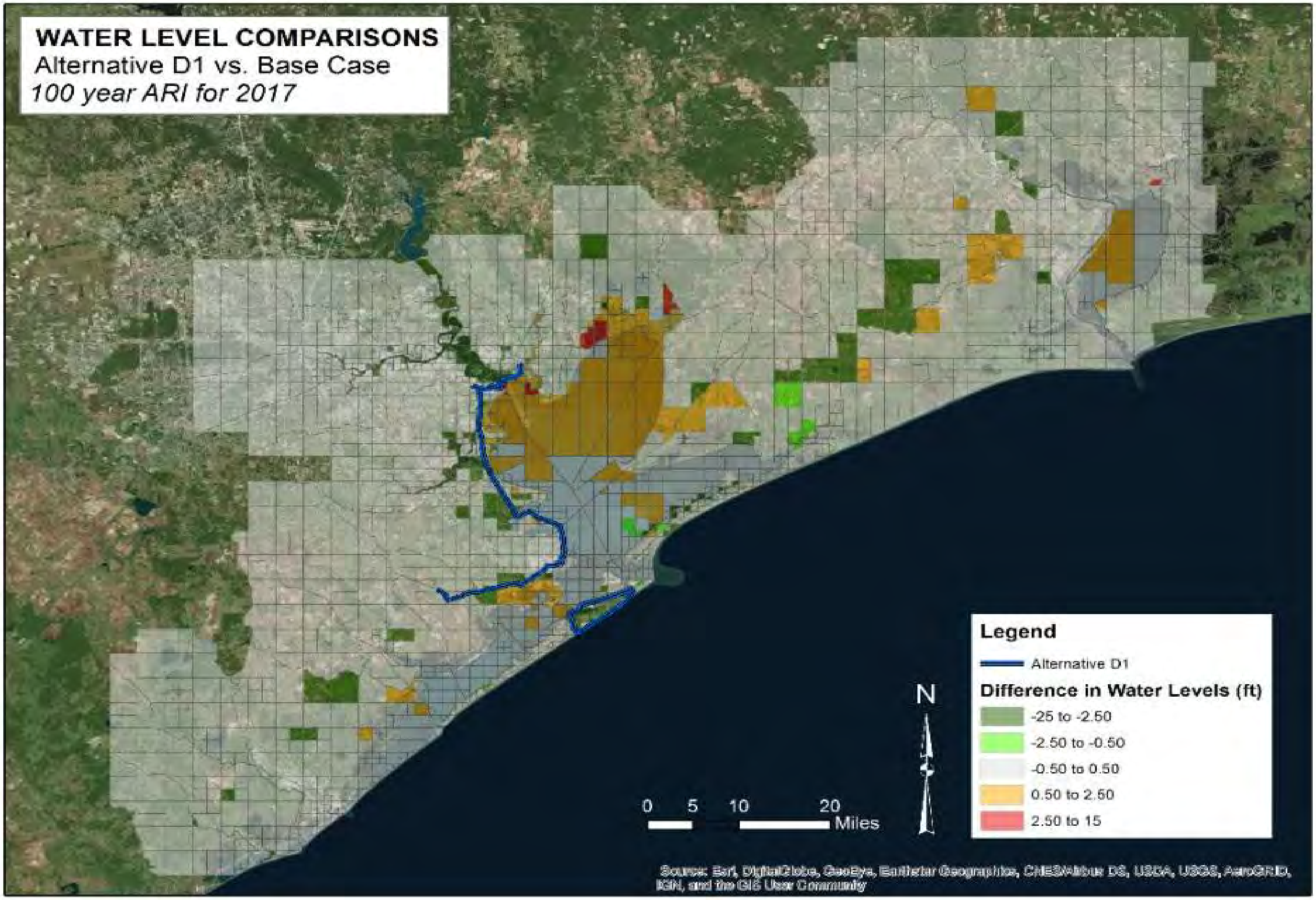

Figure 4-26: FWOP versus FWP Stages for SH 146 Alignment (Alternative D1)

A site visit of the SH 146 alignment also highlighted relocation and construction concerns. SH 146 is already a highly developed area, and plans are already in place to expand the entire highway to a 6- to 12-lane freeway. Much of the existing rights-of-way or corridors necessary to build a levee system would be unavailable because of the expanded highway. Also, a large number of vehicle and railroad gates would have to be added to the system to work with the existing infrastructure. Many of these concerns were documented at some of GCCPRD's public forums. Based on these concerns and because this alignment does not meet some of the project's key objectives, it was removed from consideration.

4.3.4.5.2 Upper Bay Barrier-Bay Rim (Alternative D2)

The second variation was named D2. The D1 plan was modified to move the structure out to the bay rim instead of adjacent to SH 146 (Figure 4-27). This option would enclose the 10,000 structures in the system with a levee or floodwall system along the existing bay rim or would be designed similar to the New Orleans Lakefront, where the system is built out into the bay for some reaches (Figure 4-28). For planning purposes, the team assumed that the system would be built on the existing bay rim and not into the water and would require relocations to build the system. The system could be optimized to avoid relocations but would generate additional costs and environmental impacts if it were built in the bay instead.

The D2 alignment would eventually tie into the existing Texas City Levee System and includes improvements to that system. Additional improvements to that system farther west into the communities of Hitchcock and Santa Fe would be necessary. The plan includes surge barrier gates at the Fred Hartman Bridge; however, this is likely a separable element that would have to be evaluated for navigation impacts and benefit to the upper ship channel if the system was recommended. The plan addresses flooding on Galveston Island with a levee system, which rings the island. As with the other plans, the team is also investigating the opportunities to integrate ecosystem features and CSRM features by reviewing the beach and dune restoration features along Bolivar Peninsula and Galveston Island. The ecosystem features should also increase the resiliency of the CSRM features.

4.3.4.6 Evaluation and Comparison of the Coastal Barrier with Complementary System of Nonstructural Measures (Alternative A) and Upper Bay Barrier-Bay Rim (Alternative D2)

Table 4-21 provides an overview of information used to compare the differences between Alternative A and D2. The sections below include the detailed discussion of the differences in the final array of alternatives A and D2.

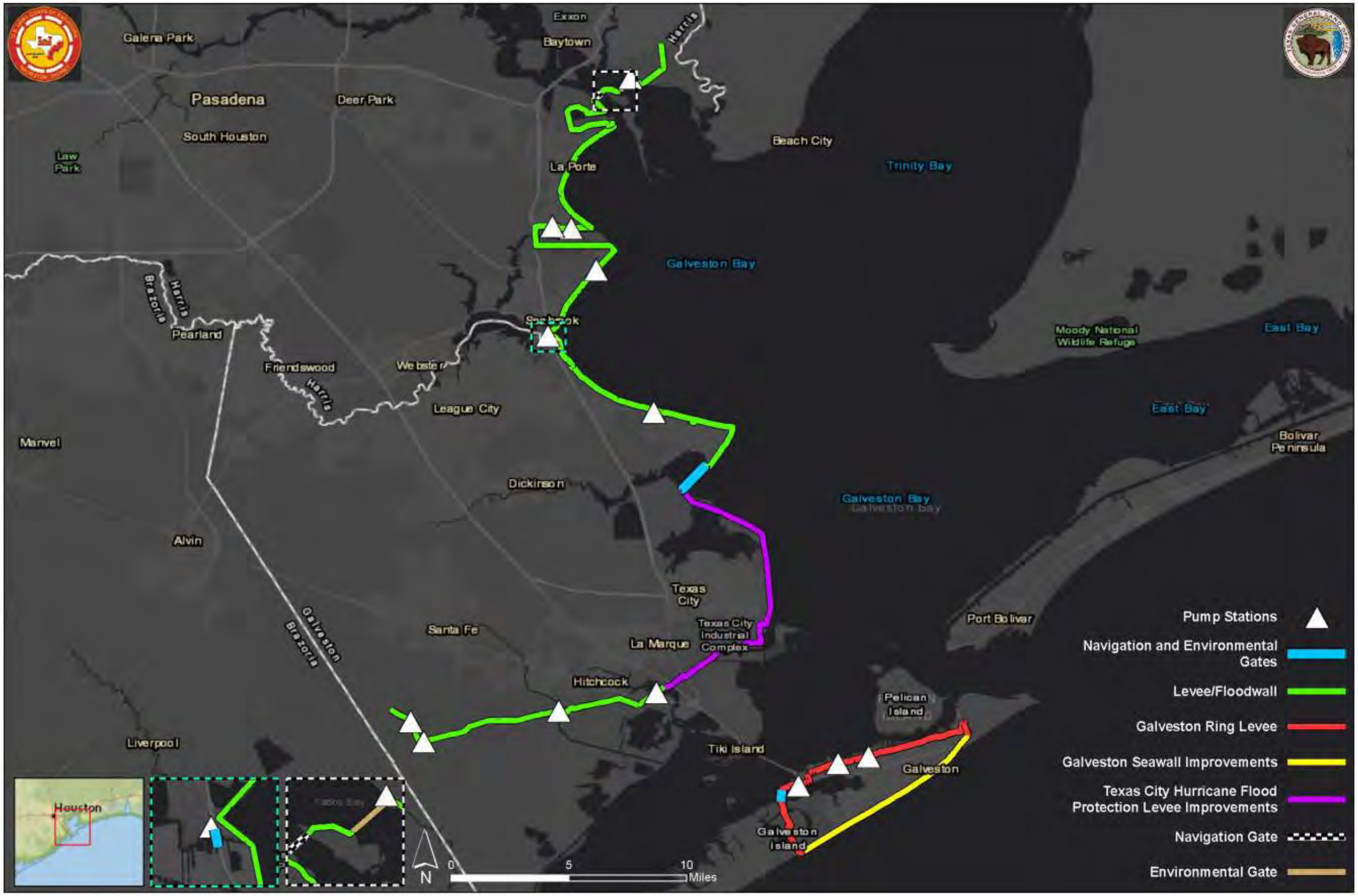

Figure 4-27: Upper Bay Barrier-Bay Rim (Alternative D2)

Figure 4-28: Lakeshore Drive, New Orleans, with Seawall and Levee System
(Michael DeMocker/NOLA.com | *The Times-Picayune*)

Table 4-21
Comparison of Alternative A and D2

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

4.3.4.7 Comparison of Design Details

As discussed above, plans were developed and assumed to have similar levels of risk reduction to the existing risk reduction systems in the upper Texas coast. Storm surge modeling will be used to estimate water levels and waves along the selected levee alignment in future planning and design phases. Outputs of surge and wave information at various locations along the proposed levee alignment will be used to optimize the level of risk reduction in future planning and design phases; however, there are some important design differences between Alternative A-Coastal Barrier and Alternative D2-Upper Bay Barrier-Bay Rim. Table 4-22 provides an overview of these differences.

Table 4-22
Differences Between Alternatives A and D2

Category	Alternative A	Alternative D2
Approximate Total Length (miles)	76	79
Total Floodwall and Levee (miles)	74	79
Total Floodwall (miles)	20	43
Total Levee (miles)	54	36
Estimated Quantities (cy) for Levees	10,000,000	15,500,000
Estimated Vehicle Gates Required	93	138
Estimated Railroad Gates Required	4	19
Estimated Drainage Structures Required	80	38
Estimated Pump Stations Required	5	14
Deep-Draft Navigation Gates Required	1	1
Size of Deep-Draft Navigation Gates	1200	1200
Shallow-Draft Gates	4	3
Total Relocations (Pipelines)	30	55
Temporary Work Area Easements (acres)	545	656
Estimated Number Property Tracts Impacted	1,709	1,703
Estimated Number Owners	1,214	1,423

Below are some key differences between the designs of the system:

- **Galveston Ring Levee.** When compared to the Coastal Barrier with complementary system of nonstructural measures (Alternative A), the Galveston ring levee associated with the Upper Bay Barrier-Bay Rim (Alternative D2) will have to be constructed with a greater level of resiliency. The Galveston ring levee with Alternative A only has to address wind-driven surges from the Galveston Bay system (north to south), while a Galveston ring levee with Alternative D2 must address surges originating from the Gulf and any surges deflected back onto the system (induced stages) from the system on the westside of Galveston Bay. Figure 4-29 shows the surge forces on the backside of Galveston Island. The yellow arrows depict potential surge directions.

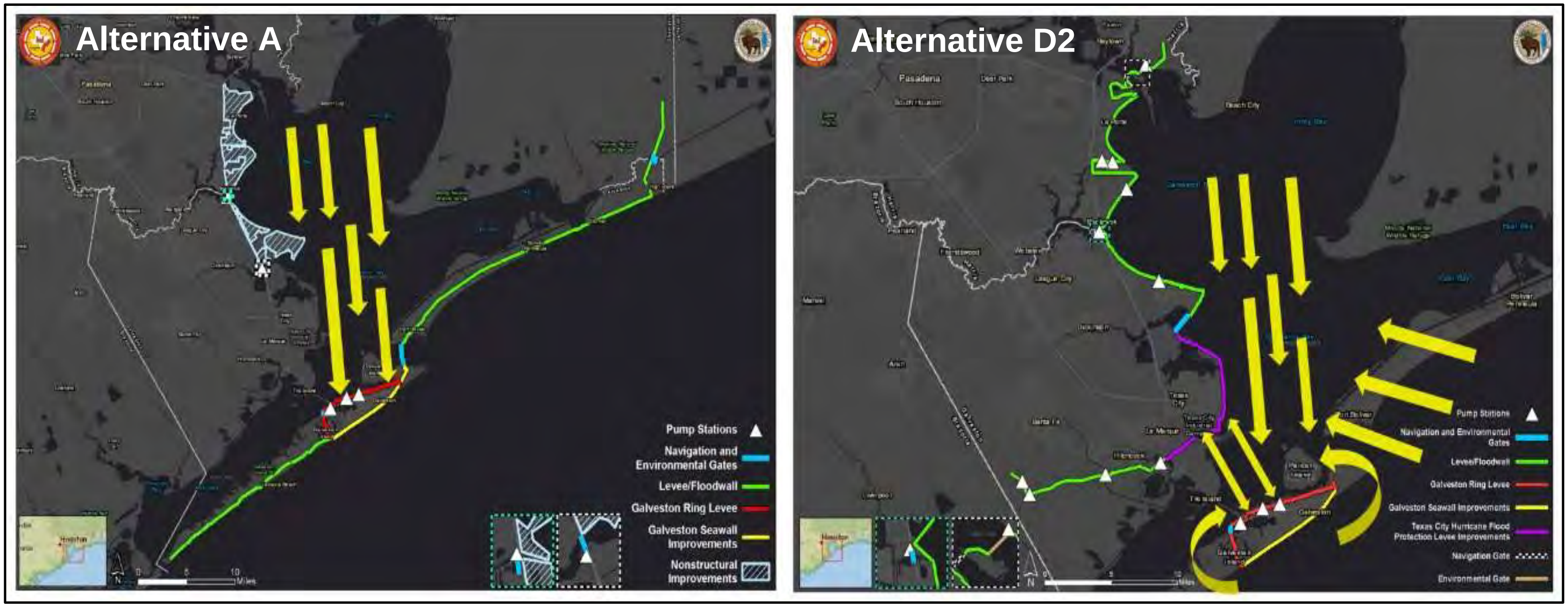

Figure 4-29: Surge Forces on Galveston Ring Levee

- **Drainage Structures.** Although both systems would require drainage features on the Galveston ring levee, Alternative D2 would require a large number of drainage features along the westside of Galveston Bay. With Alternative A, the only drainage structures needed are associated with the closures at Clear Lake and Dickinson Bayou.

- **Access Structures (Railroad/Vehicle).** With Alternative D2, the port facilities and smaller recreation water-access facilities would still require access routes. For example, with the Bayport Container Terminal, depending on the final alignment, the system may require multiple vehicle and railroad access gates (Figure 4-30).

4.3.4.8 Construction Schedule and Benefit Assumptions

Preliminary construction schedules for alternatives were needed to calculate annual cost streams and BCR. In most cases, project benefits cannot start accruing until a "closed" risk reduction system is in place, which would require, at a minimum, all structures and levees to be constructed. For planning purposes, the team assumed construction ending for both systems in 2035 to compare benefits; however, there are some important differences between the alternatives and potential construction options between alternatives.

- The footprint of the Upper Bay Barrier-Bay Rim (Alternative D2) includes a large number of properties with structures and piers that may have to be relocated or condemned. There is a real estate risk that could require an extension of the construction completion schedule if lands need to be acquired through condemnation proceedings.

- It may be possible to construct only the large surge barrier gate first for the Coastal Barrier with complementary system of nonstructural measures (Alternative A) to obtain an initial level of benefits. Currently, the existing landscapes of Bolivar Peninsula and Galveston Island provide a level of risk reduction from smaller storms. Only building the large surge barrier gate with the ecosystem features of beach and dune restoration features along Bolivar Peninsula and Galveston Island would obtain a certain level of interim risk reduction.

- Without tie-back levees into higher ground, the Upper Bay Barrier-Bay Rim (Alternative D2) will not give the region any level of risk reduction until the system is complete.

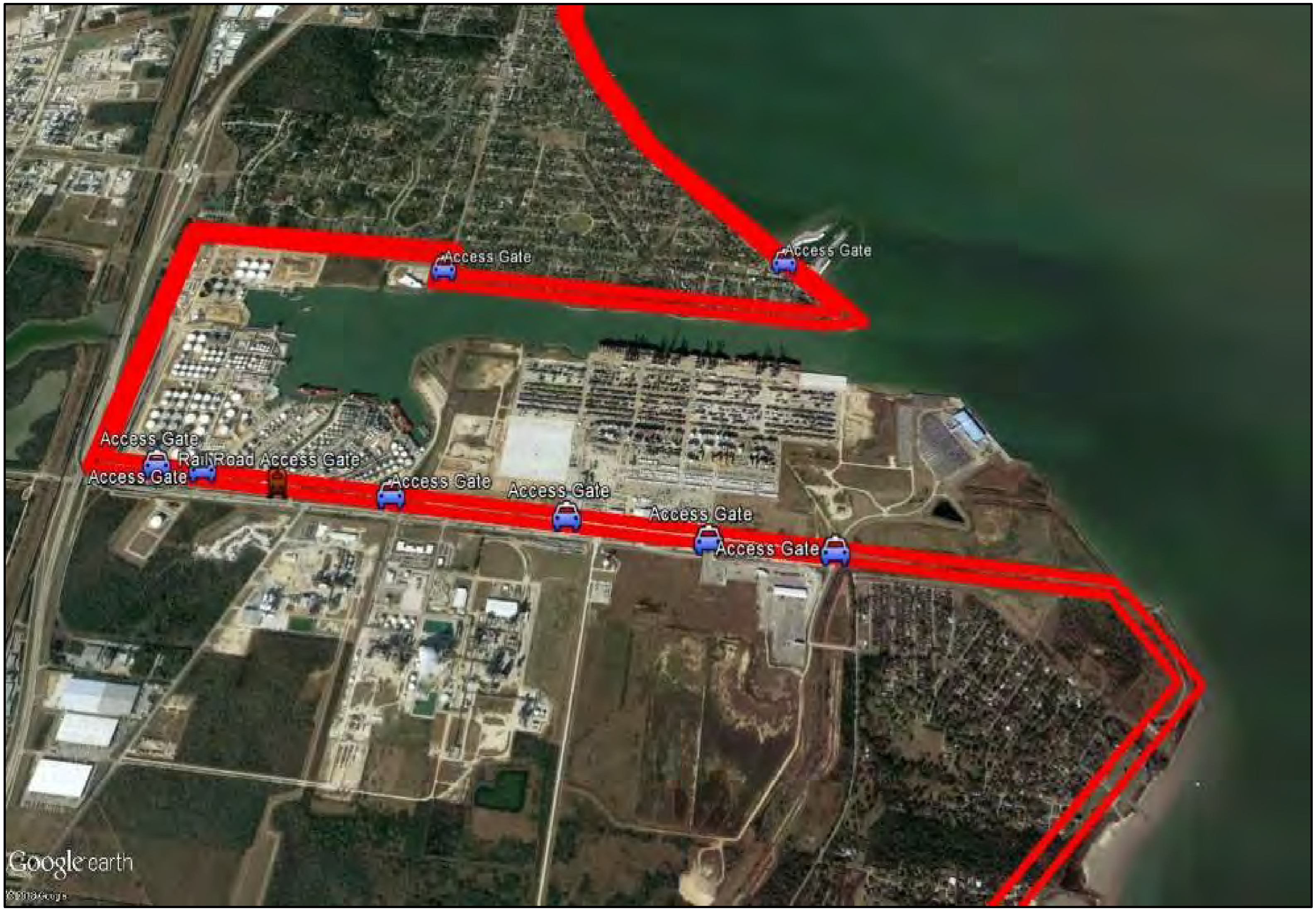

Figure 4-30: Potential Bayport Container Terminal Access Routes with Alternative D2

4.3.4.9 Environmental Impacts

The following sections briefly describe direct and indirect impacts of the alternatives. A more-detailed discussion of direct, indirect, and cumulative environmental impacts of the two alternatives and associated mitigation requirements is included in Section 5.0 and the Environmental Supporting Documentation (Appendix C-1). Because of the conservative nature of economic and engineering assumptions used during the initial planning of the TSP, it is anticipated that the final design of proposed structures will result in equal or lesser environmental impacts to those discussed in this DIFR-EIS.

The major direct impact of the project is the loss of wetlands within the project right-of-way. The direct wetland losses are calculated based on the estimated right-of-way limits, although the exact number could vary depending on wetland loss prior to construction, which could be caused by RSLR, hurricanes, or other factors. For both levee designs the impacts were based on the intermediate RSLR scenario. For the purpose of project costs and benefit estimates, impacts of the project would decrease slightly as sea level rises because there would be less wetland acres left to be impacted at the time of construction. As discussed above, a conservative design estimate was used to estimate impacts. For planning purposes, Alternative A evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island; however, a combination with an engineered dune system may reduce the direct impacts.

There are limited direct impacts associated with Alternative D2. For planning purposes, the team assumed that the system would be built on the existing bay rim and if the system has to be built into the bay, similar to the New Orleans Lakefront system (see Figure 4-28), direct impact to the bay bottom resources (e.g., oyster reefs) could result.

Direct impacts were calculated based on NOAA Coastal Change Analysis Program (C-CAP) data and similar data sets for the region. The number of acres of each type of habitat that may be impacted by the actions being considered for CSRM were measured using GIS analysis (Table 4-23).

The team and resource agencies determined which HSI models would be used to evaluate these impacts (Table 4-24). The models selected were all certified and coordinated with the Ecosystem Planning Center of Expertise and the Vertical Team. The models determine an HSI based on specific variables for each species. The species models are used to represent the habitat, not necessarily that specific species. Habitat evaluation for directly impacted areas measured the quality of each habitat category (the HSI value) multiplied by the quantity of each habitat category (acres) resulting in habitat unit measurements. Adding target years, or changes in habitat over time, allowed calculation of AAHUs. HEP allowed determination of mitigation requirements for loss of or degraded habitat due to construction of CSRM features.

Table 4-23
CSRM Alternatives Baseline Direct Cover Type Acreages

NOAA C-CAP Land Cover Classifications *	Total CSRM Footprint Acres	Developed / Upland[1]				Palustrine Emergent Wetland Freshwater Wetland and Marsh				Estuarine Emergent Wetland[2] Wetland and Marsh (Saline and Brackish)				Oyster Reef[3]	Open Water			
Land Ownership		Protected State	Protected Federal	Other[4]	Subtotal	Protected State	Protected Federal	Other[4]	Subtotal	Protected State	Protected Federal	Other[4]	Subtotal	Protected State	Protected State	Protected Federal	Other[4]	Subtotal
Alternative A – Coastal Barrier	4,525.3	43.3	218.3	1,259.3	1,520.9	19.3	15.6	477.6	512.5	5.7	52.5	279.7	338.0	--	4.3	7.0	2,142.7	2,154.0
Alternative D2 – Upper Bay Barrier–Bay Rim	2,334.3	28.8	--	1,342.4	1,371.2	2.6	--	224.6	227.1	14.5	--	157.5	172.0	0.0347	2.4	--	561.5	564.0

* Mitigation is planned for palustrine and estuarine marsh and oyster reef.

[1] The "Developed/Upland" category consists of bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub. Not considered to be significant effects to environment therefore not discussed in Section 5.0. Any that are unique would be avoided and minimized.

[2] Estuarine Emergent Wetland includes Estuarine Scrub/Shrub Wetland from the NOAA C-CAP 2010 landcover data.

[3] Oyster reef data were obtained from the GLO.

[4] The "Other" category under Land Ownership consists of privately owned tracts (including preserves owned and managed by NGOs) and GLO-state submerged lands. The "Other" category under Development/Uplands also includes USACE placement areas.

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Table 4-24
Habitats Impacted Based on NOAA C-CAP Classification and the HSI Models Used to Calculate Mitigation Requirements for Each Habitat

Habitat Impacted	Model Used
Palustrine Emergent Wetland	American Alligator (Newsom et al., 1987)
Estuarine Emergent Wetland	Brown Shrimp (Turner and Brody, 1983)
American Oysters	Oyster Model (Swannack et al., 2014)

A systemwide model was used to determine the impacts of the proposed project on hydrology and salinity to estimate indirect impacts. Due the limited enclosure of wetland with Alternative D2, indirect impacts were assumed to be negligible. Due to a partial closure at Bolivar Roads from Alternative A's structure, reduced tidal flow and a change in the tidal amplitude may occur (see the Engineering Appendix, Appendix D). The structure consists of surge barrier gates. The large surge barrier gate is currently proposed as a floating sector gate, which requires islands to be built to store the gates when not closed for storms. These islands, along with the structural base of the environmental lift gates, reduce the opening in Bolivar Roads. At the time of the TSP, the reduction of the opening at the pass was limited to 27.5 percent closure with the barrier in the open position. This closure amount may be further optimized in future planning and design phases of the study process to reduce impacts to the hydrology of the Galveston Bay system.

The team developed a methodology for determining the potential impacts to estuarine marshes within the tidal influence areas of Bolivar Roads. A 3D Adaptive Hydraulic (AdH) model was applied to assess hydrological impacts, changes in tidal prism, and tidal amplitude that may occur from the proposed CSRM gates. A change in tidal amplitude was assumed to create a situation where the high tides are lower and the low tides are higher than in a FWOP condition (see the Engineering Appendix, Appendix D). It was assumed that a change in tidal amplitude will affect tidal marsh since the potential would exist for marsh at the upper bounds of the cover type to experience less inundation, while marsh at the lower bounds of the area would experience potentially constant inundation.

To generate an estimate of indirect tidal marsh impacts due to the presence of a CSRM structure across Bolivar Roads, a spatial analysis was developed using the NOAA Marsh Migration viewer outputs associated with a projected 1 foot of RSLR. It was assumed that 2035 would represent the condition to apply potential effects from the CSRM structure on tidal marsh, which corresponds to approximately 1 foot of RSLR based on the USACE RSLR curves. For the analysis, only tidally influenced cover types, which included estuarine and brackish wetlands, were included.

Preliminary AdH modeling of the Galveston Bay system indicated that up to 0.5 foot could be eliminated from the tidal amplitude if a CSRM structure were placed across Bolivar Roads (see the Engineering Appendix, Appendix D). The reduction was assumed to be symmetric about the high and low tide. The reduction of 0.5 foot resulted in a FWP tidal range of 0.0 to +1.5 foot.

Using GIS, marsh acres were calculated. FWOP tidal marsh acres were estimated to be 38,696 acres. FWP tidal marsh acres were estimated at 35,321 acres. Subtracting the with-project acre estimate from the without-project acre estimate resulted in a total of 3,375 acres of tidal marsh indirectly impacted by a CSRM structure or storm surge barrier across Bolivar Roads. It is important to note that the exact number could vary depending on wetland loss prior to construction, which could be caused by RSLR, hurricanes, or other factors. Also, the indirect number is based on a conservative estimate related to the percent closure. The team will continue to further optimize the percent closure throughout future planning and design phases.

The HEP tool was again applied to calculate the AAHUs of impacted estuarine emergent marsh and the AAHUs and associated number of acres of mitigation that would be needed to address these impacts. Table 4-25 shows the mitigation requirements for the CSRM alternatives.

Table 4-25
Mitigation Requirements for Each CSRM Alternative

	Alternative A		Alternative D2	
Impact/Mitigation	Acres	AAHUs	Acres	AAHUs
IMPACTS:				
Direct				
Palustrine Wetlands	512.5	–93.8	227.1	–41.6
Estuarine Wetlands	338.0	–185.7	172.0	–94.5
Oyster	0	0	0	0
Total Direct Impacts	850.5	–279.5	399.1	–136.1
Indirect				
Tidal Prism Change	38,696.0	–4,738.5		
MITIGATION:				
Direct Impacts				
Palustrine Wetlands	138.0	93.7	62.0	42.1
Estuarine Wetlands	270.0	185.8	138.0	95.0
Oyster	0		0	0
Mitigation Direct Subtotal	408.0	279.5	200.0	137.1
Mitigation Indirect Subtotal	6,887.0	4,739.0		
Total Mitigation	7,295.0	5,018.5	200.0	137.1

4.3.4.10 Potential Induced Flooding

Both alternatives have the potential to increase stages to the areas exterior to the levee. With Alternative A the potential of induced flooding is limited to the structures on Bolivar Peninsula and Galveston Island. Approximately 1,000 structures are outside of the current levee/floodwall. These structures could be subject to induced stages; however, many of these issues may be addressed by switching to an engineered dune system in front of the structures. The risk with Alternative D is mainly focused on the impacts to the levee tie-ins. There is a margin of error in both the economic model and the storm surge modeling (ADCIRC), which is recognized by team hydrologists and economists. Additional investigations would be needed in the densely populated communities of Baytown and Santa Fe to determine if the levee system induces stages.

4.3.4.11 Navigation Impacts

Similar to Alternative B and Alternative C, Alternative D2 would impact interactions between deep-draft ships and shallow-draft tugs and barges (domestic traffic). Currently, Alternative D2 includes surge barrier gates near the Fred Hartman Bridge. Under the FWOP conditions, the channel in this section includes a deep-draft channel that is also sometimes used by shallow-draft traffic. If a gate is built at this location, the shallow-draft traffic would be forced to transition through the gate with the deep-draft traffic, adding to safety concerns. Two adjacent shallow-draft gates were considered but there is limited space in the upper reaches of the channel. Greater navigation impacts would occur in the Dickinson Bay area with Alternative D2 than in Dickinson Bayou with Alternative A, due to a larger system of gates and more commercial/industrial facilities within the D2 system.

Another noteworthy difference between the two action alternatives is that Alternative D2 leaves much of the navigation infrastructure at risk from storm surges, since many of the ports and channels would be outside of the system. Storm surge can move large amounts of sediment into the navigation channel during an event, adding to the annual operation and maintenance cost of dredging.

The GIWW is at risk from damage by coastal storms under the FWOP conditions. Approximately 83 million tons of cargo with a commercial value estimated at $25 billion travel on the Texas GIWW annually. Existing openings on Bolivar Peninsula, such as Rollover Pass, act as gateways for sediment to accumulate in the channel. Currently, the USACE spends over $500,000 per year to address shoaling from Rollover Pass (Figure 4-31).

That cost is expected to increase if additional breaches are allowed to develop under the FWOP conditions. Alternative A, with a levee/floodwall or even with an engineered dune system, would help to maintain existing geomorphic features along Bolivar Peninsula.

4.3.4.12 Critical Infrastructure

In addition to the critical navigation infrastructure, Alternative D2 leaves many of the region’s critical roadways at risk in the future. SH 124 is at immediate risk. This was one of the key highways that was destroyed after Hurricane Ike, leaving the communities of Bolivar Peninsula with only ferry access from Galveston. The loss of the highways can have major impacts on the recovery times for Galveston Island. Another area of concern is the future risk to the I-10 corridor (Figure 4-32). As RSLR occurs and more habitat is lost along Smith Point on the east side of Galveston Bay, the risk for surge inundating I-10 increases.

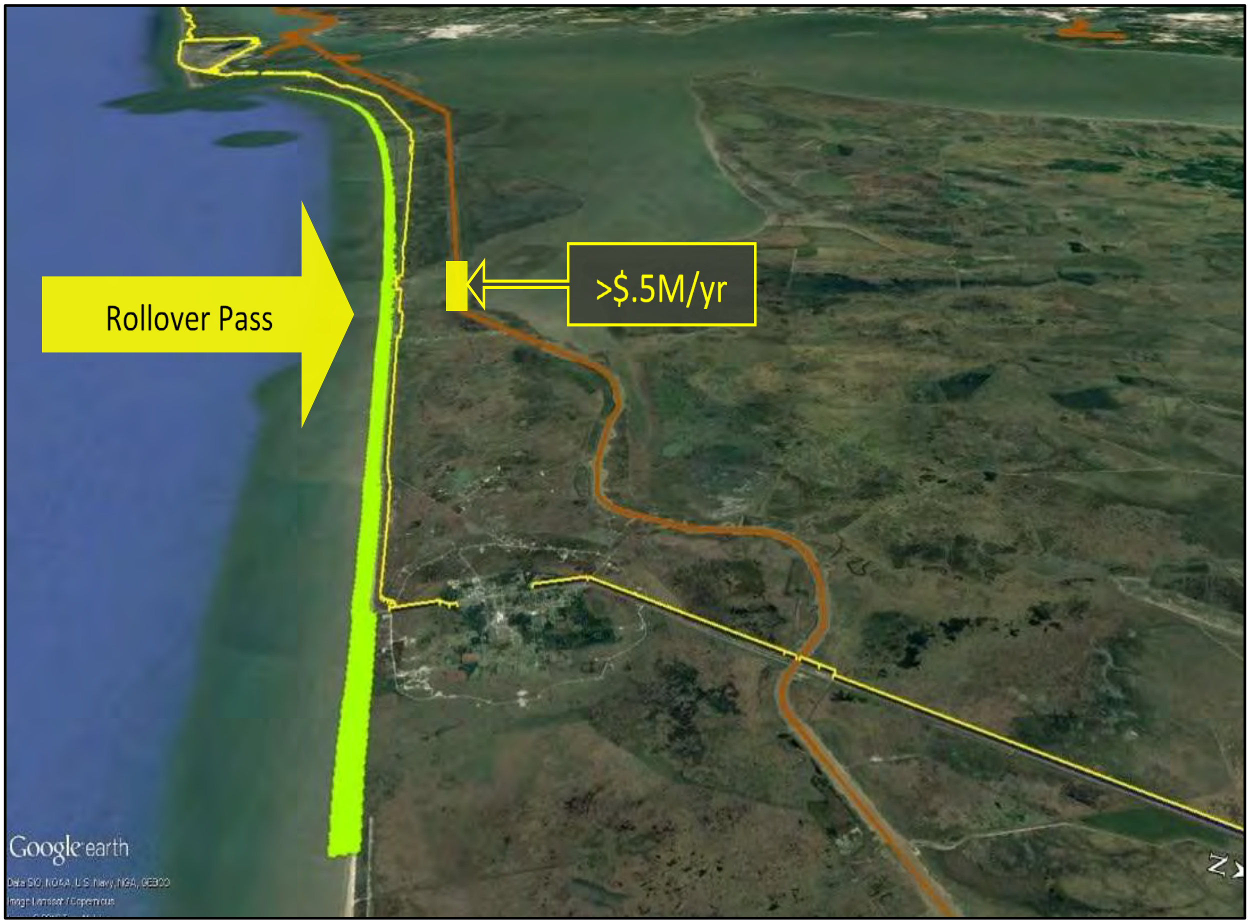

Figure 4-31: Alternative A with Current GIWW Shoaling at Rollover Pass Highlighted

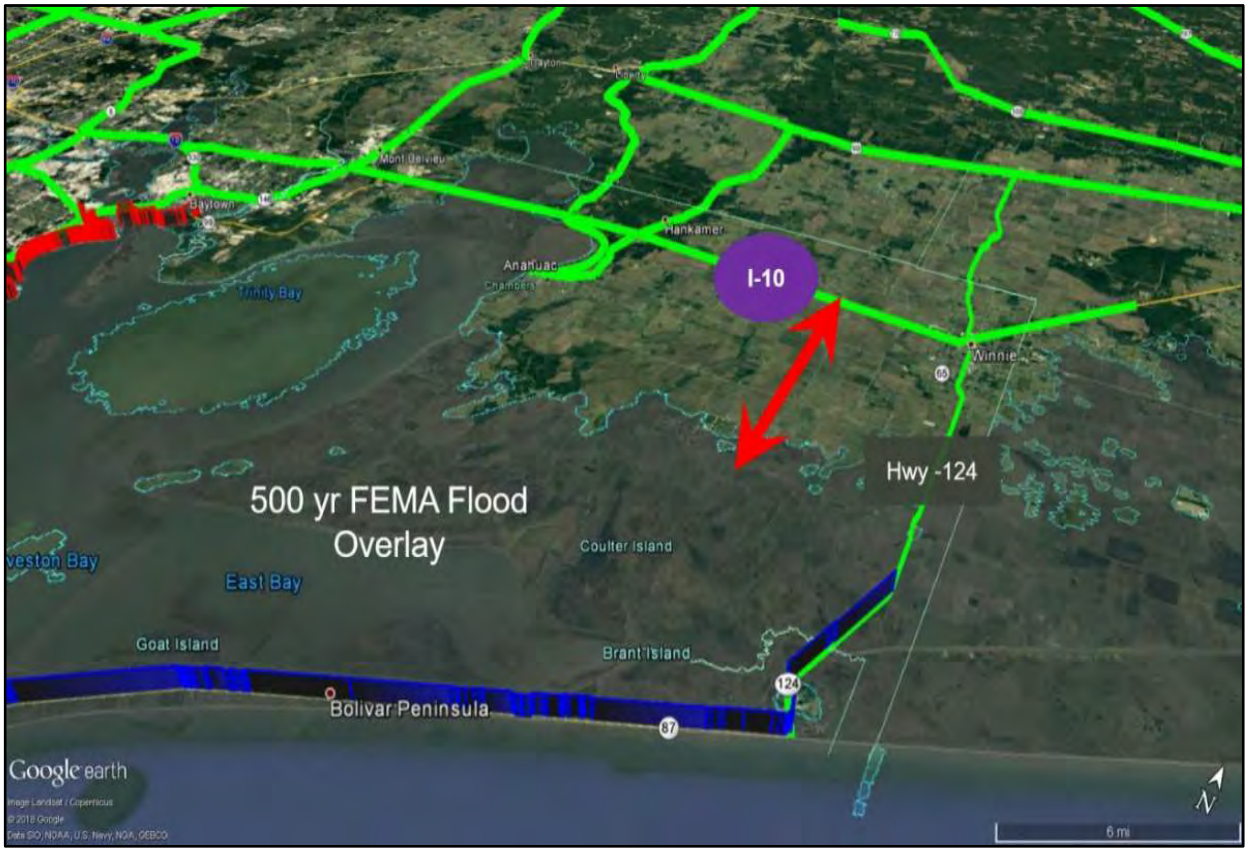

Figure 4-32: Alternative A with I-10 and SH 124 Highlighted

4.3.4.13 Relative Sea Level Rise Scenario

Since both alternatives would be constructed over a number of years, there will be opportunities to reevaluate RSLR. For example, if over time it appears that the actual RSLR rate is higher than expected, additional lifts can be added to levees; however, in the case of Alternative D2, there would be cost risk for adaptation due to the large number of floodwall sections compared to Alternative A. If RSLR rates are lower than expected, then final levee lifts will not need to be constructed, although structures may remain overbuilt.

4.3.4.14 Comparison of Alternative Project Cost

The cost estimates for the alternatives were developed with input from the GCCPRD report. Since the costs in the GCCPRD report were from FY 15, they were escalated to FY 18 using the current Civil Works Construction Cost Index System tables; the 2015 costs were escalated by 6 percent. Costs for Alternative A were obtained from the GCCPRD report with modifications made to the large closure gate by the New Orleans District structural section to meet environmental requirements. Additional design and quantities were developed for the new reaches that did not exist in the GCCPRD report. The same report format and unit costs were used to bring consistency to the two alternatives. Mitigation quantities and costs for both CSRM alternatives were also developed. Cost for the alternatives are presented as a range (Table 4-26). This was accomplished by identifying the critical cost drivers in each major feature of work in order to define ranges of potential cost for the feature/alternative. Additional information on the cost development can be found in the Engineering Appendix (Appendix D).

Table 4-26
Costs for Alternatives A and D2

	Alternative A	Alternative D2
Description	Low – High	Low – High
Real Estate Cost:		
01-Lands and Damages	$643,779,000–$736,112,000	$1,872,604,000–$2,322,029,000
02-Relocations	$60,939,000–$60,939,000	$114,717,000–$114,717,000
Total	$704,718,000–$797,051,000	$1,987,321,000–$2,436,746,000
Construction Cost:		
06-Fish and Wildlife	$652,939,000–$874,013,000	$15,240,000–$20,400,000
11-Levees and Floodwalls	$2,582,229,000–$5,005,970,000	$4,057,064,000–$7,230,854,000
13-Pumping Plants	$1,048,097,000–$1,220,583,000	$1,562,821,000–$2,027,619,000
13-Pumping Plants - Buffalo Bayou	--	$1,261,779,000–$1,298,805,000
15-Flood Control and Div Str	$297,627,000–$297,627,000	$496,106,000–$496,106,000
15-Flood Control and Div Str – "Big Gate"	$5,097,492,000–$6,304,361,000	$4,289,250,000–$4,314,226,000
Subtotal Federal Cost	*$9,678,384,000–$13,702,554,000*	*$11,682,260,000–$15,388,010,000*
30-Engineering and Design	$2,496,200,000–$3,540,435,000	$2,964,157,000–$3,921,439,000
31-Construction Management	$1,291,138,000–$1,831,260,000	$1,533,185,000–$2,028,330,000
Total Federal Cost	$13,465,722,000–$19,074,249,000	$16,179,602,000–$21,337,779,000
Total Project Cost (rounded)	**$14,170,440,000–$19,871,300,000**	**$18,166,923,000–$23,774,525,000**

4.3.4.15 Net Benefits and Benefit-Cost Ratios

The USACE NED procedure manuals for coastal and urban areas recognize four primary categories of benefits for flood risk management measures: inundation reduction, intensification, location, and employment benefits. The majority of the benefits attributable to a project alternative generally result from the reduction of actual or potential damages caused by inundation. Inundation reduction includes the reduction of physical damages to structures, contents, and vehicles and indirect losses to the national economy. The Economic Appendix (Appendix E) provides a detailed description of the methodology used to determine NED damages and benefits under existing and future conditions and the projects costs. The damages and costs were calculated using FY 18 (October 2017) price levels. Damages and benefits were converted to equivalent annual values using the FY 18 Federal discount rate of 2.75 percent and a period of analysis of 50 years with the year 2035 as the base year. The equivalent annual damage and benefit estimates were compared to the annual construction costs and the associated OMRR&R costs for each of the project alternatives. Tables 4-27 and 4-28 provide an overview of the results of these evaluations for both CSRM alternatives under a range of RSLR scenarios and cost ranges.

Table 4-27
Alternative A Net Benefits and BCRs ($ millions)

RSLR & Cost Scenario	W/O Project Damages[1]	Alt A With-Project Damages[1]	Annual Damage Reductions	Annual Benefits (Damage Reduction plus GDP Impacts*)	Annual Costs	Equivalent Annual Net Benefits (includes GDP Impacts*)	Equivalent Annual Net Benefits (Without GDP Impacts)	BCR (includes GDP Impacts)	BCR (Without GDP Impacts)
High RSLR and Low Cost	$3,106	$1,818	$1,288	$1,908	$717	$1,192	$571	2.7	1.8
High RSLR and High Cost	$3,106	$1,818	$1,288	$1,908	$956	$952	$332	2	1.35
Intermediate RSLR and Low Cost	$2,243	$1,464	$779	$1,141	$717	$424	$62	1.6	1.09
Intermediate RSLR and High Cost	$2,243	$1,464	$779	$1,141	$956	$185	($177)	1.2	0.81
Low RSLR and Low Cost	$2,044	$1,382	$662	$970	$717	$253	($55)	1.4	0.92
Low RSLR and High Cost	$2,044	$1,382	$662	$970	$956	$14	($294)	1	0.69

[1] Equivalent Annual Values, 2035-2085 period of analysis and includes future development.
* REMI model developed by Regional Economic Models Inc. was used to quantify the indirect impacts U.S. economy.

Table 4-28
Alternative D2 Net Benefits and BCRs ($ millions)

RSLR & Cost Scenario	W/O Project Damages[1]	Alt D2 With-Project Damages[1]	Annual Damage Reductions	Annual Benefits (Damage Reduction plus GDP Impacts*)	Annual Costs	Equivalent Annual Net Benefits (includes GDP Impacts*)	Equivalent Annual Net Benefits (Without GDP Impacts)	BCR (includes GDP Impacts)	BCR (Without GDP Impacts)
High RSLR and Low Cost	$3,106	$1,902	$1,204	$1,809	$887	$923	$255	2	1.29
High RSLR and High Cost	$3,106	$1,902	$1,204	$1,809	$1,122	$687	$20	1.6	1.02
Intermediate RSLR and Low Cost	$2,243	$1,543	$700	$1,049	$887	$163	($193)	1.2	0.78
Intermediate RSLR and High Cost	$2,243	$1,543	$700	$1,049	$1,122	($73)	($429)	0.9	0.62
Low RSLR and Low Cost	$2,044	$1,453	$591	$885	$887	($2)	($308)	1	0.65
Low RSLR and High Cost	$2,044	$1,453	$591	$885	$1,122	($237)	($544)	0.8	0.52

[1] Equivalent Annual Values, 2035–2085 period of analysis and includes future development.
* REMI model developed by Regional Economic Models Inc. was used to quantify the indirect impacts US economy.

In addition to the direct damages to residential and nonresidential structures, their contents and residential vehicles and the costs of debris removal, there can be indirect impacts to the local and national economy resulting from a storm event. These indirect impacts are related to disruptions in the production of goods and services by the industries affected by the storm. Businesses can be forced to curtail their normal operations because workers are displaced, facilities are inundated, and flooded roads limit access to the facilities. By implementing coastal storm risk reduction measures, the losses associated with indirect economic impacts can be reduced. The model developed by Regional Economic Models Inc. (REMI) was used to quantify the indirect impacts to the region, the remaining counties of Texas, and the rest of the U.S. economy. The model estimates the geographic redistribution of production and the net changes in national output associated with storm damage. The information is included in the above tables as separate values as a sensitivity to investigate the possible range of benefits between the alternatives when including indirect economic impacts. Additional information on the REMI model assumptions can be found in the Economic Appendix (Appendix E).

4.3.4.16 Residual Risk

While Alternative D2 is predicted to have fewer environmental impacts than Alternative A, Alternative D2 comes with residual flood and life safety risk, such that it could be classified as a non-practicable alternative. An alternative can be defined as practicable if it is capable of being implemented. Using lessons learned from the Interagency Performance Evaluation Task Force post-event investigations of Hurricane Katrina and from other

USACE Dam and Levee Safety studies, Alternative D2 might be proven not to be a practicable alternative. The Interagency Performance Evaluation Task Force report illustrates an effective platform for developing better policy and planning decisions when recommending and designing hurricane risk reduction systems. One of the key lessons learned was to use a system approach when assessing risk to make practicable, rational, and defensible decisions.

One of the key areas of assessing risk is accomplished through analyzing a system's performance for a given set of events. This performance is assessed by modeling how each structure and component of the system (levees, floodwalls, gates, etc.) would perform under the forces generated by surge and waves. Results from modeling of the Greater New Orleans Hurricane and Storm Damage Risk Reduction System illustrated that as components are added to the system, the risk for failure increases. Similar lessons have been assessed in reviews of the Dutch storm surge risk reduction system. Application of this principle helped lower risk and improve system performance for the greater New Orleans area.

If Alternative D2 were implemented, it would likely include a large number of different T-Wall sections for levee tie-in points. Alternative A tie-in points are mainly limited to the large navigation structure. Risk experts agree, and Interagency Performance Evaluation Task Force illustrated, that there will always be residual risk with any system; however, it is imperative that flooding vulnerability from extreme events is factored into planning decisions. These decisions may require designing a system to allow for more-effective evacuations or emergency responses to extreme events (i.e., greater than the recommended 100-year level of risk reduction). In the case of Alternative D2, residual risk is high due to the proximity of the levee alignment to developed areas.

Alternative D2 has the greatest residual risk since overtopping of the levee by storm surge during extreme events would immediately inundate vulnerable populated areas and key emergency service routes. Alternative A is set farther away from the developed areas of the study area; therefore, it has a lower residual risk in the event of extreme overtopping events. The nonstructural measures in the developed area also reduce this residual risk. Galveston Bay's storage capacity also plays a key role in reducing residual risk. It not only provides a storage basin for exceedance surge events, it also avoids inducing damage under extreme rainfall events. Alternative D2 includes multiple drainage and pump stations, which could be overwhelmed during an extreme rainfall event. Rainfall would stack up behind the levee system until it was pumped or drained out.

4.3.5 Summary of CSRM Alternatives Comparison

As compared to the Upper Bay Barrier-Bay Rim (Alternative D2), the Coastal Barrier with complementary system of nonstructural measures (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. Similar to the multiple lines of defense approach, it builds upon existing project and other proposed recommendation yet to be built (Figure 4-33).

4.4 OVERVIEW COASTWIDE ARRAY

The final array of alternatives carried forward for consideration include:

- **No-Action**;
- **Coastal Barrier Alternative**. Includes the Lower Texas Coast South Padre Island CSRM plan discussed in Section 4.3.2, the Coastwide ER Alternative 1-Scale 2 (1-2) discussed in Section 4.3.3, and the Upper Texas Coast Coastal Barrier CSRM with complementary system of nonstructural measures (Alternative A) discussed in section 4.3.4; and
- **Bay Rim Alternative**. Includes the Lower Texas Coast South Padre Island CSRM plan discussed in Section 4.3.2, the Coastwide ER Alternative 1-Scale 2 (1-2) discussed in Section 4.3.3, and the Upper Texas Coast Upper Bay Barrier-Bay Rim (Alternative D2) CSRM discussed in Section 4.3.4.

For detailed engineering assumptions for each component, see Appendix D. For screening to determine the final TSP, the PDT assumed that both final action alternatives would include both the **South Padre Island CSRM plan and the Coastwide ER Alternative 1-Scale 2 (1-2) since those plans were refined through multiple screening efforts and met specific needs and opportunities within the study area**. Also, due to the local sponsor's interest in exploring a larger extent of beach fill along South Padre Island, the full NEPA impacts of the beach and dune feature on all reaches were evaluated. Using this assumption, the main difference between the No-Action Alternative and the two action alternatives was the location for a Coastal Barrier CSRM in the upper Texas coast.

4.4.1 No-Action Alternative

Under the No-Action Alternative, no surge risk reduction would occur in the upper Texas coast in the vicinity of Galveston or in the lower Texas coast along the South Padre Island shoreline. Both areas would continue to experience storm surge damages, which would be exacerbated by RSLR. Increased erosional impacts to the critical barrier shorelines and wetlands would increase the storm surge risk coastwide, and the highly productive ecosystems along the Texas coast, composed of diverse habitats and wildlife, would not be sustainable in the future.

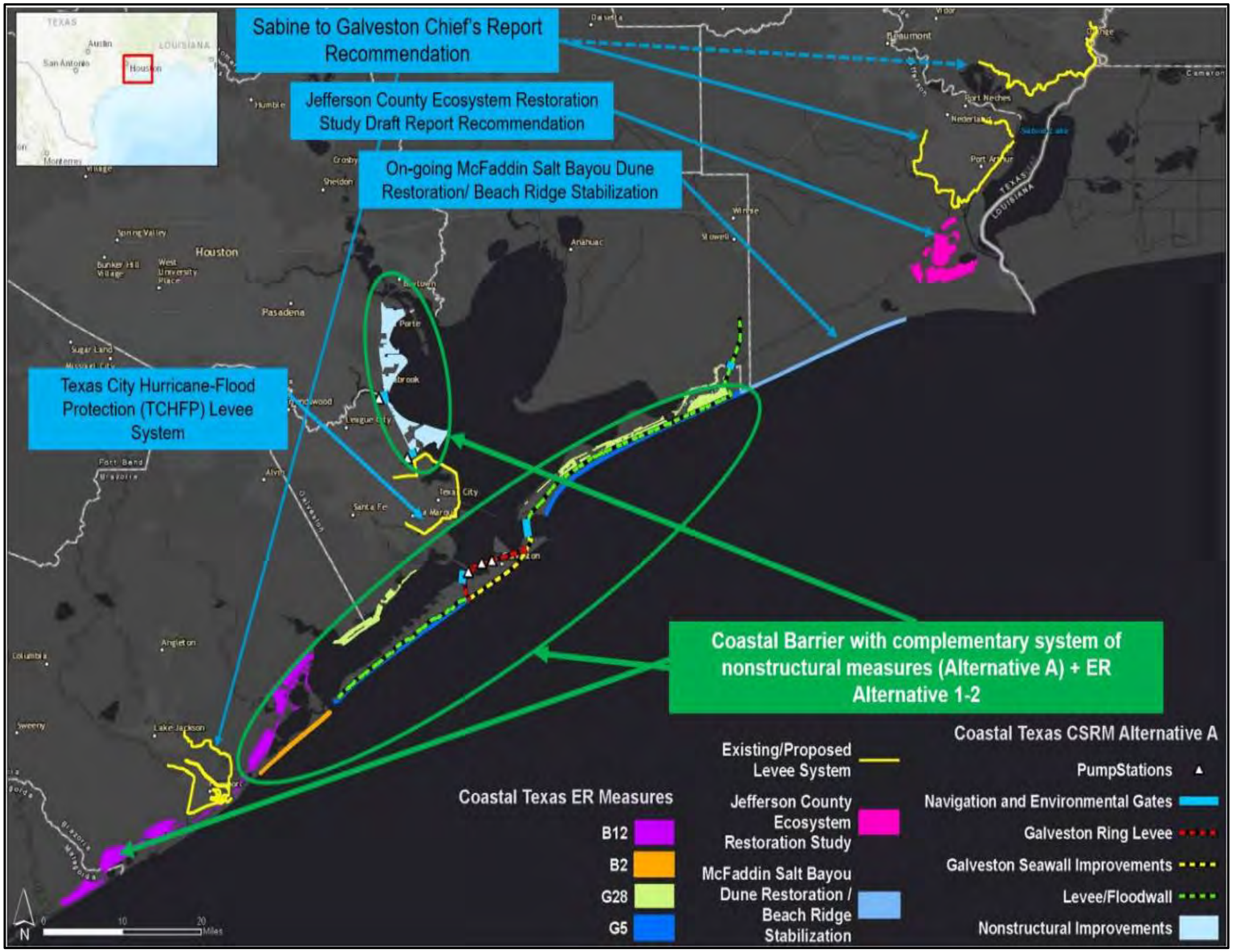

Figure 4-33: Linked ER and CSRM in the Upper Texas Coast

4.4.2 Coastal Barrier Alternative

South Padre Island CSRM Measure

The Coastal Barrier Alternative would provide risk reduction to South Padre Island as discussed in Section 4.3.2. Under the Federal proposal, approximately 2.2-miles of CSRM dune and beach system (Reaches 3 and 4) would be aligned parallel to the existing beach and dune system and would start 2 miles from and end 4.2 miles from the Brazos Santiago Pass North Jetty system. Based on the nourishment volumes and intervals, the most cost-effective scale was shown to be a 12.5-foot dune and 100-foot-wide berm with a 10-year renourishment cycle. Based on this design, initially 23,558 cy of beach fill would be placed in Reaches 3 and 4, with a total of 1.4 mcy of beach fill placed over a 50-year project period. This is the minimal amount of beach fill expected with the TSP. As stated above the local sponsor is interested in exploring a larger extent of beach fill along the entire South Padre Island reaches from Brazos Santiago Pass North Jetty system to 5.8 miles north of the Jetty (Reach 1 through Reach 6).

ER Measures

The Coastal Barrier Alternative would substantially improve the habitat suitability along the entire Texas coast. Selecting the Coastwide ER Alternative 1-Scale 2 described in Section 4.3.3, would restore, create, protect, and/or enhance approximately 26.6 miles of Gulf shoreline from High Island on Bolivar Peninsula to the Galveston East Jetty and 18.6 miles of Galveston Island shoreline west of the Galveston seawall (G-5). An initial 33 to 66 mcy of beach and dune fill for environmental restoration purposes would be placed over the area. A total of five nourishment cycles would place 27.6 mcy over a 50-year period or a one-time renourishment (27.6 mcy) in year 10 with a Sand Engine placement that would be used to reduce the dune and beach shaping needed by land equipment. A total of 5,057 acres would be restored, created, protected, and/or enhanced.

The plan would also install breakwaters and restore marsh habitat to protect 27 miles of marsh habitat along the GIWW on Bolivar Peninsula and 9 miles of shoreline along the north shore of West Bay (G-28); however, no breakwaters would be constructed where portions of the GIWW shoreline are already stabilized by adjacent dredged material placement areas. This would be accomplished by restoring 664 acres of marsh using 482,000 cy of fill. The plan would also use 5.8 mcy of sediment to restore, create, and/or enhance 326 acres of islands adjacent to the GIWW along a 5-mile stretch of shoreline habitat along the north shore of West Bay. A 26,280-linear-foot oyster reef would be created on the bayside of the restored islands for a creation of 18 acres of oyster reefs. Also, subsequently in the future, the plan would, through future construction activities along the Galveston Bay portions of the GIWW, nourish 6,891 acres of marsh expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be needed in 2065, are expected to require 10.1 mcy of fill material to address losses from RSLR impacts.

The plan would also restore, protect, and/or enhance beach and dune complex on approximately 10 miles of Gulf shoreline on Follets Island in Brazoria County (B-2). A total of 1,113.8 acres would be restored, created, protected, and/or enhanced by placing 8.7 mcy of beach fill for environmental restoration purposes. In order to maintain the habitat, a total of 11.6 mcy would be placed over five nourishment cycles over a 50-year period, or a one-time renourishment (11.6 mcy) in year 10 with a Sand Engine placement that would be used to reduce the dune and beach shaping needed by land equipment.

In Bastrop Bay, Oyster Lake, Cow Trap Lake, and the western side of West Bay, the plan would restore, create, and/or enhance critical areas of shoreline (B-12). A total of 551 acres of estuarine marsh would be restored using an estimated 400,000 cy of fill material. A total of 43.2 miles of breakwaters would be placed on the western side of West Bay and Cow Trap Lake, and along selected segments of the GIWW in Brazoria County. In the area of Oyster Lake, 3,708 linear feet of oyster reef or 0.17 acre of oyster reef would be created to prevent the lake from joining with West Bay. Also, the plan would, through future construction activities, nourish 19,794 acres of marsh along the GIWW which is expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be needed in 2065, are expected to require 29 mcy of fill material to address losses from RSLR impacts.

The plan includes the use of breakwaters to restore, protect, create, and/or enhance approximately 12.4 miles of shoreline and associated marsh along the Big Boggy NWR shoreline and eastward to the end of East Matagorda Bay (M-8); however, no breakwaters would be constructed where portions of the GIWW shoreline are already stabilized by adjacent dredged material placement areas. This would be accomplished by restoring 239 acres of estuarine marsh using 173,696 cy of fill along these areas. The plan would also restore 92.7 acres/3.5 miles of islands adjacent to the Big Boggy NWR along the GIWW, using 1.1 mcy of fill. The 31,355 linear feet of oyster reef on the bayside of the islands would also be created. Also, subsequently in the future, the plan would, through future construction activities, nourish 6,034 acres of marsh along the GIWW, which is expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be needed in 2065, are expected to require 8.8 mcy of fill material to address losses from RSLR impacts.

Along the Matagorda Bay shoreline between Matagorda Bay and Keller Bay, the plan would use breakwaters to restore, protect, create, and/or enhance approximately 6 miles of shoreline (CA-5). A total of 3.8 miles of breakwaters would be placed along the southern reach the project area, while 2.3 miles of oyster reef creation would be used on the western reaches of the project area. The plan would also, through future construction activities, nourish 623 acres of marsh directly behind the breakwaters. The out-year construction activities, estimated to be needed in 2065, are expected to require 914,647 cy of fill material to address losses from RSLR impacts.

Near the Powderhorn Lake area, along Matagorda Bay the plan would restore, create, and/or enhance critical areas of shoreline (CA-6). A total of 5 miles of breakwaters would be used for shoreline stabilization, fronting the portions of Indianola, the Powderhorn Lake estuary, and TPWD’s Powderhorn Ranch. In addition, 531 acres of estuarine marsh restoration would be created using 385,760 cy of fill material in areas near the Powderhorn Lake estuary, which has converted to unconsolidated shorelines.

The plan includes using breakwaters and/or living shorelines, BU material, and oyster reef balls to restore, create, and/or enhance the island complex of Dagger, Ransom, and Stedman islands in Redfish Bay (SP-1). The plan would include creating 391 acres of island habitat in the complex and would require 6.7 mcy of fill material. Also, along the unprotected GIWW shorelines, along the backside of Redfish Bay, and the bayside of the restored islands the plan would place 7.4 miles of breakwaters around the system. In the interior of the system, 7,392 linear feet of oyster reef would be created to enhance SAV growth.

In order to maintain the geomorphic function of the Gulf shoreline north of the Port Mansfield Channel and restore and maintain the hydrologic connection between the Laguna Madre and the Gulf, the plan would dredge 6.9 miles of the Port Mansfield Channel (W-3). The material would be used to nourish 9.5 miles of beach north of the channel. The plan would also include a bird island restoration using the dredge material to restore 27.8 acres of an existing island. A 0.7-mile breakwater would also be placed on the island to maintain the system. The action of restoring and maintaining the hydrologic connection between the Laguna Madre and the Gulf would hydrologically restore over 112,864 acres in the Lower Laguna Madre.

Coastal Barrier CSRM Measure

The Coastal Barrier Alternative also includes a CSRM system in the upper Texas coast by focusing on addressing or blocking coastal storm surge at the Gulf interface. The upper Texas coast Coastal Barrier CSRM with complementary system of nonstructural measures (Alternative A) is discussed in detail in Section 4.3.4 and mainly consists of a barrier system across Bolivar Peninsula, a closure at the pass at Bolivar Roads, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. For planning purposes for the DIFR-EIS, the PDT evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island; however, the PDT recognizes that there are opportunities to optimize the design and alignment to minimize impacts to existing structures and the environment on the peninsula and island. For example, the ER measures listed above, measures G-5 and G-28, could be modified in future designs to serve the same function as a levee/floodwall system currently proposed.

The current design includes a raised roadway/levee/floodwall that would start near Mud Bayou, south of Stowell. This reach, called the eastern Tie-in, would follow the existing SH 124 and attempt to avoid impacts to the Anahuac NWR and continue until reaching the GIWW just north of High Island. The estimated elevation for planning purposes for this reach was 20.0 feet.

> *Note*: For planning purposes the levee and floodwall heights were set at an elevation that corresponded to the existing local risk reduction system's structure heights and included additional variances for addressing intermediate RSLR impacts in the future.

Currently the Galveston seawall's structure height is set at an elevation of approximately of 17 to 21 feet NAVD 88, but over the next 50 years, under an intermediate RSLR scenario, the seawall would have to be raised to maintain the same level of risk reduction. Due to these conditions the team set the system's conceptual structure heights based these future conditions. It is important to note that the team is currently focused on the general geographic location of the barriers and the structure heights are only being used to ensure that the two CSRM features are being assessed under comparable storm conditions. Once a strategy for the risk reduction system has been selected, the team will focus on the scale of the level of risk reduction for the TSP in future planning and design phases. Individual features such as levee heights, flood heights, pump station sizes, and nonstructural features would be optimized.

The system would then transition to a combi-wall and cross the GIWW on the west side of SH 124 with a sector gate. The sector gate would accommodate navigation traffic in the 125-foot-wide authorized channel with a sill elevation at –16.0 feet mean lower low water (MLLW). The sector gate would tie into a combi-wall on the south side of the GIWW, and then transition to a levee that would continue south on the west side of SH 124 until tying into natural high ground north of Hatcher Avenue in High Island.

The next reach, the Bolivar Peninsula Reach, consists of 25 miles of levee, 2 miles of floodwall, and 20 two-lane highway gates. For planning purposes, the elevation for the Bolivar Peninsula Reach was set at 18.0 feet. The reach starts at High Island, about 0.60 mile south of the end of the eastern Tie-in, with a levee on the east side of SH 124. This levee runs south for 0.5 mile until just south of Oilfield Road southeast of where it turns west and crosses SH 124. From that point the system turns southwest and would include use of a system of levees and floods to reach the vicinity of Port Bolivar and the SH 87 ferry landing. In areas where there are existing facilities in the direct alignment of the levee, the system would transition into floodwalls to minimize impacts. The Bolivar Peninsula Reach would end with a combi-wall transition into the next reach, the Galveston Harbor Entrance Channel crossing.

The 2.08-mile Galveston Harbor Entrance Channel crossing consists of 0.6 mile of combi-wall, thirty-eight 100-foot vertical lift gates for tidal exchange, one 100-foot recreational gate, and a 1,200-foot floating sector gate across the Inner Bar segment of the Galveston Harbor Entrance Channel. For planning purposes, the elevation for the Galveston Harbor Entrance Channel crossing was set at 18.0 feet. The first part of the crossing consists of seventeen 100-foot-wide vertical lift gates with sill elevation at –15.0 feet, followed by twenty-one 100-foot-wide vertical lift gates and one recreational gate with sill elevation at –30.0 feet. The combination vertical lift gates and combi-wall tie into a 1,200-foot, two-leaf floating sector gate with a sill elevation set at –60.0 feet. This sill elevation allows for future deepening of the Galveston Harbor Entrance Channel, which is currently maintained at a depth of –48.0 MLLW with advanced maintenance at this location. The sector gate is anchored and housed in man-made “islands” on either side of the Entrance Channel. Construction of the sector gate across the Galveston Harbor Entrance Channel would require a temporary bypass for navigation. The bypass channel will be north of the existing channel, through existing anchorage areas and would be maintained at 800-foot toe-to-toe width and depth of –48.0 MLLW, which is consistent with the existing channel. The crossing continues south of the sector gate with combi-wall that ties into the existing San Jacinto Placement Area on Galveston Island, which would serve as an existing high ground tie-in point.

In order to address Gulf and bay surges, the next reach ties into the east side of the existing San Jacinto Placement Area on Galveston Island and forms a ring levee around the highly developed and low-lying portions of the city of Galveston. The Galveston Ring Levee/Floodwall Reach consists of 5.0 miles of levee, 46 two-lane highway gates, 6 four-lane highway gates, 4 railroad gates, 13.0 miles of floodwall, a 2,400-foot crossing of Offatts Bayou with a vertical gate, a series of 100-foot environmental gates, combi-wall, 3 pump stations, 8 miles of existing seawall raising with 7 two-lane highway gates. For planning purposes, the top elevations ranged from 18.0 to 18.5 feet on the west side of the system, to 11 to 17 feet along Harborside Drive, and 21 feet along the seawall. The reach would include a floodwall/levee system on the backside of Galveston Island and would continue until meeting the existing end of the seawall near 7-Mile Road and FM 3005. Improvements to 7.9 miles of the existing Galveston seawall would equate to an increase in the height of approximately 4.0 feet above the existing ground elevations. It is important to understand that the current design of the Galveston seawall initially provided a fronting protection (the upward and outward curved section to the wall) elevation of about 17.0 feet; however, subsequent modifications to the embankment behind the fronting protection places the risk reduction level at an elevation range between about 19 to 26 feet. This would be an important consideration when considering the 4 feet of additional risk reduction in the final design.

Due to the fact that Galveston Island operates currently on a gravity drainage system, the plan would include a forced drainage system for when the ring levee is closed off during storm events. Interior drainage within the risk reduction system would require three pump stations: one at Offatts Bayou (4,386 cubic feet per second) and two near Harborside Drive (1,645 and 1,243 cubic feet per second). An interior drainage analysis could refine pump station requirements and locations.

The entire Galveston Ring Levee/Floodwall Reach would tie-into a levee/floodwall system that follows the west end of Galveston Island. The West Galveston Reach consists of 13.5 miles of levee, 1.5 miles of floodwall, 14 two-lane highway gates, 35 drainage closure structures, and 3.5 miles of elevated highway and ends at a tie-in point at the San Luis Pass Bridge abutment. For planning purposes, the West Galveston Reach was set at an elevation of 17.0 feet. Similar to the Bolivar Peninsula Reach, areas where there are existing facilities in the direct alignment of levee the system would transition into floodwalls to minimize impacts.

The system also includes two closures at Clear Creek Channel and Dickinson Bayou to address wind-driven surges in the bay. The features at both areas consist of sector gates across the channel, associated barrier walls, and pump stations. For planning purposes, the elevation of the walls and gates were set at an elevation of 17.0 feet.

The plan would also include nonstructural measures along the west side of Galveston Bay to address residual damages from wind-driven bay surges. As discussed above, elevation is a common approach already being undertaken by residents and businesses in the study area. Due to the general uncertainty associated with structures' first-floor elevations and locations in the floodplain, additional structure inventory investigations would be undertaken to evaluate which structures are at risk if this alternative moves forward. The focus would be on the approximately 10,000 structures between SH 146 and the bay rim.

4.4.3 Bay Rim Alternative

As discussed above, the Bay Rim Alternative also includes the South Padre Island CSRM plan and the Coastwide ER Alternative 1-Scale 2 since those plans were refined through multiple screening efforts to meet specific needs and opportunities within the study area.

Bay Rim CSRM Measure

The Bay Rim Alternative includes an upper Texas coast CSRM barrier to potentially avoid the majority of the navigation impacts by focusing on a levee system on the west side of Galveston from Texas City to the Fred Hartman Bridge instead of trying to address surges at the Gulf interface. The Upper Bay Barrier-Bay Rim (Alternative D2), discussed in Section 4.3.4, consists of 400,000 feet of levee, 163,000 feet of floodwall, 122 two-lane highway gates, 10 four-lane highway gates, 37 drainage closure structures, and 18 railroad gates. Additionally, there would be navigation gates, environmental gates, and combi-wall at the Houston Ship Channel, Clear Creek Channel, Dickinson Bayou, Offatts Bayou, and Highland Bayou Diversion Channel.

The system starts near Tri City Beach Road and SH 99 in Baytown, Texas, with 2.5 miles of elevated two-lane road. This reach was called the Upper Bay Reach and continues southwest until reaching the Houston Ship Channel and Tabbs Bay Reach. For planning purposes, the elevation of this reach was set at 18.0 feet.

> *Note*: For planning purposes the levee and floodwall heights were set at an elevation that corresponded to the existing local risk reduction system's structure heights, and included additional variances for addressing intermediate RSLR impacts in the future.

Currently the Texas City Hurricane Flood Protection structure heights range from approximately 18.0 to 25.0 feet NAVD 88, but over the next 50 years, under an intermediate RSLR scenario, the seawall would have to be raised to maintain the same level of risk reduction. Due to these conditions, the team set the system's conceptual structure heights based on these future conditions. It is important to note that the team is currently focused on the general geographic location of the barriers, and the structure heights are only being used to ensure that the two CSRM features are assessed under comparable storm conditions. Once a strategy for the risk reduction system has been selected, the team will focus on the scale of the level of risk reduction for the TSP in future planning and design phases. Individual features such as levee heights, flood heights, and pump station sizes would be optimized.

The Houston Ship Channel and Tabbs Bay Reach crossing consists of a 4,000-foot combi-wall crossing across Tabbs Bay with a series of 100-foot environmental gates to connect the north bank of the bay with Hog Island. It is also possible that a pump station would be needed to address Buffalo Bayou flows (50 year, 210,000 cubic feet per second) during storm events. The Buffalo Bayou pumping requirement is based on peak flows from Buffalo Bayou and the San Jacinto River from the Harris County Flood Insurance Study. There are two distinct peaks in nearby water-elevation data, meaning the two upstream watersheds peak at different times. The discharge area is complex and would require further detailed hydrology and a joint-probability analysis if the alternative is carried forward.

A temporary bypass channel would first be constructed between the north bank and Hog Island to allow for the construction of the sector gate and combi-wall across the Houston Ship Channel. Once on Hog Island, 2,800 feet of levee would be constructed along the shore of the island to the west side of island where the risk reduction system would cross the Houston Ship Channel at the Lower End of Morgan's Point Cut reach near Station 57+00.000 with a combi-wall and sector gate. The 3,070-foot crossing of the ship channel at this point would consist of combi-wall and a sector gate to accommodate the existing channel width of 530 feet. The channel in this reach is maintained to a depth of –48 MLLW, which includes an advanced maintenance depth. The north and south perimeter dike of the Spillman Island Placement Area would then become a part of the system to just west of the Barbour's Cut Basin.

The next reach, the Bay Perimeter Reach, would start on the west side of Barbour's Cut at the Spillman Island Placement Area. The entire alignment would turn south and follow the bay rim until reaching the existing Texas City HFPP, 9,180 feet northwest of the Moses Lake gate structure. Floodwalls would be used to avoid impact to the port facilities along the bay rim, and, due to the existing structure, most of the reaches would consist of floodwall sections.

Once reaching Clear Creek, a sector gate would be built across the current authorized 75-foot channel and would have a sill depth of –12 MLLW. The system would then connect to a floodwall at the Kemah Boardwalk and Seabrook. The bay perimeter levee/floodwall would continue southeast until reaching the NRG Energy Power Plant outfall canal where a drainage closure structure would be constructed. The levee/floodwall would then continue around the bay rim until reaching Avenue O (Cat Point), in San Leon, where the Dickinson Bay crossing would commence.

Within all of the floodwall reaches listed above, there would need to be drainage closure structures or pump stations on features to address rainfall flooding during storm events. Currently the following drainage features have been included for a drainage closure structures and/or pump station: Buffalo Bayou**,** a drainage ditch just north of South Blackwell Street, Deer Creek, Little Cedar Bayou, Taylor Bayou (Diversion to Bayport), the Clear Creek Second Outlet discharge channel, Clear Creek, Pine Gully, HCFCD Ditch F222-00-00, and the NRG Energy Power Plant outfall. If this alternative is carried forward, additional watershed analysis would have to be performed to refine the pump station and drainage requirements.

The 1.3-mile crossing across Dickinson Bay east of SH 146 consists of combi-wall and a sector gate across the current authorized 60-foot channel, and would have a sill depth of –9 MLLW. A series of 100-foot environment gates to maintain tidal influence would be included. The system would tie into the existing Texas City HFPP 9,180 feet northwest of the Moses Lake gate structure.

The next reach in the plan would be modernization of the existing Texas City HFPS. The reach consists of 49,479 feet of levee, 7,096 feet of floodwall, and would include the inspection and rehabilitation of 22 drainage closure structures. The existing wall through the petrochemical facilities would be improved, modernized, and raised to account for future SLR. The modernization effort includes improvements to 20 two-lane highway gates, 3 four-lane highway gates, five railroad gates, and the Moses Lake gate structure. Modernization and rehabilitation effort would be required for the La Marque and Skyline pump stations also. The reach would continue until it reaches the Texas City Terminal Railway, where the Texas City West Levee Extension would start.

The Texas City West Levee Extension consists of constructing 53,980 feet of levee, 5,530 feet of floodwall, 3 drainage closure structures, 6 two-lane highway gates, 1 four-lane highway gate, and 2 railroad gates. A vertical gate structure would be required on Highland Bayou Diversion Channel to prevent storm surge up the bayou. Pump stations would be located at Highland Bayou (4,225 cubic feet per second), Highland Bayou Diversion Channel (6,265 cubic feet per second), Willow Bayou (1,453 cubic feet per second), and Cloud Bayou (1,873 cubic feet per second).

The system parallels the railroad on the south side with combi-wall for 1,650 feet until it reaches Highland Bayou, where a drainage closure structure would be constructed downstream of the railroad bridge. The system continues southwest on the south side of the railroad with floodwall crossing SH 6, Martin Luther King Avenue, a Texas City Terminal Railway spur, and Burlington Northern Santa Fe Railroad mainline track. The system would turn northwest paralleling the Burlington Northern Santa Fe Railroad with levee crossing Harbor Drive and turn west continuing with levee crossing Basford Bayou with a drainage closure structure and Highland Bayou Diversion Channel with a vertical gate. The system would continue south of the community of Hitchcock and parallel FM 2004 on the south side until reaching Tacquard Ranch Road. At that point the system would turn north crossing FM 2004 and parallel the Briscoe Canal on the east side crossing Cloud Bayou with a drainage closure structure and Vacek Street and tie into high ground northwest of Vacek Street and north of Winging Trail Street.

As discussed in Section 4.3.4, the Upper Bay Barrier-Bay Rim (Alternative D2) would leave the city of Galveston at risk of damages from storm surge and could induce storm surges in the area. Due to this concern a Galveston Ring Levee/Floodwall alignment was included with this plan. The Galveston Ring Levee/Floodwall alignment would remain the same as for the Coastal Barrier Alternative except that a portion of seawall raising along Seawall Boulevard from East Beach Drive west would no longer be required.

4.5 SELECTED TSP

The TSP that was selected to carry forward for further analysis was the Coastal Barrier Alternative.

The South Padre Island CSRM plan (Reaches 3 and 4) and the Coastwide ER Alternative 1-Scale 2, which were refined through multiple screening efforts, meet specific needs and opportunities within the study area. The South Padre Island CSRM plan (Reaches 3 and 4) was also identified as the NED plan, while the Coastwide ER Alternative 1-Scale 2 meet the ER goals of the study and was classified as the NER plan. In the upper Texas Coast the "Coastal Barrier with complementary system of nonstructural measures (Alternative A)" associated with Alternative 1 was identified as the TSP and the NED plan as determined by the evaluation criteria for the upper coast of Texas. It fulfills the focused CSRM planning objectives for the upper Texas coast, and it reasonably maximizes net benefits, consistent with protecting the Nation's environment in accordance with national environmental statutes, applicable EOs, and other Federal planning requirements.

With the inclusion of a coastwide range of ER measures, such as Gulf beach and dune restoration, GIWW and bay shoreline and island protections, and island rookery and hydrologic restoration, the plan meets many of the planning objectives set forth in the beginning of the study. Table 4-29 provides an overview of how the different portions of the ER plan meets the overall planning objectives. Additionally, ER measures included in the plan would supplement many of the overall CSRM planning objectives by serving as a buffer from some storm impacts to the area's infrastructure.

The South Padre Island CSRM plan (Reaches 3 and 4) included in the TSP would contribute to both the ER and CSRM study objectives. Although the main objective is to reduce economic damage from coastal storm surge flooding to business, residents, and infrastructure in the highly developed area of South Padre Island, the action would also reduce erosion to the barrier island, in turn preventing breaches of the island system. Breaches in the island system could impact the sensitive estuarine systems behind the islands.

In the upper Texas coast, the "Coastal Barrier with complementary system of nonstructural measures (Alternative A)" associated with the Coastal Barrier Alternative was identified as the TSP and the NED plan as determined by the evaluation criteria for the upper coast of Texas. Consistent with current planning USACE guidance, the planning efforts focused on developing a plan based on the general geographic location for addressing risk reduction. The plan is considered the NED plan when focusing on the general geographic location; however, as described in the sections above, once a strategy for the risk reduction system has been selected, the study team will focus on the scale of the level of risk reduction for the TSP in future planning and design phases. Individual features, such as levee heights, flood heights, pump station sizes, and nonstructural features, would be optimized in future planning and design phases and presented with the final recommendation.

The plan reduces economic damage from coastal storm surge flooding to business, residents, and infrastructure in the areas of the Galveston Bay system. The upper coast of Texas CSRM TSP would prevent an estimated $970 million to $1.288 billion in total equivalent annual hurricane/tropical storm surge damages, depending on the future RSLR scenario, during a period of analysis from 2035 to 2085. One of the key differences between the Coastal Barrier Alternative versus the Bay Rim Alternative was related to the evaluation of the planning objectives of reduced risks to critical infrastructure and enhancing the functionality of existing storm surge risk reduction systems. The Coastal Barrier Alternative fully meets these planning objectives since critical infrastructure and existing storm surge risk reduction systems would both be within the system. It fulfills the focused CSRM planning objectives for the upper Texas coast, and it reasonably maximizes net benefits, consistent with protecting the Nation's environment in accordance with national environmental statutes, applicable EOs, and other Federal planning requirements.

Table 4-29
Overview of ER Objectives

ER Study Objectives	Measures Included in Coastwide ER Alternative 1 – Scale 2
1. Restore fish and wildlife habitat, such as coastal wetlands, forested wetlands, bottomland forests, oyster reefs, and beaches and dunes	G-5 G-28 B-2 B-12 CA-5 M-8 SP-1 W-3
2. Reduce saltwater intrusion into sensitive estuarine systems	G-5 B-2 CA-6 W-3
3. Reduce erosion to barrier island, mainland, and interior bay and channel shoreline	G-5 G-28 B-12 B-2 CA-5 CA-6 M-8 SP-1 W-3
4. Improve water quality in coastal bays and estuaries with restoration of marshes and oyster reefs	G-28 B-12 CA-5 M-8 SP-1 W-3

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5.0 ENVIRONMENTAL CONSEQUENCES (*NEPA REQUIRED)

5.1 INTRODUCTION

Two action alternatives and the No-Action Alternative were carried forward for further analysis. The two action alternatives are made up of a combination of CSRM and ER measures for reducing coastal storm risk through structural measures, including levees, floodwalls, surge barrier gates (which includes both navigable and environmental control gates), breakwaters, and nonstructural measures, including habitat restoration and shoreline erosion control structures that take advantage of natural features like barrier islands and storm surge storage in wetlands. Under the No-Action Alternative, no coastal storm risk reduction would occur in the upper Texas coast in the vicinity of Galveston or in the lower Texas coast along the South Padre Island shoreline.

- **Coastal Barrier Alternative**. Includes the Coastal Barrier CSRM System (Coastal Barrier), the South Padre Island CSRM measure, and the nine ER measures.

- **Bay Rim Alternative**. Includes the Bay Rim CSRM System (Bay Rim), the South Padre Island CSRM measure, and the nine ER measures.

The following section describes the environmental consequences associated with the Coastal Barrier and Bay Rim alternatives. There are nine ER measures associated with both action alternatives that are made up of a combination of the following features: revetment/breakwater, island restoration, marsh restoration, oyster reef creation, dune/beach restoration, and out-year marsh nourishment in 2065. Table 5-1 lists these ER measures with the number of acres associated with each feature. Environmental consequences are discussed for the features included in the ER measures. Where applicable, specific ER measure impacts are discussed.

The Coastal Barrier and Bay Rim alternatives include storm surge gates that differ from the No-Action Alternative. The range of impacts presented in this section is based upon this design. Future iterations will refine the gate design to reduce potential impacts, improve performance, and confirm cost effectiveness.

The direct cover types for CSRM and ER measures that would be affected during initial construction are presented below (tables 5-2 and 5-3).

In areas that would convert to open water or unconsolidated shoreline over the period of analysis due to RSLR, additional footprints are proposed for marsh restoration, referred to as out-year marsh nourishments. The locations of the additional marsh restoration footprints were identified using the NOAA Marsh Migration RSLR layer of 2.5 feet for year 2065 (pers. com. N. Herold [NOAA], 2017). Table 5-4 presents the total acres of out-year nourishment proposed for the four ER measures and the direct habitat cover type acres. The timing of the additional marsh restoration has been proposed for 2065 to allow time for the marsh to mature in anticipation of RSLR, although implementation is subject to change in response to actual sea level change and the adaptive management plan.

Additionally, 112,666.4 acres of the Lower Laguna Madre would be hydrologically restored to help protect SAV with ER measure W-3, and 295.8 acres at CA-5 and 3,257.9 acres at SP-1 of SAV would be protected/enhanced.

Table 5-1
ER Measures and Features

ER Measure	ER Measure Features/Acres					
	Revetment/ Breakwater	Island Restoration	Marsh Restoration	Oyster Reef Creation	Dune/ Beach Restoration	Out-year Nourishment 2065
G-5 Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration	–	–	–	–	5,057.1	–
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	326.0	326.0	664.0	18.0	–	6,891.0
B-2 Follets Island Gulf Beach and Dune Restoration	–	–	–	–	1,113.8	–
B-12 West Bay and Brazoria GIWW Shoreline Protection	257.0	–	551.0	2.1	–	19,794
M-8 East Matagorda Bay Shoreline Protection	52.3	92.7	239.0	14.6	–	6,034.0
CA-5 Keller Bay Restoration	22.8	–	–	7.1	–	623.0
CA-6 Powderhorn Shoreline Protection and Wetland Restoration	30.3		531.0	–	–	–
SP-1 Redfish Bay Protection and Enhancement	44.5	391.4	–	2.0	–	–
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	3.9	27.8	–	–	1,404.9	–

Table 5-2
CSRM Measures Direct Habitat Cover Type Acres

CSRM Measure	Developed/ Upland[1]	Palustrine Emergent Wetland[2]	Estuarine Emergent Wetland[3]	Oyster Reef	Open Water	Dune[4]	Supra-tidal[5]	Inter-tidal[6]	Total Acres
Coastal Barrier	1,520.9	512.5	338.0	–	2,154.0	–	–	–	4,525.3
Bay Rim	1,371.2	227.1	172.0	0.03	564.0	–	–	–	2,334.3
South Padre Island	4.6	–	–	–	358.5	0.5	2.1	0.1	365.8

Source: NOAA (2017b, 2017c)

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes freshwater wetland and marsh

[3] Includes saline and brackish wetland and marsh

[4] Subaerial habitat ≥5 feet NAVD 88 and encompasses foredune, dune, and reardune

[5] Occurs from 2.0 to 4.9 feet NAVD 88. This habitat type primarily encompasses swale and may include low-elevation dune and beach habitat.

[6] Occurs from 0 to 1.9 feet NAVD 88. This habitat type encompasses intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Table 5-3
ER Measures Direct Habitat Cover Type Acres

ER Measure	Developed/ Upland[1]	Islands/ Bird Rookeries	Estuarine Emergent Wetland[2]	SAV	Oyster Reef	Open Water	Dune[3]	Supra-tidal[4]	Inter-tidal[5]	Total Acres
G-5	579.3	–	–	–	–	3,362.3	572.0	504.2	39.1	5,056.7
G-28	105.7	23.5	513.7	–	–	735.9	–	–	–	1,378.8
B-2	79.6	–	–	–	–	624.3	220.7	168.3	20.9	1,113.8
B-12	41.1	–	427.0	1.0	0.7	405.6	–	–	–	875.4
M-8	240.4	2.6	29.3	15.2	–	112.3	–	–	–	399.8
CA-5	–	–	–	295.4	2.5	27.8	–	–	–	325.7
CA-6	6.8	–	244.4	4.0	21.2	283.8	–	–	–	560.2
SP-1	90.5	117.8	–	3,088.8	5.2	434.6	–	–	–	3,736.8
W-3	4.6	3.8	–	1.8	–	1,109.4	257.6	53.3	1.0	1,431.5

Source: NOAA (2017b, 2017c).

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes saline and brackish wetland and marsh

[3] Subaerial habitat ≥5 feet NAVD 88 and encompasses foredune, dune, and reardune

[4] Occurs from 2.0 to 4.9 feet NAVD 88. This habitat type primarily encompasses swale and may include low-elevation dune and beach habitat.

[5] Occurs from 0 to 1.9 feet NAVD 88. This habitat type encompasses intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Table 5-4
Out-Year Marsh Nourishment for 2065 Direct Habitat Cover Type Acres

ER Measure	Developed/Upland[1]	Estuarine Emergent Wetland[2]	SAV	Open Water	Total Acres
G-28	543.7	5,664.0	3.5	678.4	6,889.7
B-12	751.0	10,056.4	225.6	3,514.3	14,547.3
M-8	632.2	4,513.4	92.6	794.8	6,033.0
CA-5	48.8	530.0	--	43.9	622.7

Source: Pers. com. N. Herold, NOAA (2017).

[1] Includes bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes saline and brackish wetland and marsh

Sediment volumes required to construct the CSRM measures have been estimated. Material excavated during construction of the surge barrier gates for CSRM would be placed beneficially for construction of the proposed ER measured if the quality of material is appropriate.

Borrow source locations for construction of CSRM and ER measures have been identified by the USACE. Upland commercial sources are anticipated for the CSRM features in the upper Texas coast, and a combination of routine dredging, offshore sources, and excavation from coastal barrier construction are reflected in the cost estimate and construction phasing. Commercial borrow sources were assumed for levee construction and potential sources are identified in the Engineering Appendix (Appendix D). Sources were identified throughout Galveston, Harris, Brazoria, and Chambers counties. It is anticipated the material would be hauled to the site features via major highways. The commercial sites identified as sources with suitable material for levee construction are currently active and may no longer be available at the start of construction. A detailed inventory and analyses of borrow source materials is currently underway. Study results will be available during the next phase of the study. The suitability of the material for levee construction could require structural or chemical measures to assure stability of the levee.

Measures to manage coastal storm risk are not proposed in the Coastal Texas Study for Sabine Lake, the Brazos River estuary, Brazos-Colorado Coastal Basin, Matagorda/Lavaca Bay complex, San Antonio/Aransas Bay complex, Nueces/Corpus Christi Bay complex, Laguna Madre, or the Rio Grande estuary.

Environmental consequences are discussed in additional detail in the Environmental Supporting Document (Appendix C-1). The following summarizes the environmental consequences presented in the appendix.

5.2 ESTUARINE MODELING SUMMARY

The USACE Engineer Research and Development Center conducted quantitative analyses a using a 3D AdH model for the Coastal Texas Study's Coastal Barrier CSRM Measure, which includes a levee/floodwall along Bolivar Peninsula and Galveston Island, improvements to the Galveston seawall, a ring levee around the city of Galveston, and several flow control structures across the Houston Ship Channel at Bolivar Roads, High Island, Offatts Bayou, Dickinson Bayou, and Clear Creek. The structures at Clear Creek, Dickinson Bayou, and Offatts Bayou consist of a single opening 112 feet wide with varying sill elevations: Clear Creek sill elevation –10 feet, Dickinson Bayou sill elevation –9 feet, and Offatts Bayou sill elevation –15 feet. The structure for the Houston Ship Channel at Bolivar Roads includes a single 1,200-foot-wide, –60-foot sill elevation surge barrier gate at the ship channel with thirty-nine 100-foot environmental gates (22 having a –30-foot sill elevation and 17 having a –15-foot sill elevation). All elevations are referenced to MLLW.

The AdH model was developed and validated to simulate water level, velocity, and salinity. For all simulations the model was set up to run for 2 years, the first year being a spin up period to obtain an accurate initial salinity field as well as an accurate sediment bed and the second year was used for all analyses. Documentation of the model includes the geometric modifications to the system, defined as "project," as well as the input conditions for the "present" project year zero (2035) and "future" project year 50 (2085). Additional details on the modeling can be can be found in Appendix D (Engineering Design, Cost Estimates, and Cost Risk Analysis) (McAlpin et al., 2018). Present without-project (PWOP), present with-project (PWP), FWOP, and FWP were simulated using a 3D AdH model. Present is year 2035, and future is year 2085, assuming a 50-year project lifespan. The results include changes in salinity, velocity, and water level throughout the model domain. Given the variability in several input parameters for the present and future conditions, care should be taken when reviewing the model results. Changes from present to future must be understood with no project in place in order to understand the project impacts. In other words, comparison of with- and without-project should be done on the present conditions and the future conditions separately.

Modeling was used to determine the general behavior of the bay system while comparing with- and without-project scenarios. The AdH modeling was conducted to understand potential environmental impacts and confirm whether the potential impacts made the alternative infeasible. This modeling characterizes the changes to the Galveston Bay system with the storm surge gates across Bolivar Roads in the open condition (which represents the nonstorm condition or "everyday" operations of the gate structures). All modeling was conducted using a tentative gate configuration across Bolivar Roads that would reduce the flow conveyance roughly by 27.5 percent.

Environmental modeling was completed using a 27.5 percent constriction at Bolivar Roads to represent the proposed surge barrier gates. Changes to the system geometry can impact the tidal exchange into a bay environment such as the Galveston Bay system. The Coastal Barrier impacts the cross-sectional area of the entrance into the bay system, which, as modeled, would cause changes in the volume of flow being exchanged through the inlets. The tidal prism is a calculation of the volume of water that enters and leaves through the inlets with each tide cycle. The tidal amplitude is the change in the water level from low tide to high tide and vice versa. The tidal prism gives an overall impact on the water exchange whereas the tidal amplitude may vary at locations depending on where the system modifications are made and changes in the flow patterns within the system. The average tidal prism and average tidal amplitudes vary between with- and without-project over the simulation year. The change in tidal prism with the project in place is a 13.5 and 16.5 percent reduction for the present and future conditions, respectively. The tidal amplitudes were also reduced at all bayside locations by between 9 and 22 percent. The percentage change in amplitude is generally greater for the future comparison than for the present and the comparisons within the bay vary by location but all show a decrease in the tidal amplitude for the project condition as compared to the without-project condition.

The velocity magnitudes vary little between with and without-project conditions for locations away from the structure. The mean surface and bottom velocity magnitude generally drops when the project is in place, but this change is less than 0.33 feet per second at all analysis points and for most locations it is 0.16 feet per second or less. The change from the without-project condition is greatest in areas at and immediately around where the structures are located. Eddies are also expected on the back-side of the gate structures which has not yet been fully resolved. There are changes to the magnitude of the velocity extending into the bay, but they are much smaller than the effects at the locations of the modifications. The models suggest that in certain situations the velocity differences between the with-project condition and the without-project condition could be as high as 6.6 feet per second. For example, a scenario that presented a combination of a high tide and strong winds could lead to such an increase in velocity. Future project refinements may minimize differences currently seen between with- and without-project velocities (McAlpin et al., 2018).

5.3 PHYSICAL RESOURCES

5.3.1 Geomorphology and Coastal Processes

5.3.1.1 Sediment Transport

5.3.1.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The interchanges of tidal hydraulics, hydraulically driven sediment transport, and other natural ecosystem exchanges would be impacted by the Coastal Barrier. The Coastal Barrier would result in a reduction in tidal connectivity and an associated overall reduction in sediment exchange within Galveston Bay. Under natural conditions, without a barrier system in place, storm surges provide a large influx of sediments into bay systems, which settle in the bay and adjacent marshes as storm surge dissipates. Overwash and other storm-related sediment deposition in Galveston Bay would be reduced with the Coastal Barrier in place. Losing this storm-induced sediment infusion due to the closure of the surge barrier gates during storm events would affect the post-storm sediment budgets and the health of adjacent natural features such as marsh and wetland complexes (Rosati, 2009).

During storms, an increase in water levels Gulf-ward of the Coastal Barrier resulting from storm surge build-up would result in increased flow velocities in inlets without surge barrier gates. Erosion in these unprotected inlets, like San Luis Pass, is anticipated to increase due to the increase in velocity. During non-storm conditions, the increase in velocity within and near the inlets would cause additional localized scouring, particularly at the Bolivar Roads surge barrier gates, as described in McAlpin et al. (2018). During storm events, the closed surge barrier gates at Bolivar Roads would block storm surge from entering the bay, which would reduce sloshing, thus reducing storm-induced bay-shoreline erosion.

In addition, storm surges piling against the barrier would impact erosion on Galveston Island. The beaches fronting the seawall currently experience a lack of natural sand nourishment during non-storm conditions, especially near the Bolivar Roads jetties, but would be exposed to greater surge and wave impacts during storms with the Coastal Barrier in place. Overwash and storm-induced sediment influx could be reduced with the coastal barrier in place. This could decrease the available sediment inside the bay system post-storm events, which would adversely impact the marsh sustainability on Bolivar Peninsula along the GIWW on the protected side of the Coastal Barrier (Rosati, 2009).

South Padre Island CSRM Measure

The proposed beach and dune features at South Padre Island would predominantly serve as a CSRM measure but would also provide ecological benefits not quantified by this study. Due to the interference and impoundment of naturally supplied sediments at the Brazos Island Harbor south jetty, beach sediments within the boundaries of the city of South Padre Island provide the primary source for the south to north littoral drift of the entire beach system from the city of South Padre Island to Port Mansfield (McGrail et al., 1985). Sediments placed to construct the South Padre Island beach and dune features would be transported northward by the littoral drift and eventually be impounded at the Port Mansfield south jetty. The transported sediments would contribute to the further accretion of sediment at the Port Mansfield south jetty beach, resulting in an increase of sediment bypassing to the entrance of the Port Mansfield Channel. These additional sediments would increase the shoaling rates at the entrance of the channel (Kieslich, 1977).

The beachfill component would provide a source of sediments that would be transported by aeolian processes to beneficially nourish existing and newly constructed dune cells by supplying sand for foredune accretion. In addition, sediments supplied for the beach and dune features would be washed over during storm events, which would be beneficially redistributed throughout the South Padre barrier island system undergoing SLR (Del Angel, 2012).

ER Measures

Revetment/Breakwater. The construction of revetment/breakwater features would stabilize shorelines and reduce navigation and wind-induced wave energy to adjacent wetlands, resulting in overall reduced shoreline erosion along the banks of the GIWW. This reduction in erosion would decrease the rate of sedimentation into the bays and waterways. The construction of breakwaters or revetments would replace some habitat with hardened structures, and the structures would reduce or restore habitat lost to erosion.

Island Restoration. Fill for the island restoration would be contained and protected by rock structures and stabilized with vegetation; therefore, it is expected that sediment losses from the restored islands would be minimal. During construction, temporary impacts of increased sediment suspension and dispersion within the water columns adjacent to the constructed islands should be expected.

Marsh Restoration/Out-year Marsh Nourishment 2065. Because material would be predominantly obtained from maintenance and/or new construction dredging of the GIWW, there is no net increase of sediment in the system, since it is only moved from the waterway to designated restoration areas. Restored/nourished marsh areas would contribute to trapping sediments from migrating or eroding into the waterway.

Oyster Reef Creation. Creation of oyster reefs is expected to provide additional protection to restored islands and prevent breaching of islands and shorelines. It is anticipated that oyster reef creation would enhance sediment deposition and provide shoreline protection within the vicinity of oyster reef areas by dampening wave energy.

Dune/Beach Restoration. Additional sediment would be available in the natural system and allow natural processes, such as reworking, erosion, and deposition to take place and enhance sediment availability for longshore transport. Increase in shoaling through longshore transport can be expected at tidal inlets downdrift of ER beach and dune features. Locations of anticipated shoaling increases due to proposed ER beach and dune restoration features include Bolivar Roads and San Luis Pass. The shoreline at the Surfside Village beach may temporarily benefit from the downdrift transport of sediments from the Follets Island Gulf Beach and Dune Restoration (B-2) feature. However, wave amplification at Port Freeport’s north jetty would mobilize the sediments transported to Surfside Beach carrying the sediments along the jetty and into the Port Freeport Entrance Channel (Watson, 2007). An anticipated effect from Follets Island Gulf Beach and Dune Restoration (B-2) feature is an increase in shoaling within the entrance channel at Port Freeport.

Hydrologic Restoration. Sediments dredged from the Port Mansfield Channel would be beneficially used for bird island restoration within Laguna Madre and for the beach nourishment. Dredged sediments placed along the National Seashore's shoreline would migrate northward with the littoral drift to the longshore current convergence zone located along North Padre Island at Big Shell Beach near Baffin Bay (HDR Engineering, Inc., 2014).

5.3.1.1.2 Bay Rim Alternative

Bay Rim CSRM System

The Bay Rim features disrupt natural exchange of flow and sediment across land features and through channels and passes. It can be expected that regular hydraulic flow conditions within the passes and channels would be reduced by the surge barrier gates. During non-storm periods, the reduction in tidal flows would impact the sediment and tidal exchanges between Galveston Bay and Clear Lake, and the Dickinson Bayou and Tabbs Bay watersheds. The watershed protected by the Bay Rim would experience a reduction in intertidal connectively to Galveston Bay due to the construction of the alternative.

During storm events, Galveston Bay would receive the same storm surge magnitude and associated sediment overwash into the bay as the No-Action Alternative; however, when coupled with the ER measure for Bolivar Peninsula/ Galveston Island Gulf Beach and Dune Restoration (G-5), additional volume of sediments would be available for overwash, which would beneficially nourish bay marshes and redistribute sediments on Bolivar Peninsula and Galveston Island. Conversely, the overwash sediments would also be deposited within the GIWW increasing shoals within the waterway, which would increase maintenance dredging needs.

In addition, an increase in scouring along the bay rim would be expected from storm surges and waves. The Bay Rim Alternative would not change wave-induced shoreline erosion during non-storm events, since the flow patterns from the Gulf into the bay are not manipulated by surge barrier gates.

South Padre Island CSRM Measure

Impacts to the sediment transport associated with the proposed South Padre Island CSRM measure features would be the same as those described for the Coastal Barrier Alternative.

ER Measures

Impacts to the sediment transport associated with the proposed ER measure features would be the same as those described for the Coastal Barrier Alternative, with one exception. When the Bay Rim measure is coupled with the ER measure for Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration (G-5), additional volume of sediments would be available for overwash to nourish bay marshes and for redistribution on Bolivar Peninsula and Galveston Island. An increase in shoaling within the GIWW, from these expected overwash events, would induce an increase in maintenance dredging requirements of the waterway.

5.3.1.2 Shoreline Change

5.3.1.2.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

With the Coastal Barrier, increases to Gulf-side erosion rates and shoreline retreat rates can be expected, especially in years of high storm frequency and intensity, since the beach/dune and marsh habitat fronting the barrier would experience increased impacts from storms and subsequent erosion. Bay-side erosion rates within Galveston Bay are anticipated to be reduced and would be reflected in their respective shoreline retreat rates.

At Galveston Island, the shoreface is currently partially protected by a seawall, and it is likely that the shoreline erosion rates would increase in this area, but would be stopped by the hard structure. In addition, due to the reduced exchange of flow and sediments through the tidal channels, the sediment contributed from the bay to the longshore transport along the Gulf shoreface would be reduced.

South Padre Island CSRM Measure

The South Padre Island CSRM measure would impact the configuration of approximately 4 to 8 miles of shoreline. The beach and dune complex would be renourished four times at a frequency of once every 10 years. Sediments to construct the measure would eventually be transported northward by the littoral drift and be impounded by the Port Mansfield south jetty. Impoundment and accumulation of these sediments would result in widening of the Port Mansfield south jetty and would contribute to the ongoing sediment bypassing into the entrance of the Port Mansfield Channel. The beachfill extent may be as little as 4 miles, but may extend to 8 miles following further evaluation of the recreation benefit stream in future planning and design phases of the study.

ER Measures

The ER measures would protect, create, and/or restore Gulf and bay island shorelines and marsh fringes. Placement of sediments to restore marshes, beach and dune, and island habitats may temporarily increase suspended sediments in the water column near the construction sites. Long-term effects of sediment placement on Gulf shorelines may include increase in shoaling at Bolivar Roads, San Luis Pass, and the Port Freeport Entrance Channel. Implementation of the ER measures has an overall net positive impact by protecting, creating, and restoring shorelines and marsh fringes. Breakwater construction to support the sediment placement will replace a soft shoreline, but will interrupt erosion and land loss.

5.3.1.2.2 Bay Rim Alternative

The Bay Rim Alternative features would result in reduced watershed-based sediments to be transported into Galveston Bay. During storm events, the expected scouring in front of the Bay Rim would temporarily increase suspended sediment within Galveston Bay.

Erosional patterns at the shorelines of Bolivar Peninsular would only slightly increase during storm events, when compared to the No-Action Alternative, since the surge build-up within Galveston Bay is anticipated to increase due to the Bay Rim, which would also increase surge impacts to marsh, beach, and dune habitat on the peninsula. This expected surge increase in Galveston Bay would also result in an increase in shoreline erosion rates at non-protected shorelines of the Galveston Bay rim due to an increase in impacts from flow and wave energy. At Galveston Island, the shoreface is already partially protected by a seawall; therefore, the shoreline erosion rates would increase due to beach erosion but be restricted by the hard structure as a point of no change. When compared with the No-Action Alternative, the Bay Rim could result in an increase in shoreline retreat within the non-protected bay rim areas as well as a slight increase in storm-induced shoreline retreat at Bolivar Peninsula and Galveston Island.

Impacts to the shoreline change associated with the proposed South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.2 Physical Oceanography

5.3.2.1 Tides and Currents

5.3.2.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Tides. The Coastal Barrier's proposed surge barrier gates system at Bolivar Roads reduces the cross-sectional area of Bolivar Roads by 27.5 percent for water flow and exchange through the inlet, reduces the tidal prism by 13.5 and 16.5 percent, and reduces the tidal amplitude by 9 to 22 percent. Resulting changes in tidal amplitude vary in different locations of the bay. Generally, the tidal amplitude change at locations throughout Galveston Bay will vary between 0 and 0.23 feet, with most locations experiencing a 0.16-foot tidal amplitude reduction (McAlpin et al., 2018).

Currents. The velocity magnitudes vary little between with- and without-project conditions for locations away from the gate structure. The mean surface and bottom velocity magnitude generally drops when the project is in place, but this change is less than 0.33 feet per second at all analysis points and for most locations it is 0.16 feet per second or less. The change from the without-project condition is greatest in areas at and immediately around where the structures are located. The models suggest that in certain situations the velocity differences between the with-project condition and the without-project condition could be as high as 6.6 feet per second. For example, a scenario that presented a combination of a high tide and strong winds could lead to such an increase in velocity.

Future project refinements may minimize differences currently seen between with- and without-project velocities (McAlpin et al., 2018).

Additional information can be found in the Engineering Appendix (Appendix D).

South Padre Island CSRM Measure

The South Padre Island CSRM measure is not expected to have an appreciable impact on tides, currents, and circulation. Sediments placed for the dune/beachfill features are expected to migrate northward with the littoral drift, to be impounded by the Port Mansfield Channel immediately south of the jetty. Ultimately, the sediment buildup immediately south of the jetty would migrate into the entrance of the Port Mansfield Channel and add to the shoaling of the channel. This additional accumulation of sediments within the channel may nominally contribute to the reduced tidal circulation between the Lower Laguna Madre and the Gulf. However, this impact would be somewhat offset by construction of ER measure W-3.

ER Measures

Revetment/breakwaters, island restoration, marsh restoration, oyster reef creation, dune/beach restoration, and out-year marsh nourishment ER features would protect and stabilize existing and restored island shorelines and marsh fringes. Appreciable impacts to tides, currents, and circulation are not expected, although localized current and circulation changes at the ER features may be experienced. The hydrologic restoration of the Lower Laguna Madre includes the dredging of Port Mansfield Channel, which improve the tidal circulation between Laguna Madre and the Gulf. Measurable beneficial impacts to tides, currents, and circulation with Lower Laguna Madre are expected to be induced by the dredging of the Port Mansfield Channel.

5.3.2.1.2 Bay Rim Alternative

Tides. Modifications to Bolivar Roads are not proposed for the Bay Rim; therefore, for the most part, tidal prism and tidal amplitude are expected to remain relatively unchanged between without- and with-project conditions. The exception may be in the vicinity of Tabbs Bay near the Fred Hartman Bridge where a system of surge barrier gates is proposed for the Houston Ship Channel where tidal prism and amplitude would be nominally impacted. The water bodies feeding into Galveston Bay at the Fred Hartman Bridge contribute influential amounts of freshwater to the bay during normal conditions. The tidal amplitude impacts are considerably less than those at Bolivar Roads since the area is further from the Gulf.

Currents. McAlpin et al. (2018) reported mean surface and bottom current velocities increased minimally from without- to with-project conditions at locations farther upstream within Galveston Bay for the Coastal Barrier. Although not modeled, it is anticipated based on the Coastal Barrier hydrodynamic analysis findings that there may be slight increases in current velocities induced by the Bay Rim by partially constricting tidal flows adjacent to Tabbs Bay, Clear Creek, and Dickinson Bay with the closure structures system. Throughout the rest of Galveston Bay, velocity magnitude changes are expected to be negligible.

Impacts to the tides and currents resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.2.2 Salinity

5.3.2.2.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Salinity and currents of Galveston Bay were modeled for the Coastal Barrier at Bolivar Roads by the USACE using the AdH model (McAlpin et al., 2018). Table 5-5 presents average salinities over the model period for the PWP (Year 2035), PWOP (Year 2035), FWP (Year 2085), and FWOP (Year 2085) conditions.

Table 5-5
Galveston Bay Modeled Mean Salinity with the Coastal Barrier*

Model Period	Galveston Bay at Bolivar Roads	Lower Galveston Bay	Upper Galveston Bay	Trinity Bay	East Bay	West Bay
PWP (surface)	21 (0–33)	17 (6–30)	13 (0–26)	8 (0–24)	6 (0–15)	20 (8–31)
PWP (bottom)	27 (8–35)	26 (7–34)	14 (0–26)	9 (0–25)	6 (0–15)	20 (8–31)
PWOP (surface)	23 (0–34)	18 (5–31)	14 (0–28)	9 (0–25)	7 (0–15)	22 (8–31)
PWOP (bottom)	28 (11–35)	27 (7–35)	15 (0–28)	10 (0–25)	7 (0–15)	22 (8–31)
FWP (surface)	24 (1–33)	20 (7–31)	15 (1–24)	9 (0–18)	12 (4–15)	22 (12–31)
FWP (bottom)	28 (13–35)	28 (13–34)	17 (3–26)	11 (0–19)	12 (5–15)	23 (12–31)
FWOP (surface)	25 (0–34)	21 (7–32)	15 (1–26)	9 (0–19)	13 (5–16)	24 (12–32)
FWOP (bottom)	29 (16–35)	28 (13–35)	18 (3–27)	12 (0–20)	13 (6–16)	24 (12–32)

Source: McAlpin et al. (2018)
*Values in parentheses represent modeled minimum and maximum salinities.

The reduced circulation that is expected would increase residence time in the bay upstream of the Coastal Barrier and allow greater dilution by freshwater inflows. During periods of normal to relatively high freshwater inflow ("wet" periods), the model predicts salinity from surface to bottom would be lower and remain lower for a longer time.

During periods of severe drought, with low freshwater inflow and high evaporation or when storms push saline water into the bay upstream of the barrier, saline water remains in the bay above the barrier for longer periods, and salinities would be higher than without the barrier in place. The Coastal Barrier is predicted to reduce surface and bottom water salinities throughout the entire Galveston Bay system during typical freshwater inflow conditions by about 2 ppt.

Mean modeled salinities at the mouths of Clear Creek, Dickinson Bay, and Offatts Bayou are predicted to be 1 ppt lower than without the Coastal Barrier in place for both the PWP and FWP condition. Although salinities were not modeled upstream of the barriers into these systems, the reduced tidal prism is expected to result in increased periods and extent of lower salinities than the condition without the barriers. Since there is limited freshwater inflow into Offatts Bayou, salinities may be slightly higher at times upstream of the barrier than if the barrier were not in place.

South Padre Island CSRM Measure

The South Padre Island CSRM measure would not affect salinities, because it would be constructed along the Gulf beach.

ER Measures

The hydrologic restoration portion of the W-3 ER measure, which would involve dredging and maintaining Port Mansfield Channel open, should affect salinity in the Lower Laguna Madre. Salinity in the Gulf near the Port Mansfield Channel is about 35 ppt, while salinities in the Lower Laguna Madre at the Port Mansfield Channel have ranged up to 40 to 50 ppt in the past (King et al., 2016). Measured salinities near Port Mansfield from 1995 through 2009 ranged from 7 to 45 ppt and averaged 31 ppt (Schoenbaechler and Guthrie, 2011e). Cited literature indicates salinity in the Lower Laguna Madre has averaged 32 ppt over the period from 1995 to 2002 (Rio Grande, Rio Grande Estuary, and Lower Laguna Madre Bays Basin and Bay Expert Science Team, 2012).

The ability of this ER measure to influence salinity in the Lower Laguna Madre is affected by flow patterns in the estuary. The shape and orientation, combined with prevailing winds from the southeast and a microtidal environment, result in the flow at Port Mansfield Channel flowing out of the estuary into the Gulf much of the time (King et al., 2016). This wind-driven hydrodynamic force commonly overwhelms the tidal prism on incoming tides in this microtidal environment. This flow out of Port Mansfield Channel functions more like a river mouth with outgoing currents occurring most of the time rather than a tidally influenced estuary opening. Maintaining Port Mansfield Channel open with dredging is likely to help reduce the frequency and magnitude of high salinity conditions in the Lower Laguna Madre. Effects of this ER measure on salinity have not been modeled for the Coastal Texas Study.

There may be localized and temporary changes in salinity associated with the following ER measures: G-28, B-12, M-8, CA-5, CA-6, and SP-1. These measures involve construction of structures, which would modify local current patterns, and may require enclosing areas temporarily for marsh construction. Effects of these ER measures on salinity have not been modeled. Salinity effects of these measures, if they occur, are expected to be temporary and relatively small in magnitude.

5.3.2.2.2 Bay Rim Alternative

Salinities were not modeled in portions of the system upstream from the Bay Rim, including the upper Houston Ship Channel, Buffalo Bayou and its tributaries, and the San Jacinto River tidal. Mean salinities are not expected to differ by more than 0.4 ppt in the bay system with this CSRM measure in place based on screening level analysis conducted by the USACE (pers. com H. Das [USACE], 2018). Its position in the extreme upstream end of the bay would minimize any impact on the tidal prism. This CSRM measure, upstream of most of the bay system, is expected to have the least impact on bay salinities.

As with the Coastal Barrier Alternative, surge barrier gates are proposed for Clear Creek, Dickinson Bayou, and Offatts Bayou. Impacts on these systems are expected to be like those in the Coastal Barrier Alternative.

Impacts to salinity associated with the proposed South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.3 Coastal Processes

5.3.3.1 Storm Surge Effects

Coastal storm model simulations of waves and water levels were performed, reporting on storm surge modeling scenarios, and comparing without-project versus with-project alternative CSRM project plans (Massey et al., 2018).

5.3.3.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Individual Storm Surge Reduction. Two individual storms provided maximum storm surge results from the simulations. Surge or water surface elevation comparisons between without- and with-project conditions for Storm 154 (Category 3) and Storm 356 (Category 4) are displayed on figures 5-1 and 5-2, respectively. For Storm 154 (Category 3), the Coastal Barrier provides storm surge reductions along the northern and eastern sides of Galveston Bay, with slight increases in surges along the southwestern edge of Galveston Bay (see Figure 5-1). For Storm 356 (Category 4), the Coastal Barrier reduces storm surge in the entire Galveston Bay system by between 0.5 and 10 feet. For both storms 154 and 356, the proposed Galveston Island ring levee does not appear to be overtopped by the surge.

Potential Storm Surge Reduction. For an assumed maximum surge with an estimated reoccurrence of at least once over 100 years, the Coastal Barrier reduces storm surge within the entire Galveston Bay system by between 0.5 and 10 feet. When storm surge is evaluated by individual storms and probable reoccurrence within 100 years, reduction in storm surge elevation throughout Galveston Bay is observed with the proposed Coastal Barrier.

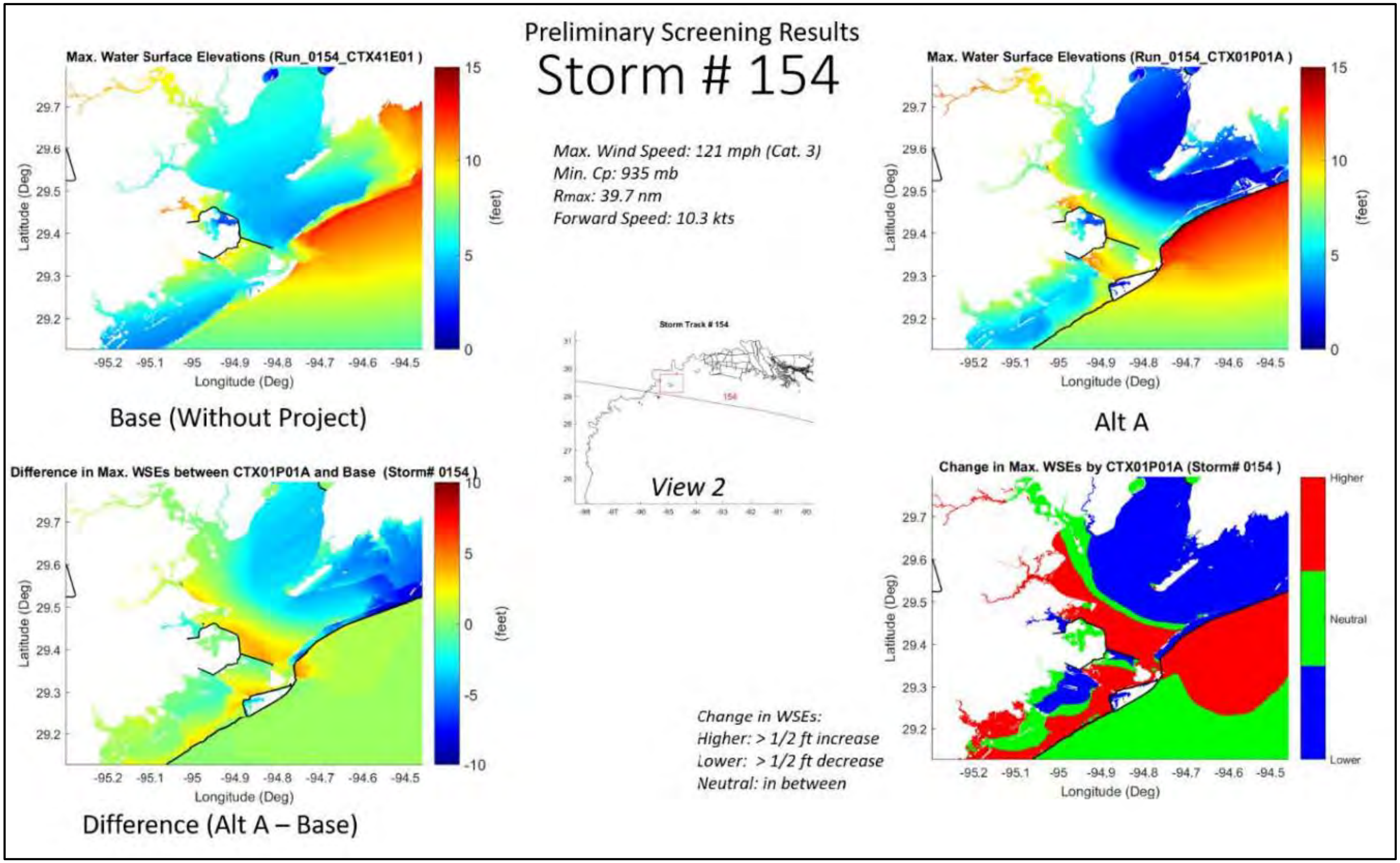

Figure 5-1: Storm Surge Results for Storm 154, Category 3 – Coastal Barrier
(Source: Massey et al., 2018)

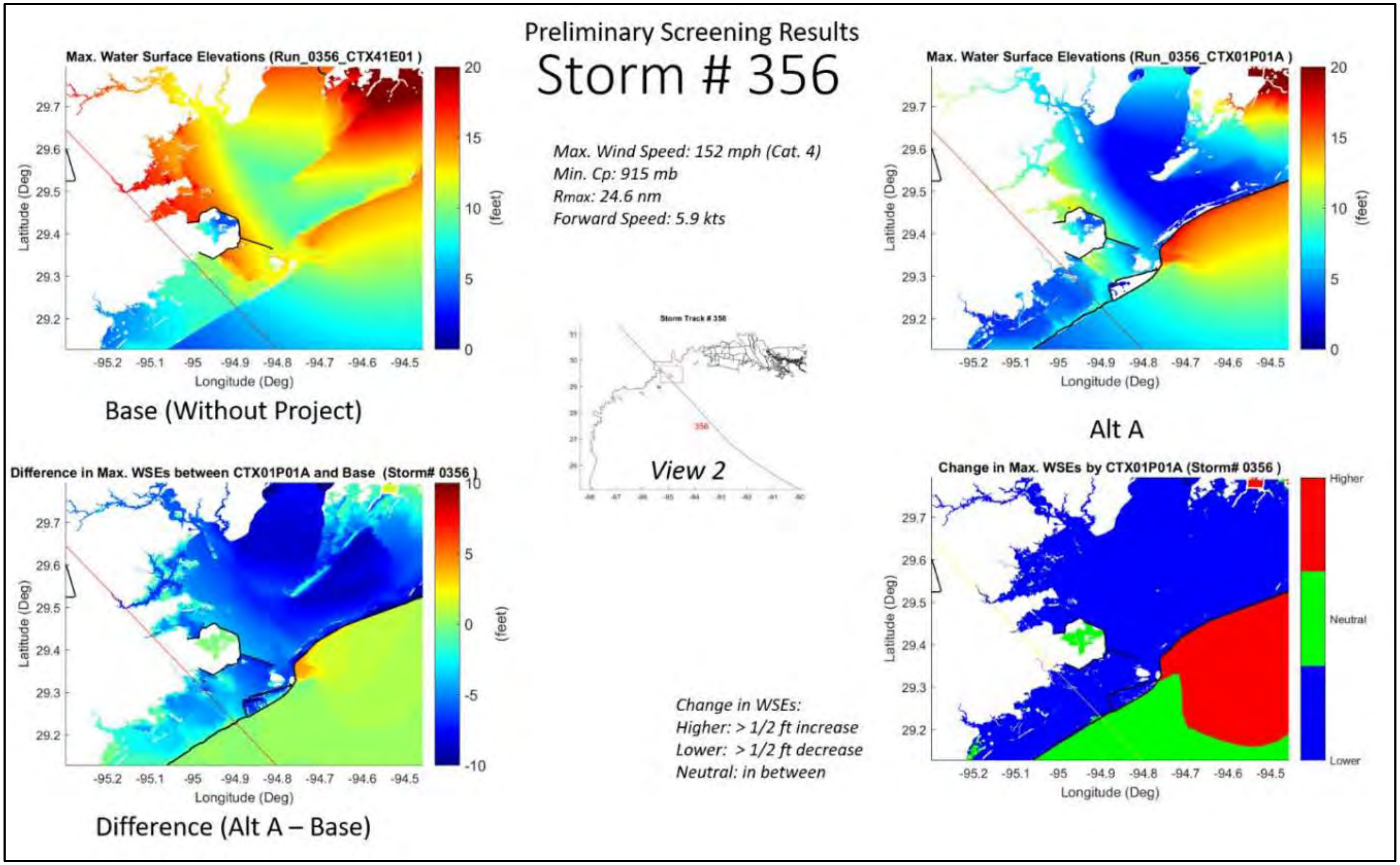

Figure 5-2: Storm Surge Results for Storm 356, Category 4 – Coastal Barrier
(Source: Massey et al., 2018)

South Padre Island CSRM Measure

The integrated engineering-economic Beach-fx model was used to simulate the condition of a beach profile as it evolves due to storms and background erosion. The model incorporated a sea level change of +0.01289 foot per year (Sanderson and Mays, 2018; Appendix E-2). This beach/dune feature would act as a natural barrier to absorb the impact of storm surges and wave attack, by reducing wave energy and elevation; however, the beach/dune features would still be overtopped by storm surge and result in flooding and damages to inland structures and infrastructure, but at a reduced level.

ER Measures

Revetment/breakwaters, island restoration, marsh restoration (including out-year marsh nourishment in 2065), oyster reef creation, and dune/beach restoration ER features would protect and stabilize existing and restored island shorelines and marsh fringes and would contribute to absorbing storm surges from tropical cyclone storm events. The hydrologic restoration of the Lower Laguna Madre includes the dredging of Port Mansfield Channel to improve the tidal circulation between Laguna Madre and the Gulf. Sediments dredged from the Port Mansfield channel would be used beneficially for bird island restoration within Laguna Madre and for the nourishment and widening of approximately 10 miles of shoreline along the Padre Island National Seashore starting immediately north of Port Mansfield's North Jetty. The island restoration and Padre Island National Seashore nourishment features would contribute to absorb storm surges from tropical cyclone storm events.

5.3.3.1.2 Bay Rim Alternative

Bay Rim CSRM System

Individual Storm Surge Reduction. Two individual storms provided maximum storm surge results from the simulations. Surge or water surface elevation comparisons between without- and with-project conditions for Storm 154 (Category 3) and Storm 356 (Category 4) are displayed on figures 5-3 and 5-4, respectively. For Storm 154 (Category 3), the Bay Rim provides no noticeable differences in maximum storm surge over the without-project condition for almost the entirety of Galveston Bay, with reduced surge values occurring only north and west of the structures (see Figure 5-4). For Storm 356 (Category 4), the Bay Rim provides storm surge reductions landward on the southwestern portions of the bay, which are areas on the protected side of the levees (see Figure 5-4). For both storms 154 and 356, the proposed Galveston Island ring levee does not appear to be overtopped by the surge.

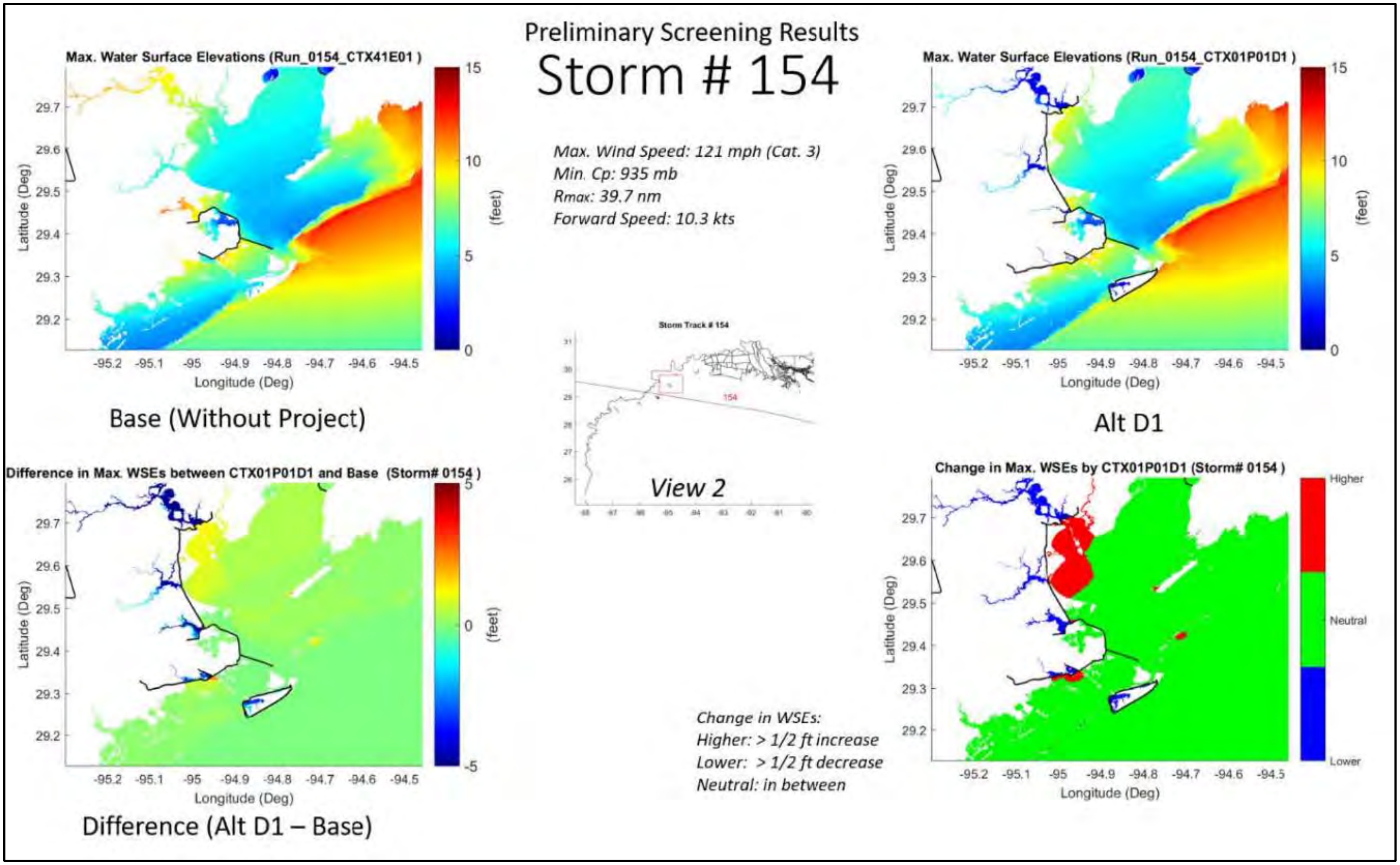

Figure 5-3: Storm Surge Results for Storm 154, Category 3 – Bay Rim
(Source: Massey et al., 2018)

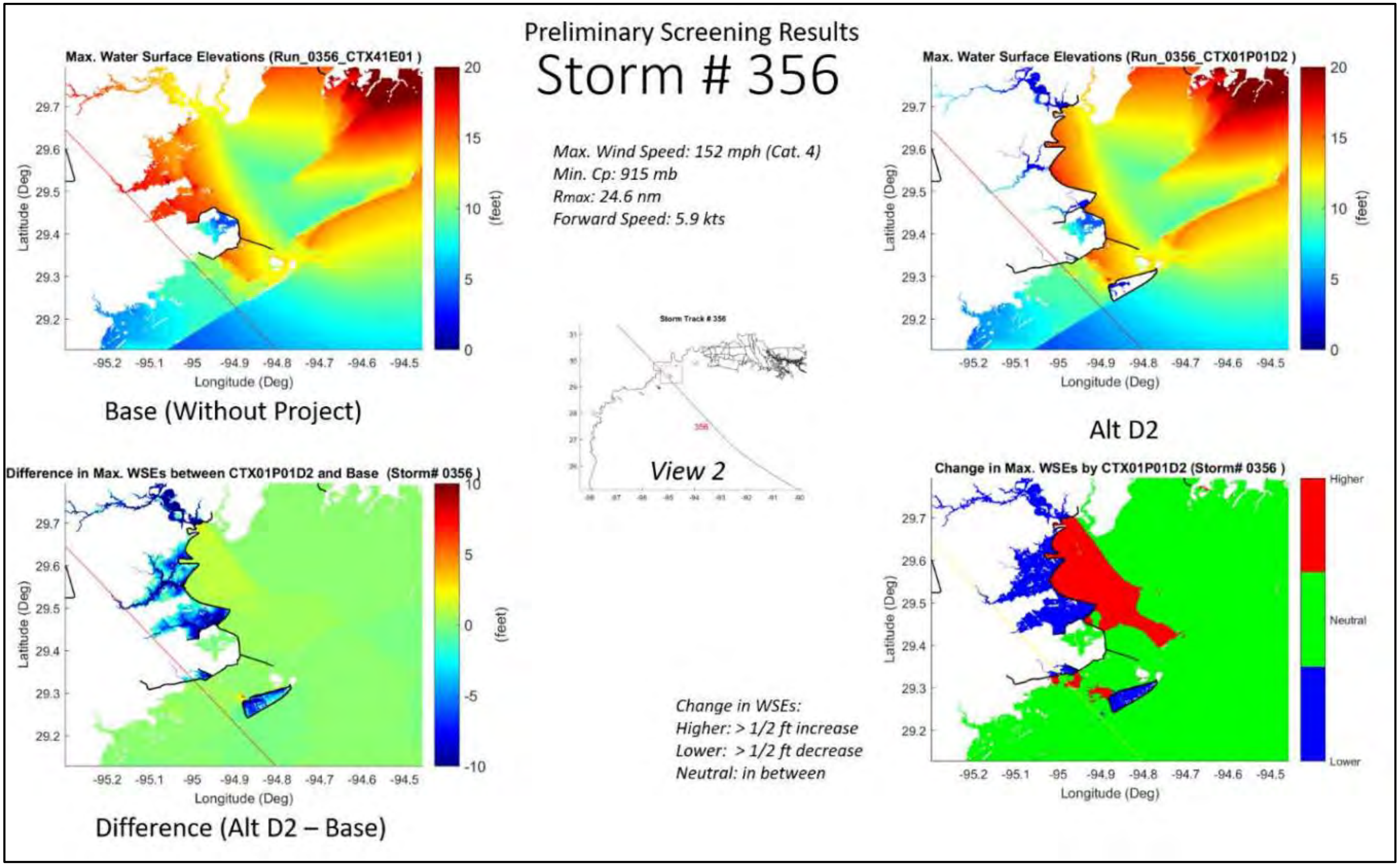

Figure 5-4: Storm Surge Results for Storm 356, Category 4 – Bay Rim
(Source: Massey et al., 2018)

Potential Storm Surge Reduction. For an assumed maximum surge with an estimated reoccurrence of at least once over 100 years, the Bay Rim provides storm surge reductions landward on the southwestern portions of the bay, which are areas on the protected side of the levees. When storm surge is evaluated by individual storms and probable reoccurrence within 100 years, reduction in storm surge elevation landward on the southwestern portions of Galveston Bay throughout Galveston Bay is observed with the proposed Bay Rim CSRM measure.

South Padre Island CSRM Measure and ER Measures

Impacts to the storm surges associated with the proposed South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.4 Water and Sediment Quality

5.3.4.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The Coastal Barrier is expected to affect water and sediment quality throughout the Galveston Bay system, because it would reduce flushing and mixing of point and nonpoint source pollutants entering the bay. Gulf water contains fewer pollutants than the bay, and tidal exchange dilutes pollutants entering the bay (Brock et al., 1996). Eighty percent of the tidal flow into and out of Galveston Bay occurs at Bolivar Roads, and the barrier is estimated to reduce the volume of tidal flow between 13.5 and 16.5 percent (Ruijs, 2011; McAlpin et al., 2018).

In addition to tidal exchange with the Gulf, water retention time in Galveston Bay is affected by freshwater inflow from the Trinity River, San Jacinto River, and Buffalo Bayou and its tributaries (Arcadis, 2017; Joye and An, 1999; Lester and Gonzalez, 2011; Rayson et al., 2016). Hydraulic modeling indicates that retention times would increase upstream of each barrier. Salinity upstream of the barriers at Clear Lake, Dickinson Bay, and Offatts Bayou may be lower on average than in the past because of this increased retention time. Increased retention may increase sediment deposition and development of low dissolved oxygen conditions upstream of the barriers.

Reduced mixing and water exchange combined with pollution, episodic storms, high phytoplankton production, and vertical stratification of the water column can contribute to low dissolved oxygen levels, which has been a major contributor of fish kills in estuaries (Howarth et al., 2011; Paerl, 2006). These conditions have occurred in the Galveston Bay system, Dickinson Bayou, and Dickinson Bay (Lowe et al., 1991; Quigg et al., 2009; Thronson and Quigg, 2008).

Reducing tidal flushing may alter the nutrient balance by reducing phosphorus input into the bay and nitrogen transport out of the bay. Changes in ratios of nitrogen and phosphorus may change plankton communities in the bay, particularly in areas where oysters rely on plankton as their primary food source (Brock et al., 1996; Howarth et al., 2011).

Parts of the bay that are farther from development and point sources of pollutants have lower nutrient concentrations and algal biomass than parts of the bay closer to urban and industrial development. Increased retention time in the Upper and Lower Galveston Bay may allow effects of high algal productivity, low oxygen, and potentially harmful algal blooms to be expressed more widely and frequently in these areas of the bay (Lester and Gonzalez, 2011).

South Padre Island CSRM Measure

There would be localized increases in turbidity in the Gulf associated with dredging and placement for this CSRM measure. There may also be release of low-oxygen water, high ammonia, and nutrients at the borrow source location as sediments are dredged (Riemann and Hoffman, 1991). These conditions, like elevated turbidity, would be expected to be temporary and localized, ending when dredging was completed.

ER Measures

Localized increases in turbidity of the sediment at borrow and beach placement locations are expected during construction. There may also be releases of low-oxygen water and nutrients at the borrow source location as sediments are dredged. These conditions, like elevated turbidity, would be expected to be temporary and localized, ending when dredging was completed.

During placement of materials for construction of breakwaters, marsh nourishment, marsh restoration, island restoration, or oyster reef creation, localized and temporary increases in turbidity would be experienced. Localized and temporary increases in turbidity associated with dredging material for marsh nourishment, marsh restoration, and island restoration would occur; however, if the dredging is associated with dredge maintenance or virgin material from navigation channels, like the GIWW, these impacts would occur even if the ER measures were not implemented. Areas receiving marsh nourishment or restoration may experience more impacts from additional periods of elevated turbidity and depressed oxygen levels associated with extended periods of construction and dredged material placement. Water and sediment quality impacts resulting from the ER measures are expected to be temporary and associated with actual periods of construction.

5.3.4.2 Bay Rim Alternative

Bay Rim CSRM System

The intensity, frequency, and severity of possible impacts may be greater with the Bay Rim than with the Coastal Barrier since most of the waste load enters the bay upstream of the proposed barriers across the Houston Ship Channel and Tabbs Bay. The area for mixing and the volume for dilution would be reduced, which could have harmful effects since this area upstream of the proposed barriers already experiences the poorest water quality in the system. Most nutrients and potential pollutants enter the upper end of the bay, particularly the Houston Ship Channel and Upper Galveston Bay. The portion of the Bay Rim alternative that is upstream of the proposed barriers across the Houston Ship Channel and Tabbs Bay creates the smallest areas where flushing would be reduced combined with the highest nutrient and pollutant loading. This combination of reduced flushing and pollutant loading may create more detrimental effects like hypoxic zones and harmful algal blooms than the Coastal Barrier.

Lester and Gonzalez (2011) identified the western, urbanized portion of the bay's watershed as the area with most of the water quality problems. Sediment concentrations of heavy metals and chlorinated organic compounds in the Houston Ship Channel that mix with Gulf waters would be reduced. This reduction in mixing and dilution may increase sediment loading in areas where hazardous materials are above screening criteria. Increased concentrations of these compounds in sediment may contribute to bioaccumulation and biomagnification of potential pathogens, heavy metals, and synthetic organic compounds in fish and shellfish in the area (Lester and Gonzalez, 2011).

Due to hazardous concentrations of PCBs and dioxins, the TDSHS has issued a fish and shellfish consumption advisory for the Houston Ship Channel and the San Jacinto River from upstream of the Fred Hartman Bridge to the Lake Houston Dam, limiting consumption of fish and blue crabs from those areas (TDSHS, 2015). A fish and shellfish consumption advisory was also issued restricting consumption of catfish, spotted seatrout, and blue crab in Upper Galveston Bay and catfish throughout Galveston Bay (TDSHS, 2013a). Sampling for PCBs in the Houston Ship Channel, its tributaries, and the San Jacinto River tidal revealed concentrations in water and fish tissue high enough to pose a concern to human health (Rifai et al., 2005).

The Bay Rim would be upstream of Trinity Bay, Upper Galveston Bay, Lower Galveston Bay, West Bay, and East Bay. Fewer nutrients, pollutants, and potential pathogens may be transported past this barrier than in the past, and Upper Galveston Bay, Trinity Bay, Lower Galveston Bay, Bolivar Roads, West Bay, and East Bay may experience improved water and sediment quality since they would be downstream of the barrier. If low-oxygen conditions or harmful algal blooms develop upstream of the barrier, they would be expected to impact some portion of the bay downstream as they move through the barrier. Water and sediment quality impacts may be minimal and possibly improve relative to recent conditions.

South Padre Island CSRM Measure and ER Measures

Impacts to water and sediment quality resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.5 Hydrology

5.3.5.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Galveston Bay. The surge barrier gates at Bolivar Roads are not expected to affect watershed hydrology except for very localized impacts where the gates connect to the shore. The structures and support systems for the barrier that are constructed on or adjacent to land may influence the direction and rate of rainfall runoff from the land, and it may influence bay or Gulf water levels where the barrier meets the land. The surge barrier gates at Offatts Bayou, Dickinson Bayou, Clear Lake, and the GIWW near High Island may increase localized flooding upstream and downstream of the barriers during extreme rainfall runoff events or water-level fluctuations in the bay (extreme high tides or storm-generated waves). This flooding may occur if the barriers reduce the existing cross-sectional area of the channels where the barriers are proposed for construction. Water might rise higher than it would without the constriction in place, flooding adjacent land that does not flood now under those conditions. The extent of flooding would depend on the amount of rainfall runoff or rise in water elevation, which is anticipated to be managed and offset by the optimized sizing of the planned pump stations associated with each gate. Based on the estuarine modeling conducted by the USACE, the tidal amplitude in the bay would be reduced, meaning the shoreline around the bay would be less frequently exposed to higher tides (McAlpin et al., 2018).

Galveston Island. The proposed ring levee around urbanized areas of Galveston would block some rainfall runoff from drainage channels and sheet flow from the watershed into the bay. Stormwater would be routed to pump stations and drainage gates, requiring hydrologic modification of watershed drainage.

Gulf Coast Aquifer. No impacts to the Gulf Coast Aquifer are anticipated from this alternative.

South Padre Island CSRM Measure

The South Padre Island CSRM measure is not expected to impact regional hydrology. The placement of sediments on the beach may have very localized effects on where rainfall runoff flows but would not block or interfere with any existing stream channels or other permanent inland waterbodies. No long-term or spatially extensive impacts to watershed hydrology are anticipated resulting from the South Padre Island CSRM measure.

ER Measures

Revetment/Breakwater. Breakwaters constructed in the water would not affect watershed hydrology. Revetments constructed on shorelines may have minor, localized effects on the direction of flow of rainfall runoff into the bay adjacent to the revetment. Revetments/breakwaters that block water exchange with tidal channels could cause flooding of land on the upstream side of the structure.

Island Restoration. Placement of material to preserve existing island features may affect rainfall runoff and its flow on the island, but any effects are expected to be temporary and localized. Impacts would not extend beyond the islands.

Marsh Restoration/Out-year Marsh Nourishment 2065. The placement of material to restore or create marsh habitat may locally change hydrology if containment levees are built on uplands. Containment levees built on uplands would probably change patterns of sheet flow from rainfall runoff towards the bay. Marsh restoration is not expected to impact any permanent bodies of inland waters like freshwater streams or ponds. Impacts to the local watershed hydrology with the out-year marsh nourishments are not anticipated, because sediments would be placed in intertidal marsh only.

Oyster Reef Creation. Oyster reefs do not induce hydrologic changes. Therefore, impacts to watershed hydrology are not anticipated to result from creation of these features.

Dune/Beach Restoration. The placement of sediments on the beach may have very localized effects on the direction in which rainfall runoff flows but would not block or interfere with any existing stream channels or other permanent inland waterbodies. No long-term impacts to watershed hydrology are anticipated to result from these ER features.

Hydrologic Restoration. ER measure W-3 (Port Mansfield Channel, Island Rookery and Hydrologic Restoration) is in the Nueces-Rio Grande Basin and the only ER measure specifically designated to achieve hydrologic improvements in the Lower Laguna Madre. Dredging the channel would enhance flow and tidal exchange between the Gulf and the Lower Laguna Madre. Sediment dredged from the channel that will be placed in an offshore berm would not impact watershed hydrology in the area.

5.3.5.2 Bay Rim Alternative

Bay Rim CSRM System

Galveston Bay. The surge barrier gates may increase localized flooding upstream and downstream of the barriers during extreme rainfall runoff events or water-level fluctuations in the bay (extreme high tides or storm-generated waves). The extent of flooding would be affected by the extent the barriers reduce the existing cross-sectional area of the channels where the barriers are proposed for construction. Because of the extensive nature of the levees and surge barrier gates proposed, rainfall runoff in drainage channels and as sheet flow is expected to be intercepted by the levees and forced into areas not typically inundated or into different channels for additional stormwater runoff. Channel designs would need to ensure drainage features to pumps have adequate capacity to transport flood flows. Pump stations would be installed upstream of the levees, and hydrologic modifications would be required to direct flood flows to the pump stations.

Galveston Island and Gulf Coast Aquifer. Impacts would be the same as those described for the Coastal Barrier Alternative.

South Padre Island CSRM Measure and ER Measures

Impacts to the hydrology resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.3.6 Soils (Prime and Other Important Unique Farmland)

Prime and unique farmlands were mapped using the NRCS Web Soil Survey website (NRCS, 2018). The NRCS database was used to calculate prime farmland impacts associated with construction right-of-way.

The Coastal Barrier Alternative would impact a total of 25.2 acres of prime farmlands. The Coastal Barrier CSRM system would convert 2.3 acres of prime farmlands located north of High Island on FM 124 into a levee barrier. Most of this area has been converted from grasslands and wetlands to farmlands and cattle pastures. The South Padre Island CSRM measures are not expected to impact prime farmlands as there are none located on the island. ER measures would directly impact prime farmlands: revetment/breakwaters 1.6 acres adjacent to the GIWW, wetland/marsh restoration 0.9 acre in Brazoria County, and out-year marsh nourishment 20.4 acres in Brazoria County and East Matagorda Bay.

The Bay Rim Alternative would impact a total of 354.9 acres of prime farmlands, 332 of these are with the Bay Rim CSRM system. The South Padre Island CSRM and ER measures are the same as those for the Coastal Barrier Alternative. The majority of impacts to prime farmlands are located on the west extension of the Texas City HFPS and along the western edge of Galveston Bay. This CSRM measure would have the most impact to prime and unique farmlands. Areas affected are currently used for residential, commercial, and agricultural practices.

The ER measures would have very little impact to prime farmlands since there is little farmland associated with the measures. Steps would be taken to avoid, minimize, and reduce any potential impacts to the best extent practicable. Upon completion, the Coastal Barrier is expected to benefit prime farmlands by providing a buffer and protective barrier against rising sea level and erosive wind/wave action that could potentially wash out prime farmland soils. Prior to construction, the NRCS would be consulted to minimize or avoid impacts to prime farmlands.

5.3.7 Energy and Mineral Resources

A preliminary desktop analysis was conducted performing a historical use and regulatory records search and using digital data from the Railroad Commission of Texas to determine location and density of oil and gas activities. Table 5-6 summarizes the energy and mineral resources located in the project area.

Table 5-6
Summary of Energy and Mineral Resource Sites

Measure	Pipelines Within 1 Mile	Pipeline Intersections	Oil/Gas Wells Within 1 Mile	Oil/Gas Well Intersections
Coastal Barrier CSRM	49	36	1,267	57
Bay Rim CSRM System	206	103	3,813	89
ER Measures	164	65	2,826	1,223
South Padre Island CSRM	0	0	0	0

The following general conclusions can be made from these data (see Table 5-6):

- Oil and gas activities are generally concentrated within Galveston, Matagorda, and Nueces bays.
- The Coastal Barrier Alternative has the least oil and gas wells and pipelines within the project footprint and 1-mile radius and the Bay Rim Alternative has the most.
- Approximately 5 percent of the oil and gas wells and 74 percent of the oil and gas pipelines occur within the Coastal Barrier footprint and 1-mile radius.
- Approximately 2 percent of oil and gas wells and 50 percent of the oil and gas pipelines are located within the Bay Rim footprint and 1-mile radius.
- More oil and gas activities and infrastructure are found within ER measure footprints than the Coastal Barrier, but less oil and gas activities and infrastructure than the Bay Rim. A total of 1,223 oil and gas wells intersect the ER measures. This is the largest number of oil and gas wells to intersect any of the measures.
- Approximately 43 percent of the oil and gas wells and 40 percent of the oil and gas pipelines are located within the footprints of the ER measures and 1-mile radius.
- No oil and gas activities occur within a 1-mile radius of the South Padre Island CSRM.

Steps would be taken to avoid, minimize, and reduce any potential impacts to oil and gas activity to the best extent practicable. A more-detailed oil and gas activity record is included in the Draft HTRW Assessment (Appendix C-7).

5.3.8 Hazardous, Toxic, and Radioactive Waste

A preliminary desktop analysis was conducted using historical use and regulatory records to identify the existence of, and potential for, HTRW contamination. Table 5-7 summarizes the HTRW sites in the project area. A detailed desktop analysis will be conducted in future planning and design phases.

Table 5-7
Summary of HTRW Sites

Measure	1-Mile Radius	Intersect
Coastal Barrier CSRM System	112	13
Bay Rim CSRM System	147	8
ER Measures	61	1
South Padre Island CSRM	8	0

The following general conclusions can be made from these data (see Table 5-7):

- The largest number of HTRW sites occur within a 1-mile radius of the Bay Rim.
- Most HTRW site intersections occur within the Coastal Barrier footprint.

- The fewest HTRW sites occur within a 1-mile radius of the South Padre Island CSRM.
- The EPA Facility Registry Service sites and TCEQ Petroleum Storage Tank sites make up 92 percent of the HTRW sites within a 1-mile radius of the Coastal Barrier Alternative (Coastal Barrier, ER Measures, and South Padre Island).
- The EPA Facility Registry Service sites and TCEQ Petroleum Storage Tank sites make up 88 percent of the HTRW sites within a 1-mile radius of the Bay Rim Alternative (Bay Rim, ER Measures, and South Padre Island).

Potential HTRW concerns have been identified for the TSP. A desktop HTRW assessment was conducted to identify the existence of, and potential for, HTRW contamination that could impact or be impacted by the TSP. The assessment follows guidance provided by Engineer Regulation 1165-2-132 and consists of a review of recent and historic aerial photographs and a review of Federal, State, and local regulatory agency database information. Steps would be taken to avoid, minimize, and reduce any potential impacts to HTRW concerns to the best extent practicable. The draft HTRW Assessment is included as Appendix C-7.

5.3.9 Air Quality

Impacts to air quality would be similar for both alternatives. Air emissions during construction would consist primarily of tailpipe emissions (due to fossil fuel combustion from dredging equipment and land-side vehicles) and fugitive dust (ground surface disturbance). Air quality impacts would include an increase in particulate matter (PM) with particle diameters of 10 micrometers or less (PM_{10}) and particle diameters of 2.5 micrometers or less ($PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), volatile organic compound (VOC), and carbon dioxide (CO_2). VOC and nitrogen oxide (NO_X) emissions from these activities can combine under the right conditions to form ozone (O_3), possibly increasing the concentration of O_3 in the region.

Estimates of air contaminant emission rates for the Coastal Texas Study alternatives require more-detailed construction schedule and phasing details that are developed at the time of this DIFR-EIS. Therefore, the following is a qualitative description of the methods that will be used to estimate air emissions and a preliminary discussion of potential impacts to air quality in the study area. It is anticipated that additional construction-related information will be developed for the alternatives as the project analysis progresses through future planning and design phases.

5.3.9.1 Coastal Barrier Alternative

Construction Emissions. Temporary increases in air pollution would result from equipment associated with the construction of the Coastal Barrier Alternative including dredge and support equipment, non-road construction equipment, on-road and employee vehicles, maintenance dredging, and landside maintenance. The marine vessel emission sources would be primarily diesel-powered engines. The off-road and on-road equipment may be assumed to be a mix of gasoline and diesel-powered vehicles. Once construction details are developed for the alternative, air contaminant emissions due to construction activities associated with this alternative will be compared to an emissions inventory for the affected counties within the study area. It is anticipated that air contaminant emissions from the construction activities associated with this alternative would result in a relative increase in emissions above those from the existing inventory of emissions sources in the affected counties. As a result, the estimated increase in emissions may also result in corresponding impact on air quality in the immediate vicinity of the project area.

The rate of emissions from project construction equipment is directly related to the horsepower rating of each engine, load factor, duration of use, and the projected amount of dredged material and surface area disturbed. The rate of emissions from employee commuter vehicles is directly related to the type of vehicle and total miles traveled for each vehicle. The combustion of diesel fuel in internal combustion engines during the construction operations would result in air emissions of particulate matter (PM_{10} and $PM_{2.5}$), SO_2, CO, NO_2, VOC, and CO_2. Air contaminant emissions will be estimated using emission factors currently approved or recommended by the EPA and TCEQ.

Non-Road Construction Equipment. Air contaminant emissions from non-road construction equipment used for onshore excavation and construction will be estimated based on the anticipated type of equipment, activity, horsepower, and anticipated hours of operation. Onshore construction equipment would include cranes, trucks, dozers, front-end loaders, backhoes, compactors, graders, dump trucks, etc. The operation of construction vehicles would generate air emissions typical of vehicles powered by diesel-fueled internal combustion engines.

Marine Vessels and Support Equipment. Marine vessel emissions would include those that would be expected to result from the use of dredging vessels, tug boats, and miscellaneous support vessels used in support of dredging activities. Air emissions directly related with the dredging equipment will be calculated on an annual basis based on the anticipated type of engine, activity, horsepower, and anticipated hours of operation.

Tugboat Assisted Barge Equipment. Tugboat assisted barges may also be used to transport construction materials and equipment to the construction sites. For purposes of General Conformity, the emissions may also be broken out by area, e.g., those that would occur in the Houston-Galveston-Brazoria Nonattainment Area, the Beaumont-Port Arthur Maintenance Area, and the Baton Rouge, Louisiana, Nonattainment Area traversed by the tug-assisted barges enroute to the construction delivery docks.

On-Road Mobile Sources. Mobile source emissions associated with the project construction would be generated from on-road construction vehicles, employee commuter vehicles, buses, and supply vehicles. Commuter vehicles may also be used to transport the crew and staff from the shore to land-side locations and back to the shore.

Operating Emissions. Operating emissions are anticipated to be minor. It is anticipated the proposed surge barrier gates across Bolivar Roads and other surge barrier gates would be electrically powered; therefore, there would be no direct emissions from routine gate operation. These gates would be operated periodically for maintenance and testing for operational readiness. It is anticipated that diesel-fueled generators would also be installed to provide power during an emergency event, such as a hurricane, which would require operation of the gate. In case of an emergency event that would result in an electrical power failure, the generator would activate to provide power for movement of the gate. It is anticipated this event would normally last until the emergency event is gone and power is restored.

Maintenance Activities. Annual maintenance activities will result in higher air contaminant emissions in the localized area of activity compared to the No-Action Alternative. Air emissions would result from the combustion of fuel used in dredging and support equipment and for land-side equipment necessary to support maintenance operations.

5.3.9.2 Bay Rim Alternative

Impacts to air quality from the construction of the Bay Rim Alternative are anticipated to be similar to those described for the Coastal Barrier Alternative.

Construction Emissions. Construction emissions would be the same as those described for the Coastal Barrier Alternative. Air contaminant emissions will be estimated in tons per year for each vehicle or piece of equipment based on the equipment horsepower, fuel type, and expected operating hours during the year of construction activity. These construction activities would be considered one-time activities, i.e., the construction activities would not continue past the date of completion.

Operating Emissions. Operating emissions are anticipated to be minor. It is anticipated that the proposed surge barrier gate across the Kemah-Seabrook Channel would be electrically powered; therefore, there would be no direct emissions from routine gate operation. These gates would be operated periodically for maintenance and testing for operational readiness. It is anticipated diesel-fueled emergency generators would also be installed to provide emergency power during an emergency event, such as during a hurricane, which would require operation of the surge barrier gate. In case of an emergency event that would result in an electrical power failure, the emergency generator would activate to provide emergency power for movement of the gate. It is anticipated this event would normally last until the emergency event is gone and power is restored. The emergency generators would require testing on a monthly basis, but usually no more than 100 hours per year of operation for purposes of maintenance and testing for operation readiness.

Maintenance Activities. Annual maintenance activities for the Bay Rim Alternative would result in higher air contaminant emissions compared to the maintenance activities required under the No-Action Alternative. Air emissions would result from the combustion of fuel used in dredging and support equipment and for land-side equipment such as bulldozers.

5.3.9.3 Conformity of General Federal Actions – General Conformity Determination

The Coastal Texas Study, as a Federal action, is subject to the General Conformity Rule promulgated by the EPA pursuant to the CAA, Section 176(c)(1). The rule mandates that the Federal government not engage in, support, or provide financial assistance for licensing or permitting, or approving any activity not conforming to an approved SIP. In Texas, the applicable plan is the SIP, an EPA-approved plan for the regulation and enforcement of the NAAQS in each air quality region within the state.

General Conformity is applicable only to nonattainment or maintenance areas and refers to the process of evaluating plans, programs, and projects to determine and demonstrate they meet the requirements of the CAA and the SIP. The General Conformity Rule establishes conformity in coordination with and as part of the NEPA process.

The Coastal Barrier and Bay Rim alternatives will include components located within Chambers, Galveston, Harris, and Brazoria counties. These counties are part of the eight-county Houston-Galveston-Brazoria O_3 nonattainment area that is currently classified as “marginal” in terms of its degree of compliance with the current 8-hour O_3 standard (TCEQ, 2007b).

As previously stated, the details necessary to estimate the air contaminant emissions rates for the action alternatives are not available at the time of this DIFR-EIS. If it is determined during future planning and design phases of the study for the action alternatives that air contaminant emissions resulting from construction activities would exceed VOC and NO_X thresholds during any year of the anticipated duration of the construction period, then it will be necessary to prepare a General Conformity Determination for estimated emissions of NO_X and VOC emissions for these activities. If a General Conformity Determination is prepared, then following a 30-day comment period, the USACE will be required to publish a “Final General Conformity Determination” prior to project construction. This document will include concurrence from the TCEQ and the EPA that this project is consistent with the SIP.

5.3.9.4 Potential Air Quality Mitigation Measures

Measures that could be used to reduce emissions for the project would consider the equipment used for the project over the expected life of the project and the feasibility and practicality of such measures. Alternatives considered for their ability to reduce or mitigate emissions are those that may provide for enhanced energy efficiency, lower NO_X-emitting technology, repowering, etc., as appropriate, for the construction and operating equipment and vehicles to be used. Efforts to reduce emissions from the construction and operation of the project could include the following.

Dredging Mitigation Options

- Contracting with dredging companies that have energy efficient equipment
- Design of the dredging operation and schedule to reduce overall fuel use and hours of operation
- Repowering/refitting with cleaner diesel engines; i.e., those that would emit less air contaminant emissions
- Selection of newer dredges with more efficient engines, if possible
- Selection of dredges equipped with emissions control equipment; e.g., selective catalytic reduction, etc., if available

- Provision of electric power to dredging equipment

Land-side Mitigation Options

- Use of vehicles fueled by compressed natural gas or liquefied petroleum gas – compressed natural gas and liquefied petroleum gas could provide a reduction in CO_2 emissions compared to the use of gasoline fuel
- Repowering/refitting with cleaner, more-fuel-efficient, diesel engines
- Use of newer vehicles with more-fuel-efficient engines, if possible
- Use of non-road ultra-low sulfur diesel fuel

5.3.10 Noise

The following sections describe noise impacts during construction, maintenance, and operation activities. Underwater noise is addressed in Section 5.4.4.5 (Marine Mammals).

5.3.10.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Direct impacts to noise-sensitive receivers such as residential, recreational, and worship areas are expected during initial construction of the levee/floodwall and during periodic maintenance activities along the levees/floodwall. Construction and maintenance activities would be temporary, and therefore, noise generated by those activities would be temporary. Except for isolated areas and under rare circumstances, the levee/floodwalls have no noise-generating components. Due to the existing high volume of traffic within the region, the potential increase in heavy trucks traveling throughout the region to transport materials related to the proposed project would be inconsequential. General areas near the proposed levee/floodwall with noise-sensitive receivers would be primarily limited to the residential areas on Galveston Island and Bolivar Peninsula. Noise impacts associated with construction would be temporary and would typically take place during normal working hours (daytime) and therefore are considered minor. In addition, many of these homes are likely weekend homes that may not be continuously occupied during peak times of construction (weekdays) or during winter months.

Construction and operation of the surge barrier gates within Bolivar Roads and the GIWW are not expected to impact noise-sensitive receivers due to the distance of receptors from the proposed gates. Initial construction, long-term maintenance, and intermittent operation of proposed gates at Clear Lake, Dickinson Bayou, and Offatts Bayou would likely result in temporary noise and the operation of the surge barrier gates for the Coastal Barrier are expected to be minor.

A long-term beneficial effect on noise (i.e., a reduction in noise near noise-sensitive receivers) is expected in residential areas protected from storm surges. The long-term reduction in noise would be from the expected decrease in infrastructure damage and subsequent construction/rehabilitation activities near receivers following storm surges. This would be an indirect noise effect, and due to the infrequency of potentially damaging storm surges, the benefit is considered minor.

South Padre Island CSRM Measure

Similar to the Coastal Barrier, direct impacts to noise-sensitive receivers such as residential, recreational, and worship areas are expected during initial construction of the levee/floodwall and during periodic maintenance activities along the levees/floodwall. General areas near the proposed levee/floodwall with noise-sensitive receivers would be primarily limited to the beach-front recreational, residential, and commercial areas along South Padre Island. This area is more heavily utilized during the summer months and weekends. As such, potential noise impacts would likely be less during peak times of construction (weekdays) and during winter months. Potential noise impacts related to the construction and periodic maintenance of the South Padre Island CSRM measure are expected to be temporary and minor. Noise-sensitive areas protected from storm surges by the South Padre Island CSRM measure are expected to benefit from a minor long-term reduction in construction noise due to the reduction of storm damage.

ER Measures

Revetment/breakwaters, island restoration, marsh restoration, out-year marsh nourishment, and oyster reef creation are proposed for undeveloped areas that are not near permanent noise-sensitive receivers like residences. Intermittent recreational activities like recreational fishing may take place near the proposed locations, and noise generated by the operation of barges and other heavy equipment could result in temporary noise impacts to recreational fishermen or boaters. However, active construction areas could be restricted from recreational access during construction, which would limit the potential for noise impacts. Construction activities related to the operation of heavy equipment during construction of temporary levees and drainage structures during the one-time out-year marsh nourishment could result in temporary noise impacts at recreational areas. Potential impacts from these ER restoration activities are expected to be temporary and minor.

Construction activities related to the operation of heavy equipment during dune and beach restoration could result in temporary noise impacts at beach-front recreational areas and residences. During construction, access for recreational uses may be limited at the areas of construction, which would reduce the potential of noise impacts. In addition, many of the beach-front residences are likely weekend homes that may not be continuously occupied during peak times of construction (weekdays) or during winter months. Potential noise impacts from dune and beach restoration are expected to be temporary and minor.

5.3.10.2 Bay Rim Alternative

Bay Rim CSRM System

Temporary and minor noise impacts related to construction noise along the proposed levee/floodway are expected. Typical construction-related noise sources would be heavy construction machinery (e.g., excavators, front-end loaders) and movement of heavy trucks hauling construction spoils and materials within the construction right-of-way. Due to the existing high volume of traffic within the region, the potential increase in heavy trucks traveling throughout the region to transport materials related to the proposed project would be inconsequential. The expected temporary noise impacts from the Bay Rim would be in the developed, urban areas with high concentrations of residences in the cities of Galveston, Hitchcock, Texas City, San Leon, Bacliff, Kemah, Seabrook, and La Porte. This CSRM measure is expected to have greater noise impacts from construction of the levee/floodway than the Coastal Barrier due to the greater lengths of proposed levee/floodway in proximity to residential areas.

Construction of the surge barrier gates within Tabbs Bay is not expected to result in noise impacts to noise-sensitive receivers, like residential and recreational areas, due to the distance from the proposed gate to these areas. Similarly, the operation of the gates is not expected to result in noise impacts. Construction, long-term maintenance, and intermittent operation of proposed surge barrier gates at Clear Lake, Dickinson Bay, the Bay Rim levee/floodwall, and the Texas City Hurricane Flood Protection Improvements would likely result in temporary and/or short-term noise impacts to a small number of residences near these proposed facilities. These areas have a low concentration of potential noise-sensitive receivers, and as such, noise impacts related to the construction and operation of surge barrier gates for the Bay Rim are expected to be minor.

Construction of proposed pump stations along the Bay Rim to drain the protected systems during storms would likely result in temporary noise impacts to noise-sensitive receivers during construction. Long-term maintenance and operation of the pump stations would likely not result in noise impacts, because the proposed pump stations would typically be enclosed and thereby would not generate offsite noise during operation. Noise impacts related to the construction and operation of the pump stations along the Bay Rim are expected to be minor.

Noise-sensitive areas protected from storm surges by the Bay Rim are expected to benefit from a minor long-term reduction in construction noise due to the reduction in rebuilding after storm events.

South Padre Island CSRM Measure and ER Measures

Potential noise impacts resulting from the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4 ECOLOGICAL AND BIOLOGICAL RESOURCES

5.4.1 Wetlands

5.4.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The proposed Coastal Barrier is expected to have direct and indirect impacts to wetland and marsh habitats in the Galveston Bay region. Approximately 512.5 acres of non-tidal and 338.0 acres of tidal wetlands are expected to be altered or damaged due to the construction of this measure. Construction of the measure components on Bolivar Peninsula and Galveston Island would require clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for erosion and increased sedimentation during construction could affect the water quality and bury or damage adjacent vegetation in marshes. The wetland and marsh habitats located south of the proposed footprint could potentially be exposed to higher salinity from the Gulf for longer periods of times during storm events (Harvey et al., 2011). Proper best management practices, including implementation of a Storm Water Pollution Prevention Plan and general avoidance and minimization measures can contain and prevent sediments from entering wetlands. Silt fencing, silt curtains, rock berms, and mulch socks may be used to prevent sediment and contaminant transport to wetlands.

The surge barrier gates associated with the Coastal Barrier would alter the hydrology of Galveston Bay, which could affect the ecology of the estuary by altering habitat conditions for various fish and shellfish species. This in turn would impact birds and wildlife species, which depend on the resources provided by the marshes (Minello et al., 2012; Minello et al., 2015).

As a result of changes in tidal amplitude and tidal prism, potential changes to the characteristics and abundance of wetland and marsh vegetation could occur (McAlpin et al., 2018). Less tidal inundation could potentially convert wetland areas to ephemeral wetlands or uplands. The constriction would likely increase residence time in the bay upstream of the Coastal Barrier and allow greater dilution by freshwater inflows. This could potentially result in a conversion of plant communities and an expansion of freshwater wetlands on the bayside of the structure.

To estimate the potential area of affected wetland and marsh habitats within Galveston Bay resulting from the reduction in tidal amplitude due to the surge barrier gate structures across Bolivar Roads, an analysis was conducted using the NOAA C-CAP 2010 landcover dataset for estuarine wetlands. Approximately 3,375 acres of wetlands along the interior of the bay are expected to be indirectly impacted resulting from altered hydrology potentially leading to eventual deterioration of those habitats. A total of 7,818 acres of mitigation will be required for these impacts. Refer to the Mitigation Plan (Appendix C-9) for a more detailed discussion of mitigation for indirect wetland impacts.

Once construction is complete, the levee may benefit tidal and freshwater wetlands north of SH 87 on Bolivar Peninsula and FM 3005 on Galveston Island by providing a physical barrier against erosion during storm surges. Compared to the No-Action Alternative, the freshwater wetlands near Moody NWR and Anahuac NWR north of Bolivar Peninsula would be less likely to be inundated with seawater from the Gulf for long periods of time during storm events, which could result in a conversion of plant communities and an expansion of freshwater tidal on the bayside of the structure.

South Padre Island CSRM Measure

The beach and dune restoration feature proposed for South Padre Island is not likely to have direct impacts on adjacent wetland and marsh habitats resulting from the sediment placement. Once construction is complete, the restored beach and dune complex would likely help preserve existing wetland and marsh habitats on the bayside of the measure by providing increased risk reduction from storm surges and RSLR.

ER Measures

Revetment/Breakwater. Revetment and breakwaters along bay and Gulf shorelines would act as protective barriers to prevent saltwater tides and wave energy from damaging wetland and marsh habitats and improve SAV growth (TPWD, 2018a). They are intended to protect intertidal and freshwater marsh complexes from erosion caused by RSLR and increased wave energy from vessel traffic and storms. Construction of breakwaters would protect SAV along the shoreline of Keller and Redfish bays. Wetland impacts are expected to be temporary. Breakwaters and living shorelines would protect coastlines, accumulate sediments, and provide stable habitat for marsh expansion.

Island Restoration. Islands would be designed so the material (from dedicated dredging of the GIWW or another adjacent navigation channel) would form a natural slope and would create elevations suitable for marsh growth, wading birds, and SAV colonization. Marsh vegetation would be planted in the intertidal range on the backslope of the island. Nesting habitat on the crest of the islands would be improved with nesting platforms and native shrub planting, which would cover approximately half of the island. No long-term impacts are anticipated from construction, dredging, or placement activities associated with the island restoration features. Impacts to existing wetlands and SAV, such as sedimentation from placement of fill material, increased turbidity, installation of containment levees, or disturbances due to channel maintenance operations, would be temporary and localized.

Marsh Restoration/Out-year Marsh Nourishment 2065. Construction activities include temporary containment levees and draining structures to contain the dredged material, followed by planting and marsh establishment, which would take 10 years to complete. Thin layer placement of material may also be used to add sediment to the existing degraded marsh areas. Supplying sediments to subsiding marshes is a method that has demonstrated success in potentially slowing wetland loss (Ray, 2007). Many projects have been implemented that are successful in restoring wetland and marsh habitat using dredged material in areas that have seen degradation due to coastal erosion and subsidence (Atkins, 2017; Galveston Bay Estuary Program, 2018; Jenkins, 2008). The newly restored vegetation has provided increased habitat for birds, wildlife, and marine species and shoreline stabilization and resiliency.

Disposal of dredged material can adversely affect wetland and marsh habitats and water quality if the restoration sites are not properly managed. USACE guidelines will be followed to minimize adverse impacts, which include: using suitable, uncontaminated dredged material; using containment levees and stabilizing sites with vegetation to reduce erosion; managing dredge pipes to avoid habitat damage; and additional considerations should be accounted for when temporary impacts are unavoidable, so the site can be restored to pre-project conditions (USACE, 2015d). Dredging and placement of sediment material can create turbidity and suspend sediments, which may increase opacity and inhibit photosynthesis in SAV, but these impacts are expected to be temporary and localized (Newell and Koch, 2004).

The overall benefits to the marsh restoration and out-year marsh nourishment features as part of the ER measures are expected to outweigh short-term construction impacts. Wetlands and marshes provide numerous benefits, including improvement of water quality, flood attenuation, aesthetics, and recreational opportunities, as well as mitigating for RSLR and impacts to coastal infrastructure and ecosystems from storm events (USFWS, 2018h).

Oyster Reef Creation. Oyster reefs are effective for shoreline stabilization and provide many positive ecological benefits in open water and intertidal marsh complexes. Oyster reef creation would involve placement of oyster cultch or reef balls in shallow, nearshore water. Direct impacts resulting from construction activities would likely not affect the wetland and marsh habitats, because the reefs would be in nearshore waters, away from the marshes. The features would protect valuable wetland and marsh habitats from erosion and improve resiliency against coastal storms. The creation of new oyster reefs can improve water clarity and in effect increase available habitat for SAV (Newell and Koch, 2004).

Dune/Beach Restoration. Direct impacts resulting from construction activities would likely not affect the wetland and marsh habitats where dune and beach restoration features are proposed. The features would protect valuable wetland and marsh habitats from further erosion and would provide resiliency against coastal storms and RSLR.

5.4.1.2 Bay Rim Alternative

Bay Rim CSRM System

Construction of the Bay Rim could directly affect approximately 227.1 acres of non-tidal and 172.0 acres of tidal wetland and marsh habitat. The majority of these impacts would occur on private land. Construction of the levee/ floodwall features along the bay rim are proposed to start near the intersection of SH 99 and 146B in Baytown, Texas, and end northwest of the intersection of FM 2004 and SH 646 south of Santa Fe, Texas. Construction activities would include clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for erosion and increased sedimentation during construction could affect the water quality, bury, and damage adjacent vegetation in marshes. However, proper best management practices, including implementation of a Storm Water Pollution Prevention Plan, and general avoidance and minimization measures can contain and prevent sediments from entering wetlands. Silt fencing, silt curtains, rock berms, and mulch socks may be used to prevent sediment and contaminant transport to wetlands.

Direct and indirect impacts associated with constructing the surge barrier gates would be similar to those described for the Coastal Barrier (Section 5.4.1.1). Freshwater and tidal wetland and marsh habitats in Tabbs Bay and the Upper San Jacinto Bay would likely be impacted from construction of the crossing south of the Fred Hartman Bridge due to decreased tidal exchange. Once construction is complete, the Bay Rim would likely benefit freshwater wetlands situated inland of the structure, such as wetlands within Clear Creek Lake, Dickinson Bay, Dickinson Bayou, and Moses Bayou, by providing a physical barrier against erosion during storm surges and high winds.

However, tidal wetlands along the Bay Rim could be negatively impacted by the construction of the levee/floodwall by disconnecting the tidal exchange on the portion of those wetlands on the interior of the system. The wetlands outside of the system may also be negatively impacted by the changes in hydrology and sediment exchange that could occur as a result of construction.

South Padre Island CSRM Measure and ER Measures

Impacts to wetland and marsh habitats resulting from construction of the South Padre Island CSRM and ER measure would be the same as those described for the Coastal Barrier Alternative.

5.4.2 Aquatic Communities

5.4.2.1 Freshwater Habitats and Fauna

5.4.2.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Although hypersaline (high salinity) and hyposaline (low salinity) events occur within Galveston Bay, depending on amounts of freshwater inflow (drought conditions result in hypersaline conditions, large amounts of rainfall lead to fresher conditions); the impacts of these events could have greater effects with the Coastal Barrier in place. Salinity modeling (McAlpin, et al., 2018) indicates portions of Galveston Bay upstream of the barrier would have lower salinities for longer periods when freshwater inflows are normal to high. Conversely, these areas would maintain higher salinities for longer periods when freshwater inflows are below normal for extended periods and evaporation is high or when a storm from the Gulf pushes large volumes of more-saline water upstream of the barrier. Areas upstream of the barrier, which are fresher for longer periods, may allow temporary expansion of freshwater fish, invertebrate, and plant communities into some of those areas. These areas with salinities most favorable to freshwater organisms are expected to be near freshwater inflows entering the bay.

The exact design and positioning of the Coastal Barrier and surge barrier gates at Dickinson Bayou, Clear Lake, and Offatts Bayou would be optimized during future planning and design phases. Preliminary design includes gates placed near shore in shallow water at Bolivar Roads to facilitate ingress and egress of aquatic organisms moving along the shore. These barriers may be designed and operated in ways that avoid or minimize impacts on movements of freshwater organisms. The Coastal Barrier might have the greatest impact on American eel, because it may reduce access to the bay system at its confluence with the Gulf and its tributaries which provide habitat for maturing eel. The Coastal Barrier may have less impact on alligator gar because the barrier is at the mouth of the bay and would not appear to inhibit movement of the fish between spawning tributaries and the bay. Since alligator gar occur in the bay, they may occasionally move into the Gulf through Bolivar Roads; however, this movement is not necessary for completion of their life cycle and not believed to be frequent. Since other freshwater organisms are not known to move between the bay and Gulf under ordinary conditions, the Coastal Barrier is not expected to impact movement of other freshwater organisms through the gate systems (Hendrickson and Cohen, 2015).

When low salinities occur in the bay, the barriers at Dickinson Bayou, Clear Lake, and Offatts Bayou may inhibit movement of freshwater fish and shellfish past the barriers.

South Padre Island CSRM Measure

The South Padre Island CSRM measure is not expected to impact freshwater organisms. American eel migrate through the Gulf, and it may be possible they migrate near the sediment source area in the Gulf. Monitoring data suggest the probability of American eels occurring near the sediment source area is very low when dredging is occurring. If American eels do move past the sediment source area, they may be mobile enough to avoid entrainment by the dredge.

ER Measures

All ER measures involve construction of breakwaters, some of which are proposed to be miles long. These breakwaters may create barriers to movement of American eels and alligator gar but are not expected to impair their movement through the estuaries, because breakwaters will also be designed to facilitate movement of organisms back and forth through the breakwaters. ER measures G-28, B-12, M-8, CA-5, and CA-6 include combinations of marsh restoration and nourishment, which could impact freshwater organisms. The degree of impact would be determined by the salinity when restoration and/or nourishment is occurring. If salinities are below 8 to 10 ppt, some species of freshwater organisms could be in the marsh and would be impacted by increased turbidity, possible increased temperatures, increased ammonia, and lowered oxygen in the marsh enclosed by the marsh restoration levees. ER measures like SP-1 and W-3, which include breakwaters and island restoration, are not expected to impact freshwater organisms.

Beach and dune restoration ER measures (G-5 and B-2) would be constructed on the beach; sediment placement is not expected to affect freshwater organisms. American eel migrate through the Gulf, and it may be possible they migrate near the sediment source areas in the Gulf. Monitoring data suggest there is a relatively low probability of American eel occurring near the sediment source area. If American eel do move near the sediment source area, they may be mobile enough to avoid entrainment by the dredge.

5.4.2.1.2 Bay Rim Alternative

Bay Rim CSRM System

The CSRM measure with the least impact on American eel is most likely the Bay Rim Alternative, because the alternative would reduce access only to the upper Houston Ship Channel, San Jacinto River tidal, and Buffalo Bayou, Dickinson Bayou, and Clear Creek watersheds, and it is unlikely that those watersheds are utilized by American eel. The Bay Rim is also the only CSRM measure that would allow unobstructed eel access to the Trinity River and its watershed below Lake Livingston. The Trinity River watershed below Lake Livingston is a fourth of the potential habitat for eel in the Galveston Bay system downstream of Lake Livingston.

About 3 percent of the area of Galveston Bay occurs upstream of the Bay Rim. This relatively small area of the bay receives about 38 percent of the average combined freshwater inflow to the estuary (TWDB, 2018). Having a large portion of the bay's freshwater inflow into only 3 percent of the bay would be expected to reduce salinities and create longer periods with low salinity upstream of the barrier. These lower salinity conditions should benefit freshwater organisms.

Effects of the barriers at Dickinson Bay, Clear Lake, and Offatts Bayou on freshwater organisms would be similar to the effects in the Coastal Barrier Alternative.

South Padre Island CSRM Measure and ER Measures

Impacts to freshwater organisms resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.2.2 Estuarine Habitats and Fauna

5.4.2.2.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The Coastal Barrier would result in a loss of 2,154 acres of open water and bay bottom habitat. The majority occurring at Bolivar Roads, which would be covered by the support structures and gates for the surge barrier gates.

Open Bay and Bay Bottom. During construction of the Coastal Barrier, temporary disturbances and impacts to benthic organisms, plankton, and nekton assemblages would occur. Water column turbidity is expected to increase during dredging and construction operations, which can create a sediment plume that can impact a wide array of organisms; however, these impacts would be localized and temporary (Hirsch et al., 1978; Stern and Stickle, 1978;

Wilber and Clarke, 2001; Wilber et al., 2005; Wright, 1978). Turbidity from total suspended solids tends to reduce light penetration and thus reduce photosynthetic activity by phytoplankton, algae, and seagrass (Wilber and Clarke, 2001). Reductions in primary productivity would be temporary and localized around the immediate area of the dredging and placement operations. Turbidities can be expected to return to near ambient conditions within a few months after dredging ceases in a given area, thus, no long-term effects are anticipated (Teeter et al., 2003).

Increased concentrations of suspended sediment can temporarily impact benthic macroinvertebrates and juvenile and adult finfish and shellfish by disrupting foraging patterns, reducing feeding rates and effectiveness, burying habitat for feeding and reproduction, and reducing respiration rates by coating gills with sediment (Clarke and Wilber, 2000; Newcombe and Jensen, 1996; Wilber and Clarke, 2001). These impacts are expected to be localized and for short durations and would return to normal once activities are completed.

Although the bay bottom at Bolivar Roads is considered a loss, the area of the Houston Ship Channel between the surge barrier gate would be left as natural bay bottom and regularly maintenance dredged by the USACE. There would be direct impacts during construction due to the removal of material from the seabed that removes benthic organisms living on and in the sediment. Dredging can result in a reduction of species diversity by 30 to 70 percent; however, recolonization would occur through immigration of postlarval organisms from the surrounding area (Bolam and Rees, 2003; Newell et al., 1998; Newell et al., 2004). Communities in these dynamic ecosystems tend to be dominated by opportunistic species tolerant of a wide range of conditions (Bolam et al., 2010; Bolam and Rees; 2003, Newell et al., 1998; Newell et al., 2004). Although changes in community structure, composition, and function may occur, these impacts would be temporary in some dredging areas (Bolam and Rees, 2003).

Dredged material from construction of the Coastal Barrier features would be used beneficially for construction of ER measures, mitigation features, and/or other CSRM structures.

Salinity. Construction of the Coastal Barrier could slightly decrease bay salinities on average of 2 ppt based on the estuarine modeling conducted by the USACE (McAlpin et al., 2018). During normal flow conditions, average salinities range from less than 10 ppt in upper Trinity Bay to 30 ppt at Bolivar Roads (Lester and Gonzalez, 2011). Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Therefore, no adverse effects on fauna are expected due to changes in salinity that may result from the construction of the Coastal Barrier.

Fisheries. The predicted reduced flow and increased velocities through Bolivar Roads could impede the migrations and movements of various life stages of fish into and out of the Galveston Bay system. Eggs and larval stages of aquatic organisms are transported by currents, moving into the bay on the incoming tides. Larval forms of some species drop near the bottom on outgoing tides, particularly in the shallow areas nearshore to reduce transport out of the bay. An environmental gate along the shore of Bolivar Roads is expected to help alleviate some of the potential impacts to aquatic organisms that utilize shallow edge habitats.

Fisheries productivity is dependent upon environmental conditions and habitats that are present in marshes. Marshes form a transition between aquatic and terrestrial ecosystems consisting of vegetation interspersed with shallow open water (Minello et al., 2008). The vegetation/edge of the marsh is important in providing access to the marsh surface, which is used by aquatic organisms when it is flooded. The less the marsh surface is flooded the less surface area is available for these species to utilize as nursery habitat (Minello et al., 2012; Minello et al., 2015). Tidal inundation is very important in determining marsh value and use (Minello et al., 2012). The predicted tidal amplitude reduction means less of the marsh would be flooded (McAlpin et al., 2018), which could result in a reduction of fish and shellfish densities thus reducing the overall populations in the bay. This, coupled with reduced immigration of eggs and larvae from the Gulf into the bay because of the flow constriction, could exacerbate the impacts further. It's worth noting that numerous anthropogenic modifications have occurred in the Galveston Bay system (e.g., Causeway Bridge, Texas City Dike, Galveston Jetties, and the establishment of numerous dredge material placement areas), and while those modifications may have had adverse effects on fisheries, the ecosystem in Galveston Bay has proved resilient. For further discussion see Section 5.10 (Cumulative Impacts).

Oyster Reef. Information from the GLO GIS maps and database for oyster reefs was used to determine impacts to oysters. No mapped oyster reefs occur in the direct footprint of the Coastal Barrier; therefore, no direct impacts are anticipated. The interagency team has noted that oysters do occur in locations that are not included in the GLO dataset, specifically where the proposed Galveston ring levee/floodwall would cross Offatts Bayou. A more detailed impact assessment, including additional oyster information from the interagency team, will be conducted on the TSP in future planning and design phases.

Water column turbidity would increase during project construction that could affect survival or growth of oysters nearby. Turbidity increases from construction of the Coastal Barrier should be temporary and local (Cake, 1983; Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clarke, 2001). Indirect effects to oyster reef habitat may result from a lower salinity regime due to the reduced flow of water into and out of the bay and the longer retention times.

An overall decrease in salinity of about 2 ppt could be expected based on the estuarine modeling conducted by the USACE (McAlpin et al., 2018). It is not anticipated that this potential salinity decrease would cause any long-term impacts to oyster reefs in the Galveston Bay system. A benefit of a slight decrease in salinity is a potential reduction in exposure to oyster predators and pathogens, drills, and Dermo, which may occur more frequently with higher salinities (Cake, 1983; Soniat and Kortright, 1998). It is not anticipated that this potential salinity decrease would cause any long-term impacts to oyster reefs in the Galveston Bay system.

South Padre Island CSRM Measure

Impacts to the estuarine habitats and fauna could occur in the Gulf portions of the South Padre Island CSRM measure due to increased water-column turbidity and sediment placement that can be expected during construction activities. A total of 358.5 acres of open water would be impacted. Turbidity impacts would be the same as those described above for the Coastal Barrier and would be expected to return to normal once construction is completed. Renourishment of the measure every 10 years throughout the period of operation would cause short-term water-column turbidity and impacts to benthos during placement activities. No long-term impacts to the aquatic community are anticipated to result from the South Padre Island CSRM measure.

ER Measures

Revetment/Breakwater. A total of 802 acres of bay bottom habitat and open bay habitat would be lost. Impacts associated with bay bottom habitat loss and temporary disturbances to water-column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier, open bay and bay bottom and would be expected to return to normal once construction is completed. No long-term impacts to finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of revetment/breakwater features of ER measures. The constructed revetment/breakwaters would attract marine organisms and provide a greater ecological service than without the structure in place. If water quality is adequate, revetments/breakwaters provide habitat for oyster colonization and the biological communities associated with oysters (Dugan et al., 2011; Fowler and Booth, 2013). These structures would also protect valuable marsh, SAV, and oyster reef habitat from eroding, in turn protecting valuable nursery grounds for the many fish and shellfish species that live within these estuaries.

Island Restoration. Bay bottom habitat and open bay habitat would be lost. Impacts associated with bay bottom habitat loss and temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom and would be expected to return to normal once construction is completed. Notwithstanding the potential harm to some individual organisms, no long-term impacts to finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of island restoration features of ER measures.

Marsh Restoration/Out-year Marsh Nourishment 2065. The area of bay bottom habitat and open bay habitat under the revetment/breakwater features would be lost. A total of 28,092.7 acres are proposed for out-year marsh nourishment. Impacts associated with bay bottom habitat loss and temporary disturbances to water-column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom and would be expected to return to normal once construction is completed. Once the marsh is functioning, the overall benefits outweigh the initial impacts. Wetlands and marshes provide numerous ecosystem services including providing nursery and feeding habitat for juvenile and adult fish and shellfish species, which in turn provide economic value to the community (Schuster and Doerr, 2015). It is expected that the marsh restoration features would improve the fish and shellfish habitat in the areas compared to the No-Action Alternative (Minello, 2000; Minello et al., 1994; Rozas et al., 2005; Yoskowitz et al., 2012).

Oyster Reef Creation. Creation of oyster reefs is expected to protect restored islands, prevent breaching of islands and shorelines, protect SAV, and increase oyster populations. Impacts during construction of the oyster reefs include water-column turbidity and bay bottom habitat loss and would be the same as those described above for the Coastal Barrier. Water column turbidity would be expected to return to normal once construction is completed. Oyster reefs have a positive benefit to the estuaries by providing ecosystem services such as water filtration and nutrient removal, fisheries habitat, benthic invertebrate habitat, and stabilization of adjacent habitats and shorelines (Baggett et al., 2014; LaPeyre et al., 2014; Schuster and Doerr, 2015). The overall benefits from oyster reef creation as part of an ER measure outweigh any short-term construction impacts. These benefits, coupled with the benefits from the other ER features, work together in the multiple lines of defense strategy to help protect the Texas coast.

Dune/Beach Restoration. Impacts to the aquatic community could occur in the Gulf portions of the project area due to increased water-column turbidity that can be expected during construction of the dune/beach restoration feature. Impacts associated with temporary disturbances to water-column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom and would be expected to return to normal once construction is completed. Renourishment of the feature would occur through standard renourishing every 5 to 10 years or continuously through a sand motor. Renourishment of the measure throughout the period of operation would cause short-term water-column turbidity during placement. If a sand motor is used, large amounts of sand would be deposited at one location along the shoreline near the feature. Placement of the sand would cause benthic organisms to be smothered and water-column turbidity impacts as described above for the Coastal Barrier. However, no long-term impacts to the aquatic community are anticipated resulting from dune/beach restoration features.

5.4.2.2.2 Bay Rim Alternative

Bay Rim CSRM System

The Bay Rim would result in a permanent loss of 564.0 acres of open water and bay bottom habitat. About half of that loss would occur at Fred Hartman Bridge, which would also convert to deeper-water habitat resulting from the underwater footprint needed to construct the surge barrier gates.

Direct impacts associated with constructing the Bay Rim would be similar to those described for the Coastal Barrier, with the exception of the smaller open water impacts. The Bay Rim has much less open water impacts compared to the Coastal Barrier. Minimal indirect impacts are anticipated with this alternative.

Open bay and bay bottom habitat would be disturbed during construction of the Bay Rim. The same types of temporary disturbances to water-column turbidity and construction impacts would occur as those described for the Coastal Barrier. Turbidity and bottom conditions would be expected to return to normal once construction is completed. Effects on salinity and velocity have not been modeled for the Bay Rim. Similar effects to those caused by the Coastal Barrier may be expected with reduced flow through the barrier, reduced tidal amplitude upstream of the barrier, and periodically measurably higher velocities around the surge barrier gates. Aquatic organism exchange between upper Galveston Bay and Tabbs/Upper San Jacinto/Burnet bays and Buffalo Bayou could be impeded with construction of Bay Rim. However, due to this measure being located in the upper portions of

Galveston Bay, impacts would not be as great as those seen with the Coastal Barrier, which reduces flow to the entire bay complex. Gates at Clear Lake, Dickinson Bay, and Offatts Bayou could also impede aquatic organism exchange with lower Galveston Bay.

Oyster Reef. A total of 0.03 acre of oyster reef falls in the direct footprint of the Bay Rim and would be lost resulting from this measure. Impacts to nearby oysters during project construction would be the same as those described for the Coastal Barrier. The interagency team has noted that oysters do occur in locations that are not included in the GLO dataset, specifically where the proposed Galveston ring levee/floodwall would cross Offatts Bayou and along the bay shoreline. A more detailed impact assessment, including additional oyster information from the interagency team, will be conducted on the TSP in future planning and design phases. Due to the small amount of impact, mitigation for oysters would be determined during future planning and design phases to include this and any additional impacts.

South Padre Island CSRM Measure and ER Measures

Impacts to the estuarine habitats and fauna resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.3 Wildlife Resources

5.4.3.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Most of the levee barrier would be placed adjacent to roadways and developed areas. The proposed levee would be located parallel to SH 87 and TX-124. Construction of the levee barrier would further limit and fragment the wildlife corridors between adjacent habitats from the Gulf-bay side of Bolivar Peninsula and east-west through wetlands and pastures near Anahuac NWR (Beier et al., 2008). Due to the proximity of construction along the Gulf coast, it is expected that shorebirds and coastal wildlife would be most impacted by the Coastal Barrier. Construction activity and noise can potentially disrupt and disturb wildlife behavior and their ability to hear (Dufour, 1980). Clearing and grubbing vegetation would remove potential habitat for wildlife species. Wildlife can avoid the area and potentially relocate away from the project area to adjacent habitat.

Once construction of the levee barrier and surge barrier gate are completed, terrestrial wildlife displaced from construction activity would be able to recolonize the earthen levee and access corridors to adjacent habitat. It would be assumed that the levee barrier would be routinely maintained, regularly mowed, and vegetation prevented from growing on the structure (Bayoumi and Meguid, 2011). Levees on Bolivar Peninsula would maintain the existing coastal dune habitat characteristics. The marshes and wetlands impacted by the levee barrier are in previously impacted areas, parallel to the highway or along grazed cattle pastures. Wildlife resources along Galveston Bay would benefit in the long-term risk reduction from coastal storms. No long-term impacts to wildlife resources are anticipated from the construction of the Coastal Barrier.

South Padre Island CSRM Measure

Impacts to wildlife from the South Padre Island CSRM measure would be limited. The placement area is located on beachfront residential and commercial property and does not provide pristine habitat for wildlife. South Padre Island beach is fragmented and used heavily for human recreation. Urban wildlife such as raccoons, rodents, and coyotes found within the area are highly adaptable and familiar with living near humans and would be able to occupy new habitats (Adams et al., 2005). For the coastal wildlife found within the project area, temporary construction activity and noise can disturb and disrupt foraging, nesting, and roosting behavior (Dufour, 1980). Construction and fill placement can temporarily increase turbidity and bury productive foraging habitat within the surrounding area. Turbidity can potentially inhibit bird foraging. Beach bulldozing can cause sand compaction and impact populations of sand and ghost crabs (Greene, 2002). Wildlife could avoid the construction area or potentially relocate to adjacent habitat. Future renourishment of the measure every 10 years would continue to temporarily affect wildlife within the project area. No long-term impacts are anticipated from the South Padre Island CSRM measure.

ER Measures

Revetment/Breakwater. Temporary disturbance of wildlife is expected during the construction and placement phase of the revetment and riprap breakwater. Localized turbidity is also expected around the riprap placement area, which might impact water quality and foraging efficiency for wildlife in the area (Greene, 2002). Once completed, breakwater and revetment structures can provide hard surface areas for oyster colonization and habitat for small fish, crustaceans, and mollusks, which provide food for wildlife such as raccoons, skunks, reptiles, and small mammals (see Section 5.4.2). Revetment and breakwater structures would also slow the rate of shoreline erosion of marshes, SAV, wetlands, and tidal flats, which are used by wildlife for foraging, nesting, and roosting (Swann, 2008). Overall benefits from revetment and breakwater structures as part of the ER measures likely outweigh short-term construction impacts.

Island Restoration. Short-term disturbance of island wildlife is possible during the construction, dredging, and placement phase of the project. Concrete blocks placed on the GIWW side of the island, used for erosion control, can impair nesting and foraging habitat. Island restoration is expected to increase vegetation coverage and increase available nesting habitats. Wildlife is expected to recolonize the island as soon as construction is completed with migratory birds, insects, rodents, and reptiles. Native and nesting platforms would provide additional habitat for bird species such as brown pelicans, double-crested cormorants, and great egrets (Schreiber and Schreiber, 1978). As the island matures, habitat for greater species diversity is expected to increase. Trees, shrubs, and groundcover would increase cover for nesting and roosting habitats and attract different species of wildlife (Michel et al., 2013; Schreiber and Schreiber, 1978). Long-term negative impacts are not expected with island restoration.

Marsh Restoration/Out-year Marsh Nourishment 2065. Short-term impacts to wildlife from marsh restoration and nourishment can include disturbance from construction activities, noise, and turbidity in the water column from dredging and sediment placement (Dufour, 1980; Greene, 2002; Michel et al., 2013). Impacts to water quality from turbidity are expected to be localized and temporary (Greene, 2002). Wildlife may relocate during the construction phase of the ER measures but would be expected to return to the area once the wetlands are restored (Greene, 2002; Rewa, 2007). Wildlife are expected to benefit from marsh restoration measures (Swann, 2008). The improved marsh habitat would include circulation channels and tidal access for marine life and provide shelter, forage, roost, and nursery habitat for wildlife.

Oyster Reef Creation. Oyster reefs are expected to be constructed away from the shoreline and would not directly affect terrestrial habitats. Construction of the oyster reefs can potentially cause turbidity in the water column, which can affect foraging for shorebirds and coastal wildlife. Once the reefs are completed, a functioning oyster reef can support an abundance of fish, crustaceans, and macroinvertebrates, which are food resources for wildlife such as raccoons, water snakes, and herons. In addition, oyster reefs and living shorelines would reduce wave action and protect vulnerable wildlife habitat close to the shoreline (Swann, 2008). There are no anticipated long-term impacts to wildlife resources from oyster reef creation.

Dune/Beach Restoration. During the period of construction, noise from machinery may disturb some wildlife and cause turbidity, potentially reducing bird foraging efficiency (Greene, 2002; Notice Nature, 2007). Disturbances to wildlife are expected to be a short term with recolonization of beaches and dunes once construction is completed. Upon completion, the restored beaches and dunes are expected to enhance wildlife habitat. Sand dunes and beaches would provide a natural barrier to erosive wind and wave action (United Nations Environment Programme, 2018).

5.4.3.2 Bay Rim Alternative

Bay Rim CSRM System

A majority of the levee associated with the Bay Rim would be placed on developed property and along the western rim of the Galveston Bay shoreline. Since most of the CSRM measure would be in developed areas, species affected would include urban wildlife, such as raccoons, rodents, and coyotes. Most of affected wildlife would be habitat generalists that traverse between urban areas to Galveston or West Bay uplands and marsh habitats. Urban wildlife are usually more adaptive to changes in the environment (Adams et al., 2005). The Bay Rim would have less of an impact on wetland and upland habitats than the Coastal Barrier. Segments of the Bay Rim would be constructed along areas that have been previously disturbed and fragmented. Nevertheless, construction activity and noise around the project area could potentially interfere with wildlife behavior and their use of corridors (Dufour, 1980). Grubbing and removal of vegetation along the levee footprint would decrease available woodland wildlife habitat. The levee barrier can potentially fragment the north-south migration corridor of wildlife from West Bay to developed areas north near Hitchcock and FM 2004. After construction, the earthen levee system would continue to allow wildlife to traverse and move through to adjacent habitat. No long-term impacts to wildlife resources are anticipated from the Bay Rim.

South Padre Island CSRM Measure and ER Measures

Impacts to wildlife resources resulting from the construction of the South Padre Island CSRM and ER measures would be the same as those described the Coastal Barrier Alternative.

5.4.4 Protected Resources

5.4.4.1 Protected Lands

5.4.4.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Approximately 300 acres within the Anahuac NWR are expected to be directly impacted by construction operations from the Coastal Barrier, including potential grubbing and clearing, levelling, and piling of fill material. The impacts would be limited to a section of the proposed levee system that would parallel the east side of SH 124 adjacent to the refuge north and west of High Island. Direct impacts from the proposed levee system are expected to result in permanent loss of approximately 100 acres of potential wetlands and marshes along the eastern and southern border of the refuge within the structure footprint and temporary impacts to wetlands and marshes due to construction of access roads and staging sites. The indirect impacts to the refuge are expected to result in changes to wildlife migration patterns and natural topography and drainage patterns of the area.

Approximately 70 acres within Galveston Island State Park are expected to be directly impacted by construction operations from the Coastal Barrier, including potential grubbing and clearing, levelling, and piling of fill material. The impacts would be limited to a section of the proposed levee system on Galveston Island that would parallel the north side of FM 3005 adjacent to the park. The park is already bisected by FM 3005. Direct impacts from the levee system would continue to fragment the coastal ecosystem of the barrier island and decreased accessibility between the two halves of the park.

Upon completion of the Coastal Barrier, several Federal, State, and privately owned protected lands within the Galveston Bay region would indirectly benefit from the coastal levee protection measures by gaining risk reduction from storm surges and RSLR. These areas include the Atkinson Island WMA and Candy Abshire WMA owned by TPWD, Moody NWR owned by USFWS, North Deer Island owned by the Audubon Society, and Scenic Galveston Preserve owned by Scenic Galveston.

South Padre Island CSRM Measure

The beach and dune restoration feature footprint proposed for South Padre Island does not overlap with any Federal, State, local, or privately owned protected lands. Therefore, no direct impacts are expected in conjunction with the measure. Other protected lands outside of the measure footprint, including the Lower Rio Grande Valley

NWR and Laguna Atascosa NWR owned by USFWS, would most likely receive some level of risk reduction from storm surges and RSLR provided by the restored beach and dune complex on South Padre Island.

ER Measures

Revetment/Breakwater. Constructing the revetments/breakwaters would result in a permanent loss of approximately 240 acres of bay bottom habitat in the upper and mid Texas coast. Specifically, approximately 35 acres of the Anahuac NWR, 113 acres of the Brazoria NWR, 13 acres of the Justin Hurst WMA, 68 acres of the San Bernard NWR, and 9 acres of the Big Boggy NWR would be converted from bay bottom habitat to rock revetments/breakwaters that would act as shoreline stabilization features. No long-term impacts are anticipated from construction, dredging, or placement activities associated with the construction of the revetment/breakwater features. Although there is a permanent loss of bay bottom habitat within the structural footprints, the measures would protect valuable wetland and marsh habitats from eroding and would provide resiliency against coastal storms and RSLR.

Island Restoration. Island restoration footprints do not overlap with any Federal, State, local, or privately owned protected lands. Therefore, no direct impacts are expected in conjunction with the island restoration features. Other protected lands outside of the measure would most likely experience indirect effects and benefit from the increased protection provided by the islands.

Marsh Restoration. Approximately 500 acres of protected lands are expected to be restored by the marsh restoration features and would be subject to temporary impacts during construction. Specifically, approximately 31 acres of the Anahuac NWR, 2 acres of the Muddy Marsh Bird Sanctuary owned by TNC, 320 acres of the Brazoria NWR, 15 acres of the Justin Hurst WMA, 130 acres of the San Bernard NWR, and 5 acres of the Big Boggy NWR would be temporarily impacted during construction but would ultimately benefit as restored marsh. The overall benefits from the marsh restoration features as part of the ER measures are expected to outweigh short-term construction impacts. Wetlands and marshes provide numerous benefits, including improvement of water quality, flood attenuation, esthetics, and recreational opportunities, as well as mitigating for RSLR and impacts to coastal infrastructure and ecosystems from storm events (USFWS, 2018h).

Out-year Marsh Nourishment 2065. Approximately 18,500 acres of Federal, State, or privately owned lands are expected to be restored by the out-year marsh nourishment features and would be subject to temporary impacts during construction. This includes approximately 2,500 acres of the Anahuac NWR, 30 acres of the McFarlane Marsh owned by TNC, 6,250 acres of the Brazoria NWR, 2,000 acres of the Justin Hurst WMA, 6,000 acres of the San Bernard NWR, and 1,700 acres of the Big Boggy NWR would be impacted during construction but would ultimately benefit as restored marsh. The benefits are expected to outweigh short-term construction impacts. Wetlands and marshes provide numerous benefits, including improvement of water quality, flood attenuation, aesthetics, recreational opportunities, and mitigating RSLR impacts to coastal infrastructure and ecosystems from storm events (USFWS, 2018h). The out-year marsh nourishment features would provide a long-term approach to enhance resiliency of coastal communities and improve our capabilities to prepare for, resist, recover, and adapt to coastal hazards.

Oyster Reef Creation. Approximately 2 acres of bay bottom habitat within the Brazoria NWR would be directly impacted resulting from oyster reef creation along the eastern shorelines of Oyster Lake in West Bay. However, the overall benefits of oyster reef creation are expected to outweigh short-term construction impacts to the refuge. Oyster reef creation would protect valuable wetland and marsh habitats from eroding, act as a shoreline stabilization alternative, and provide resiliency against coastal storms and RSLR (Schuster and Doerr, 2015). No other direct or indirect impacts to Federal, State, or privately owned lands are expected resulting from these features.

Dune/Beach Restoration. Approximately 1,950 acres of protected lands are expected to be impacted by the dune and beach features and would be subject to temporary impacts during construction, including pumping and spreading of material on the shoreline, planting of dune vegetation, and installment of sand fencing for erosion control. Specifically, approximately 70 acres of McFaddin NWR, 330 acres of Anahuac NWR, 20 acres of Bolivar Flats Shorebird Sanctuary, 130 acres of Galveston Island State Park, and 1,400 acres of the Padre Island National Seashore would be temporarily impacted during construction but would ultimately benefit from the restored beach and dune profile.

5.4.4.1.2 Bay Rim Alternative

Bay Rim CSRM System

The proposed levee system and surge barrier gate structures of the Bay Rim are expected to indirectly impact State and Federally owned lands. No protected lands are within the footprint of the measure, and therefore, no direct impacts are expected. Other protected lands outside of the Bay Rim would most likely not be affected by the proposed levee system or surge barrier gate structures. Upon completion of the Bay Rim, water velocities could potentially increase near the structures and decrease exchange into and out of Galveston Bay. Atkinson Island WMA, which is located in the very northern tip of Galveston Bay on the edge of Harris and Chambers counties, could be indirectly impacted resulting from the erosional effects from increased velocity against the northern portion of the island. Protected lands upstream of the proposed levee system and gate structure, such as the San Jacinto Battleground and Battleship Texas State Historic site, may experience inundation and drainage issues when the gates are closed during storm surge events.

South Padre Island CSRM Measure and ER Measures

Impacts to protected lands resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described the Coastal Barrier Alternative.

5.4.4.2 Threatened and Endangered Species

There are 23 Federally listed threatened or endangered species with potential to occur within the proposed alternatives project areas (Table 5-8). Federally listed species that potentially occur within these project areas include the endangered prairie dawn-flower, interior least tern, northern aplomado falcon, whooping crane, Kemp's ridley sea turtle, and hawksbill sea turtle. Federally listed threatened species include West Indian manatee, piping plover, red knot, green sea turtle, and loggerhead sea turtle. Candidate species include red-crowned parrot, golden orb, smooth pimpleback, Texas fawnsfoot, and Texas pimpleback. The CSRM and ER measures are not expected to have an impact on the following listed species: slender rush-pea, South Texas ambrosia, Texas ayenia, Attwater's greater prairie chicken, ocelot, Gulf coast jaguarundi, blue whale, fin whale, humpback whale, sei whale, sperm whale, leatherback sea turtle; and candidate species: red crowned parrot, golden orb, smooth pimpleback, Texas fawnsfoot, and Texas pimpleback (USFWS, 2018g). Species not affected by the CSRM and ER measures lack suitable habitat within the project areas. They are found farther inland in upland, forested woodlands, or freshwater riverine habitat. The species life history, habitat preference, and potential effects of the project on Federally protected species are considered in more detail in the Biological Assessment provided in Appendix C-3.

5.4.4.2.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Dredging and other marine construction activities could potentially impact sea turtles and manatees. The construction of the surge barrier gates could impair and prevent manatee and sea turtle migration, feeding, and reproductive behavior. Construction can produce underwater vibrations and noise at many different low and high frequencies, which could disrupt marine mammal communication (Peng et al., 2015). During construction, increased traffic with construction vehicles, ships, and barges through the Houston Ship Channel may increase the likelihood of collisions with slower-moving species such as sea turtles and manatees (Department of Environmental Resources Management, 1995; NOAA, 2017d). The dredging of fill material for levees can injure or kill sea turtles, and increased turbidity can impede foraging ability of visual predators like sea turtles, piping plovers, red knots, and least terns (Greene, 2002). Construction activity near tidal flats and sand dunes may affect the behavior of overwintering piping plovers and red knots, if present. Construction activity near tidal flats and sand dunes may affect behavior of overwintering piping plovers and red knots due to increased construction noise and lighting. Increased artificial lighting on the construction beachfront may potentially disorient nesting and hatching sea turtles (NOAA, 2014). Disorientation of nesting female turtles and hatchlings and injury to sea turtles

Table 5-8
Endangered, Threatened, or Candidate for Listing Species of Potential County[1]
Occurrence in the CSRM and ER Project Areas

Common Name	Scientific Name	Federal Status	Potential of Occurrence within the Project Areas
PLANTS			
Slender rush-pea	*Hoffmannseggia tenella*	E	No
South Texas ambrosia	*Ambrosia cheiranthifolia*	E	No
Texas ayenia	*Ayenia limitaris*	E	No
Texas prairie dawn-flower	*Hymenoxys texana*	E	Yes
BIRDS			
Attwater's prairie chicken	*Tympanuchus cupido attwateri*	E	No
Interior least tern	*Sterna altillarum*	E	Yes
Northern aplomado falcon	*Falco femoralis septentrionalis*	E	Yes
Piping plover	*Charadrius melodus*	T	Yes
Red knot	*Calidris canutus rufa*	T	Yes
Red-crowned parrot	*Amazona virdigenalis*	C	No
Whooping crane	*Grus americana*	E	Yes
MAMMALS			
Gulf coast jaguarundi	*Herpailurus yagouaroundi cacomitli*	E	No
Ocelot	*Leopardus pardalis*	E	No
Blue whale	*Balaenoptera musculus*	E	No
Fin whale	*Balaenoptera physalus*	E	No
Humpback whale	*Megaptera novaeangliae*	T	No
Sei whale	*Balaenoptera borealis*	E	No
Sperm whale	*Physeter macrocephalus*	E	No
West Indian manatee	*Trichechus manatus*	E	Yes
REPTILES			
Hawksbill sea turtle	*Eretmochelys imbricata*	E	Yes
Kemp's Ridley sea turtle	*Lepidochelys kempii*	E	Yes
Leatherback sea turtle	*Dermochelys coriacea*	E	No
Green sea turtle	*Chelonia mydas*	T	Yes
Loggerhead sea turtle	*Caretta caretta*	T	Yes
MOLLUSKS			
Golden orb	*Quadrula aurea*	C	No
Smooth pimpleback	*Quadrula houstensis*	C	No
Texas fawnsfoot	*Truncilla macrodon*	C	No
Texas pimpleback	*Quadrula petrina*	C	No

Source: USFWS (2017a, 2018g) and NMFS (2016a)

E – Endangered; T – Threatened; C – Candidate for Federal listing

[1] Counties within the project area include Brazoria, Calhoun, Cameron, Chambers, Galveston, Harris, Kenedy, Matagorda, Nueces, and Willacy.

can be avoided by turning off or shielding visible lights facing nesting beaches, switching to low-pressure sodium vapor-lighting or amber-colored lights, tinting windows, and closing the curtains or blinds to cover windows facing the beach (Sea Turtle Conservancy, 2017).

The operation of surge barrier gates under both action alternatives may potentially affect sea turtles and shorebirds by changing the hydrology and salinity characteristics of the respective areas. The surge barrier gates may impede movement or strike marine mammals and sea turtles (Department of Environmental Resources Management, 1995; NOAA, 2017d). Upon completion, the levee is expected to shield a small amount of light from the bay side of the levee. This may benefit some threatened and endangered species sensitive to light pollution.

The Coastal Barrier would directly impact 89 acres of designated piping plover critical habitat at the southern tip of Galveston Island, Unit TX-34: San Luis Pass during construction of the levee barrier (USFWS, 2017c). Portions of critical habitat would be impacted from the footprint of the levee barrier. Adjacent critical habitat would be temporarily impacted by earth moving activity, placement of fill material, and burial of resources. Impacts to piping plovers can be minimized by avoiding foraging grounds and roosting areas, reduction of oil and gas leaks from vehicles, restricting activities within coastal foredunes, and avoidance of driving within the swash zones (USFWS, 2009). Once completed the levee barrier feature would provide storm protection and shoreline stabilization for piping plover critical habitat.

South Padre Island CSRM Measure

The South Padre Island CSRM measure is expected to impact piping plovers, red knots, and sea turtles due to placement of fill material on tidal flats and beach, which could bury foraging and roosting habitat. Dredging of fill material from offshore sources could injure or kill sea turtles and manatees or increase turbidity, potentially impairing feeding efficiency. Construction windows will be constrained to time frames when protected and listed species are less likely to be present in the project area; those construction windows will be identified through collaboration with the interagency team. In addition, turtle deflecting devices will also be utilized to avoid impacts (Greene, 2002; NOAA, 2017d). Construction activity and noise from bulldozers and heavy machinery used to shape the dunes and beach can disrupt piping plovers, least terns, northern aplomado falcons, red knots, and sea turtles foraging, nesting, and roosting behavior (Bottalico et al., 2015; Greene, 2002). Artificial beach front lighting from construction vehicles which can cause disorientation of nesting females and hatchlings can be reduced by covering or shielding lights and windows or substituting with alternative bulbs (Sea Turtle Conservancy, 2017). Constructed beach profiles are expected to mimic the natural slope and sand composition (grain size, shell content, etc.) of the beach to promote sea turtle nesting (Brock et al., 2007). Coarse sediments or high in shell content, potentially associated with dredged material, may inhibit shorebird ability to probe and extract macroinvertebrates and food particles from the sand (Greene, 2002); however, beach-quality sand would likely be used for the nourishment. Benthic macroinvertebrates impacted by the placement of fill material are expected to return to pre-construction conditions a year after placement (Michel et al., 2013).

Beach nourishment is expected to benefit sea turtles by restoring eroded beach nesting habitat (Greene, 2002). The South Padre CSRM measure is expected to benefit green, Kemp's ridley, and loggerhead sea turtles that are known to nest on the island (Turtle Island Restoration Network, 2018). Federally listed shorebirds and sea turtles are expected to benefit from the project since beach habitat would be expanded for nesting, foraging, and roosting habitat.

There is no piping plover critical habitat designated near the South Padre Island CSRM measure (USFWS, 2017c). There are no temporary or permanent impacts to critical habitat anticipated from this measure.

ER Measures

Revetment/Breakwater. Movement of construction vehicles and barges with riprap or revetment material along the GIWW could potentially increase the risk of a collision with an animal (NOAA, 2017d). Navigational lighting on revetments or breakwaters may also disorient sea turtles (NOAA, 2014). There are no known sea turtle nesting sites along the GIWW due to lack of suitable habitats; therefore, impacts to sea turtles from these ER features are not expected (Turtle Island Restoration Network, 2018). Revetments and breakwaters are expected to benefit Federally listed shorebirds such as piping plovers, red knots, and least terns. Breakwater and revetment structure would provide a hard surface for oysters and clams to colonize. Colonized hard structures such as breakwaters can provide habitat for fish, crabs, and invertebrates, which would attract red knots and whooping cranes (see Section 5.4.2.2; Cornell Lab of Ornithology, 2018). Accretion of sand and sediments behind the breakwater structure would increase tidal flat areas for foraging and loafing shorebirds such as piping plovers (USFWS, 1996). Revetment/breakwater ER features would also indirectly benefit Federally listed shorebirds and inland species by providing coastal shoreline protection from erosive wave action from barge traffic or rising sea levels.

Approximately 4 acres of piping plover critical habitat would be impacted (USFWS, 2017c). The impacts to Unit TX-37: Rollover Pass are expected to be permanent with riprap or revetment structures and placement. However, the breakwater would stabilize the shoreline and prevent further erosion from storms and ship wake. The ER measure is expected to provide a net benefit to critical habitat and undesignated piping plover and rufa red knot habitat by protecting vulnerable habitat from erosion.

Island Restoration. Due to lack of suitable habitat, there are no known sea turtle nesting locations along the GIWW (Turtle Island Restoration Network, 2018). Impacts to sea turtles are not expected to result from island restoration measures. Prey species, such as marine worms, small crustaceans, and small mollusks that piping plovers and red knots rely on may become buried with sediment placement on islands, but these impacts would be temporary (Michel et al., 2013). Turbidity is expected to be localized to the placement area and would quickly disperse or settle down (Greene, 2002). In the long term, piping plovers, red knots, and northern aplomado falcons would benefit from the ER features due to increased island size and stability for foraging, nesting, roosting, and hunting (Greene, 2002; Schreiber and Schreiber, 1978). No long-term effects are anticipated from island restoration ER features.

Marsh Restoration. There are four ER measures that are proposed to restore approximately 1,871 acres of marsh along the Texas Gulf coast. Potential impacts to Federally listed species would primarily occur during the construction phase when placement of fill, construction vehicle activity, and noise can disturb wildlife and create turbidity (Greene, 2002). Prairie dawn-flowers are primarily found at the base of pimple mounds or in barren areas on slightly saline soils. Avoiding and minimizing the alteration of the hydrology and physical characteristics of these structures should be considered when operating construction vehicles and constructing containment levees for marsh restoration (USFWS, 1989). Post-construction, threatened and endangered species would benefit from the restored wetlands and marshes. A restored marsh would attract blue crabs, amphibians, and provide cover and nesting habitat for whooping cranes (Cornell Lab of Ornithology, 2018). Overall, restored marsh and wetlands would provide improved habitat for plants and wildlife and a coastal buffer from RSLR and storms.

Approximately 7 acres of piping plover critical habitat would be impacted within Unit TX-37: Rollover Pass (USFWS, 2017c). Temporary impacts to critical habitat include bulldozing, placement of dredge material, and burying habitat. There are no anticipated permanent impacts to critical habitat from marsh restoration.

Out-year Marsh Nourishment 2065. Construction activity, noise, and turbidity may disturb wildlife within the area. However, effects on Federally listed species are not expected since most out-year marsh nourishment areas are away from critical habitat (USFWS, 2017c). There are no reports of sea turtles, piping plovers, red knots, or whooping cranes reported near the GIWW or marsh nourishment footprints. Piping plovers and red knots are usually found in sandy coastal tidal flats, whooping cranes are normally located near Aransas NWR, and there is no sea turtle nesting habitat along the GIWW (Cornell Lab of Ornithology, 2018; Turtle Island Restoration Network, 2018; USFWS, 2018g). After construction is complete, there may be potential foraging and wintering habitat available for whooping cranes (Cornell Lab for Ornithology, 2018).

Approximately 2 acres of piping plover critical habitat would be impacted within the Unit TX-37: Rollover Pass tract (USFWS, 2017c). Impacts to the critical habitat would include earth moving, placement of fill material, and burial of vegetation and habitat. The impacts are expected to be temporary, and conditions along the designated critical habitat are expected to improve and return to historic conditions once construction is completed. These ER features are expected to improve and stabilize marsh functionality, which would provide additional resources for the plovers.

Oyster Reef Creation. Oyster cultch placement via boat or barge would produce localized turbidity, boat traffic, and construction noise. These actions could temporarily affect Federally listed species but would be limited to the period of construction only (Greene, 2002; Peng et al., 2015). Oyster reefs provide habitat and attract a variety of fish, crustaceans, and invertebrates. Piping plovers, red knots, whooping cranes, and sea turtles would directly benefit from additional food resources and improved water quality from oysters (NOAA, 2018c). The overall benefit from oyster reefs are expected to outweigh short-term construction impacts. In addition, oyster reefs also provide shoreline protection from waves, floods, and tides.

Dune/Beach Restoration. Construction of sand dunes would add additional hunting and nesting habitat available for aplomado falcons which are typically found in sand ridges in coastal prairies along the barrier islands (USFWS, 1990). Sea turtles are known to nest on South and North Padre islands and therefore would be temporarily impacted by the ER feature. The beach on the north and south side of the Port Mansfield Channel is an important nesting site for Kemp's ridley sea turtles and is a designated critical habitat for piping plovers. Piping plovers, red knots, and other shorebirds may be temporarily disturbed by pipelines, bulldozers, and other construction activities during the placement of sediment material and beach shaping. Disturbances to listed species are expected to be short term; the species are expected to return and recolonize beaches and dunes once construction is completed. Restored dunes and beaches are also expected to indirectly benefit threatened and endangered species by protecting coastal habitat and providing a barrier to erosive wave action and RSLR.

There are approximately 388 acres of piping plover critical habitat from Unit TX-36: Bolivar Flats to Unit TX-34: San Luis Pass (USFWS, 2017c). Impacts to critical habitat would be temporary and would include construction activities associated with beach nourishment and environmental restoration (e.g., placement of dredge material, contouring using bulldozers, and planting of dunes with native species). There are no anticipated permanent impacts to critical habitat associated with the project. Tidal areas and beach habitat would be enhanced and continue to provide foraging, nesting, and loafing habitat for piping plovers.

5.4.4.2.2 Bay Rim Alternative

Bay Rim CSRM System

Construction noise and turbidity from construction of navigational gates between Hog and Spillmans islands can disturb individuals and limit visibility, potentially affecting foraging and migrating sea turtles and marine mammals within Galveston Bay. Nesting habitat for sea turtles would not be impacted since there are no sandy beaches or suitable habitat found along the west side of Galveston Bay (Turtle Island Restoration Network, 2018). Construction noise and activity around the Texas City Prairie Preserve could potentially disturb aplomado falcons and other migratory birds within the area (Bottalico et al., 2015). Construction activity is also expected to disturb populations of Federally listed shorebirds such as piping plovers, rufa red knots, and least terns that have been observed foraging and loafing along the Texas City Dike, Tarpey Park, and Pine Gully Park. Construction noise and turbidity associated with the placement of fill near the bay can inhibit communication between the birds and decrease foraging rates (Bottalico et al., 2015; Greene, 2002). The effects are expected to be localized and temporary (Michel et al., 2013).

The operation of the surge barrier gates can potentially impede or harm migrating sea turtles attempting to traverse upstream to the San Jacinto River. There are no anticipated impacts to Federally listed birds, mollusks, fish, amphibians, cetaceans, or mammals after the completion of the Bay Rim. A greater portion of the Bay Rim is developed and would impact less wetland and beach habitat.

The Bay Rim would result in less impact to threatened and endangered species and their critical habitat when compared to the Coastal Barrier since much of the area is developed. There are no anticipated impacts to any Federally designated critical habitat for whooping cranes or piping plovers (USFWS, 2017c).

South Padre Island CSRM Measure and ER Measures

Impacts to threatened and endangered species because of the construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.4.3 Migratory Birds

5.4.4.3.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Construction of the Coastal Barrier, the surge barrier gates at Bolivar Roads, the GIWW, Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall) can temporarily indirectly affect migratory birds. Activity, lighting, and noise during the construction of the levee, gates, and floodwalls can disturb, disorient, and harm migratory birds. Construction noise can mask bird calls and reduce their abilities to communicate. Construction activity near tidal flats and beach areas can displace shorebirds and gulls (Bottalico et al., 2015). Turbidity from dredging activities and sediment placement in the water column can decrease foraging rates and cause birds to relocate to adjacent habitats (Greene, 2002). Migratory birds may benefit from the Coastal Barrier by long-term protection of habitat from coastal storms. The levee on Bolivar Peninsula would maintain the historical coastal dune habitat characteristic and provide nesting habitat for migratory plovers and sandpipers (TPWD, 2018b). Completed levee barriers and floodwalls along the coast could limit recreational vehicular traffic to tidal flat and beach areas which could limit human disturbance to birds. Once operational, however, lighting could disorient migrating birds and the structures could also increase the risk of bird strikes.

South Padre Island CSRM Measure

South Padre Island CSRM measure can potentially impact migratory birds due to placement area burying foraging and roosting habitats. Benthic macroinvertebrates that plovers and sandpipers feed on are expected to return to pre-construction conditions a year after project completion (Michel et al., 2013). Construction activity and noise from bulldozers and heavy machinery shaping the dunes may disturb roosting and foraging birds (Bottalico et al., 2015). Increased turbidity and sediments in the water column can impede foraging capabilities and cause birds to relocate to adjacent habitats. Impact to turbidity would be localized and is expected to normalize once dredging and construction is completed (Greene, 2002; Wilber et al., 2010). Beach nourishment every 10 years would cause short-term water-column turbidity during placement activities. Benefits include an expanded shoreline for foraging, nesting, and roosting for migratory shorebirds and coastal habitat buffer from future storm events.

ER Measures

Revetment/Breakwater. Construction of revetments and placement of breakwaters can disturb migratory birds roosting or loafing within the vicinity (Dufour, 1980). Turbidity within the water column can decrease foraging efficiency of birds (Greene, 2002). Once completed, breakwater and revetment structures can provide hard structures for oyster colonization and habitat for fish, crustaceans, and mollusks, which would provide food for migratory birds such as oystercatchers, sandpipers, and plovers. The structures would indirectly benefit migratory birds by protecting vulnerable beaches, wetlands, and tidal flats from wave action and erosion. The structures would protect marsh, SAV, and oyster reef habitat from eroding, which in turn would protect marsh, beaches, and other valuable nursing grounds, loafing, and foraging habitat for migratory birds (Swann, 2008). There are no long-term impacts to migratory birds expected from the construction of revetments and breakwaters.

Island Restoration. Possible short-term impacts to island reconstruction can include increased turbidity from sediment placement and bird disturbance from construction activity. Overall, island restoration is expected to benefit to migratory bird species. The expansion and restoration of functionality to islands along the Texas coast can increase available habitat for nesting, foraging, and roosting for migratory birds. The construction of nesting platforms and native shrub plantings can attract birds to establish rookeries on the islands (Schreiber and Schreiber, 1978). There are no long-term impacts expected with the restoration of islands.

Marsh Restoration/*Out-year Marsh Nourishment 2065*. During construction, migratory birds may be disturbed by human activity and relocate to adjacent habitats (Bottalico et al., 2015). After construction is completed, wetland restoration measures would benefit migratory birds by providing forage, roosting, and nesting habitat (Schreiber and Schreiber, 1978; Stewart, 2016). Marsh nourishment construction of containment levees and pumps, placement of fill within the levees, and creating sinuous circulation channels and pond with marsh buggies are expected to disturb and disrupt migratory birds (Bottalico et al., 2015; Michel et al., 2013). The restored marsh would provide shelter, forage, roost, and nursery and stopover habitat for migratory bird species (Stewart, 2016).

Oyster Reef Creation. Placement of oyster reef balls may disturb the bay bottom and create localized turbidity. Turbidity would be temporary, and conditions are expected to normalize after reef construction is complete (Greene, 2002). Oyster reefs can indirectly benefit migratory birds similarly to breakwaters, by providing fisheries, crustacean, and benthic macroinvertebrate habitats, and stabilizing shoreline. Oyster reefs can provide food for migratory species, such as oystercatchers, godwits, and plovers. In addition, oyster reefs and living shorelines can reduce erosive wave action and protect bird habitat such as rookery islands and marsh (Swann, 2008). There are no anticipated long-term impacts to migratory birds from oyster reef creation.

Dune/Beach Restoration. Noise associated with construction can disturb waterfowl and other migratory birds (Bottalico at al., 2015). Sand dunes are also natural barriers for wave and wind action that could potentially erode the shoreline and fragile habitats (United Nations Environment Programme, 2018). Disturbances to wildlife are expected to be short term, and wildlife species are expected to return and recolonize beaches and dunes once construction is completed. Benthic macroinvertebrates provide important forage for shorebirds. Dredging impacts to benthic macroinvertebrates can be minimized by using similar grain-sized fill materials and avoiding the placement of fill during peak periods of larval recruitment (Wilber et al., 2010).

5.4.4.3.2 Bay Rim Alternative

Bay Rim CSRM System

The section of levees and floodwalls constructed along west Galveston Bay rim of the Bay Rim is not likely to affect many migratory bird species. Revetments and bulkheads currently along the Bay Rim are unlikely to provide suitable habitat for many migratory birds. Most of the impacts to migratory birds would occur along the West Extension of the Texas City HFPS. Most of the Texas City West Extension CSRM measures would be located close to existing roadway, railroads, and levee structures. These areas have been previously fragmented. Construction activity and noise could potentially interfere with migratory birds (Bottalico et al., 2015; Dufour, 1980). The Bay Rim would have less of an impact on wetland and upland habitats than the Coastal Barrier. After the construction of the Bay Rim is completed, migratory birds would continue to traverse across the levee barrier. No long-term impacts are anticipated from the Bay Rim.

South Padre Island CSRM Measure and ER Measures

Impacts to migratory birds associated with the construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.4.4 Essential Fish Habitat

The species that NMFS and the Gulf of Mexico Fishery Management Council identify in the study area as EFH are listed in Table 2-10. The categories of EFH that occur within the study area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves. EFH and all impacts associated with the project are described in detail in Appendix C-4. The following sections provide a brief summary of the impacts described in Draft EFH Assessment (Appendix C-4).

5.4.4.4.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Impacts from the Coastal Barrier on Federally managed species would be the same as those described in Section 5.3.2.2.1. The reduction of cross-section area at Bolivar Roads could impede the migrations and movements of various life stages of fish into and out of the Galveston Bay system. Tidal amplitude reduction means less of the marsh would be flooded, resulting in a loss of marsh surface area available for aquatic organisms to use as nursery habitat which could impact Federally managed species and their prey. Turbidity during construction would cause temporary disturbances but is general localized and short lived. No impacts from the slight decrease in average salinity is expected. Benthic organisms would be removed during construction of the Coastal Barrier but would be expected to recover over time.

No mapped oyster reefs fall in the direct footprint of the Coastal Barrier system; therefore, no direct impacts are anticipated. Water column turbidity increases that are expected during construction could temporarily affect survival or growth of oysters nearby. Lower salinity regime due to the reduced flow of water into and out of the bay and the longer retention times could indirectly affect oyster reef habitat. No long-term impacts to oyster reefs in the Galveston Bay system are expected.

South Padre Island CSRM Measure

Impacts to Federally managed species would be the same as those described in Section 5.3.2.2.1 and include increased water-column turbidity and sediment placement that would be expected during construction activities. No long-term impacts to the aquatic community are anticipated resulting from the South Padre Island CSRM measure.

ER Measures

Impacts to Federally managed species would be the same as those described in Section 5.3.2.2.1. Bay bottom habitat and open bay habitat would be lost, temporary disturbances to water-column turbidity would occur, but no long-term impacts to Federally managed species are anticipated. Although open bay and bay bottom habitat would be lost resulting from constructing ER features, the habitats created would benefit Federally managed species by attracting fish and invertebrate communities, and structures would protect valuable EFH habitats such as marsh, SAV, and oyster reef habitat from eroding, in turn protecting valuable nursery grounds for the many fish and shellfish species that live within these estuaries. The overall benefits from construction of the ER measures outweigh any short-term construction impacts and work together in the multiple lines of defense strategy to help protect the Texas coast.

5.4.4.4.2 Bay Rim Alternative

Bay Rim CSRM System

Impacts to Federally managed species resulting from construction of the Bay Rim would be similar to those described for the Coastal Barrier Alternative but on a smaller scale.

Direct impacts associated with constructing the Bay Rim would be similar to those described for the Coastal Barrier, with the exception of the smaller open water impacts. The Bay Rim has much less open water impacts compared to the Coastal Barrier. Minimal indirect impacts are anticipated with this alternative. Temporary disturbances to water-column turbidity and construction impacts would occur but are expected to return to normal once construction is completed. Although no modeling was conducted for the Bay Rim, similar effects to salinity and velocities caused by the Coastal Barrier may be expected. Aquatic organism exchange between upper

Galveston Bay and Tabbs/Upper San Jacinto/Burnet bays and Buffalo Bayou could be impeded with construction of Bay Rim. However, due to this measure being located in the upper portions of Galveston Bay impacts would not be as great as those seen with the Coastal Barrier, which reduces flow to the entire bay complex. A total of 0.03 acre of oyster reef falls in the direct footprint of the Bay Rim and would be lost resulting from this measure and impacts would be the same as those described for the Coastal Barrier Alternative.

South Padre Island CSRM Measure and ER Measures

Impacts to Federally managed species resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.4.5 Marine Mammals

West Indian Manatee. While the number of manatee migrating into Texas is small, construction activities or the presence of a physical barrier may discourage migrant or stray individuals from taking refuge in Galveston Bay due to similar disturbance concerns outlined below for bottlenose dolphin.

Bottlenose Dolphin. Direct threats to bottlenose dolphins from construction and operational activities may include damage caused by noise exposure (permanent or temporary threshold shifts) and collisions with increased vessel traffic and equipment. Additional consequences may initially appear less severe but occur more frequently and are often more important over the long term on a population level. These may include temporary or permanent changes to habitat availability, behavioral changes affecting energy budgets, changes to physical properties of waters (i.e., decreased salinity), and indirect temporary (e.g., construction) or long-term loss of aquatic habitat, and indirect effects on aquatic prey organisms.

Potential construction and operational impacts vary based on geographical project location, seasonality, and activity type. Impacts of highest concern to marine mammals from construction and operational project activities are categorized below.

Noise. Sound plays a critical role in the life of most marine mammals, and the impacts of noise are of increasing concern in the aquatic environment. Potential impacts on bottlenose dolphin populations utilizing Texas waters, include 1) the physiological effects of high-intensity sound exposure; 2) masking of biologically important sounds; and 3) behavioral disruptions that may result in a decline in vital rates.

High-intensity sound exposure from pile driving can cause direct physical injury to marine mammals in the form of permanent or temporary threshold shifts (Clark et al., 2009; Jensen et al., 2009; Nowacek et al., 2007). Dolphins rely heavily on sound for communication, navigation, predator avoidance, and foraging, using both active echolocation and passive listening for detection of prey (Allen et al., 2001; Nowacek et al., 2007; Tyack, 2008). Therefore, increased noise pollution in an important habitat could cause disruption to dolphin activities.

Noise reduction measures are necessary where unmitigated sound levels exceed desired thresholds. The effectiveness of noise mitigation measures are highly site specific and must be chosen carefully and validated based on real time conditions. Mitigation measures that may be used, but are not limited to, include bubble curtains, double-walled piles, Hydro Sound Dampers, noise mitigation screens, cofferdams, "soft-start" operational procedures, and dolphin exclusion zones (Elmer and Savery, 2014; Reinhall et al., 2015; Stokes et al., 2010; Würsig, Green, et al., 2000).

Dredging. Noise, vessel activity, sediment suspension, and habitat modification are all concerns surrounding dredging activities with the potential to cause negative consequences to dolphin populations. Pirotta et al. (2013) found that higher intensities of dredging, even in an area of high baseline industrial activity, caused bottlenose dolphins to spend less time in the important foraging sites. While few studies have focused on the effects of dredging on marine mammals, Todd et al. (2015) provide a review of available data and conclude that effects are likely to vary by location and equipment type.

Increased Vessel Traffic. Vessel traffic is expected to increase temporarily during construction due to vessel-based construction activities. Dolphins are known to change their behavior in response to vessel traffic (Bejder et al., 2006; Nowacek et al., 2001; Piwetz and Würsig, 2015; Allen and Read, 2000). While there are many factors that play into how vessels may affect behavior, a common trend implies that smaller vessels quickly changing speed and direction have more of an immediate behavioral effect than larger vessels on a steady path such as cargo ships. Short-term responses to vessels can range from attraction (bow riding) to changes in behavioral state, dive patterns, and orientation. Reactions to vessel traffic appear to be highly related to the environment and dolphin behavior, necessitating site-specific observations to validate assumptions made from other studies.

Physical Barrier. The operational presence of the surge barrier gates have the potential to act as a hindrance to dolphin movements. Operational closing of the gates for emergency hurricane preparations would entirely close off the pass. These closures have a potential for injury, noise disturbance, separation of social groups, effects on prey items, and disruption of foraging.

Prey Source. Dredging, changes in tidal prism, water quality, and the effects of physical barriers can all impact recruitment through passes by fish and shellfish, which are important prey sources for Texas bottlenose dolphin bay, sound, and estuary stocks. These factors have the potential to impact the availability of prey sources for Texas bottlenose dolphin BSE stocks.

5.4.4.5.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The location and size of the Coastal Barrier makes it the most likely structure to impact dolphin populations. The extended construction time and geographical extent of pile driving necessary to build the Bolivar Roads reach will make noise an important consideration for marine mammal stocks utilizing this region, as discussed above. The Bolivar Roads surge barrier gates have the potential to hinder dolphin movements in and out of the inlet. If dolphins are hesitant to pass through the vertical lift gate openings, functional passage may be restricted to the Houston Ship Channel surge barrier gate where there is the potential for vessel traffic impacts.

Mean salinity isohaline plots indicate that some areas of the bay where dolphins frequent may already be considered marginal dolphin habitat, dipping below the 11-ppt threshold for at least a portion of the year. Dolphin habitat use and health in these zones could be affected by even a small decrease in salinity under project conditions. Storm surge reductions in the bay afforded by the Coastal Barrier may provide protection to dolphins residing within the Galveston Bay estuary by reducing the risk of these dolphins being stranded “out of habitat” during a storm.

South Padre Island CSRM Measure

Impacts to marine mammals due to activities for the South Padre Island CSRM measure would be as described above for dredging operations and would be expected to occur during initial construction and renourishment of the measure every 10 years throughout the period of operation. Due to the Gulf coast location of this measure, minor disturbance may be expected for the Western Coastal Stock and possibly the Laguna Madre BSE stock. However, no long-term impacts to marine mammals are anticipated resulting from the South Padre Island CSRM measure.

ER Measures

ER measure impacts to marine mammals are expected to vary based on geographical location, seasonality, and activity type. ER features, including rock breakwaters and marsh restoration, which would occur behind these features and out-year marsh nourishment in 2065, incorporate land reclamation where bay bottom habitat and open-bay habitat would be lost. These losses have the potential to modify BSE dolphin habitat use and ranging patterns in the localized areas where they occur. Noise, dredging, and vessel activity during construction have the potential to cause short-term disruption to dolphin activities and possible temporary habitat abandonment as described above. Suspended sediment should be mitigated using silt curtains to avoid contamination of surrounding bay waters.

ER measures have direct benefits to marine mammals by providing improved water quality and enhanced production of prey organisms such as finfish, squid, and shrimp.

5.4.4.5.2 Bay Rim Alternative

The Bay Rim Alternative includes construction of surge barrier gates at inlets to Offatts Bayou, Clear Creek, Dickinson Bayou, and Tabbs Bay (Houston Ship Channel and San Jacinto River). The importance of these habitats to dolphins is not currently known, but they are likely to utilize them on occasion and impacts to travel in and out of these areas should be evaluated.

South Padre Island CSRM Measure and ER Measures

The effects of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.4.4.5.3 Summary

Table 5-9 presents a summary of the potential impacts and mitigation for Coastal Barrier and Bay Rim alternatives.

5.4.5 Hazardous Wildlife Attractants on or Near Airports

Due to the increasing concern about aircraft-wildlife strikes, the Federal Aviation Administration has implemented standards, practices, and recommendations for holders of Airport Operating Certificates issued under Title 14, CFR Part 139, Certification of Airports, Subpart D (Part 139), to comply with the wildlife hazard management requirements of Part 139. Airports that have received Federal grant-in-aid assistance must use these standards.

When considering proposed dredged spoil, beneficial use features, and mitigation areas, developers must take into account whether the proposed action will increase wildlife hazards. The Federal Aviation Administration recommends minimum separation criteria for land use practices that attract hazardous wildlife to the vicinity of airports. These criteria include land uses that cause movement of hazardous wildlife onto, into, or across the airport's approach or departure airspace or air operations area.

These separation criteria include:

- Perimeter A: For airports serving piston-powered aircraft, hazardous wildlife attractants must be 5,000 feet from the nearest air operations area (includes one airport within the study area);
- Perimeter B: For airports serving turbine-powered aircraft, hazardous wildlife attractants must be 10,000 feet from the nearest air operations area (includes two airports within the study area); and
- Perimeter C: 5-mile range to protect approach, departure, and circling airspace (includes four airports within the study area).

Table 5-9
Potential Impacts and Mitigation Summary for the Coastal Barrier and Bay Rim Alternatives

Action	Potential Threat(s)	Possible Mitigation Measures
Pile Driving	• Sound-induced permanent threshold shifts/temporary threshold shifts • Acoustic masking and behavioral disturbance o Habitat abandonment, (*including critical foraging habitat in Bolivar Roads) o Effects on energy budgets o Increased risk of predation, injury, and stranding	• Sound mitigation technology o Bubble curtains o Double walled piles o Noise mitigation screen o Cofferdams o Hydro Sound Dampers • Dolphin exclusion zones • "Soft start" procedures • Seasonal and/or diurnal timing in some locations
Dredging	• Sediment disruption o Increased exposure to contaminants (if present) o Effects on prey • Acoustic masking and behavioral disturbance o Habitat abandonment, (*including foraging habitat in Bolivar Roads) o Effects on energy budgets o Increased risk of predation, injury, and stranding	• Silt curtains • Seasonal and/or diurnal timing in some locations
Vessel Traffic	• Collision, physical injury • Acoustic masking and behavioral disturbance o Habitat abandonment, *including critical foraging habitat in Bolivar Roads o Effects on energy budgets o Increased risk of predation, injury, and stranding	• Vessel speed limits • "Safe" zones
Physical Barrier and other Actions	• Hindrance of travel in and out of pass* and bayou inlets by bottlenose dolphin • *Water quality consequences o Increased exposure to contaminants (if present) o Reduction of optimal habitat greater than 11 ppt or increased exposure to low salinity water • Habitat modification and displacement • *Increased tidal flow velocity at gates and decreased overall tidal prism in bay • Potential indirect impacts to primary prey species (e.g., shrimp, drum, flounder) during spawning migrations of adults to the Gulf and as larvae/juveniles immigrating back into estuaries	• Construction and operational measures to minimize impacts should be explored and addressed in engineering plans
In-water ER measures	• Acoustic masking and behavioral disturbance o Temporary habitat abandonment o Effects on energy budgets o Increased risk of predation, injury, and stranding • Sediment disruption o Increased exposure to contaminants (if present) o Effects on prey • Habitat modification/land reclamation	• Vessel speed limits • "Safe" zones • Seasonal and/or diurnal timing in some locations • Silt curtains

* Potential threat only included for the Coastal Barrier Alternative

Table 5-10 lists the public use airports that fall within the study area that must comply with these standards Proposed land uses for the Preferred Alternative were evaluated to determine if they could increase wildlife aviation hazards in the study area. The airports in the study area include Baytown, La Porte Municipal, Scholes International, Mustang Beach, McCampbell-Porter, and Charles R. Johnson. All six airports sell Jet-A fuel, and it was assumed that a separation distance of 10,000 feet for any of the hazardous wildlife attractants would apply in addition to the 5-mile range to protect approach, departure, and circling airspace. Certain land-use practices, such as waste disposal facilities, water management facilities, golf courses, agricultural cropland, and dredged material placement areas can act as attractants to wildlife that pose a strike hazard. Some natural areas, such as wetlands, may attract wildlife associated with aircraft strikes. According to the Memorandum of Agreement between the Federal Aviation Administration and the USACE, the top five bird groups involved in damage-inducing aircraft strikes are gulls, geese, hawks, ducks, and vultures. In addition, white-tailed deer are by far the most commonly struck mammal species (Federal Aviation Administration, 2003).

Table 5-10
Public Use Airports in the Study Area

Name	Site Number	City	County	Perimeter	Nearby Action	Distance (miles)
Baytown Airport	23412.1*A	Baytown	Harris	C	Alt 2	3.9
La Porte Municipal	24190.*A	La Porte	Harris	C	Alt 2	1.9
Scholes International	23915.*A	Galveston	Galveston	A, B	Alt 1 and 2, ER Gav beach/dune	0.9, 1.1
Mustang Beach	24528.2*A	Port Aransas	Nueces	C	ER Redfish Bay	3.8
McCampbell-Porter	24096.62*A	Ingleside	San Patricio	C	ER Redfish Bay	3.9
Charles R. Johnson	24543.*A	Port Mansfield	Willacy	B, C	ER Port Mansfield, Island Rookery	0.7, 2.1

Project features of the Coastal Barrier and Bay Rim alternatives and the ER measures that could serve as attractants are bird islands, placement areas, and beneficial use marsh restoration areas. There are several project features that could serve as attractants within the separation perimeters of nearby airports.

The Redfish Bay Protection and Enhancement (SP-1) ER measure is located within the 10,000-foot and 5-mile perimeter of Mustang Beach and McCampbell-Porter airports. In addition, Port Mansfield Channel, Island Rookery, and Hydrologic Restoration (W-3), the goal of which is to improve bird nesting, is located approximately 2.1 miles from Charles R. Johnson Airport, which is between the 10,000-foot and 5-mile perimeters. This project would likely increase the number and species of birds associated with aircraft strikes. Project features for the Coastal Barrier and Bay Rim alternatives and Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration (G-5) ER measure are within the separation buffers of Baytown, Scholes International, and La Porte Municipal airports; however, the infrastructure or action is not expected to serve as an attractant for wildlife species. A copy of the DIFR-EIS and notification letter will be sent to the Federal Aviation Administration.

5.5 CULTURAL RESOURCES

An initial assessment identified 210 previously recorded cultural resources including 96 archeological sites, 11 cemeteries, and 88 possible submerged archeological resources as well as 20 recorded National Register of Historic Places properties within the Coastal Barrier Alternative footprint. The primary consideration concerning cultural resources is the threat to archeological and historic sites from construction of CSRM and ER features and the associated staging and borrow areas. Additionally, there is a potential for direct impacts to submerged resources from dredging, the erosion of sites due to landscape modification, and visual impacts to historic buildings, structures, or districts from aboveground construction.

5.5.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

The upland areas along Galveston Island and the Bolivar Peninsula, outside of the city of Galveston, that have not been developed have a moderate to high probability for encountering intact prehistoric and historic archeological sites. Impacts from earth moving, levee/floodwall construction, and staging areas have a potential to impact historic properties in these upland areas. The material used to construct levees will be dredged from offshore in the Gulf, which poses a risk to submerged archeological resources. Within the city of Galveston, the construction of the ring levee and improvements to the Galveston seawall have a potential to impact both the physical aspects of adjacent historic properties and the historic setting, or view shed of historic buildings, structures, and districts. Additionally, there is a moderate to high probability for encountering historic archeological sites within the city of Galveston. The construction of the surge barrier gates across submerged lands at Bolivar Roads and portions of Galveston Bay has a moderate to high probability to impact submerged archeological resources. The surge barrier gate is also close to Fort Travis, a historic coastal fort built in 1899. However, the conceptual alignment for the levee and barrier was intentionally drawn to avoid any impacts to the fort.

South Padre Island CSRM Measure

The project area along South Padre Island includes the construction of a coastal dune along approximately four miles of beach with beach nourishment over subsequent years. The upland areas along this portion of South Padre Island have been extensively developed for residential and commercial use, and there is a low probability for encountering intact archeological deposits. However, there is a potential for encountering shipwrecks along the beach and in the shallow waters adjacent to the beach. Furthermore, beach nourishment material will be dredged from existing offshore dredged material placement areas that have a moderate to high probability for encountering submerged archeological resources, even if they have been previously investigated.

ER Measures

The probability for encountering intact archeological resources in the upland portions of these ER measures is moderate to high. These archeological resources may consist of prehistoric or historic terrestrial sites that may be exposed on shorelines or shallowly submerged. Activities in these upland areas such as nourishment of marshes and beaches (G-5, G-28, B-2, B-12, M-8, and W-3) are expected to have a minimal impact on the integrity of intact resources. However, beach nourishment material will be obtained by dredging material from offshore and there is a moderate to high potential for impacting submerged archeological sites in those areas. Earth-moving activities in the uplands that involve dune building and modifications to existing islands and landforms (G-5, G-28, B-2, CA-6, M-8, and SP-1) has a potential to adversely affect historic properties. Additionally, some measures include impacts to submerged lands including breakwaters and oyster reefs (G-28, B-12, CA-5, CA-6, M-8, and SP-1), as well as dredging in the Laguna Madre (W-3).

The Area of Potential Effect for the proposed undertaking includes the footprint of all areas of direct impacts and a 1,000-foot buffer for indirect impacts to standing structures or buildings as a result of new construction, construction of staging and access areas, ecosystem restoration features, offshore dredging, and project maintenance activities. Based on the current information for the preferred alternative, there is a potential to affect historic properties. These affects consist of direct impacts to upland and submerged areas, both inshore and offshore, from construction and maintenance of storm and flood risk management features, the construction and maintenance of ecosystem restoration features, and offshore dredging for beach nourishment. The USACE recommends intensive cultural resources investigations to identify and evaluate any historic properties within proposed areas of direct and indirect impacts. The scope of these investigations will be determined in concert with the Texas State Historic Preservation Officer and Native American Tribes and in accordance with the Draft Programmatic Agreement for this project. The Programmatic Agreement is currently being coordinated with applicable agencies. Once executed, it will be included in future planning and design phases of the project.

5.5.2 Bay Rim Alternative

The western rim of Galveston Bay has seen extensive development for residential, industrial, and commercial use. The potential for encountering intact prehistoric archeological sites is low to moderate. However, there is a moderate to high probability for encountering historic-age buildings, structures, and archeological sites. Impacts from the ring levee and improvements to the Galveston seawall, as well as impacts to submerged lands, are the same as for the Coastal Barrier. Impacts to cultural resources resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.6 SOCIOECONOMICS

5.6.1 Coastal Barrier Alternative

The Coastal Barrier and the South Padre Island CSRM measures of the Coastal Barrier Alternative would reduce risks to public health and safety associated with storm surges and reduce infrastructure damage. These risk reduction measures would allow businesses and industries to resume normal operations in a shorter period following a storm event and enhance the sustainability of the communities.

It is anticipated that local building codes would be in place, requiring the elevation of future construction in the area to address impacts from RSLR. The Coastal Barrier Alternative would also include nonstructural measures along the west side of Galveston Bay to address residual damages from wind-driven bay surges. Raising structure elevation is an approach presently employed and may be addressed further in future planning and design phases. The ability of lower income groups to participate in these programs could be impacted by out-of-pocket expenses, including temporary relocation costs during structure elevation and any additional costs possibly required to meet the eligibility criteria. This could potentially offset the risk reduction in overall social vulnerability in lower income communities. As nonstructural measures are further developed in future planning and design phases, additional considerations related to community cohesion and environmental justice concerns along the west side of the Galveston Bay will be reviewed.

It is not expected that the CSRM measures directly impact public facilities or services; however, public facilities could have temporarily interrupted services until the project is completed. Indirect impacts would include the reduced risk of damage from hurricane storm surge for public facilities and services.

There would be minor, temporary transportation impacts resulting from increased vehicular congestion along roads, highways, and streets during construction. There would also be a degradation of local roads and highways resulting from transporting construction materials. Indirect impacts would include a lower risk of storm-related damages to the transportation infrastructure protected by the proposed barrier, South Padre Island CSRM, and ER dune/beach nourishment.

The Ecosystem Restoration measures would reduce the adverse impacts to socioeconomic resources that are resulting from continued land loss and habitat fragmentation and degradation. The proposed action would increase marsh-related leisure activities and recreational and commercial fishing opportunities, resulting in positive, regional economic impact and improved sustainability.

5.6.2 Bay Rim Alternative

The socioeconomic resource impacts associated with the South Padre Island CSRM and ER measures would be the same as the Coastal Barrier Alternative. However, the location of the Bay Rim would have socioeconomic impacts in the upper coast region.

There is potential for induced flooding in the communities of Baytown and Santa Fe. Rural areas on the east side of Galveston Bay and structures along the barriers (West Galveston Island and Bolivar Peninsula) would still receive damages from hurricane surges. Overtopping of the levee by storm surge during extreme events would immediately inundate vulnerable populated areas and key emergency service routes. This risk is a key concern for communities such as La Porte, Santa Fe, and La Marque, where the Social Vulnerability Index is high and includes a large number of households with low-income, elderly, or minority populations.

The Bay Rim Alternative leaves many of the region's critical roadways at risk. The alignment near the bay rim would have direct impacts to the area's transportation infrastructure. There are notable impacts to the Port

Facilities along the bay rim since roadway and railway gates would have to be built to maintain water access. The bay rim construction would increase vehicular congestion along roads, highways, and streets during construction while also degrading transportation infrastructure due to the transport of construction materials.

5.7 NAVIGATION

5.7.1 Commercial and Waterborne Commerce

5.7.1.1 Coastal Barrier Alternative

Coastal Barrier CSRM System

Per McAlpin et al. (2018), at Bolivar Roads, the structural elements of the gate system would reduce the cross-sectional area of the inlet by 27.5 percent, constricting inlet tidal flows, and increase current velocities. Ship simulations will be required to determine if FWOP/FWP changes to the inlet's maximum and mean velocities would impact deep-draft vessel transits through the ship channel. Current velocity changes within Galveston Bay induced by the Coastal Barrier system should not impact commercial and recreational navigation. Construction of the surge barrier gates across Bolivar Roads would require constructing a temporary bypass for navigation to the north of the existing channel. Future ship simulation of the bypass channel alignment would ascertain vessel movement impacts and would inform decisions to adjust alignments to reduce impacts.

The USACE (2017) reported that in 2015 the Houston Ship Channel served 8,325 oceangoing vessels' arrival including break bulk, bulk carrier, containers, roll-on/roll-off, tankers, tug tow, and vehicle carriers. It is expected inbound transit of a similar number and mix of vessels would continue during and after construction of the surge barrier gates. Risks to navigation safety are expected to increase due to a reduction in vessel operating margin of error associated with the temporary bypass channel constrictions, outbound recreational and commercial vessel traffic, and mobilized construction platforms and permanent constrictions associated with the constructed surge barrier gates and outbound recreational and commercial vessel traffic.

The gate at Dickinson Bayou may induce slight increases in velocity by partially constricting tidal flows, potentially impacting smaller commercial vessels transiting the gates.

South Padre Island CSRM Measure

The CSRM measure proposed for South Padre Island is not expected to have an appreciable impact on navigation. Sediments placed for the dune/beachfill features are expected to migrate northward with the littoral drift, to be impounded by the Port Mansfield Channel immediately south of the jetty. Ultimately, the sediment buildup immediately south of the jetty would migrate into the entrance of the Port Mansfield Channel and add to the shoaling of the channel. The Port Mansfield Channel is a Federally authorized channel eligible for Federal maintenance; however, the USACE no longer prioritizes the Port Mansfield Channel for maintenance dredging since the purpose of the channel has evolved over time to become primarily recreational. However, the shoaling of the Port Mansfield Channel contributed by the South Padre Island CSRM measure would be offset by the need to dredge sediments from the channel as an ER measure feature to hydrologically restore Laguna Madre, with the added benefit of renourishing the shoreline of Padre Island National Seashore with dredged material.

ER Measures

There may be temporary impacts to navigation traffic within the GIWW during mobilization and positioning of floating construction platforms to construct the revetments/breakwaters, islands, and wetlands and marsh. The stabilized shoreline systems are anticipated to reduce shoaling into the GIWW. The reduction would fluctuate based on location and proximity to inlets and bay/GIWW interconnections. Sediments to restore the islands and for marsh restoration/nourishment may be harvested from the GIWW, which would contribute to the long-term maintenance of the waterway's operating depths.

With the dune/beach restoration, additional sediments would become available in the natural system and allow natural processes such as reworking, erosion, and deposition to take place and enhance sediment availability for longshore transport. Increase in shoaling through longshore transport can be expected at navigation entrance channels downdrift of ER beach and dune features. Locations of anticipated shoaling increases due to proposed ER beach and dune restoration features include Bolivar Roads and San Luis Pass. An increase in shoaling within the GIWW, from these expected overwash events, would induce an increase in maintenance dredging requirements of the waterway.

5.7.1.2 Bay Rim Alternative

Although not modeled, it is anticipated based on the Coastal Barrier system hydrodynamic analysis findings that the Bay Rim measure may induce slight increases in velocity by partially constricting tidal flows within Tabbs and Dickinson bays with the closure structures system. Ship simulations may be used to determine if FWOP/FWP changes to the Tabbs Bay current velocities would impact deep-draft vessel transits through the inlet's ship channel. Throughout the rest of Galveston Bay, the velocity magnitudes are expected to vary little between with- and without-project conditions. Therefore, current velocity changes within Galveston Bay induced by the Bay Rim measure should not impact commercial and recreational navigation.

The Bay Rim would have impacts on interactions between deep-draft ships and shallow-draft tugs and barges. The navigation channel at Tabbs Bay currently includes a north- and southbound shallow-draft channel adjacent to the deep-draft channel. If a gate is built at this location, the shallow-draft traffic would likely be forced to use the deep-draft channel to transition through the gate, or a design requirement could be established to grant the same navigational passages.

To construct the gate structures across the Houston Ship Channel at Tabbs Bay, a temporary bypass channel would first be constructed between the north bank and Hog Island. At Tabbs Bay, risks to navigation safety are expected to increase due to a reduction in vessel operating margin of error associated with the temporary bypass channel constrictions, outbound recreational and commercial vessel traffic, and mobilized construction platforms, and permanent constrictions associated with the constructed surge barrier gates and outbound recreational and commercial vessel traffic. To construct the gate structures across Dickinson Bay, a bypass channel or a temporary disruption in access will be necessary. Current users of Dickinson Bay include shallow-draft vessels and some large recreational vessels.

The Bay Rim would leave navigation infrastructure at risk to storm surges, since many of the ports and channels would be outside of the risk reduction system. Storm surge can move large amounts of sediment into the deep-draft navigation channel during an event, adding to the annual cost of maintenance dredging.

Impacts to the commercial navigation resulting from construction of the South Padre Island CSRM, and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.7.2 Recreational

5.7.2.1 Coastal Barrier Alternative

Impacts to recreational navigation would be similar to those described for commercial navigation, just increased, including temporary bypass channel access, higher velocities, and constricted access. Additional temporary impacts to recreational navigation traffic would be induced by construction of the flow control structures at Clear Creek, Dickinson Bayou, and Offatts Bayou, which are proposed to each consist of a single opening.

Impacts to resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.7.2.2 Bay Rim Alternative

Impacts to recreational navigation would be similar to those described for commercial navigation. Additional temporary impacts to recreational navigation traffic would be induced by construction of the flow control structures at Clear Creek and Offatts Bayou, which are both proposed to consist of a single opening. The structure at Dickinson Bay will consist of a navigation gate and environmental gates. The levee proposed along the bay perimeter would temporarily impact availability of recreational piers and permanently change the access from homes requiring stairs or walkovers across the levee to the piers.

Impacts resulting from construction of the South Padre Island CSRM and ER measures would be the same as those described for the Coastal Barrier Alternative.

5.8 FLOOD RISK REDUCTION

Texas City HFPP. Texas City HFPP is part of the Bay Rim Alternative with the line of risk reduction being extended on either end of the current project. There will be no alterations to the Texas City alignment under the Coastal Barrier Alternative. However, the construction of the coastal barrier will increase the robustness of the entire coastal system by reducing coastal storm risk in the area.

Lynchburg Pump Station. No changes or impacts are anticipated with the construction of the Coastal Barrier and Bay Rim alternatives. However, the construction of either alternative will increase the robustness of the entire coastal system by reducing coastal storm risk in the area.

Colorado River Flood Protection at Matagorda. No changes or impacts are anticipated with the construction of the Coastal Barrier and Bay Rim alternatives.

5.9 ENVIRONMENTAL CONSEQUENCES SUMMARY

Table 5-11 presents the alternatives comparison table that includes the plan comparison design details and potential impacts to the physical and biological resources evaluation criteria.

5.10 CUMULATIVE IMPACTS

NEPA regulations require that cumulative impacts of a proposed action be assessed and disclosed in an EIS or Environmental Assessment (EA). The Council on Environmental Quality (CEQ) regulations define cumulative impacts as:

> *"…the impacts on the environment which result from the incremental impact of the action (project) when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time"* (40 CFR 1508.7).

For purposes of this analysis, cumulative impacts are evaluated if the indirect and direct impacts of the TSP have substantial temporary adverse or positive impacts to the resource, when considering past, present, and reasonably foreseeable future actions. Table 5-11 provides a summary of the direct and indirect impacts of the TSP. Potential impacts of the past, present, and reasonably foreseeable future actions include both potential direct effects (caused by the actions and occurring at the same time and place as the Preferred Alternative), and indirect effects (caused by the action but removed in distance and later in time, and reasonably foreseeable).

The cumulative effects analysis considers the magnitude of the cumulative effect on the resource health. Health refers to the general overall condition, stability, or vitality of the resource and the trend of that condition. Laws, regulations, policies, or other factors that may change or sustain the resource trend were considered to determine if stress on the resource is likely in the foreseeable future. Cumulative impacts may also occur when the occurrence of disturbances is so close that the effects of one are not dissipated before the next occurs, or when the timings of disturbances are so close that their effects overlap. The general approach provided in the CEQ's C*onsidering Cumulative Effects Under the National Environmental Policy Act* was used to conduct the analysis (CEQ, 1997).

Table 5-11
Alternatives Comparison Table – Potential Impacts to Evaluation Criteria

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
DESCRIPTION	No surge risk reduction would occur in the upper Texas coast in the vicinity of Galveston or in the lower Texas coast along the South Padre Island shoreline.	**Coastal Barrier CSRM Measure**: Includes a CSRM system on the upper Texas coast with a complementary system of nonstructural measures and consists mainly of a barrier system across Bolivar Peninsula, a closure at Bolivar Roads, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. Additionally, there would be navigation gates, environmental gates, and combi-wall at the Houston Ship Channel, Clear Creek Channel, Dickinson Bayou, Offatts Bayou, and Highland Bayou Diversion Channel. **South Padre Island CSRM Measure**: Approximately 2.2 miles of CSRM dune and beach system (Reaches 3 and 4) would be aligned, parallel to the existing beach and dune system, and would start 2 miles from the Brazos Santiago Pass North Jetty system and end 4.2 miles from the Brazos Santiago Pass North Jetty system. **ER Measures:** Restore, create, protect, and/or enhance habitat suitability along nine locations on the entire Texas coast.	**Bay Rim CSRM Measure**: Includes a CSRM system to potentially avoid a majority of the navigation impacts by focusing on a levee system on the west side of Galveston from Texas City to the Fred Hartman Bridge instead of trying to address surges at the Gulf interface. Consists of a levee, floodwall, highway and railroad gates, and drainage closure structures. Additionally, there would be navigation gates, environmental gates, and combi-wall at the Houston Ship Channel, Clear Creek Channel, Dickinson Bayou, Offatts Bayou, and Highland Bayou Diversion Channel. **South Padre Island CSRM Measure**: Approximately 2.2 miles of CSRM dune and beach system (Reaches 3 and 4) would be aligned, parallel to the existing beach and dune system, and would start 2 miles from the Brazos Santiago Pass North Jetty system and end 4.2 miles from the Brazos Santiago Pass North Jetty system. **ER Measures:** Restore, create, protect, and/or enhance habitat suitability along nine locations on the entire Texas coast.
PLAN COMPARISON DESIGN DETAILS			
Differences			
Approximate Total Length	--	76 miles	79 miles
Total Floodwall and Levee	--	74 miles	79 miles
Total Floodwall	--	20 miles	43 miles
Total Levee	--	54 miles	36 miles
Estimated Quantities (cy) for Levees	--	10,000,000 cy	15,500,000 cy
Estimated Vehicle Gates Required	--	93	138
Estimated Railroad Gates Required	--	4	19
Estimated Drainage Structures Required	--	80	38
Estimated Pump Stations Required	--	5	14
Deep-Draft Navigation Gates Required	--	1	1
Size of Deep-Draft Navigation Gates	--	1,200	1,200
Shallow-draft Gates	--	4	3
Total Pipeline Relocations	--	30	55
Temporary Work Area Easements	--	545 acres	656 acres
Estimated Number Property Tracts Impacted	--	1,709	1,703
Estimated Number Owners	--	1,214	1,423
Comparison			
Comparison of Design Details	--	Complex design only focused on large navigation structure	Complex design due to multiple tie-ins
Construction Schedule and Benefit Assumptions	--	Lower acquisition risk	High acquisition risk
Environmental Impacts	--	High indirect environmental risk (Galveston Bay)	Localized direct and indirect risk (smaller waterbodies)
Potential Induced Flooding	--	Localized manageable risk	Localized to levee tie-in points
Navigation Impacts	--	Potential impacts to deep-draft operation but reduces risk to navigation infrastructure from storm surges	Potential impacts to both deep-draft and shallow-draft operations and navigation infrastructure still at risk from impacts from storm surges
Critical Infrastructure	--	Highway and navigation infrastructure included in the system	Critical highway and navigation infrastructure left out of the system

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
Relative Sea Level Rise Scenario	--	Limited cost for adaptation (Galveston Bay storage)	Substantial cost for adaptation (floodwall modification)
Project Cost	--	Low cost range – high cost range: $14.2 – $19.9 billion	Low cost range – high cost range: $18.2 – $23.8 billion
Net Benefits ($ millions) and Benefit-Cost Ratios	--	Range: High RSLR and Low Cost - Low RSLR and High Cost Without GDP Impacts: $571 – ($294) and 1.8–0.6 With GDP Impacts: $1,192 – $14 and 2.7–1.0	Range: High RSLR and Low Cost - Low RSLR and High Cost Without GDP Impacts: $255 – ($544) and 1.3–0.5 With GDP Impacts: $923 – ($237) and 2.0–0.8
Residual Risk	--	Galveston Bay's storage capacity mitigates risk	Risk from exceedance surge events and rainfall events
DIRECT ECOLOGICAL COVER TYPE ACRES			
Coastal Barrier CSRM			
Palustrine Emergent Wetland (Non-tidal)	--	512.5	227.1
Estuarine Emergent Wetland (Tidal)	--	338.0	172.0
Oyster Reef	--	--	0.035
Open Water	--	2,154.0	564.0
Dune	--	--	--
Supratidal	--	--	--
Intertidal	--	--	--
Developed/Upland	--	1,520.9	1,371.2
Total Footprint	--	4,525.3	2,334.3
South Padre Island CSRM			
Palustrine Emergent Wetland (Non-tidal)	--	--	
Estuarine Emergent Wetland (Tidal)	--	--	
Oyster Reef	--	--	
Open Water	--	358.5	
Dune	--	0.5	
Supratidal	--	2.1	
Intertidal	--	0.1	
Developed/Upland	--	4.6	
Total Footprint	--	365.8	
ER Measures (total acres for all ER measures combined)			
Estuarine Emergent Wetland (Tidal)	--	1,214.4	
SAV	--	3,406.2	
Oyster Reef	--	29.6	
Open Water	--	7,096.0	
Dune	--	1,050.3	
Supratidal	--	725.8	
Intertidal	--	61.0	
Islands/Bird Rookeries	--	147.7	
Developed/Upland	--	1,148.0	
EVALUATION CRITERIA - PHYSICAL RESOURCES			
Geomorphology and Coastal Processes			
Sediment Transport	Increased sediment transport in bays due to increased tidal amplitude and velocities resulting from higher water surface elevation with RSLR	**Coastal Barrier CSRM:** *Indirect*: Reduction of sediment exchange in Galveston Bay due to reduced natural nourishment from storm-induced sediment overwash and smaller tidal prism; Gulfside erosion expected to increase thus increasing nourishment of beaches and dunes	**Bay Rim CSRM:** *Indirect*: Reduction of sediment exchange between Galveston Bay and the bay's watersheds expected; overwash during storms, when coupled with ER measures, additional volume of sediments would be available to nourish marshes and the barrier island; increase in shoaling of GIWW from overwash events; increase in storm-induced shoreline erosion along the western edge of Galveston Bay

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		South Padre Island CSRM: *Indirect*: Sediments placed to construct measure would be transported northward to the Port Mansfield south jetty; beachfill component of feature would provide a source of sediments that would be transported by aeolian processes to beneficially nourish existing and newly constructed dunes by supplying sand for foredune accretion; during storm events, sand would wash over, beneficially redistributing throughout the barrier island **ER Measures:** *Direct*: Increased suspended sediments during construction *Indirect*: The addition of sediment to the system for marsh and sand/dune restoration would increase the overall sediment budget in the system; increased shoaling at Bolivar Roads, San Luis Pass, and Port Freeport Entrance Channel	**South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Shoreline Change	Increased shoreline erosion due to increased tidal amplitude and velocities resulting from higher water surface elevation with RSLR; prone to future erosion, fragmentation, and loss resulting from continued coastal development and reduced sediment delivery affecting the natural processes to sustain these features	**Coastal Barrier CSRM:** *Indirect*: Increases to Gulfside erosion rates expected because beach/dune and marsh habitat fronting the barrier would experience increased impacts from storms and erosion thus causing an increase in shoreline retreat, especially along Bolivar Peninsula; due to reduced exchange of flow through Bolivar Roads, sediments contributed from the bay to the longshore transport along the Gulf shoreface would be reduced **South Padre Island CSRM:** Sediments used to construct this measure would eventually be transported north by littoral drift and impounded by the Port Mansfield south jetty **ER Measures:** Increased suspended sediments during construction; increased shoaling at Bolivar Roads, San Luis Pass, and Port Freeport Entrance Channel; net positive impact by protecting, creating, and restoring shorelines and marsh fringes	**Bay Rim CSRM:** *Indirect*: Reduced watershed-based sediments transported into Galveston Bay; during storms, scouring expected in from the structure would increase suspended sediments in the bay; with RSLR slight increase in erosional patterns along the shoreline of Bolivar Peninsula due to increased surge; increased shoreline retreat within the non-protected bay rim areas **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Storm Surge Effects	Increased storm surge heights due to increased tidal amplitude and velocities resulting from higher water surface elevation with RSLR	**Coastal Barrier CSRM:** *Indirect*: Storm surge reductions along the northern and eastern sides of Galveston Bay, with slight increases in surges along the southwestern edge of Galveston Bay for a Category 3 storm; storm surge reduced for entire Galveston Bay during Category 4 storm; ring levee not overtopped by surge during a storm **South Padre Island CSRM:** *Indirect*: Acts as a natural barrier to absorb the impact of storm surges and wave attacks to help reduce flooding and damages to inland structures and infrastructure **ER Measures:** *Indirect*: Protect and stabilize existing and restored island shorelines and marsh fringes and would contribute to absorbing storm surges	**Bay Rim CSRM:** *Indirect*: No major differences in maximum storm surge for Category 3 storm; reduction landward on the southwestern portions of Galveston Bay with Category 4 storm; ring levee not overtopped by surge during a storm **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Physical Oceanography			
Tides, Currents, Circulation	Due to higher water surface elevations with RSLR, could increase tidal range, volume of tidal prism, storm surge heights	**Coastal Barrier CSRM:** *Indirect*: Reduces the cross-sectional area of Bolivar Roads by 27.5 percent and tidal prism by 16.5 percent; Houston Ship Channel Entrance Channel would experience an increase in tidal amplitude due to the reduction in flow area at Bolivar Roads and water piling up on the Gulf side of the project features; current velocities are expected to increase slightly; localized circulation changes are expected near the surge barrier gate structures including high velocity magnitudes, eddy formation, and large water surface elevations (McAlpin et al., 2018) **South Padre Island CSRM:** Not expected to have an appreciable impact **ER Measures:** Not expected to have an appreciable impact	**Bay Rim CSRM:** *Indirect*: Tidal prism and amplitude are expected to remain unchanged except near Tabbs Bay where the surge barrier gates are proposed and could be nominally impacted; could be a slight increase in current velocities induced by the gate structures partially constricting tidal flows; localized circulation changes near Tabbs Bay surge barrier gates **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
Salinity	Expected to change due to higher water surface elevations with RSLR: increased tidal exchange could increase salinities in some bays; flooding estuaries with Gulf waters followed by extended periods of drought could increase salinities, particularly in the middle coast	**Coastal Barrier CSRM:** *Indirect*: Salinity expected to be reduced by less than 2 ppt throughout Galveston Bay; due to increased residence time of water in the bay, salinities could remain lower for longer periods; salinities at Clear Creek, Dickinson Bayou, and Offatts Bayou predicted to decrease 1 ppt (McAlpin et al., 2018) **South Padre Island CSRM:** No effects on salinities **ER Measures:** *Direct*: Localized and temporary changes during construction of measures G-28, B-12, M-8, CA-5, CA-6, and SP-1 *Indirect*: Hydrologic restoration at W-3 should positively affect salinities in the Lower Laguna Madre by decreasing salinities	**Bay Rim CSRM:** *Indirect*: Salinities are not expected to differ by more than 0.4 ppt in the bay system and would have the least impact on bay salinities; salinities at Clear Creek, Dickinson Bayou, and Offatts Bayou predicted to decrease 1 ppt (McAlpin et al., 2018) **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Water and Sediment Quality			
	Not expected to be affected; increased flooding from storms may mobilize contaminants and transport them into estuaries; may be affected by treatment of municipal and industrial wastewater and management of nonpoint-source pollution; increase in ocean acidity and reduced oxygen concentrations due to climate change	**Coastal Barrier CSRM:** *Indirect*: Reduced flushing and mixing of Galveston Bay System expected to impact pollutants entering the bay and contribute to low dissolved oxygen levels; increased retention times may increase sediment deposition and development of low dissolved oxygen conditions upstream of the barriers; reduced tidal flushing may alter nutrient balance by reducing phosphorous input into and nitrogen transport out of the bay; increased retention times in developed areas may allow effects of high algal productivity, low oxygen, and potentially harmful algal blooms to be expressed more widely and frequently in these areas of the bay **South Padre Island CSRM:** *Direct*: Localized increases in turbidity at the Gulf associated with dredging and placement; release of low oxygen water, high ammonia, and nutrients at the borrow source location as sediments are dredged but are temporary and localized, ending when dredging is completed **ER Measures:** *Direct*: Temporary and localized increases in turbidity and releases of low oxygen water and nutrients at sediment borrow and beach placement locations experienced every 5 to 10 years; increases in turbidity with construction of ER measures; out-year marsh nourishment or restoration (G-5, B-12, M-8, CA-5, CA-6) may experience more impacts from additional periods of elevated turbidity and depressed oxygen levels associated with extended periods of construction and dredged material placement	**Bay Rim CSRM:** *Indirect*: Intensity, frequency, and severity of impacts may be greater since most of the waste load enters the bay upstream of the Bay Rim, the area for mixing and volume for dilution is reduced, and this area experiences the poorest water quality in the system; most water-quality problems in the western, urbanized portion of the bay's watershed; reduction of heavy metal and chlorinated organic compounds in sediments would be reduced with mixing of Gulf waters; Fish and Shellfish Consumption Advisories are in effect for the Houston Ship Channel and the San Jacinto River from upstream of the Fred Hartman Bridge to the Lake Houston Dam for the San Jacinto River, Upper Galveston Bay, and throughout Galveston Bay; fewer pollutants and potential pathogens would be transported past the surge barrier gates, which could result in improved water and sediment quality downstream **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Hydrology			
	Increased usage for agriculture, municipal, industrial, and commercial sources would diminish reservoir storage and freshwater inflows to coastal bays and estuaries; RSLR and saltwater intrusion into bays, rivers, and creeks causing habitat changes; river flows could be impacted	**Coastal Barrier CSRM:** *Indirect*: Localized impacts where the surge barrier gates connect to the shore that could influence the direction of rainfall runoff and influence water levels at that location; may increase localized flooding upstream and downstream of the surge barrier gates at Offatts Bayou, Dickinson Bayou, Clear Lake, and the GIWW near High Island; the Galveston ring levee would block some rainfall runoff from drainage channels and sheetflow from the watershed into the bay **South Padre Island CSRM:** No effects on hydrology **ER Measures:** *Direct*: If containment levees are built on uplands during construction of marsh restoration and out-year marsh nourishment patterns of sheet flow from rainfall runoff towards the bay could change, but these impacts would be temporary and local only during construction	**Bay Rim CSRM:** *Indirect*: Increase localized flooding upstream and downstream of surge barrier gates during extreme rainfall runoff events or water level fluctuations in the bay (extreme high tides or storm-generated waves); rainfall runoff in drainage channels and as sheet flow is expected to be intercepted by the levees and forced into areas not typically inundated or into different channels for additional stormwater runoff; hydrological modifications would be required to channel flood flows to the pump stations **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		Indirect: Localized effects on the direction of flow of rainfall runoff into the bay adjacent to revetments could cause flooding on upstream side of the structure if water exchange is blocked; ER measures would provide an overall positive benefit to the ecosystem	
Soils (Prime and Other Important Unique Farmland)			
	Continued degradation and loss of soil resources as well as prime and unique farmlands due to RSLR, saltwater intrusion, repeated inundation, tidal wetland conversion to open water, and development	**Coastal Barrier CSRM:** *Direct*: Convert 2.3 acres into a levee barrier, construction activities that will cause impacts include grubbing and clearing, levelling, borrow, and piling fill material; construction access roads and staging areas may temporarily impact additional land *Indirect*: Levees may affect fragmentation, soil compaction, and development; benefit other prime farmlands by providing a buffer and protective barrier against rising sea level and erosive wind/wave action that could potentially wash out prime farmland soils **South Padre Island CSRM:** *Indirect*: Benefit to soils and prime farmlands in the future by providing a storm buffer and protecting soils from erosive wave and wind action **ER Measures:** *Direct*: Convert 1.6 acres to revetment/breakwaters, 0.9 acre for marsh restoration, and 20.4 acres for out-year marsh nourishments; construction during marsh restoration and out-year nourishments of temporary containment levees and placement of fill material could impact prime farmlands around the measure *Indirect*: Overall benefit from shoreline protection, stabilization, providing a buffer area for rising sea level and storm surges, and prevent washing out of soils	**Bay Rim CSRM:** *Direct*: Convert 332 acres located on the west extension of the Texas City HFPS and along the western edge of Galveston Bay *Indirect*: Benefit by providing a buffer and protective barrier against rising sea level and erosive wind and wave action that could potentially wash out prime farmland soils **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Energy and Mineral Resources			
	Subject to increased exposure and reduced protection due to loss of natural shoreline buffers would increase susceptibility of oil and gas infrastructure to rupture or damage	**Coastal Barrier CSRM:** 1,267 oil and gas wells are located within 1 mile with 57 intersecting the footprint; 49 pipelines are located within 1 mile with 36 intersecting the footprint **South Padre Island CSRM:** No oil and gas wells and pipelines are located within 1 mile or intersect the footprint **ER Measures:** 2,826 oil and gas wells are located within 1 mile with 1,223 intersecting the footprint; 164 pipelines are located within 1 mile with 65 intersecting the footprint	**Bay Rim CSRM:** 3,813 oil and gas wells are located within 1 mile with 89 intersecting the footprint; 206 pipelines are located within 1 mile with 103 intersecting the footprint **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Hazardous, Toxic, and Radioactive Waste			
	RSLR and storm surges would increase degradation of natural and man-made protection leaving facilities more susceptible to damage	**Coastal Barrier CSRM:** 112 HTRW sites were identified within 1 mile with 13 intersecting the footprint; half of the sites identified within 1 mile are TCEQ Petroleum Storage Tank sites **South Padre Island CSRM:** 8 HTRW sites were identified within 1 mile with none intersecting the footprint; most of the sites identified within 1 mile are TCEQ Petroleum Storage Tank sites **ER Measures:** 61 HTRW sites were identified within 1 mile with 1 intersecting the footprint; the majority of the sites identified within 1 mile are EPA Facility Registry Service and TCEQ Petroleum Storage Tank sites	**Bay Rim CSRM:** 147 HTRW sites were identified within 1 mile with 8 intersecting the footprint; half of the sites identified within 1 mile are EPA Facility Registry Service and TCEQ Petroleum Storage Tank sites **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
Air Quality			
	Continued degradation due primarily to increasing populations, commercialization, industrialization, increased use of motor vehicles, continued oil and gas exploration and refinement operations, and continued loss of vegetation in wetlands and forests, which may decrease the removal rate of gaseous pollutants from the atmosphere	*Direct*: Air contaminant emissions from construction activities would result in temporary and localized impacts on air quality in the immediate vicinity of the project site as they are considered one-time activities; temporary impacts to air quality would continue due to maintenance and renourishment activities; VOC and NOx emissions from these activities can combine under the right conditions to form ozone, possibly increasing the concentration in the region *Indirect*: Minor increase in air contaminant emissions above those for existing emissions sources in Galveston County from operation of the surge barrier gate A General Conformity Determination is required	*Direct*: Air contaminant emissions from the construction activities associated with this alternative would also result in an increase in emissions above those from the existing inventory of emissions sources in the affected counties; the estimated increase in emissions may also result in corresponding impacts on air quality in the immediate vicinity of the project area; it is anticipated impacts would be less for the Bay Rim Alternative than the Coastal Barrier Alternative due to the need for construction of a larger surge barrier gate and the larger area for the Coastal Barrier; temporary impacts to air quality would continue due to maintenance and renourishment activities *Indirect*: Minor increase in air contaminant emissions above those for existing emissions sources in Galveston County from operation of the surge barrier gate A General Conformity Determination is required
Noise			
	Noise generated by existing noise sources (e.g., waterborne transportation, automobile and train transportation, recreation and commercial enterprises, industrial operations, port activities) would continue	**Coastal Barrier CSRM:** *Direct*: Noise impacts to residential, recreational, and worship areas are expected during initial construction of the levee/floodwall and during periodic maintenance activities, these impacts would be temporary; noise impacts from construction of the surge barrier gates at Bolivar Roads are not expected due to the distance from residential and recreational areas; construction of gates at Clear Lake, Dickinson Bayou, and Offatts Bayou, and pump stations would likely result in temporary, short-term noise impacts to a small number of residences nearby *Indirect*: A reduction in noise near noise-sensitive receivers is expected in residential areas, and from a decrease in infrastructure damage and subsequent construction/rehabilitation activities **South Padre Island CSRM:** Same as described for the Coastal Barrier CSRM **ER Measures:** *Direct*: Temporary impacts during construction from equipment to recreational fishermen, boaters, and recreational areas immediately adjacent to the ER areas	**Bay Rim CSRM:** *Direct*: Temporary and minor noise impacts related to construction along the proposed levee/floodway are expected, these impacts would be greater than for the Preferred Alternative due to the length of the features; temporary impacts expected during construction in the developed, urban areas with high concentrations of residences in the cities of Galveston, Hitchcock, Texas City, San Leon, Bacliff, Kemah, Seabrook, and La Porte; temporary impacts during construction of the surge barrier gates and pump stations expected **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
EVALUATION CRITERIA - ECOLOGICAL AND BIOLOGICAL RESOURCES			
Wetlands			
Non-Tidal Wetlands (Freshwater)	Continued loss mainly due to development; also from increased water demand, hydrologic alterations of watersheds and floodplains, population growth, RSLR converting wetlands to a more halophytic plant community	**Coastal Barrier CSRM:** *Direct*: 512.5 acres are expected to be altered or damaged due to construction of this measure; project features to be built on Bolivar Peninsula and Galveston Island would require clearing, grubbing, levelling, and filling of wetland and marsh habitats; during construction the potential for erosion and increased sedimentation could affect water quality and bury/damage adjacent marshes; best management practices would be used to prevent sediment from entering wetlands. *Indirect*: Levees would act as hydrological barriers potentially leading to loss of sheet flow, marsh and wetland degradation, and fragmentation of the ecosystem; marsh habitats located south of the project footprint would be exposed to higher salinities for longer periods during storm events; levee would provide some level of protection to wetlands serving as a barrier from saltwater intrusion during storm events; the cross-sectional constriction at Bolivar Roads would lead to marsh habitats being regularly or seasonally flooded, which could convert wetland areas to ephemeral wetlands or uplands; increased residence time would allow greater	**Bay Rim CSRM:** *Direct*: 227.1 acres are expected to be altered or damaged due to construction of this measure, most occurring on private land; during construction the potential for erosion and increased sedimentation could affect water quality and bury/damage adjacent marshes, best management practices would be used to prevent sediment from entering wetlands *Indirect*: Similar to those described for the Preferred Alternative **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		dilution of freshwater inflows that could result in a conversion of plant communities and an expansion of freshwater wetlands on the bayside of the structure; 3,375 acres are expected to be indirectly impacted resulting from altered hydrology primarily leading to eventual deterioration of those habitats and will require 7,818 acres of mitigation **South Padre Island CSRM:** No impacts to non-tidal wetlands **ER Measures:** *Direct*: Increased sedimentation and decreased water quality during construction, dredging, and placement activities would be temporary *Indirect*: Revetment/breakwaters, island restoration, and oyster reef creation would protect marsh complexes from erosion caused by RSLR and increased wave energy from vessel traffic and storms; marsh restoration/out-year marsh nourishments would have an overall benefit by improvement of water quality, flood attenuation, aesthetics, and recreational opportunities, as well as mitigating for RSLR and impacts to coastal infrastructure and ecosystems from storm events	
Tidal Wetlands/Seagrass	Urban and industrial development on the coastline, which would reduce wetland habitat and prevent tidal wetlands from migrating inland. RSLR impacts include changes to hydrology, nutrient inputs, flood or tide timing and intensity. Potential migration inland in response to RSLR, which could result in an increase Current trends of decreases and increases in seagrass would continue. With predicted climate changes, increasing frequency and strength of coastal storms and hurricanes can damage or bury seagrass meadows with sediments at a higher frequency or intensity. It is possible that seagrass could migrate in response to SLR	**Coastal Barrier CSRM:** *Direct*: 338.0 acres are expected to be altered or damaged due to construction of this measure; remaining impacts same as for non-tidal wetlands **South Padre Island CSRM:** No impacts to tidal wetlands **ER Measures:** *Direct*: 1,214.4 acres are expected to be impacted due to construction, dredging, and placement of G-28, B-12, M-8, and CA-6 *Indirect*: Protection of intertidal marsh and seagrass	**Bay Rim CSRM:** *Direct*: 172.0 acres are expected to be altered or damaged due to construction of this measure, most occurring on private lands; remaining impacts same as for non-tidal wetlands **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Aquatic Resources			
Freshwater Habitats and Fauna	Continued loss of freshwater habitats across the coast would continue due to channelization, development, and water demands. RSLR has increased saltwater flooding of coastal freshwater marshes	**Coastal Barrier CSRM:** *Indirect*: Areas upstream of the barrier would have lower salinities and remain fresher for longer periods of time and could allow temporary expansion of freshwater fish, invertebrate, and plant communities into those areas; may reduce access of American eel to the bay system and tributaries, which provide habitat for maturing eel; when salinities are low, the barriers at Dickinson Bay, Clear Lake, and Offatts Bayou may inhibit movement of freshwater fish and shellfish **South Padre Island CSRM:** No impacts to freshwater habitats and fauna **ER Measures:** *Direct*: Possible impacts at measures G-28, B-12, M-8, CA-5, and CA-6 if salinities fall below 8 to 10 ppt during restoration and/or nourishing activities *Indirect*: Breakwaters may create barriers to movement of American eels and alligator gar but are not expected to impair their movement through the estuaries; if salinities are below 8 to 10 ppt, some species of freshwater organisms could be in	**Bay Rim CSRM:** *Indirect*: Would have the least impact on American eel because they do not utilize habitats in this area; lower salinity conditions expected upstream of the barrier should benefit freshwater organisms; when salinities are low, the barriers at Dickinson Bay, Clear Lake, and Offatts Bayou may inhibit movement of freshwater fish and shellfish **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		the marsh and would be impacted by increased turbidity, possible increased temperatures, increased ammonia, and lowered oxygen in the marsh enclosed by the marsh restoration levees	
Estuarine Habitats (Open Bay, Bay Bottom, Oyster Reef, Commercial and Recreational Fisheries)	Climate change stressors (SLR, temperature increases, salinity changes, and wind and water circulation changes), storm severity and frequency, and USACE dredging and maintenance dredging operations would continue to have an impact on the aquatic communities. Migration of marsh and SAV could impact fish and shellfish either positively or negatively. Fish species could benefit from larger areas of available habitat if marshes migrate due to RSLR. Oyster reefs would continue their current decline. Maintenance dredging activities would continue to increase water-column turbidity and bury benthic organisms	**Coastal Barrier CSRM:** *Direct*: Permanent loss of 2,154 acres of open water and bay bottom habitat, the majority at Bolivar Roads; temporary and localized increased turbidity and concentrations of suspended sediments during construction could affect phytoplankton/algal assemblages, disrupt foraging patterns, feeding habits, reproduction, and respiration in benthic organisms and juvenile and adult finfish and shellfish; bay bottom habitat would be lost during construction activities resulting in permanent loss in some areas and changes in community structure, composition, and function in areas that would be able to recover; construction lasting for extended time periods could cause estuarine habitats and fauna in those areas to take longer to recover to pre-construction conditions; potential long-term direct impacts to fish and shellfish with larval and juvenile life stages that depend largely on passive transport could result from the cumulative impacts of the Coastal Barrier *Indirect*: Bay bottom habitat in areas that can recover will likely see changes in community structure, composition, and function; average of 2 ppt decrease in bay salinities, no adverse effects expected; reduced flow and high velocities through Bolivar Roads could impede the migrations and movements of various life stages of fish into and out of the Galveston Bay system; reduction in tidal amplitude would result in loss of marsh surface area available for aquatic organisms to use as nursery habitat, which could reduce overall populations of fish and shellfish densities in the bay; the slight decrease in salinity could benefit oysters by reducing exposure to oyster predators and pathogens; loss of fish and shellfish larval and juvenile life stage that depend on passive transport could result from 1) reduced numbers entering the bay proportional to the reduced volume flowing into the bay; 2) loss of individuals trapped in eddies that could form on the backside of the gate structures; 3) increased exposure to predation while migrating across the open bay to the marshes due to reduced velocities and increased transport times; and 4) reduced area of accessible marsh caused by reduced tidal amplitude. **South Padre Island CSRM:** *Direct*: A total of 358.5 acres of open water would be impacted; impacts could occur in the Gulf portions of the South Padre Island CSRM measure due to increased water-column turbidity and sediment placement that can be expected during construction activities and would be the same as those described for the Coastal Barrier CSRM; renourishment every 10 years would cause short-term water-column turbidity and impacts to benthos during placement activities; no long-term impacts anticipated **ER Measures:** *Direct*: Permanent loss of 802 acres of open water and bay bottom habitat; impacts associated with bay bottom habitat loss and temporary disturbances to water-column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier CSRM *Indirect*: Gain of rocky areas provides habitat for oyster colonization and associated biological communities; protection of marsh, SAV, and oyster reef habitat from eroding, protecting nursery habitat; restored marsh habitats and nourishment benefits outweigh initial impacts associated with construction; oyster reef creation	**Bay Rim CSRM:** *Direct*: Permanent loss of 564 acres of open water and bay bottom habitat, half of that occurring at Fred Hartman Bridge, which would also permanently convert to deeper-water habitat resulting from the underwater footprint needed to construct the surge barrier gates; a total of 0.03 acre of oyster reef falls in the direct footprint of the Bay Rim and would be lost, mitigation for these acres is described in Appendix C-9; impacts associated with construction of the Bay Rim would be similar to those described for the Preferred Alternative, with the exception of the smaller open water impacts *Indirect*: Minimal impacts are anticipated **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		expected to protect restored islands, prevent breaching of islands and shorelines, protect SAV, and increase oyster populations	
Wildlife Resources			
	Continued human development and encroachment into wildlife habitat, RSLR, and invasive species could decrease species diversity and abundance	**Coastal Barrier CSRM:** *Direct*: Construction activity and noise can potentially disrupt and disturb wildlife behavior and their ability to hear *Indirect*: Construction of the levee barrier would further limit and fragment the wildlife corridors between adjacent habitats from the Gulf-bay side of Bolivar Peninsula and east-west through wetlands and pastures near Anahuac NWR; shorebirds and coastal wildlife would be most impacted by the Coastal Barrier due to the proximity of construction along the Gulf coast; wildlife displaced during construction would recolonize the earthen levee and access corridors to adjacent habitat; would benefit in the long-term risk reduction from coastal storms **South Padre Island CSRM:** *Direct*: Construction and fill placement could temporarily increase turbidity and bury productive foraging habitat within the surrounding area; turbidity could potentially inhibit bird foraging; beach bulldozing could cause sand compaction and impact populations of sand and ghost crabs *Indirect*: Would benefit from additional habitat and stabilized shoreline for foraging, nesting, and roosting **ER Measures:** *Direct*: Temporary and localized turbidity increases are expected during construction, dredging, and placement activities for revetment/breakwaters, island restoration, marsh restoration/nourishments, oyster reef creation; during marsh restoration/nourishment construction, wildlife may relocate but would return once complete; noise during construction would disrupt sensitive wildlife *Indirect*: Would benefit by slowing the rate of shoreline erosion for habitats used for foraging, nesting, and roosting; concrete blocks placed for island restoration can impair nesting and foraging habitat; species diversity expected to increase as restored islands mature; restored habitats expected to enhance wildlife habitat	**Bay Rim CSRM:** *Direct*: Construction activities and noise could interfere with wildlife behavior and their use of corridors *Indirect*: Levee barrier could potentially fragment the north-south migration corridor of wildlife from West Bay to developed areas north near Hitchcock and FM 2004 **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Protected Resources			
Protected Lands	Continued upland and tidal wetland loss, tidal conversion to open water, land loss, shoreline erosion would occur	**Coastal Barrier CSRM:** *Direct*: The proposed levee system is expected to result in permanent loss of approximately 100 acres of potential wetlands and marshes along the eastern and southern border of Anahuac NWR within the structure footprint and temporary impacts to wetlands and marshes due to construction of access roads and staging sites; approximately 70 acres within Galveston Island State Park are expected to be directly impacted by construction operations including potential grubbing and clearing, levelling, and piling of fill material *Indirect*: Changes to wildlife migration patterns and natural topography and drainage patterns of Anahuac NWR; several Federal, State, and privately owned protected lands within the Galveston Bay region would benefit from the coastal levee protection measures by gaining risk reduction from storm surges and RSLR **South Padre Island CSRM:** No impacts to protected lands **ER Measures:** *Direct*: Approximately 35 acres of the Anahuac NWR, 113 acres of the Brazoria NWR, 13 acres of the Justin Hurst WMA, 68 acres of the San Bernard NWR, and 9	**Bay Rim CSRM:** *Direct*: No protected lands fall within the footprint of this measure *Indirect*: Water velocities could potentially increase near the structures and decrease exchange into and out of Galveston Bay, which could increase erosional effects along the northern portion of Atkinson Island WMA; San Jacinto Battleground and Battleship Texas State Historic site may experience inundation and drainage issues when the gates are closed during storm surge events **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		acres of the Big Boggy NWR of bay bottom habitat would be converted to revetment/breakwaters; approximately 31 acres of the Anahuac NWR, 2 acres of the Muddy Marsh Bird Sanctuary owned by TNC, 320 acres of the Brazoria NWR, 15 acres of the Justin Hurst WMA, 130 acres of the San Bernard NWR, and 5 acres of the Big Boggy NWR would be temporarily impacted during marsh restoration activities; approximately 2,500 acres of the Anahuac NWR, 30 acres of the McFarlane Marsh owned by TNC, 6,250 acres of the Brazoria NWR, 2,000 acres of the Justin Hurst WMA, 6,000 acres of the San Bernard NWR, and 1,700 acres of the Big Boggy NWR would be impacted during out-year marsh nourishment activities; approximately 2 acres of bay bottom habitat within the Brazoria NWR would be impacted during oyster reef creation; approximately 70 acres of McFaddin NWR, 330 acres of Anahuac NWR, 20 acres of Bolivar Flats Shorebird Sanctuary, 130 acres of Galveston Island State Park, and 1,400 acres of the Padre Island National Seashore would be temporarily impacted during dune/beach restoration activities *Indirect*: Restored marsh habitats and created oyster reefs would provide numerous benefits including improvement of water quality, flood attenuation, aesthetics, and recreational opportunities, as well as mitigating for RSLR and impacts to coastal infrastructure and ecosystems from storm events; out-year marsh nourishment features would provide a long-term approach to enhance resiliency of coastal communities and improve our capabilities to prepare for, resist, recover, and adapt to coastal hazards	
Threatened and Endangered Species	RSLR, shoreline erosion, and loss of coastal prairie would reduce sea turtle, piping plover, rufa red knot habitat and Attwater's prairie chicken habitat	**Coastal Barrier CSRM:** *Direct*: Construction activities could impair and prevent manatee and sea turtle migration, feeding, and reproductive behavior between the Gulf and Galveston Bay; underwater noise could disrupt marine mammal communications; dredging of fill material for levees can injure or kill sea turtles, and increased turbidity can impede foraging ability of visual predators like sea turtles, piping plovers, red knots, and least terns; construction activity near tidal flats and sand dunes may affect the behavior of overwintering piping plovers and red knots; construction activities on the beach and tidal areas within the critical habitat may also cause an increase in noise and light, which may disturb individuals, decrease nesting success, and impact foraging for species such as piping plovers, red knots, and sea turtles; artificial lighting on the construction beachfront may potentially disorient nesting and hatching sea turtles; critical habitat for piping plover could be altered by grubbing, levelling, sediment borrowing, and discharge of fill on loafing, nesting, and foraging areas; 89 acres of designated piping plover critical habitat would be directly impacted; portions of critical habitat would be permanently impacted from the footprint of the levee barrier *Indirect*: Operation of the surge barrier gates may potentially affect sea turtles and shorebirds within the area by changing the hydrology and salinity characteristics of the bay; gate structures may impede movement or crush manatees, marine mammals, and sea turtles travelling between Galveston Bay and the Gulf; the levee is expected to shield a small amount of light from the bayside that may benefit species sensitive to light pollution; the measure could benefit piping plover and rufa red knots by protecting their habitats from coastal storms and RSLR; may limit recreational vehicle access to tidal flats and beach areas on Bolivar Peninsula and Galveston Island, which could potentially decrease shorebird and sea turtle disturbance; benefit Federally listed species along the Galveston Bay system by protecting critical wetland and coastal shoreline habitat from RSLR and erosive wind and wave forces	**Bay Rim CSRM:** *Direct*: Impacts to sea turtles and marine mammals would be the same as those described for the Coastal Barrier CSRM; a salinity difference between the Gulf and bay may create a barrier to migration of sea turtles; construction noise and activity could impact the northern aplomado falcon and other migratory birds around the Texas City Preserve; construction noise and turbidity associated with the placement of fill near the bay can inhibit communication between the birds and decrease foraging rates *Indirect*: Operation of the surge barrier gates can potentially impede or harm migrating sea turtles attempting to traverse upstream to the San Jacinto River; would result in less impacts to threatened and endangered species and their critical habitat than the Coastal Barrier. **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		South Padre Island CSRM: *Direct*: Piping plovers, red knots, and sea turtles impacted due to placement of fill material on tidal flats and beach, which could bury foraging and roosting habitat; dredging of fill material from offshore sources could injure or kill sea turtles and manatees or increase turbidity, potentially impairing feeding efficiency; construction noise can disrupt piping plovers, least terns, northern aplomado falcons, red knots, and sea turtles foraging, nesting, and roosting behavior; lighting from construction vehicles can cause disorientation of nesting female sea turtles and hatchlings *Indirect*: Constructed beach profiles are expected to mimic the natural slope and sand composition to promote sea turtle nesting; restoration of eroding beach would benefit sea turtle nesting habitat **ER Measures:** *Direct*: Construction and placement for ER measures could potentially disturb marine mammals and sea turtles in the water and Federally listed birds nearshore, increase the risk of collision with an animal, noise disturbances to shorebirds and nesting sea turtles; piping plover critical habitat to be impacted at Rollover Pass includes 4 acres for revetments/breakwaters, 7 acres for marsh restoration, and 2 acres for out-year marsh nourishment; dune/beach restoration is expected to impact 388 acres of piping plover critical habitat at Bolivar Flats and San Luis Pass *Indirect*: Benefit shorebirds such as piping plovers, red knots, and least terns by providing habitat for prey items, provide shoreline protection from erosion wave action from barge traffic, rising sea levels; accretion of sand and sediments behind the breakwater structure would increase tidal flat areas for foraging and loafing shorebirds such as piping plovers; increased island size would increase stability for foraging, nesting, roosting, and hunting; restore 1,871 acres of highly productive marsh that would provide habitat for many species including endangered whooping cranes and prairie dawn-flower	
Migratory Birds	Population increase, development, and RSLR would continue to encroach on wetlands and marshes, which provide habitat and resources for migratory birds as they overwinter or stopover along their migration routes	**Coastal Barrier CSRM:** *Direct*: Clearing and grubbing vegetation prior to levee construction can harm migratory species and reduce available habitat for roosting and nesting; activity, lighting, and noise during construction can disturb, disorient, and harm migratory birds; increased water-column-turbidity during construction can decrease foraging rates and cause birds to relocate to adjacent habitats *Indirect*: Changes to the hydrology and salinity of Galveston Bay when the surge barrier gates are closed may indirectly affect fisheries and the foraging habits of shorebirds; would benefit from the long-term protection of habitat from coastal storms; completed levee barriers and floodwalls along the coast can limit recreational vehicular traffic to tidal flat and beach areas, which can limit human disturbance to birds **South Padre Island CSRM:** *Direct*: Potential impacts during placement area burying foraging and roosting habitats; benthic organisms they feed on would be disturbed during construction but return to pre-construction conditions once the project is complete; construction activity and noise may disturb roosting and foraging birds; increased turbidity and sediment in the water column during construction can impede foraging capabilities and cause birds to relocate to adjacent habitats	**Bay Rim CSRM:** *Direct*: Construction activity and noise could potentially interfere with migratory birds; grubbing and clearing vegetation along the levee footprint would remove habitat used by migratory birds for nesting and roosting *Indirect*: Could change the hydrology and fisheries communities in Galveston Bay and indirectly affect migratory birds **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
		Indirect: Benefit from expanded shoreline for foraging, nesting, and roosting for migratory shorebirds and coastal habitat buffer from future storm events **ER Measures:** *Direct*: During construction increased turbidity and noise can decrease foraging efficiency of birds and displace and disturb birds *Indirect*: Benefits by protecting vulnerable beaches, wetlands, and tidal flats from wave action and erosion in turn increasing available habitat for nesting, foraging, and roosting for migratory birds; measures would increase available habitat for nesting, foraging, and roosting for migratory birds	
Marine Mammals	Continue to be exposed to environmental conditions, habitat, resources, and stressors as modified by increased human populations, urbanization, and different climatic conditions. The major additional factors that may influence dolphin stocks are climate change stressors (SLR, temperature increases, salinity changes, and wind and water circulation changes) and projected water demand that would reduce freshwater inflows	**Coastal Barrier CSRM:** *Direct*: Noise from pile driving during construction can cause direct physical injury to marine mammals in the form of permanent or temporary threshold shifts; anthropogenic noise can mask important sounds used by marine mammals; increased noise pollution in an important habitat could cause disruption to feeding and socializing behaviors, temporary or permanent habitat abandonment, and increased risk of predation, injury, and stranding; noise, vessel activity, sediment suspension, release of toxic compounds (if present in the sediment), and habitat modification from dredging are all concerns surrounding dredging activities with the potential to cause negative consequences to dolphin populations; increased vessel traffic during construction can cause changes in behavioral state, dive patterns, and orientation *Indirect*: Potential to hinder dolphin movements in and out of Bolivar Roads and bayous with the physical barrier of the surge barrier gates; tidal flow is known to influence dolphin movements and foraging patterns; dolphin habitat use and health in these zones could be affected by even a small decrease in salinity under project conditions; storm surge reductions in the bay may provide protection to dolphins residing within the Galveston Bay estuary by reducing the risk of these dolphins being stranded “out of habitat” during a storm; impacts to prey species of marine mammals can impact prey availability for marine mammals **South Padre Island CSRM:** *Direct*: Same as those described for the Coastal Barrier CSRM for dredging operations and during renourishment cycles *Indirect*: Minor disturbances may be expected for the Western Coastal Stock and possibly the Laguna Madre BSE stock **ER Measures:** *Direct*: Noise, dredging, and vessel activity during construction have the potential to cause short-term disruption to dolphin activities and possible temporary habitat abandonment as described for the Coastal Barrier CSRM *Indirect*: Potential to modify BSE dolphin habitat use and ranging patterns in the localized areas where they occur; benefits to marine mammals by providing improved water quality and enhanced production of prey organisms	**Bay Rim CSRM:** Same as the Coastal Barrier CSRM except for impacts directly described at Bolivar Roads **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Essential Fish Habitat	Climate change stressors (SLR, temperature increases, salinity changes, and wind and water circulation changes), storm severity and frequency, and USACE dredging and maintenance dredging operations would continue to have an impact on the aquatic communities. Migration of marsh and SAV could impact fish and shellfish either	**Coastal Barrier CSRM:** Impacts would be the same as those described for Estuarine Habitats **South Padre Island CSRM:** Impacts would be the same as those described for Estuarine Habitats	**Bay Rim CSRM:** Impacts would be the same as those described for the Coastal Barrier Alternative but on a smaller scale **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
	positively or negatively. Fish species could benefit from larger areas of available habitat if marshes migrate due to RSLR. Oyster reefs would continue their current decline. Maintenance dredging activities would continue to increase water-column turbidity and bury benthic organisms	**ER Measures:** Impacts would be the same as those described for Estuarine Habitats	
Cultural Resources			
	Submerged cultural resources would continue to be at risk from future dredging activities, shifting bars, and wave damage for shallow sites and from high-energy storms that can dislodge wrecks from the seafloor or impact wrecks on beaches or in shallow water Upland historic and prehistoric sites would continue to be at risk from shoreline erosion and commercial, industrial, and residential development	**Coastal Barrier CSRM:** *Direct*: Moderate to high probability for encountering intact prehistoric and historic archeological sites in upland areas along Galveston Island and Bolivar Peninsula; greatest threat from construction and associated staging and borrow areas; impacts to submerged resources from dredging, the erosion of sites due to landscape modification, and visual impacts to historic buildings, structures, or districts from aboveground construction; moderate to high probability of encountering sites throughout the project area; moderate to high probability for encountering historic archeological sites within the city of Galveston **South Padre Island CSRM:** *Direct*: Low probability for encountering intact archaeological deposits; potential for encountering shipwrecks along the beach and in the shallow waters adjacent to the beach; beach nourishment material will be dredged from existing offshore dredged material placement areas that have a moderate to high probability for encountering submerged archeological resources **ER Measures:** *Direct*: Moderate to high probability of encountering intact archaeological resources in the upland portions; beach nourishment material will be obtained by dredging material from offshore and there is a moderate to high potential for impacting submerged archeological sites; potential to adversely affect historic properties during construction activities in upland areas	**Bay Rim CSRM:** *Direct*: Low to moderate potential for encountering intact prehistoric archeological sites along the western rim of Galveston Bay; moderate to high probability for encountering historic-age buildings, structures, and archeological sites **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Socioeconomics			
	Population expected to increase, which would increase employment, business, and industrial activity; increased potential for flood damage to structures due to RSLR; critical infrastructure, community cohesion, and other social effects at greater risk from hurricane storm surge and RSLR	*Direct*: Construction of the features may have minimal short-term impacts to residences located behind the system, but these impacts would be the same regardless of race or income; temporary impacts in the form of increased vehicular congestion along roads, highways, and streets during construction, which would cease upon construction completion *Indirect*: Reduction in risks associated with damages from hurricane storm surge events to housing units, public facilities, and commercial structures; overall improvement in the health and safety of those residents; community cohesion and Environmental Justice concerns were less of a concern with the construction of the proposed barrier and dune/beach nourishment features; public facilities could have temporarily interrupted services and could inconvenience users until the non-structural measures are completed; reduce adverse impacts that are resulting from continued land loss, and habitat fragmentation and degradation especially with regard to the vulnerability of existing transportation (navigation and roads), oil and gas infrastructure, and recreational and commercial fishing opportunities; social vulnerability would be reduced by increasing wetland EFH habitat for aquatic species associated with recreational and commercial fishing	*Direct*: Impacts would be the same as those described for the Coastal Barrier Alternative, except the Bay Rim would have socioeconomic impacts in the upper coast region; alignment near the bay rim would have direct impacts to the area's transportation infrastructure; major impacts to the Port Facilities along the bay rim since roadway and railway gates would have to be built to maintain water access *Indirect*: Potential for induced flooding in the communities of Baytown and Santa Fe; many of the structures in the rural areas of the study area would still receive damages from hurricane surges; overtopping of the levee by storm surge during extreme events would immediately inundate vulnerable populated areas and key emergency service routes; leaves the region's critical roads at risk;

Alternatives	No-Action Alternative	Coastal Barrier Alternative (TSP/Preferred Alternative)	Bay Rim Alternative
Navigation			
Commercial and Waterborne Commerce and Recreational	Economy expected to grow placing greater demands on port infrastructure and efficiency of transport; increased safety concerns as population and shoreline development increase; expect increase in cargo throughput with expanded Panama Canal	**Coastal Barrier CSRM:** *Direct*: Ship simulations will be required to determine if FWOP/FWP changes to the inlet's maximum and mean velocities would impact deep-draft vessel transits through the ship channel *Indirect*: Overwash and other storm-related sediment deposition in Galveston Bay would be reduced, potentially reducing future storm-event-driven maintenance dredging requirements of the GIWW; risks to navigation safety are expected to increase due to a reduction in vessel operating margin of error associated with the temporary bypass channel constrictions, outbound recreational and commercial vessel traffic, and mobilized construction platforms and permanent constrictions associated with the constructed surge barrier gates and outbound recreational and commercial vessel traffic; temporary impacts to recreational navigation traffic would be induced by construction of the flow control structures at Clear Creek, Dickinson Bayou, and Offatts Bayou, which are proposed to each consist of a single opening **South Padre Island CSRM:** *Indirect*: Sediments placed for dune/beachfill features are expected to migrate northward with the littoral drift, to be impounded by Port Mansfield Channel immediately south of the jetty, with sediments migrating into the entrance of the Port Mansfield Channel and adding to the shoaling of the channel **ER Measures:** *Direct*: Temporary impacts to navigation traffic within the GIWW during construction *Indirect*: Measures would provide protection to the GIWW and its barge traffic from wind-induced wave energy	**Bay Rim CSRM:** Similar to those described for the Preferred Alternative **South Padre Island CSRM and ER Measures:** Same as Preferred Alternative
Flood Risk Reduction			
	Protection provided by hurricane flood protection, pump stations, and flood protection projects would continue	Texas City HFPP is part of the Bay Rim (Bay Rim Alternative) with the line of protection being extended on either end of the current project. There will be no alterations to the Texas City alignment under Coastal Barrier Alternative No changes or impacts are anticipated to the Lynchburg Pump Station with the construction of the Coastal Barrier or Bay Rim alternatives No changes or impacts are anticipated to the Colorado River Flood Protection at Matagorda with the construction of the Coastal Barrier or Bay Rim alternatives	

This cumulative impact analysis was scoped with a temporal boundary of approximately 100 years in the past (1918), from the beginning of the study, and approximately 50 years into the future (2085), from construction completion. This timeframe accounts for the period of time when significant hydrologic modifications occurred within the focused study area. This period of analysis also captures the period of time when a significant number of environmental laws were enacted in which resource protection became a priority. The future timeframe aligns with the planning and economic period of analysis, and the HEP modeling.

For a spatial boundary to scope this cumulative impact analysis, projects or actions considered were mostly bounded by Galveston Bay to the Rio Grande. Some projects or actions within Jefferson County and Sabine Lake region were included as they have the potential to contribute beneficial effects to nearby ER measures in Chambers and Galveston counties. In addition, some inland projects were also considered as they have potential to affect the TSP and contribute to cumulative impacts (e.g., Harris County and Houston-area flood damage reduction projects).

5.10.1 Past or Present Actions

5.10.1.1 Upper Coast

GIWW Maintenance. The USACE Galveston District published “Maintenance Dredging, Gulf Intracoastal Waterway, Texas Section – Main Channel and Tributary Channels” (an EIS) in October 1975. This document identified and evaluated the environmental impacts of continued maintenance dredging of the GIWW Texas Section and tributary channels. The proposed action was continued maintenance by periodic dredging of shoal deposits. The main channel was authorized at a 12-foot depth and a 125-foot bottom width. The typical means of dredging is by hydraulic pipeline dredge, with the exception of the Port Mansfield Channel that can be maintained by either pipeline or hopper dredge. At the time of the 1975 EIS, the environmental impact and adverse environmental effects of the proposed action were addressed based on the best available information (USACE, 1975).

Sabine-Neches Waterway Channel Improvement Project. The Sabine-Neches Waterway is a 64-mile-long Federally constructed deep-draft navigation project serving Jefferson and Orange counties in Texas and Cameron and Calcasieu parishes in Louisiana. The Sabine-Neches Waterway is home to 2 of our Nation’s 17 Department of Defense’s Strategic Seaports. The Port of Beaumont at the upstream end of the channel and the Port of Port Arthur closer to the downstream end of the channel. The existing waterway consists of a jettied entrance channel, 42 feet deep and 500 to 800 feet wide from the Gulf; a channel 40 feet deep and 400 feet wide to Beaumont via the Neches River; and a channel 30 feet deep and 200 feet wide to Orange via the Sabine River. The USACE’s recommended plan includes modifying the existing waterway by deepening the channel to 48 feet to avoid congestion and delays, increase safety, and improve efficiency and throughput capacity. The Sabine-Neches Waterway Channel Improvement Project was authorized for construction in Section 7002 of Water Resources Reform and Development Act 2014. However, the project economics excluded the latest investments that were under construction along the waterway at the time with more than $30 billion in improvements to the Sabine-Neches Waterway’s refining and petrochemical industries. In April 2013, the Sabine-Neches Navigation District requested and was granted a modified design agreement that allowed for a reevaluation of the economics during preconstruction, engineering, and design. The Limited Reevaluation Report for the Sabine-Neches Waterway was completed in October 2016 and confirms the increased national economic significance of the Sabine-Neches Waterway. This economic analysis resulted in a benefit-cost ratio of 2.28 (using the FY 16 Federal interest rate of 3.125 percent), demonstrating that improvements to the Sabine-Neches Waterway will increase navigational efficiency while maintaining the ecological value of coastal and estuarine resources within the project area (USACE, 2018a).

McFaddin NWR Beach Dune Restoration. Jefferson County is acting to restore 104,150 linear feet of dune ridge and beach face along the 20 miles of beach along McFaddin NWR. Offshore 1.5 miles from the beach, a 241-acre borrow site will serve as the source for sand. The beach nourishment and dune creation would involve the discharge of approximately 4.1 mcy of sandy material into 1,004.16 acres of tidally influenced beach and open water. The proposed beach widths would range from 20 to 300 feet and the dune crest heights would be approximately +6 to +9 feet NAVD 88. The design criterion for dune elevation and beach height and width is intended to reduce inundation events into the NWR marshes, reduce shoreline erosion rates, and return sandy sediment to the littoral system. As of June 2017, approximately 3 miles of beach and dune restoration have been completed (SWG-2015-00444).

Smith Oaks Bird Sanctuary Rookery Island Restoration and Enhancement. The Texas Audubon Society has proposed bird sanctuary improvements to the Smith Oaks Bird Sanctuary on High Island. Excavation and fill activities will impact 3.2 acres of wetland habitat, and 6,791 cy will be discharged into wetlands during the process. Material will be used to create two bird rookery island sites, one in each pond, and to form emergent and shrub-scrub fringe wetland habitat (SWG-2017-00277).

East Bay and GIWW Shoreline Protection and Restoration. The Galveston Bay Foundation joined the USFWS along with other partners to protect the Anahuac NWR bay shorelines from continued erosion. The work began in 2006 and was completed through three phases in 2011. Rock breakwaters, reef dome breakwaters, and ReefBLK breakwaters were utilized to achieve the desired shoreline protection goals. The combined project phases had the effect of protecting 56,770 feet of refuge shoreline, and thousands of acres of marsh habitat. In addition, 5.5 acres of intertidal marsh was created through the planting of smooth cordgrass by volunteers.

Bolivar Peninsula Beach/Dune Restoration. Galveston County has ongoing efforts to improve the beaches and dunes on the Gulf side of Bolivar Peninsula primarily through nourishment activities on the beach front. Early efforts included the use of dredged sand from Rollover Bay for use in geo-tubes, while recent permit updates include sourcing sand from upland borrow sites on Bolivar Peninsula. The county plans to dredge approximately 300,000 cy of material for use in beach nourishment from Rollover Pass to beyond High Island (SWG-2007-00391).

Burnet Bay Marsh Mound Creation. Aerial imagery dating back to the early 1900s shows extensive marsh loss due to an estimated 5–8 feet of subsidence in Burnet Bay, west of Baytown. In response, the Galveston Bay Foundation discharged approximately 34,000 cy of material to construct an additional 15 marsh mounds within a

43.9-acre area on the northwest side of Burnet Bay. The mounds were constructed by hydraulically pumping sediment from nearby borrow areas, one previously authorized borrow area, and another newly proposed. The mounds add to an existing mound complex and provide additional habitat and ecological benefits (SWG-2008-00127). Upon completion of the project, volunteers planted wetland vegetation on the newly created mounds.

Houston Ship Channel Dredging and Bulkhead Construction. Kinder Morgan Terminals performed dredging, filled 3.25 acres of open water, and constructed 2,400 linear feet of bulkhead in the process of expanding operations at an existing liquid bulk cargo facility. Approximately 250,000 cy of material was dredged, 80,000 cy of which was placed into 3.25 acres of open water for the construction of two additional storage tanks. The remaining dredged material was placed in authorized privately owned placement areas (SWG-2014-00023).

Barbours Cut Ethane Terminal Improvements. Enterprise Products Operating LLC created a new vessel terminal, mooring locations, and bulkhead, and performed dredging to accommodate discharging and loading vessels. Terminal construction involved dredging to a depth of –45 feet mean low tide, and impacted 12.6 acres of open water, including 0.48 acre of estuarine intertidal emergent wetlands, and 0.84 acre of oyster reef. Approximately 421,000 cy of material was placed in approved placement areas. A new bulkhead was also constructed along the shoreline of Spillman’s Island to maintain stability from dredging activities (SWG-2014-00905).

Bayport Ship Channel Container Terminal Dredging. The Port of Houston Authority dredged 7,000 linear feet of ship berths adjacent the Bayport Ship Channel Container Terminal in an area totaling 36.2 acres. The previously authorized depth of –40 feet was increased to –45 feet mean low tide, plus 2 feet of advanced maintenance and 2 feet of allowable overdepth, for a maximum of –47 feet. Approximately 1,231,000 cy of material was removed and placed in nearby placement areas adjacent the ship channel (SWG-1998-01818).

Dickinson Bayou Wetland Restoration and Protection. The TPWD teamed with numerous partners to accomplish a wetland restoration, creation, and protection project along the shoreline of Dickinson Bayou, which protected 17.7 acres of wetlands, and created approximately 12.3 acres of intertidal wetland complex. Marsh creation was achieved through the beneficial use of dredge material from three borrow areas in the Dickinson Bayou Channel. Earthen berms totaling 3,000 linear feet were placed around the created wetlands, and riprap was placed along the bayou-facing sides for erosion protection. The new wetlands were planted and seeded with smooth cordgrass (SWG-2013-00148).

Moses Lake Shoreline Protection. The Galveston Bay Foundation has proposed the construction of 7,500 linear feet of limestone breakwaters along the western shoreline of Moses Lake. The breakwaters will be placed from 25 to 250 feet from the shoreline along the –2.0 feet NAVD 88 contour. The designed width of the breakwaters is 27 feet, and the crest elevation will be +2.0 feet NAVD 88. The project would utilize 16,670 cy of riprap, and three bird nesting pads would also be incorporated into the structures (SWG-2015-00687).

Swan Lake Restoration. In response to significant marsh loss over the past 50 years, a rock breakwater was constructed in 2003, and in 2007, 77 acres of marsh were restored in Swan Lake. Up to 200,000 cy of beneficial use dredge material was used for the marsh restoration effort. The material was pumped from a nearby source into habitat restoration cells and placed at a suitable elevation to support marsh planting. In response to ongoing habitat degradation, the TPWD and the GLO are planning to restore an additional 250 acres of intertidal marsh complex in Swan Lake.

Greens Lake Shoreline Erosion Protection. Ducks Unlimited Inc. has proposed the construction of a breakwater along the northern bank of the GIWW from the mouth of Carancahua Lake and extending 3.3 miles northeast to the Flamingo Isles development. Approximately 25,848 cy of graded riprap would be utilized for breakwater construction. The breakwaters would be 20 feet wide, have a 3-foot crest height, and be placed 10 to 150 feet from the existing bank. To accommodate tidal flushing and boat traffic, there would be two separate breakwaters, forming an opening at Greens Lake (SWG-2015-00415).

North Deer Island Protection and Restoration. North Deer Island, one of the few remaining natural islands in Galveston Bay, has undergone several attempts to protect the vital bird rookery habitat. Under Phase I a breakwater protecting 5,750 feet of shoreline was constructed in 2003 around the southwest portion of the island and benefiting 57 acres of marsh. Phase II of the effort was completed in 2008 and included an additional 3,600 feet of breakwater protection on the south end, groins along the northern shoreline near the GIWW, and a 900-foot breakwater on the northwest shoreline. Phase II improvements were expected to protect 49 acres of marsh and 25 acres of upland habitat. Approximately 8 acres of marsh were restored through beneficial use of sediments dredged from barge access channels and planted with marsh cordgrass.

Galveston Bay Oyster Reef Restoration. The TPWD completed oyster restoration efforts at four sites in Galveston Bay in 2017. The sites included Todd's Dump Reef, South Redfish Reef, and two locations on the north side of the Texas City Dike. Oyster cultch was distributed into 10-foot diameter mounds, with 10 to 15 feet of space between mounds. Maximum crown height of the reef mounds did not exceed 3 feet below MLLW elevation of 5 feet. Approximately 9,670 cy of oyster cultch was placed between the sites, at about 4 cy per mound (SWG-2016-00252, 00270).

Galveston Island Beach Nourishment. The Galveston Park Board and partners teamed to address ongoing erosion by placing over 1 mcy of sand hydraulically dredged from the Bolivar Roads south jetty along nearly 4 miles of beachfront. The beach was renourished between 12th and 61st streets and was completed in the spring of 2017, adding between 100 and 150 feet of beachfront after settling. This most recent project, combined with previous nourishment projects west of 61st Street, accounts for over 5 miles of beach nourishment on Galveston Island (SWG-2000-02888).

Pierce Marsh Restoration. The Galveston Bay Foundation has begun the process of using hydraulically dredged material from GIWW maintenance for placement in Basford Lake in West Bay, southwest of Bayou Vista, in an area known for marsh loss. In total, 1,464,000 cy of hydraulically dredged material will be placed into 364 acres of submerged bay bottom to support the restoration of marsh habitat. In addition, 50,000 cy of mechanically dredged material will be placed into 10.8 acres of submerged bay bottom for the creation of perimeter berms at +2.7 NAVD 88. The berms will be planted and constructed to protect the interior hydraulically dredged material (SWG-2015-00313).

Galveston Island State Park Marsh Restoration and Protection. The TPWD is constructing 12,900 linear feet of rock breakwater in the Carancahua Cove, Butterrowe Bayou, Oak Bayou, and Dana Cove areas. In addition, 400,000 cy of sandy material from a nearby borrow in West Bay was used to restore intertidal elevations in the marsh behind the breakwaters. The dredged material was used to create marsh mounds with a maximum elevation of +2.7 NAVD 88 (SWG-2009-00148).

Sweetwater Preserve Shoreline Protection and Oyster Habitat Enhancement. The Galveston Bay Foundation has constructed 1,900 linear feet of oyster hash breakwater and planted 1.75 acres of smooth cordgrass along the eastern shoreline of Sweetwater Lake. The breakwaters occupy approximately 0.35 acre of former open water (SWG-2014-00258).

Snake Island Restoration. Snake Island Cove is a 900-acre, shallow, marsh-lined cove located in Galveston Bay. Seagrass degradation and loss were cause for concern in the area, and in 2007 and 2011, 4,900 linear feet of geotextile tube breakwater was installed to protect 200 acres of estuarine intertidal marsh complex. The result was also the creation of over 75 acres of protected calm shallow water habitat, which has led to the reestablishment of seagrasses within the project area.

Gang's Bayou Marsh Restoration and Protection. The TPWD completed a marsh restoration and protection project in West Bay at Gang's Bayou, west of Sportsman Road. The 45,000 cy of sediment from an 88.4-acre borrow site and access channel was hydraulically dredged and placed as marsh mounds with a height of +2.5 feet NAVD 88. A 3,800-linear foot breakwater using 13,000 cy of riprap was also constructed to protect 17.4 acres of saltmarsh and the constructed marsh mounds (SWG-2015-00652).

Oyster Lake Habitat Protection and Marsh Restoration. The USFWS completed a multi-phased project addressing erosion protection between a narrow strip of shoreline and marsh between Oyster Bay and West Bay in the Brazoria NWR. Initial stages included the installation of 500 feet of reef ball breakwaters on either side of the shoreline in 2012. In 2015, 2,500 linear feet of riprap breakwater was constructed to the north and south of the existing reef balls. The long breakwater segments displaced approximately 2.6 acres of bay bottom with approximately 7,000 cy of material (SWG-2012-00679). Ultimately, the project resulted in the construction of a 4,786-foot riprap breakwater that protects 5,150 feet of shoreline. The breakwater also protects upwards of 60 acres of coastal habitat that are part of the Brazoria NWR. Behind the shoreline protection features, the project now has the potential to restore intertidal wetlands in a 14-acre calm-water protected area. As of 2016, approximately 1.5 acres of this area has been planted with smooth cordgrass (Galveston Bay Estuary Program, 2016).

Surfside Beach Groins and Nourishment. The Village of Surfside Beach previously completed a beach nourishment project in March 2015 that placed 118,000 cy of sand from three upland sand pits along the beachfront, stretching 4,800 feet north from the Freeport jetties. The construction of two rock groins has been proposed, along with approximately 2,000 feet of beach nourishment on the northeast end. The rock groin footprint totals 1.7 acres and includes 1,650 cy of material (SWG-1998-02508).

Bryan Beach Renourishment. Using GLO Coastal Erosion Planning and Response Act funds, the Town of Quintana has renourished approximately 0.37 mile of beachfront in an area called Bryan Beach. An upland sand pit near the Colorado River and south of Bay City was used to source 99,600 cy of sand for the 16-acre dune reconstruction and beach nourishment project (SWG-2013-00640).

GIWW Barge Facility Expansion and Maintenance. Texas Barge and Boat performed maintenance and expansion of their facilities located off the GIWW, northeast of the Brazos River floodgates. Work was performed without a permit, and the company filed for an after-the-fact permit to retain impacts to waters of the U.S. Approximately 100,602 cy of material was dredged from uplands, resulting in the creation of 6 acres of open water, and approximately 2,288 cy of dredge material was placed into wetlands and open water. The applicant also constructed approximately 856 linear feet of steel bulkhead and placed approximately 305 cy of riprap below the high tide line for erosion protection. Pipe piling mooring structure was also installed for 1,682 linear feet within the project area (SWG-2001-01994).

5.10.1.2 Mid to Upper Coast

Mad Island WMA Shoreline Protection. The TPWD has completed 1.8 miles of breakwater to protect the Mad Island WMA shoreline along the GIWW from erosion. The TPWD is proposing to construct an additional 0.57 mile east of the previously constructed breakwater to Culver Cut. The final length of the breakwater will be approximately 2.37 miles. Approximately 4,900 cy of graded riprap will be used for the remaining segment of the project; upon completion, 20,400 cy will have been used. The final segment of the breakwater has not been completed (SWG-2009-00124).

Half Moon Reef Restoration. The TNC and USACE Galveston District teamed to restore a large historic subtidal reef in Matagorda Bay. In 2014, construction was completed on the 60-acre restoration project of one of the largest oyster reefs in the Gulf. Recycled concrete in various sizes was placed in a specific pattern to encourage the reef to grow vertically and to create niches and passageways for all kinds of marine organisms.

Formosa Plastics Plant. Formosa currently operates eight plants and support facilities at a 2,500-acre complex in Point Comfort. The plant started operations in 1983 and was further expanded in 1994, 1998, and 2002. The facility has added several new plastics production units, a wastewater treatment facility, and power co-generation. The facility manufactures plastic resins and petrochemical products. The Formosa Plastics Receiving Water Monitoring Program was established in 1993 and continues to monitor the discharge of treated wastewater into Lavaca Bay from the facility (Formosa Plastics Corporation USA, 2017).

Alcoa Alumina Plant. Alcoa operates one plant and support facilities at a 3,500-acre complex in Point Comfort. The plant has been in operation since 1948 and produces alumina and alumina chemicals. As of 2017, due to high imports of aluminum and high cost of power, the Point Comfort plant has been idled. The area around the plant was designated as a superfund site by the EPA in 1994 for its wastewater release of mercury. Portions of Lavaca Bay remain closed to finfish and crab harvest due to unsafe levels of mercury (EPA, 2017b).

GIWW. The GIWW is a shallow-draft, inland waterway used to transport cargo and goods throughout the Gulf coast. The channel stretches from St. Marks, Florida, to Brownsville, Texas, and was designed to be 12 feet deep by 125 feet wide. The GIWW West Matagorda Bay section (channel mile 454 to 473) is proposed to be rerouted from its original course to one farther north for safety and maneuverability. Dredging activities for the Matagorda Bay reroute have not started and are pending Federal funding (USACE, 2012b).

The Sanctuary at Costa Grande Mitigation Plan. D.H. Texas Development LP is proposing modifications to their mitigation plans for the Sanctuary at Costa Grande housing development. The development firm is amending the original permit and proposing to create 16 acres of freshwater wetlands instead of tidal wetlands and to relocate the planned 1.8-acre seagrass mitigation site to a site on the northeast point of Dewberry Island. The project is not yet completed (SWG-2005-00181).

5.10.1.3 Mid to Lower Coast

Park Road 13 Seawall Improvements. The TPWD is proposing to elevate approximately a 300-foot-long section of Park Road 13 (Trout Street) approximately 12 to 24 inches. The TPWD is also planning on constructing a 624-foot-long concrete seawall to tie in with the existing seawall on each side of the project site. The footprint of the design would require filling 0.261 acre below the annual high tide line and 0.0081 acre below the mean high water. The project has been approved but not yet completed (SWG-2003-01546).

Rockport Beach Nourishment Project. The project provided beach nourishment along Rockport Beach in Aransas County. The beach area experienced approximately 4,800 feet of shoreline erosion. Approximately 9,154 cy of sand was placed to repair the beach. Approximately 1.6 acres of sand was placed below the mean high water line, and 2.6 acres was placed below the annual high tide line. The project was completed in 2016 (SWG-1991-01789).

Rockport Harbor Maintenance Dredging. Aransas County Navigational District conducted maintenance dredging of Rockport Harbor. An estimated 109,876 cy was dredged from the harbor. Dredged materials were placed in an adjacent upland area. The project was completed in 2017 (SWG-2016-00194).

Ingleside Ethylene Cracking Plant. Occidental Chemical Corporation and Mexichem have completed construction on and have started up an ethylene cracking facility with the capacity to produce 1.2 billion pounds of ethylene per year. The ethylene will be used to manufacture vinyl chloride monomer and polyvinyl chloride. The plant was completed and started production in February 2017 (Chemical-Technology, 2017).

OXY Ingleside Energy Center. The OXY Ingleside Energy Center terminal has a total storage capacity of 2.1 million barrels and throughput capacity of 300,000 barrels per day. The facility can accommodate Aframax- and Suezmax-sized vessels. The crude oil storage and export terminal was completed and began operations in 2016 (Port of Corpus Christi, 2017a).

Corpus Christi Liquefaction Project. Cheniere Energy, through its affiliate, Corpus Christi Liquefaction LLC, is proposing the construction and operation of an LNG exporting facility on the La Quinta Ship Channel. The 1,000-acre site will include five liquefaction trains, marine tanker loading facilities, and 23 miles of pipeline. The marine loading berths will require dredging to create a turning basin and deepening of the La Quinta Channel. Project construction has begun and is in progress (Cheniere Energy, 2017).

Corpus Christi Ship Channel Improvements. The Port of Corpus Christi Authority is proposing to increase the capabilities of the existing ship channels. The Port of Corpus Christi Authority has already extended the channel 1.4 miles and deepened the La Quinta extension to –47 feet msl. The second phase is to widen the Corpus Christi Ship Channel to 530 feet and deepen the channel from –47 to –54 feet msl. The first phase of the project has been completed. The second phase of the project is pending (SWG-2005-01290).

Corpus Christi New Harbor Bridge. The city of Corpus Christi and TxDOT are currently in the construction phase of the new Harbor Bridge design. The new Harbor Bridge will have a main span of 3,285 feet and a vertical clearance of 205 feet. The new bridge will allow larger ships to enter the Corpus Christi Ship Channel. Construction on the bridge began in 2017 and is expected to be completed in 2020 (Flatiron Dragados USA, 2017).

Lake Padres Subdivision Canal. Gulf Shores Joint Venture is proposing to construct a canal-type connection between Lake Padre and the existing canal at Cruiser Street. The canal will extend under Park Road 22, along Padre Isles Golf Course. The project, as proposed, would impact a total of 122.6 acres of waters of the U.S., including 90.8 acres of wetlands, 20.1 acres of sand flats, and 11.8 acres of tidal open water (Lake Padre). Dredging of the wetlands and placement of fill for the project has started. The project is not yet complete (SWG-2000-02743).

5.10.1.4 Lower Coast

South Padre Island Beach Nourishment. South Padre Island beach has been nourished multiple times since the first nourishment in 1997, facilitated by Coastal Erosion Planning and Response Act funding and through collaboration among the Texas GLO, USACE, and the Town of South Padre Island. Coastal Erosion Planning and Response Act Cycle 1 funded the first nourishment and continues to support the long-term nourishment of South Padre Island beach. Beneficial use of dredged material from Brazos-Santiago Pass was utilized during routine maintenance dredging of the Brownsville Ship Channel. During Cycle 2, a total of 348,000 cy of sand was placed on 3,780 feet of shoreline using beneficial use of dredged material. An additional Cycle 2 project utilized 120,000 cy of sand harvested from Park Road 100 by TxDOT on 2,000 linear feet of beach. A Cycle 4 nourishment project saw another 7,100 cy taken from Park Road 100 and placed on the beach, and wind-blown sand from the road continues to be used for nourishment and to rebuild dunes. In 2016, a USACE nourishment project moved 651,000 cy of beneficial use of dredged material from the Brownsville Harbor navigation channel to renourish approximately 0.75 mile of South Padre Island beach.

Adolph Thomae Jr. County Park Improvements. Cameron County has begun the process of improving facilities at the Adolph Thomae County Park, located near the mouth of the Arroyo Colorado River within the Laguna Atascosa NWR. The heavily used park has improved facilities and has begun shoreline repairs and stabilization efforts along the 2-mile stretch on the south bank of the river. The project will include 870 linear feet of precast concrete block wall with gravel backfill, 3,200 linear feet of habitat bench including riprap stone, 315 linear feet of articulated concrete block mattress, 200 linear feet of riprap breakwater, and riprap transitional sections between structures. Habitat bench installation will involve the discharge of approximately 6,100 cy of riprap, 3,415 cy of gravel backfill, and 3,200 cy of base stone below the high tide level elevation. An additional 0.156 acre of wetlands would be filled with base stone (SWG-2015-00602).

5.10.2 Reasonably Foreseeable Actions

5.10.2.1 Upper Coast

Texas Coastal Resiliency Master Plan. The GLO developed a master plan that identified critical coastal issues and potential projects to address those issues. Some of the common issues identified include altered or degraded habitats, Gulf beach erosion and dune degradation, bay shoreline erosion, coastal storm surge damages, coastal flood damages, water quality and quality degradation, impacts of other coastal resources, and abandoned derelict vessels, structures, and debris. To address these issues, the GLO identified several strategies including restoration of beaches and dunes, bay shoreline stabilization and estuarine wetland restoration, GIWW stabilization, freshwater wetlands and coastal uplands conservation, delta and lagoon restoration, oyster reef creation and restoration, and implementation of plans, policies, and programs. The Master Plan effort considered numerous projects to address coastal issues and ultimately identified a total of 59 coastal resiliency projects (during this iteration of the Master Plan), including 25 in the upper Texas coast, 12 in the mid to upper Texas coast, 16 in the mid to lower Texas coast, and 6 in the lower Texas coast. Future iterations of the Master Plan will reflect a greater depth and breadth of analysis as the planning process matures, and as additional data and analytical techniques are developed. Subsequent planning is also expected to include additional emphasis on life cycle and phasing aspects of recommended projects, an enhanced focus on storm surge defense and flood risk reduction, restoration of water quality, and community development and revitalization to achieve a more robust and resilient coast (GLO, 2017).

Texas GLO Coastal Erosion Planning and Response Act (CEPRA) Program. The GLO administers the CEPRA Program and it is intended to implement coastal erosion response projects and related studies to reduce the effects of and to understand the processes of coastal erosion as it continues to threaten public beaches, natural resources, coastal development, public infrastructure, and public and private property. CEPRA projects ultimately yield positive or beneficial effects to coastal resources. Some of the CEPRA Program reasonably foreseeable actions include the following beneficial coastal projects:

- Jamaica Beach Dune Restoration
- Rollover Pass Closure
- Rollover Recreational Amenities Plan
- Follets Island Nearshore Beach Nourishment
- Virginia Point Wetland Restoration and Protection
- West Galveston Island Bayside Marsh Restoration

- Beach Monitoring and Maintenance Plan Monitoring
- Bolivar Beach Restoration
- Dellanera Park Beach Nourishment
- GIWW-Rollover Bay Reach Beneficial Use Beach Nourishment
- Babes Beach Nourishment
- Texas Coastwide Erosion Response Plan Update 2018
- Indian Point East Shoreline Protection

Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration. The USACE proposed to reduce the risks of tropical storm surge impacts by constructing the Orange 3 CSRM system in Orange County, and improving flood protection in Port Arthur, Freeport, and Hurricane Flood Protection systems in Jefferson and Brazoria counties. The Orange 3 project would consist of a 26.7-mile-long levee/floodwall system along the edge of the Sabine and Neches river floodplains from Orange to Orangefield, Texas. The Port Arthur and Freeport projects would raise or reconstruct 11.6 and 18.2 miles of existing levees/floodwalls, replace vehicular closures, construct navigable surge gates, and increase resiliency through erosion protection. The hydrologic condition of the area is not anticipated to be affected by the features of the TSP. The Orange 3 project would result in the loss of 69.5 acres of forested wetlands and 203 acres of estuarine marsh, as well as functional impacts to 2,137.2 acres of estuarine marsh. The impacts would result in the loss of 43 average annual habitat units for forested wetlands and 143 average annual habitat units for estuarine marsh. Mitigation would restore 453 acres of estuarine marsh and preserve 559.5 acres of forested wetlands to compensate for the impacts from the project (USACE, 2017a).

Jefferson County Ecosystem Restoration. The USACE, in partnership with Jefferson County and the Sabine Neches Navigation District, prepared an Integrated Feasibility Report and EA for the Jefferson County Ecosystem Restoration Study in Jefferson County, Texas (USACE, 2018b). In addition to the "no-action" alternative, four alternatives with varying levels of ER were evaluated, including the recommended plan. Implementation of the recommended plan would include restoration of 8,421 acres of marsh and construction of 6,592 linear feet (1.25 miles) of offset breakwaters that would be placed along the south bank of the GIWW. Dredged material used in the recommend plan would be provided during implementation of normal dredging operations or through the Sabine-Neches Waterway Channel Improvement Project. Marsh restoration would beneficially use material dredged from the Sabine-Neches Waterway to increase the marsh elevation in five restoration units. Renourishment would occur at approximately year 30 to increase the target elevation to provide resiliency and sustainability in anticipation of projected RSLC (USACE, 2018c). The USFWS concurred that the recommended plan would not adversely affect any listed species. The NMFS issued biological opinions for normal dredging operations and the Sabine-Neches Waterway Channel Improvement Project in 2003 and 2007, respectively. Both Biological Opinions determined that the recommended plan will not jeopardize the continued existence of Federally listed species or adversely modify designated critical habitat. All terms and conditions resulting from previous consultations shall be implemented to minimize take of endangered species during dredging operations.

Cedar Bayou Navigation Improvements. The USACE has evaluated improvements to Cedar Bayou. Cedar Bayou is a coastal stream that originates in Liberty County, Texas, east of Houston. It becomes navigable on the north end and meanders south along the urbanized eastern portion of the city of Baytown before entering Galveston Bay and the Houston Ship Channel. The project is supported by the Port of Houston Authority, the busiest barge channel in the United States; Kirby Corporation, the largest barge company in the United States; and the community and the companies who rely on the channel for their business. Companies that utilize the channel now and plan to use it in the future include Bayer Material Science LLC, Koppel Steel, Walmart, Home Depot, Dorsett Brothers Concrete, Reliant Energy, and Angel Brothers Cemex, to name a few. The channel primarily serves chemical, aggregate, steel, and asphalt. The waterway currently carries more than 1.5 million tons per year. Recent economic updates project a significant increase in the future; increases that depend on a normalized channel with a depth of 11 feet and a width of 100 feet. Constructing the Locally Preferred Plan would extend the barge transport benefits up to Mile 11, reduce environmental impacts, create a safer channel for the increased future traffic, and serve anticipated heavy development along the channel. The additional channel depth will accommodate barge traffic using the Houston Ship Channel and the GIWW without light loading. In addition, the wider channel and the cutoff of the bend at Devil's Elbow will result in much safer transport of materials and an area for barge tie up. The previously authorized and improved portion of the navigation project extends from its junction with the Houston Ship Channel near Barbours Cut container terminal at Mile 25, eastward across Galveston Bay to the mouth of Cedar Bayou to a point 3 miles upstream. The project dimensions are 11 feet by 100 feet. The proposed and newly authorized project extends the channel by 8 miles to SH 146 (USACE, 2018c).

Trinity Bay Living Shoreline and Erosion Protection. Chambers County is proposing to install 1,571 linear feet of living shoreline at Fort Anahuac Park on the eastern shore of Trinity Bay. The living shoreline would be constructed of concrete or limestone riprap, and smooth cordgrass would be planted on the protected shoreward side. A total discharge of 0.54 acre of fill material is expected (SWG-2016-00260).

Trinity Bay Discovery Center Shoreline Protection and Habitat Creation. The Galveston Bay Foundation has proposed the installation of a 1,200-linear-foot breakwater on the eastern shoreline of Trinity Bay. The breakwater would be composed of riprap and recycled oyster shells and occupy 0.5 acre of bay bottom. The action would also result in 2,070 cy of fill material. To facilitate marsh creation, smooth cordgrass would be planted between the existing shoreline and the proposed breakwater (SWG-2017-00589).

Buffalo Bayou and Tributaries Flood Risk Management. The Addicks and Barker Dam and Reservoirs are part of the Buffalo Bayou and Tributaries flood risk management system located within the west side of the city of Houston. The Addicks and Barker Dams Dam Safety Modification Study by the USACE was the first (Phase 1) of a two-phase effort to fully address all dam safety issues associated with the Addicks and Barker Dams/Reservoirs. The Phase 1 of the study was initiated in 2009 and completed to primarily to address the issues near the conduits. A follow-on the Phase 2 study is proposed to assess risks associated with flows around and over the auxiliary spillways at the ends of the dams and flood risk in the pool areas upstream of the Addicks and Barker reservoirs and downstream along Buffalo Bayou. The purpose of this Section 216 study will be to investigate flood risk management problems in the Buffalo Bayou watershed that are not part of the Addicks and Barker

Dams Dam Safety Modification Study Phase 1 or 2, including non-breach risk from spillway flow, residual risk in the upstream pool areas and downstream of the dams, water drainage from Cypress Creek watershed, and the potential need for a third reservoir in the Cypress Creek watershed (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Houston Regional Watershed Assessment. The USACE study area would include 22 primary watersheds within Harris County, 1,756 square miles encompassing Houston metropolitan region, each having unique flooding problems. These include Spring Creek, Little Cypress Creek, Willow Creek, Cypress Creek, Addicks, Barker, Buffalo Bayou, Clear Creek, Sims Bayou, Brays Bayou, White Oak, Greens Bayou, Hunting Bayou, Vince Bayou, Armand Bayou, Carpenters Bayou, San Jacinto River, Jackson Bayou, Luce Bayou, Cedar Bayou, Spring Gully and Goose Creek, and San Jacinto and Galveston Bay estuaries. Flooding problems in the watershed are frequent, widespread, and severe. Recent historical flooding in the region was documented in 1979, 1980, 1983, 1989, 1993, 1994, 1997, 2001, 2006, 2007, 2008, 2015, April 2016 with the loss of 8 lives, widespread damages to 5,400 homes and about $3 billion worth of damages to businesses, and most recently August 2017 with the loss of over 60 lives and billions in damages that are yet to be quantified. The principle purpose of the study is to develop a watershed management plan that would provide a system wide approach to water resources management. There is a significant opportunity to integrate and improve the operations of existing flood risk management systems and activities in Houston, Texas, the 4th largest metropolitan region in the Nation, while seeking opportunities to restore degraded ecosystems (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Brays Bayou Flood Risk Management Project. The USACE authorized project consists of 4 detention basins (Sam Houston, Old Westheimer Road, Eldridge Road, and Willow Waterhole), enlargement or modification of 21.1 miles of earthen channel, replacement and/or lengthening of 27 bridges. The project is being implemented under the authority of Section 211(f) of WRDA of 1996 where the work is accomplished by the NFS and following approval, the sponsor is reimbursed by the Federal Government for the Federal share. Direct benefits provided by the project are reduction of the 100-year return period floodplain by 97 percent. The project is about 80 percent complete and just beginning to reach critical life safety and health infrastructure in the community. This project will reduce the risk of flooding to the Texas Medical Center, which is the largest medical patient care, teaching, and research center in the world and includes patient’s life and health in the 14 Texas Medical Center hospitals during major flood events due to staff and physicians not being able to travel through high water. The project will also reduce the risk of flooding along major traffic commuter routes such as SH 288, which is below ground level for much of its length crossing the Brays Bayou watershed. In addition, the project will reduce the risk of high-water causing life safety concerns on feeder roads and adjacent roadways along I-45, a hurricane evacuation route through Houston and Harris counties (USACE, 2018a).

White Oak Bayou Flood Risk Management Project. The USACE evaluated flood risk management on White Oak Bayou. White Oak Bayou is a tributary of Buffalo Bayou which originates northwest of FM 1960 and flows generally toward the southeast. The watershed covers about 110 square miles and includes three primary streams: White Oak Bayou, Little White Oak Bayou, and Cole Creek. The existing Federal channel in the lower reach of White Oak Bayou was completed in the mid 1970s under the authorization of the Flood Control Acts of 1954 and 1965 for Buffalo Bayou and tributaries. In 1986 the project was reauthorized under Buffalo Bayou and tributaries (Upper White Oak Bayou) in the WRDA of 1986 Section 401(a) based on the Chief of Engineers report dated June 13, 1978. In 1990 the Upper White Oak project was included in WRDA 1990 Section 101(a)(21) for the authorization of Buffalo Bayou Tributaries, which included six separate flood damage reduction plans for the tributary streams of Carpenters, Greens, Halls, Hunting, Little White Oak, and Brays bayous. When the study was initiated in 1999, it began as a feasibility study of 9.2 miles of channel modifications on the upper reach of White Oak Bayou including nonstructural flood plain management of future suburban development. The sponsor, HCFCD completed the General Reevaluation Report under Section 211(f) of WRDA 96 and received the Assistant Secretary of the Army (Civil Works) approval on August 28, 2014. The recommended plan includes earthen channel modification from Cole Creek to FM 1960; four detention basins of approximately 2,940 acre-feet of storm water storage; 4.99 acres of compensatory wetland credits in the Greens Bayou Wetlands Mitigation Bank; and approximately 12 miles of a linear bikeway. The proposed project reduces the extent of the 10 percent and 1 percent floodplain areas so that 1,285 and 1,511 structures, respectively, would now be located outside of the two reduced floodplain areas, leaving 48 and 4,563, structures, respectively, within the floodplains (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Hunting Bayou Flood Risk Management Project. The USACE evaluated flood risk management on Hunting Bayou. The Hunting Bayou watershed is located in central Harris County, Texas, northeast of downtown Houston, and is about 30 square miles. Hunting Bayou runs approximately 15 miles from its headwaters west of U.S. Highway 59 to its confluence with Buffalo Bayou near the Houston Ship Channel. Flooding problems on Hunting Bayou are primarily the result of flat topography and channel inadequacy to discharge increased runoff from urban development that occurred prior to local watershed management policies. The existing flood risk impacts life, health and safety of many who live in Harris County. The infrastructure within the Hunting Bayou 0.2 percent floodplain includes Lyndon B. Johnson General Hospital, the State's busiest Level III trauma center, which serves some of the 4.1 million people living in and beyond the Hunting Bayou watershed. Infrastructure impacted within the Hunting Bayou watershed: public schools, water treatment plant, hospitals, clinics, police and fire stations, daycare centers, and elder care facilities. Regionally significant infrastructure: electrical transmission and oil and gas product pipelines and two major railroad yards traverse the Hunting Bayou and broader watershed. Access to freeways, major transportation routes, and connections to hurricane evacuation corridors such as I-610, U.S. Highway 59, and I-10, and emergency response for medical transportation, police and fire officials have been, and likely will be, significantly hindered during a major flood event. Sections of these facilities are in the Hunting Bayou watershed. Consequently, the interregional transportation system is compromised during intense rainfall that accompanies tropical weather systems; freeway access flooding which precedes hurricane evacuation and can be a significant detriment to coastal residents fleeing low-lying areas for higher ground. The Hunting Bayou 1990 Authorized Plan is part of the Buffalo Bayou Tributaries, Texas, authorization found in Section 101(a)(21) of WRDA 1990. The approved General Reevaluation Report of December 2014 defines a Locally Preferred Plan of 3.8 miles of grass lined channel, 75 acres of detention basin, 14 bridge modifications, three railroad bridge replacements, and 5.16 acres of wetland credits at Greens Bayou Wetland Mitigation Bank. The EA demonstrates that the Selected Plan falls within the 1990 authorized footprint and intent for flood prevention along Hunting Bayou (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Bolivar Peninsula Debris Removal. The GLO has proposed to remove debris, pilings, and abandoned oil and gas infrastructure along the Gulf-facing beaches of Bolivar Peninsula. A barge mounted crane and material barge, in addition to smaller craft, would be utilized to retrieve and transport debris for disposal. The GLO plans to use RESTORE Act funds for the project (SWG-2016-00338).

Houston Ship Channel Expansion and Channel Improvement Project. As of August 2017, the USACE has produced a DIFR-EIS that identifies a plan to deepen and widen the Houston Ship Channel and several ancillary navigation channels. Several impacts were identified in the draft EIS. The proposed deepening project may result in a minor increase in bottom salinities farther up the channel. The project may also result in unavoidable temporary impacts to unvegetated estuarine bay and river bottom and permanent impacts to between 469 and 538 acres of oyster reef. Temporary avoidance and disturbance would occur during construction and maintenance dredging. The project may affect, but is not likely adversely affect, endangered sea turtles; a Biological Assessment is being coordinated with the NMFS and USFWS for concurrence. No specific cultural resource impacts have been identified; cultural resource investigations will be performed in the next planning phases. The USACE has determined that the TSP has the potential to cause effects on historic properties and will execute a Programmatic Agreement in coordination with the State Historic Preservation Officer (SHPO) to address the identification and discovery of cultural resources that may occur during the construction and maintenance of the project (USACE, 2017b).

Houston Ship Channel Barge Fleeting Expansion. The Port of Houston has proposed the expansion of a barge fleeting facility located near the confluence of the Houston Ship Channel and Old River. The expansion would include the dredging of approximately 550,000 cy of material from a 28.5-acre area, and the installation of 9 monopiles and 70 mooring structures. While the majority of dredged material would be moved to approved placement areas, 85,000 cy would be used to raise the grade at a site adjacent to the dredge area (SWG-2016-00441).

Buffalo Bayou Petroleum Storage and Marine Terminal. Magellan Terminal Holdings LP has proposed the construction of a 188-acre petroleum bulk storage marine facility to receive, store, and transport petroleum hydrocarbons. The terminal would be located on a former dredge material placement area and include up to 86 storage tanks and associated infrastructure, as well as ship and barge births and bulkheads. A total of 5,457,700 cy of material would be excavated, 1,200,700 on land, and 4,257,000 by dredging. One million cy of material would be used on site to increase base elevation, and the remaining material would be placed in approved placement areas (SWG-2016-00635).

Bayport Turning Basin. The USACE will investigate the feasibility of assumption of maintenance for the Bayport Turning Basin. The Bayport Turning Basin was constructed in 2008 by the Port of Houston to accommodate the Post-Panamax and large container vessels. Current conditions require vessels to travel to the end of the Bayport Ship Channel in order to turnaround and exit to the Houston Ship Channel. The importance of this investigation is to identify an efficient option to reduce congestion delays and safety concerns with other vessels at the container, bulk, and petrochemical terminals. The study area includes the Bayport Turning Basin located on the south side of the Bayport Ship Channel. The Bayport Ship Channel is located along the west side of the Houston Ship Channel, southeast of the City of Houston along Texas State Highway 146 north of the City of Seabrook. The study will review the feasibility of assuming the operation and maintenance of the channel constructed by the Port of Houston Authority. The study will use existing economic, environmental, and dredging cost data to complete a rapid assessment of viability. The study will determine if the constructed channel and turning basin is economically justified, environmentally acceptable, and that they were constructed in accordance with applicable permits and appropriate engineering standards. The Port of Houston Authority has requested the USACE Galveston District to assess the scope of the required studies and work towards an expedited path to complete the study. Funds provided in fiscal year 2018 will be used to initiate and complete the feasibility study. The general scope of the study includes calculation of economic benefits associated with the facility, determination of environmental acceptability, estimation of future maintenance cost, and evaluation of facility design and construction (USACE, 2018a).

Galveston Channel Extension. WRDA of 1996 authorized the USACE to deepening and widening of the Galveston Harbor Channel from 40 feet deep to 45 feet. This deepening was completed in January of 2011; however, the deepening effort stopped at Station 20+000 of the Galveston Harbor exclusive of the last 2,571 feet at the most westward end to the Galveston Channel. At the time of the 1996 WRDA authorization, the remaining 2,571 feet had been evaluated for deepening to 45 feet but was determined to not be economically justified since there were no portside services facilities in place. In the intervening years, conditions changed and beginning in 2006 portside service facilities began operation and utilizing the 40-foot channel. A feasibility study is currently being conducted to investigate the feasibility of extending the 45-foot-deep Galveston Harbor Channel the additional 2,571 feet to reach the end of the limits of the existing 40-foot channel (USACE, 2018a).

Clear Creek Flood Risk Management. The USACE project provides flood risk management for an extensively developed urban area. There are 17 cities at least partially within the Clear Creek watershed including Houston, Pasadena, Pearland, Friendswood, Webster, and League City, some of the fastest growing cities in the Houston area. Flooding in 1973, 1976, twice in 1979, 1989, 1994, 2001, 2006, 2009, and 2017 (Harvey) caused extensive property damage. The authorized project consists of approximately 15.3 miles of channel enlargement and bend easing, more stringent regulations restricting development of the 100-year floodplain, and a second outlet channel with a gated structure between Clear Lake and Galveston Bay. In June 1986 a Local Cooperation Agreement was signed to execute the construction of the project. Under the Local Cooperation Agreement, the second outlet work structure and channel were constructed; however, environmental concerns were raised on the plan of construction for the upstream reaches due to potential of induced flooding on the downstream reaches. Construction was placed on hold pending reformulation of the project under a General Reevaluation Report. The report was approved on

February 11, 2013. The recommended plan includes conveyance improvements in high flood damaged reaches on Clear Creek, Mud Gully, Turkey Creek, and Mary's Creek and linear detention within the Clear Creek conveyance improvements. The local sponsors are the HCFCD and Galveston County (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

GIWW Coastal Resilience Study. The study area includes the section of the GIWW located in Brazoria and Matagorda counties, which experiences excessive shoaling following floods and hurricanes. Erosion of the barrier islands along this section of the GIWW allows sediment from Caney Creek and the Gulf inlet flow directly into the GIWW causing draft restrictions and traffic delays. The USACE would evaluate potential solutions to alleviate the excessive shoaling that could include training structures or jetties, replacing erosion of the barrier islands, increase advance maintenance to increase the dredging interval, locks to prevent high shoaling during heavy flows, and many others. These proposals are expected to greatly increase waterborne transit efficiency. The general scope of the study includes analyzing alternatives to reduce the channel sedimentation and protecting the inland waterway from the waves and currents from the Gulf. Replacement of these land losses will decrease the vulnerability of continued safe and reliable barge tow transit on the GIWW to disruption. Decreased vulnerability includes less exposure of the GIWW to the forces of the Gulf open sea conditions to shallow draft navigation. It also would reduce exposure of sedimentation from the Gulf, diminishing the frequency and volume of channel shoaling and associated maintenance dredge requirements. This would result in cost savings to the USACE GIWW channel maintenance program (USACE, 2018a).

Dickinson Bay Waterbird Rookery. The Galveston Bay Foundation has proposed the construction of an 8.9-acre bird rookery island to provide 4.5 acres of upland habitat and 1 acre of oyster reef habitat. The U-shaped island would be composed of material from either beneficial use of dredged material in the mid-bay reach of the Houston Ship Channel or fill from an unnamed borrow site. The base material would be surrounded by a rock breakwater on three sides to protect and stabilize the island. An opening on the northwestern side of the island would make room for a shallow-water beach and a submerged oyster reef to attenuate wave action (SWG-2015-00810).

Dollar Bay and Moses Lake Marsh Terraces. The Galveston Bay Foundation has proposed the placement of fill material into two sites for the creation of planted marsh terraces. Site 1 is 12.9 acres in Dollar Bay, and Site 2 is 4.53 acres in Moses Lake. The 46,900 cy of material would be placed into Site 1, and 14,400 cy would be placed into Site 2. Rock breakwaters would be installed at both sites to protect from wave erosion. The breakwaters would have a crest width of 3 feet and an elevation of +2 feet NAVD 88. Geotextile fabric would be used under the breakwater to limit scouring and settling (SWG-2017-00032, 00033).

Texas City Turning Basin Improvements. The Texas City Terminal Railway Company has proposed dredging, dock removal, and other shoreline improvements to the inner Port of Texas City. Extensive dredging would be performed in a 9.2-acre berthing area, and 2.2 acres of upland would be converted to open water, creating a total of 431,000 cy of material for placement. Other work includes the demolition of a 320-foot dock, three dry docks, and 920 feet of existing bulkhead. A new 1,193-foot dock would be constructed, along with 840 feet of steel bulkhead, and 45,000 square feet of articulated concrete mat in front of the new bulkhead for erosion protection (SWG-2013-00042).

Spoonbill Bay Mixed Use Development. A mixed-use development is planned for a 115.37-acre tract in West Bay, 3 miles northeast of San Luis Pass. The proposed development will consist of a single marina, water front homes, access roads, and two channels. Approximately 10.76 acres of jurisdictional waters would be impacted; 6.08 acres of non-tidal wetlands, 1.53 acres of tidal wetlands, and 0.40 acre of sandflats. An additional 2.75 acres would be impacted through the dredging of the navigable channels, where 44,333 cy of material would be used to build up the site. The applicant has proposed on-site mitigation through the creation of 2.23 acres of non-tidal wetlands, 0.83 acre of living shoreline, and 6.52 acres of tidal wetlands (SWG-2007-01475).

San Luis Pass Dredge and Follets Island Nourishment. Brazoria County has proposed to dredge approximately 376,200 cy of sand material from West Bay and San Luis Pass for beach nourishment on the north end of Follets Island. The 160-foot-wide by 12,000-foot-long dredge area would improve vessel access through San Luis Pass and would be excavated to –9 NAVD 88. Sand would be placed nearshore, within the submerged portion of beach to reduce wave action and allow for onshore movement of material (SWG-2015-00306).

San Bernard River Mouth Restoration. Brazoria County has proposed to hydraulically dredge approximately 400,000 cy of material from the existing San Bernard River channel to restore consistent flow through the river mouth. A total of 30.1 acres is expected for the dredge footprint, with 21.6 acres of channel bottom, and 8.5 acres of side slope. Suitable dredge material would be beneficially used to restore marsh habitat along the GIWW, and sandy material would be placed in a 17.6-acre surf zone placement area. The two primary restoration areas are located in Cedar Lakes within the San Bernard NWR, and total 133.32 acres. Restored areas would also be planted with smooth cordgrass about 60 days after dredge material placement. A third 69.86-acre restoration area would be used after completion of areas 1 and 2 and involves shoreline protection with levees along the GIWW (SWG-2015-00603).

5.10.2.2 Mid to Upper Coast

Harbor of Refuge Bulkhead. The City of Port Lavaca is proposing to construct approximately 4,500 feet of bulkhead and remove and replace approximately 2,000 feet of existing bulkhead around the Harbor of Refuge. The construction will impact 1.82 acres of bay bottom and 0.17 acre of wetland. The 4 acres of saltmarsh has been constructed to mitigate the impacts. The project has not been completed (SWG-1995-02218).

Mid-Coast Bird Rookery Island. The TNC is proposing the construction of an 803-foot-long by 445-foot-wide bird rookery in San Antonio Bay. The plan calls for placing 239,500 cy of fill material and rock riprap shoreline armoring. The rookery island will provide 4 acres of bird habitat and 1 acre of submerged reef habitat. The project has not started (SWG-2017-00516).

Port of Port Lavaca-Point Comfort and Matagorda Ship Channel Expansion. The Calhoun Port Authority is proposing to construct an additional turning basin and deepen the existing berthing facilities to accommodate larger ships at the port of Port Lavaca-Point Comfort from 36 to 44 feet. The Calhoun Port Authority is also proposing to deepen the channel from 36 to 44 feet and widen from 200 to 400 feet for the entire 26 miles of the ship channel. The project has not started (SWG-2006-00092).

Palacios Channel Maintenance Dredging. The Port of Palacios is proposing to maintain the Palacios Ship Channel. The channel will be dredged from a depth of 11 to 14 feet, and the bottom with be widened to 125 feet. Approximately 731,904 cy of material will be removed. Dredged material will be placed at a beneficial use of dredged material site near Sartwelle Lakes to restore hydrological function to the low-lying marsh. The project has not started (SWG-2014-00782).

5.10.2.3 Mid to Lower Coast

Port Bay Harbor Dredging. Landowners and developers plan to excavate a 3.973-acre harbor canal from an upland site. Approximately 58,000 cy of material will be removed and spread over the remaining upland areas. The 10-foot-deep harbor will be connected to an existing canal in Port Bay. The perimeter of the harbor will be capped-concrete bulkhead, and the created canal will be routinely dredged. The project has not been completed (SWG-2008-00997).

Aransas County Oyster Reef Restoration. The Harte Research Institute at Texas A&M University-Corpus Christi is proposing to construct a 1-acre educational oyster reef and 10 acres of restored oyster reef on State Tracts 67 and 68 in St. Charles and Aransas bays. The project will use reclaimed oyster shells from seafood wholesalers and restaurants, cleaned crushed concrete, limestone, river rocks, and other clean hard surfaces. The materials will be placed in 24-inch mesh bags containing approximately 3 gallons of oyster shells. The reef mounds will be 12 inches high by 10 yards wide by 60 yards long (SWG-2011-00365).

Fulton Beach Road Shoreline Stabilization Project. Aransas County is proposing the construction of 3,220 feet of breakwater to protect the shoreline and coastal wetlands from erosion. Each breakwater will measure 70 feet long, 26 feet wide at the base, a 4-foot-wide crest, 2:1 side slopes, and a total height of 4.5 feet. There will be 46 overlapping breakwaters covering an area of 1.3 acres. The area along the shoreline behind the breakwaters will be planted with smooth cordgrass and saltmeadow cordgrass. No work on the project has been completed, and a request to extend the time limit of the standard permit by 5 years has been submitted (SWG-2011-01237).

La Quinta-Ingleside Dredging. OXY Ingleside Energy Center is planning to use Berry Island, an existing confined area, as a dredged material placement area. The area will be used to place 1,200,000 cy of initially dredged material and 200,000 cy of maintenance material (every 3 to 5 years) afterwards from the La Quinta Ship Channel (SWG-1995-02221).

La Quinta Ship Channel Crude Condensate Storage and Marine Terminal. Cheniere Liquids Terminal, LLC is proposing a duAI vessel berthing area, two docks, an onsite dredged material placement area, and various supporting infrastructure (such as storage tanks, roads, parking areas, and administrative buildings).

Approximately 2.6 mcy of stiff clay will be mechanically or hydraulically dredged including a 40-acre berthing basin and two marine docking structures. Work on the project has not yet started (SWG-2014-00848).

OXY Ingleside Energy Pier Dredging Activities. OXY Ingleside Energy Center, LLC is proposing the deepening of approximately 67 acres of channel depth adjacent to their east and west docking slips. Approximately 478,498 cy of dredged materials will be removed and placed in a dredged material placement area. Seagrasses are present in the west slip areas but are not expected to be disturbed. Work on the project has not yet started (SWG-1995-02221).

North Beach Sand Placement. The city of Corpus Christi is proposing beach nourishment activities on a 3,900-foot stretch of North Beach. The proposal calls for placing 130,000 cy of imported inland sand and 20,000 cy of excavated and redistributed sand from the accretional end of the existing beach. Beach nourishment activities for the project have not yet started (SWG-1998-00131).

McGee Beach Sand Placement. The city of Corpus Christi is proposing beach nourishment activities on a 1,700-foot stretch of McGee Beach. The proposal calls for placing 14,000 cy of beach quality sand over approximately 4.18 acres. Sand placement has not yet begun (SWG-2002-01934).

Nueces Bay Rookery Island Shoreline Armoring. Coastal Bay Bend and Estuaries Program is proposing to install shoreline protection measures for several bird island rookeries in Nueces Bay. The islands will be armored with articulated concrete blocks or rock riprap. Approximately 4,200 cy of fill materials will be used to protect the islands. The project has not begun (SWG-2013-01068).

Nueces Bay Shoreline Protection Measures. Coastal Bay Bend and Estuaries Program is proposing to construct 3,901 linear feet of concrete breakwater to provide shoreline protection to the Nueces Bay Delta. The breakwater system will consist of 12 structures and utilize approximately 1,008 cy of porous concrete (SWG-2014-00725).

Corpus Christi Channel Marine Terminal Expansion. Plains All-American Pipeline LP is proposing the construction of an import/export liquid terminal and storage facility along the Corpus Christi Channel large enough to support Aframax ships and oceangoing barges. The proposal calls for dredging 514,557 cy of material over 12.7 acres of water (SWG-2014-00260).

Magellan Crude and Hydrocarbon Bulk Storage Terminal. Magellan Terminal Holdings LP is proposing to construct a 95-acre bulk storage holding terminal and docking facility along the Corpus Christi Ship Channel. The facility will include 27 bulk storage tanks, 4 docking platforms, bulkheading, and shoreline protection (SWG-2016-00285).

Dagger Island Breakwater and Containment Area. TPWD is proposing to construct rock breakwaters parallel to the existing shoreline of Dagger Island. TPWD is also planning to construct a 28-acre containment area around a historic island footprint to accept dredged materials for beneficial use. The project has been proposed but construction has not started (SWG-2017-00295).

Pipelines. There are several pipeline projects that are reasonably foreseeable along the Corpus Christi Ship Channel. These include the 8.6-mile-long Oxy Viola station pipeline (SWG-2014-01002), 2-mile-long M&G Polymers plant pipeline (SWG-2015-00136), 3 parallel 16-mile-long Magellan pipelines across the Corpus Christi Ship Channel (SWG-2014-00518), 70-mile-long Flint Hills Refinery pipeline (SWG-2016-00657), and 8.2-mile-long Gravity Midstream pipeline (SWG-2016-00032).

5.10.2.4 Lower Coast

Brownsville Resacas Ecosystem Restoration. The USACE has evaluated ER actions with Brownsville Resacas. The project is located along the Resaca Boulevard near the Rio Grande in the southern half of Cameron County, Texas. The Resaca consists of former channels of the Rio Grande that have been cut off from the river, having no inlet or outlet because of siltation of the oxbow channels, and loss of critical native aquatic and riparian habitat. The unique thorn scrub riparian vegetation associations of the resacas are found exclusively in Resaca and riparian corridors of the Lower Rio Grande Valley, and they have been designated by the TPWD as habitats critically imperiled with extinction or elimination. The Resaca and its associated thorn-scrub riparian habitat are listed in the draft USFWS Ocelot Recovery Plan as critical transportation corridors for dispersing ocelots. The USFWS has determined that close to 99 percent of this habitat has been degraded on the Lower Rio Grande Basin within the United States and Mexico. Before land development and water control, floodwaters from the Rio Grande drained into resacas from the surrounding terrain. The primary hydrologic function of the resacas was diversion and dissipation of floodwater from the river. Measures that would be implemented per the NER plan include dredging accumulated sediment (completed by sponsor at no cost to the project), restoring wetland habitats, and restoration of the imperiled riparian vegetation associations. Restoration of the resacas would potentially provide habitat benefits for the Federally endangered species ocelot, a Federally endangered cat, jaguarondi, a Federally endangered cat, black-spotted newt (amphibian), and Rio Grande Cooter (turtle). The NER Plan would provide a total of 5.4 average annual habitat units over the current 0.03 average annual habitat units of the degraded ecosystem (USACE, 2018a).

Brazos Island Harbor Improvement Project. The Port of Brownsville has proposed to deepen Brazos Island Harbor, thereby expanding local industry and opening the harbor to larger ships now utilizing the improved Panama Canal. The project has been approved by the USACE, but congressional authorization remains for Federal funding. The Brazos Island Harbor entrance channel and jetty channel are proposed to be deepened to –54 MLLW from a current depth of –42 MLLW. No channel widening is proposed; however, where necessary, the channel may be extended or varied to maintain the channel side slopes. Dredged material is to be placed into upland dredge material placement areas and placed for beneficial use onto a feeder berm offshore of South Padre Island (SWG-2016-00038).

Port of Brownsville LNG Terminal #1. Texas LNG Brownsville LLC has proposed construction of an LNG storage and export facility adjacent to the Brownsville Ship Channel. The 625-acre site is between the north side of the channel and SH 48, approximately 19 miles northeast of the city of Brownsville, in Port Isabel, Cameron County. The facilities would be composed of a terminal to liquefy and store natural gas and marine facilities to export LNG and serve as port for vessels during construction. Included in the project is the removal of an abandoned pipeline that runs parallel to the Brownsville Ship Channel (SWG-2015-00175).

Port of Brownsville LNG Terminal #2. Rio Grande LNG has proposed construction of an additional LNG export facility on Port of Brownsville land south of SH 48, bounded to the west by the Bahia Grande Channel. The 984-acre terminal site would have up to six liquefaction trains, natural gas pretreatment facilities, four LNG storage tanks, operational infrastructure, and truck-loading facilities. The LNG facility would also include marine loading berths for LNG vessels, and require dredging to create a turning basin adjacent to the loading berth. Rio Grande LNG is also proposing onsite restoration and enhancement for mitigation of unavoidable impacts to waters of the U.S. The primary objective is to fund and restore the widening of the Bahia Grande Channel, to improve the tidal connection with the Brownsville Ship Channel (SWG-2015-00114).

Port of Brownsville LNG Terminal #3. Annova LNG has proposed the construction of an LNG terminal on the south side of the Brownsville Ship Channel, across the channel from the Bahia Grande. The proposed 731-acre facility would include LNG and marine transfer facilities, in addition to an access road. The project would permanently impact 37.1 acres of wetlands, 0.1 acre of estuarine emergent marsh, 36 acres of palustrine emergent ponds, 0.5 acre of estuarine open water, and 1.2 acres of tidal flat. Temporary impacts would include 19.2 acres of wetlands for initial clearing and fencing construction. The applicant is developing a final mitigation plan that should consist of aquatic resource preservation onsite, enhancement, creation, and/or restoration (SWG-2015-00110).

Port of Brownsville Subsea 7 Spool Base Facility. The Brownsville Navigation District has proposed the construction of a 60-acre spool base facility on the south side of the Brownsville Ship Channel to load, store, and transport piping for pipe lay projects. The waterfront features of the project would include construction of a three-sided vessel slip with bulkhead, slope revetment, and installation of a mooring and a breasting structure. Other planned structures include buildings, a piperack for joining pipe units, drainage corridors, and an access road to SH 4. The 13-acre vessel slip would have dimensions of 1,000 feet long by 900 feet wide and accommodate 525-foot pipelay vessels. The vessel slip would be dredged to –35 feet mean low tide, and approximately 654,000 cy of dredge material would be removed and placed in approved placement areas. Project impacts include 7.6 acres of permanent impact from vessel slip dredging, and 3.03 acres of impact to jurisdictional features from onshore facilities (SWG-2017-00250).

Arroyo Colorado Aeration Structures. The Port of Harlingen has proposed the installation of three aeration water control structures in the main stem of the Arroyo Colorado River. Each structure is essentially a riprap weir meant to create a riffle, adding dissolved oxygen and improving water quality. Each structure would be 0.03 acre of impact to jurisdictional river bottom totaling 0.09 acre of permanent impacts (SWG-2016-00303).

East Wye Channel Widening. The Port Isabel-San Benito Navigation District has proposed to widen the East Wye Channel from 200 feet to approximately 350 feet in width. Additionally, the channel would be deepened to –38 NAVD 88 with 2 feet of overdepth. Approximately 195,630 cy of material is to be removed by hydraulic dredge from the 10.48-acre area and placed in the existing Dredge Disposal Area 3 Brazos Island Project. A 10-year maintenance dredge permit was also requested, which would result in an additional 20,000 cy of material removed over that time span. The applicant proposed the use of silt control measures, and to avoid all seagrass areas and oyster beds (SWG-2014-00849).

Bahia Grande Main Channel Project. The Brownsville Navigation District has proposed to widen and deepen the existing pilot channel between the Bahia Grande and the Brownsville Ship Channel. Approximately 200,000 cy of material would be excavated from the existing pilot channel and adjacent land and moved into adjacent placement areas. Permanent impacts include the conversion of 8.06 acres of jurisdictional area to open water, and 22.32 acres of jurisdictional area converted to upland, for a total of 30.38 acres. Affected jurisdictional features include tidal flats, open water, and palustrine emergent and palustrine scrub-shrub wetlands (SWG-2003-01954).

Long Island Village Residential Development. The estate of John Freeland has proposed to excavate 11.99 acres and place fill in 99.04 acres of jurisdictional waters to construct a residential canal subdivision in the Port Isabel area. The applicant proposed mitigation for the project, consisting of the onsite construction of a 22-acre mangrove and seagrass habitat area, and the preservation of 108.4 acres east of the project site. The protected area includes 89.6 areas of submerged seagrass habitat and 18.8 acres of mangrove wetlands (SWG-1999-02327).

South Padre Island Second Access. An additional access route to and from South Padre Island was proposed through a partnership among the Cameron County Regional Mobility Authority, TxDOT, and the Federal Highway Administration. The project consists of South Padre Island and mainland road improvements, and a bridge spanning the Laguna Madre. Approximately 139.14 acres of wetlands would be affected by the preferred Alternative 6, primarily due to bridge supports impacting Laguna Madre bay bottom. SAV in the form of seagrasses would also be affected. Construction is expected to begin in 2020.

5.10.3 Cumulative Impacts from TSP Implementation

The following portions of the cumulative impact analysis considers the primary drivers of change along the Texas coast, in the context of past, present, and reasonably foreseeable future actions. Understanding the main causes of coastal changes are necessary to frame the TSP and its potential effects (both positive and negative) and how they may contribute to cumulative impacts.

5.10.3.1 Primary Drivers of Change

The primary drivers of change in the various regions of the Texas coast are similar. Although petrochemical industries are more prevalent in the upper Texas coast, all regions of the coast include the presence and influence of the petrochemical industry. Also, each region of the Texas coast includes ports and navigation channels, with channel improvements proposed for each region. From the upper Texas coast to the lower Texas coast, the common primary drivers of change include:

- Petrochemical Industry
- Shipping, Ports, and Navigation
- Commercial Fishing

- Agriculture
- Recreation and Conservation

Land use and cumulative impacts in the Galveston Bay region are historically the result of the petrochemical and shipping industries (with commercial fishing, agriculture, and recreation and conservation playing a smaller role). In the upper Texas coast, much of the growth was facilitated by the development of the Houston Ship Channel and construction of the Texas City Dike and several dredge material placement islands. The upper Texas coast is home to one of the world's largest ports in the Port of Houston, and also encompasses the ports of Texas City, Freeport, Galveston, Cedar Bayou, Port Arthur, Beaumont, and Orange. Shipping is a vital industry to the region, and it relies heavily on the natural resource of the region's natural coastal bays. The Houston Ship Channel has been utilized to ship goods since the 1800s; however, in 1914 the newly dredged 25-foot-deep channel was officially opened for deep-water ships. Large-scale anthropogenic modification of bay physiography has resulted from numerous improvements, expansions, and dredging projects that have transformed the Houston Ship Channel into a massive industrial trade waterway, with a current depth of –45 feet and a width of 530 feet. Bay modifications have increased the salinity and changed the natural hydrology of Galveston Bay (Klinck et al., 2002). The ship channel includes barge bulk docks, liquid cargo ship piers, barge terminal, and multipurpose docks. Supported by the proximity to Texas oilfields and the Houston Ship Channel, the second-largest petrochemical complex in the world resides in this region and is a large part of the economy. The Houston Ship Channel and other navigation channels have also altered hydrosalinity and sedimentation dynamics in the area.

Within Matagorda Bay, much of the growth was facilitated by development of the Matagorda Ship Channel, GIWW, and other navigation channels (e.g., Victoria Barge Canal, Palacios Boat Channel). Shrimping and other commercial fishing is prevalent. Cotton and rice are historically produced in the region. Oil and gas productivity on the Eagle Ford Shale Formation has contributed to recent regional growth.

The Matagorda Ship Channel was completed in 1965 with numerous improvements from 1972 to 2004. Before the Matagorda Ship Channel Jetty was cut in 1963, Pass Cavallo was the only natural inlet into Matagorda Bay. The ship channel has since increased the salinity and changed the natural hydrology of the bay. The ship channel includes barge bulk docks, liquid cargo ship pier, barge terminal, and multipurpose docks. Exports from the Matagorda Ship Channel include oil, cotton, seafood, and cattle (Van Borssum, 2005). The Calhoun Port Authority is planning to improve approximately 26 miles of the Matagorda Ship Channel to allow for deeper-draft vessels and more ship traffic. The deeper channel can modify the hydrology, tidal circulation, and sediment patterns of the bay.

Large-scale changes to hydrology have also occurred in Matagorda Bay due to the manipulation of the Colorado River (Colorado River Diversion; Barcak et al., 2007). Although several large changes have occurred with the Colorado River in respect to Matagorda Bay (including a 40-mile log jam that created a delta and land bridge and dredging of the river to flow directly into the Gulf in 1935), the most recent large change occurred in 1992 when the USACE diverted 100 percent of the river into West Matagorda Bay and the Colorado River Lock System was implemented (Barcak et al., 2007; Simon, 2005). These primary activities, including noteworthy past projects

(Colorado River Diversion, Formosa Plastics, Alcoa Point Comfort, and the South Texas Nuclear Project), have influenced land use and impacts in the region.

Land use and cumulative environmental impacts in the Corpus Christi Bay region are historically the result of growth of the petrochemical industry, related shipping, commercial/recreational fishing, and agriculture. Much of the growth resulted from the development of Aransas Pass, Corpus Christi Ship Channel, GIWW, and other navigation channels (e.g., both Lydia Anne Channel and LaQuinta Channel). Commercial fishing is prevalent, and Aransas Pass and Corpus Christi harbor commercial processing facilities. Cotton, sorghum, and wheat are historically produced in the region.

Aransas Pass was opened in 1910 by dredging, which led the way for shipping through Corpus Christi Bay. In 1925, the Corpus Christi Ship Channel was completed across the bay to the Corpus Christi Inner Harbor. In the 1930s the first industries began operations at the Port of Corpus Christi (World Port Source, 2017). Since then Corpus Christi has developed into a major hub for commercial and industrial facilities. The ship channel has been widened and deepened over the years to accommodate larger ocean-faring vessels. The Corpus Christi Ship Channel is currently 400 feet wide, with a depth of –45 feet msl. The Port Authority of Corpus Christi currently has plans to widen the channel to 530 feet and dredge to a depth of –54 feet msl (Port of Corpus Christi, 2017b). The ship channel improvement project has been approved and construction is pending. When the project is completed, the Corpus Christi Ship Channel will be able to handle larger bulk cargo ships and oil and gas bulk vessels (Port of Corpus Christi, 2017a). The deeper draft channel will further modify the natural hydrology, tidal circulation, and sediment patterns of the bay.

Of importance are the alterations to the Nueces River and its delta, and how these alterations have affected hydrosalinity gradients in Corpus Christi Bay. About 15 percent of the mean flow of the Nueces River has been diverted for water supply to agriculture and the city of Corpus Christi. With the continuing growth of the city and the increasing demand for water, the freshwater flow to the Nueces River Delta has decreased (Hodges et al., 2012). In combination, two reservoirs upstream of the delta have also reduced freshwater inflows, as well as nourishing sediments (Coastal Bend Bays and Estuaries Program, 2009). This has led to saltwater intrusion and the conversion of freshwater wetlands to brackish or brackish marsh to open water. Coastal Bend Bays and Estuaries Program is active in purchasing and managing tracts within the delta for conservation, restoration, and education. These primary activities and drivers, including noteworthy past projects (Corpus Christi Channel and LaQuinta Channel Improvements, Corpus Christi Liquefaction Project, OXY Ingleside, and other port-related activities), have influenced land use and impacts in the region.

Land use and cumulative environmental impacts in the Lower Rio Grande Valley and Laguna Madre are characterized by growth of the petrochemical industry, related shipping, commercial fishing, and agriculture. Much of the growth was facilitated by development of the Brownsville Ship Channel, GIWW, and other navigation channels. Conservation and recreation also drive land use in the region, and the area includes the Lower Rio Grande Valley NWR complex, the Laguna Atascosa NWR complex, and Las Palomas WMA. The region is seeing continued growth through the Port of Brownsville, primarily from the petrochemical industry. The Brownsville Ship Channel is also slated for channel improvements.

Each region is affected by the GIWW, which links all of the Texas coast. For portions of the upper Texas coast relevant to this study, the GIWW runs parallel to and behind Bolivar Peninsula, Galveston Island, and Follets Island before crossing the Brazos and San Bernard rivers. A floodgate system is in place at the intersection of the GIWW and the Brazos River, which closes off the GIWW from sedimentation and high river flows. The GIWW and the floodgate system have altered hydrosalinity and sedimentation dynamics in the area. The GIWW was constructed parallel to the inland Matagorda Bay shoreline and intersects the Colorado River Lock System, the Palacios Boat Channel, and the Matagorda Ship Channel while crossing behind Matagorda Peninsula. The GIWW crosses the Victoria Barge Canal Seadrift as it crosses San Antonio Bay. The GIWW continues southward Corpus Christi Bay and the Corpus Christi Ship Channel, then through the Laguna Madre, then terminates at the Brownsville Ship Channel. Freshwater from rivers, tidal flows from the GIWW, and construction of other navigation channels, can change the natural salinity gradient and circulation of the bay.

Recreation and conservation lands (NWRs, WMAs, and State parks) are an important component of land use and local culture. In the upper Texas coast, Anahuac NWR, McFaddin NWR, Brazoria NWR, and San Bernard NWR are Federally owned and managed lands in the region. Atkinson WMA, Justin Hurst WMA, J.D. Murphree WMA, Galveston Island State Park, and Sea Rim State Park are all state-owned tracts of land in the region. The TNC also owns and manages the Texas City Prairie Preserve, a regional model for native prairie restoration. Within the mid Texas coast, Big Boggy NWR is a Federally owned and managed tract in the region. Matagorda Island WMA, Mad Island WMA, Guadalupe Delta WMA, Welder Flats WMA, and the proposed Powderhorn Ranch State Park are all State tracts of land in the region. The TNC also owns and manages the Mad Island Marsh Preserve. Several WMAs, NWRs, and national and state parks occur in the mid to lower portions of the Texas coast and protect and conserve large areas in the region. State parks include Goose Island State Park and Mustang Island State Park. WMAs include Matagorda Island WMA and Redhead Pond WMA. The TNC manages Shamrock Island Preserve, an important colonial bird nesting site. Padre Island National Seashore, managed by the NPS, is the largest stretch of undeveloped barrier island in the world. In the lower Texas coast conservation and recreation areas include the Lower Rio Grande Valley NWR complex, the Laguna Atascosa NWR complex, and Las Palomas WMA. These lands are intended for natural resource management, recreation, and conservation for the foreseeable future.

5.10.3.2 Synergy with the TSP and Potential Cumulative Impacts

The TSP would result in several direct and indirect positive and negative impacts to the environment. Some of these positive and negative impacts have the potential to result in positive and negative cumulative effects when considered in conjunction with past, present, and reasonably foreseeable future actions. Past, present, and reasonably foreseeable future actions that may contribute cumulative impacts with the TSP can be grouped into the following categories:

- Coastal Resources Restoration Actions
- Flood and Coastal Storm Risk Management Actions
- Navigation and Dredging Actions

- Petrochemical and Industrial Actions
- Developments and Roadway Transportation Actions

Each category of past, present, and reasonably foreseeable actions has the potential to contribute both positive and negative cumulative effects when considering the TSP. Below is explanation on how each category of actions may interact with the TSP. Table 5-12 provides a list of the past, present, and reasonably foreseeable actions, summarizes the potential resource that may be affected (positively or negatively, short or long term), and identifies synergy with the TSP and potential cumulative impacts.

Coastal Resources Restoration Actions. Actions or projects described in this category include a wide variety of potential restoration actions that also range in size. Some of the larger restoration actions include the recommendations within GLO's Texas Coastal Resiliency Master Plan, Jefferson County Ecosysterm Restoration, GLO's CEPRA Program, and large-scale beach nourishments for several barrier islands and peninsulas. In addition, there are numerous smaller marsh and oyster restorations, bird island projects, and shoreline protection projects coastwide. Also, worth mentioning is the RESTORE Act, since some projects considered in this analysis are funded by this Act. The RESTORE Act was passed by the U.S. Congress and signed into law on July 6, 2012. The RESTORE Act grants 80 percent of all money collected from the CWA fines into a RESTORE Trust Fund to be distributed to the five states impacted by the Deep-Water Horizon oil spill. Projects funded by RESTORE Act are intended to restore and protect coastal resources, just like the TSP. Similarly, the GLO's Texas Coastal Resiliency Master Plan was developed in conjunction and acknowledgment of the Coastal Texas Study and is intended to be synergistic and contribute beneficial cumulative effects to Texas coastal resources. Coastal restoration projects (both large and small), combined with the TSP, contribute to the concepts of coastwide restoration and protection, and beneficial cumulative impacts are anticipated (see Table 5-24).

Flood and Coastal Storm Risk Management Actions. The Texas coast has experienced several hurricanes and unprecedented flooding events in the recent past, which have highlighted the need for more flood and coastal storm risk management actions. All projects or actions described are being undertaken by the USACE. The largest is the Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration project. This project recommends several levees, which support risk reduction along a broader extent of the Texas coast, and they complement the TSP's objectives. Direct compatibility of risk reduction efforts with the TSP would expand resiliency of the Texas coast and implementation of a systems approach to restoration and protection, yielding positive cumulative impacts (see Table 5-12). Within Harris County and the Houston area, the USACE has several authorizations to assess flood risk management (opportunities in Buffalo Bayou and Tributaries, Brays Bayou, Clear Creek, Hunting Bayou, and White Oak Bayou). Flood risk management efforts, which result from these authorities, will reduce risk from different damage mechanisms, such as precipitation. In combination with the TSP, they can complement a systems approach to risk reduction. Features designed to reduce inundation from rainfall could increase capacity, volume, and timing of water flow to rivers, bayous, and bays. The hydrologic changes from the flood risk management features could be greater than the salinity changes from the TSP features,

Table 5-12
Cumulative Effect Impacts

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
Coastal Resources Restoration Actions					
Texas GLO Coastal Resiliency Master Plan Recommendations (GLO)	Coastwide	RF	1, 2, 3, 4, 10, 11, 12, 13, 17	1 – Geomorphology and Coastal Processes 3 – Water and Sediment Quality 10 – Wetlands 11 – Aquatic	The Master Plan identifies priority actions for GLO to enhance resiliency of the Texas coast. Recommended actions of the Master Plan evolve from collaboration with agency partners and support the TSP objectives. The likely cumulative impacts would be increased resiliency of resources from a systems approach to coast-wide restoration and protection of water and sediment quality and landscape features.
Jefferson County Ecosystem Restoration (USACE)	Jefferson County	RF	1, 3, 4, 10, 12, 13, 16	10 – Wetlands 12 – Wildlife Resources	Coastal restoration projects include oyster, marsh, beach, and rookery island restoration efforts. Some restoration efforts include erosion reduction. The likely cumulative impacts of these measures in combination with the TSP would be increased resiliency of resources from a systems approach to coastwide restoration and protection of water and sediment quality and landscape features. Potential short-term impacts of construction would be minimal in combination, and could be reduced through coordination and phased implementation.
McFaddin Beach Dune Restoration (Jefferson County)	Bolivar Peninsula	PP/RF	1, 2, 3, 4, 10, 12, 13	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
East Bay and GIWW Shoreline Protection and Restoration (Galveston Bay Foundation)	East Bay	PP	1, 2, 3, 4, 10, 11, 16	16 – Navigation 4 – Hydrology	
Bolivar Peninsula Beach/Dune Restoration (Galveston County)	Bolivar Peninsula	PP/RF	1, 2, 3, 4, 10, 11, 12, 13	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
Burnet Bay Marsh Mound Creation (Galveston Bay Foundation)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Dickinson Bayou Wetland Restoration and Protection (TPWD)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Moses Lake Shoreline Protection (Galveston Bay Foundation)	Galveston Bay	PP	3, 4, 10, 11, 12	10 – Wetlands 11 – Aquatic	
Swan Lake Restoration (TPWD)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Greens Lake Shoreline Erosion Protection (Ducks Unlimited)	Galveston Bay	PP	2, 3, 4, 10, 11, 16	10 – Wetlands 11 – Aquatic	
North Deer Island Protection and Restoration (Galveston Bay Foundation)	Galveston Bay	PP	10, 11, 12,	12 – Wildlife Resources	
Galveston Bay Oyster Reef Restoration (TPWD)	Galveston Bay	PP	1, 3, 11	3 – Water and Sediment Quality 11 – Aquatic	
Galveston Island Beach Nourishment (Galveston Park Board)	Galveston Bay	PP	1, 2, 3, 4, 11, 12, 13, 15	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource 15 – Socioeconomics	
Pierce Marsh Restoration (Galveston Bay Foundation)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Galveston Island State Park Marsh Restoration and Protection (TPWD)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Sweetwater Preserve Shoreline Protection and Oyster Habitat Enhancement (Galveston Bay Foundation)	Galveston Bay	PP	1, 2, 3, 4, 10, 11	3 – Water and Sediment Quality 11 – Aquatic	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
Snake Island Restoration (Galveston Bay Foundation)	Galveston Bay	PP	1, 2, 3, 4, 10, 11	3 – Water and Sediment Quality 10 – Wetlands 11 – Aquatic	
Gang's Bayou Marsh Restoration and Protection (TPWD)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Oyster Lake Habitat Protection and Marsh Restoration (USFWS)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Surfside Beach Groins and Nourishment (Village of Surfside)	Follets Island	PP	1, 2, 3, 4, 12, 13	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
Bryan Beach Renourishment (Town of Quintana)	Follets Island	PP	1, 2, 3, 4, 12, 13	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
Texas GLO Coastal Erosion Planning and Response Program - Various Projects (GLO)	Coastwide	PP/RF	1, 2, 3, 4, 10, 11, 12, 13, 16	1 – Geomorphology and Coastal Processes 3 – Water and Sediment Quality 10 – Wetlands 11 – Aquatic	
Trinity Bay Living Shoreline and Erosion Protection (Chambers County)	Galveston Bay	RF	3, 10, 11	3 – Water and Sediment Quality 11 – Aquatic	
Trinity Bay Discovery Center Living Shoreline and Habitat Creation (Galveston Bay Foundation)	Galveston Bay	RF	3, 10, 11	3 – Water and Sediment Quality 11 – Aquatic	
Dickinson Bay Waterbird Rookery (Galveston Bay Foundation)	Galveston Bay	PP	11, 12	12 – Wildlife Resource	
Dollar Bay and Moses Lake Marsh Terraces (Galveston Bay Foundation)	Galveston Bay	PP	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
San Luis Pass Dredge and Follets Island Nourishment (Brazoria County)	Galveston Bay	RF	1, 2, 3, 4, 11, 13, 12	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
San Bernard River Mouth Restoration (Brazoria County)	Brazoria County	RF	1, 2, 3, 4, 11, 13	1 – Geomorphology and Coastal Processes 4 – Hydrology	
Mad Island WMA Shoreline Protection (TPWD)	Matagorda Bay	PP	1, 2, 3, 4, 10, 11, 12	12 – Wildlife Resource	
Half Moon Reef Restoration (TNC and USACE)	Matagorda Bay	PP/RF	1, 2, 3, 4, 11	3 – Water and Sediment Quality 11 – Aquatic	
Mid-Coast Bird Rookery Island (TNC)	San Antonio Bay	RF	11, 12	12 – Wildlife Resource	
Aransas County Oyster Reef Restoration (Texas A&M University – Corpus Christi)	Copano Bay	RF	1, 2, 3, 11	3 – Water and Sediment Quality 11– Aquatic	
Rockport Beach Nourishment Project (Aransas County)	Copano Bay	PP	1, 2, 3, 11, 12	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
North Beach Sand Placement (Corpus Christi)	Corpus Christi Bay	RF	1, 2, 3, 11, 12	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
McGee Beach Sand Placement (Corpus Christi)	Corpus Christi Bay	RF	1, 2, 3, 11, 12	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource	
Nueces Bay Rookery Island Shoreline Amoring (Coastal Bend Bays and Estuaries Program)	Corpus Christi Bay	RF	11, 12	12 – Wildlife Resource	
Nueces Bay Shoreline Protection Measures (Coastal Bend Bays and Estuaries Program)	Corpus Christi Bay	RF	1, 2, 3, 4, 10, 11, 12	12 – Wildlife Resource	
Dagger Island Breakwater and Containment Area (TPWD)	Corpus Christi Bay	RF	1, 2, 3, 4, 10, 11, 12	10 – Wetlands 12 – Wildlife Resources	
Adolph Thomae Jr. County Park Improvements (Cameron County)	Laguna Madre	PP/RF	1, 3, 15	15 – Socioeconomics	
Bahia Grande Main Channel Project (Brownsville Navigation District)	Laguna Madre	PP/RF	1, 2, 3, 4,	3 – Water and Sediment Quality 4 – Hydrology	
Arroyo Colorado Aeration Structures (Port of Harlingen)	Laguna Madre	RF	3	3 – Water and Sediment Quality	
South Padre Island Beach Nourishment (Town of South Padre Island)	South Padre Island	PP/RF	1, 2, 3, 4, 11, 12, 13, 15, 17	1 – Geomorphology and Coastal Processes 12 – Wildlife Resource 15 – Socioeconomics 17 – Flood Risk Reduction	
Brownsville Resaca Ecosystem Restoration (USACE)	Cameron County	RF	1, 3, 4, 10, 11, 17	3 – Water and Sediment Quality 4 – Hydrology	Resaca restoration efforts include hydrologic connectivity and habitat improvements. The likely cumulative impacts of these measures in combination with the TSP would be limited since resacas are not immediately within the coastal area. The hydrologic condition of the area will not be affected by the CSRM features of the TSP. No cumulative impacts are expected from restoration features of the improvements to resacas would be unlikely to flow into areas affected by the TSP.
Flood and Coastal Storm Risk Management Actions					
Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration (USACE)	Sabine Lake to San Luis Pass	RF	1, 2, 3, 4, 10, 12, 13, 15, 16, 17	4 – Hydrology 17 – Flood Risk Reduction	Levees proposed within this project would reduce inundation from coastal storms. In combination with the TSP, the features provide comparable risk reduction to adjacent areas, and will provide beneficial risk reduction along a broader portion of the Texas coast. The hydrologic condition of the area is not anticipated to be affected by the features of the TSP.
Buffalo Bayou and Tributaries Flood Risk Management (USACE)	Harris County	RF	1, 3, 4, 10, 11, 15, 17	4 – Hydrology 17 – Flood Risk Reduction	Flood risk management efforts within the metro Houston and non-coastal areas will reduce risk from different damage mechanisms, such as precipitation. In combination with the TSP, they can complement a systems approach to risk reduction. Features designed to reduce inundation from rainfall could increase capacity, volume, and timing of water flow to rivers, bayous and bays. The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.
Brays Bayou Flood Risk Management Project (USACE)	Harris County	PP/RF	1, 3, 4, 10, 11, 15, 17	4 – Hydrology 17 – Flood Risk Reduction	
Metro Houston Regional Watershed Assessment (USACE)	Harris County	RF	1, 3, 4, 10, 11, 15, 17	3– Water and Sediment Quality 4 – Hydrology 17 – Flood Risk Reduction	
Clear Creek Flood Risk Management (USACE)	Harris and Galveston counties	PP/RF	1, 3, 4, 10, 11, 15, 17	4 – Hydrology 17 – Flood Risk Reduction	
Hunting Bayou Flood Risk Management (USACE)	Harris County	RF	1, 3, 4, 10, 11, 15, 17	4 – Hydrology 17 – Flood Risk Reduction	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
White Oak Bayou Flood Risk Management (USACE)	Harris County	RF	1, 3, 4, 10, 11, 15, 17	4 – Hydrology 17 – Flood Risk Reduction	
Navigation or Dredging Actions					
Houston Ship Channel Expansion and Channel Improvement Project (USACE)	Galveston Bay	RF	1, 2, 3, 4, 6, 8, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	Houston Ship Channel improvements will displace oysters and can increase the flow and amount of saline water into the bay through a deeper and wider channel. In combination with the TSP, tidal attenuation impacts from a coastal barrier may be reduced by a deeper and wider Houston Ship Channel. Beneficial use (BU) of sediment from Houston Ship Channel work may support a broad systems approach to coastwide restoration and protection.
GIWW Maintenance (USACE)	Coast-wide	PP/RF	1, 2, 3, 4, 6, 10, 11, 12, 13, 16	3 – Water and Sediment Quality 16 – Navigation	The TSP may reduce frequency of maintenance dredging through restoration measures that reduce erosion along the banks of the GIWW, and CSRM features may reduce large sediment deposition following storm events. Dredging sediment may be beneficially used for TSP restoration measures, supporting a systems approach to coastwide restoration and protection.
Sabine-Neches Waterway Channel Improvement Project (USACE)	Sabine Lake	PP/RF	1, 2, 3, 4, 6, 8, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	Navigation improvements can affect localized flow and salinity. BU of sediment may support a broad systems approach to coastwide restoration and protection.
Galveston Channel Extension (USACE)	Galveston Bay	RF	1, 2, 3, 4, 11, 16	3 – Water and Sediment Quality 16 – Navigation	
Cedar Bayou Channel Extension (USACE)	Galveston Bay	RF	1, 2, 3, 4, 11, 16	3 – Water and Sediment Quality 16 – Navigation	
Matagorda Ship Channel Expansion (USACE/Calhoun County Port Authority)	Matagorda Bay	RF	1, 2, 3, 4, 6, 8, 10, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	
Palacios Channel Maintenance Dredging (Port of Palacios)	Matagorda Bay	RF	2, 3, 10, 11, 16	3 – Water and Sediment Quality 16 – Navigation	
Corpus Christi Ship Channel Improvement Project (USACE)	Corpus Christi Bay	RF	1, 2, 3, 4, 6, 8, 10, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	
Bayport Ship Channel Container Terminal Dredging (Port of Houston Authority)	Galveston Bay	PP	2, 3, 11, 16	3 – Water and Sediment Quality 11 – Aquatic Resources 16 – Navigation	Navigation improvements can affect localized flow and salinity. BU of sediment may support a broad systems approach to coastwide restoration and protection.
GIWW Barge Facility Expansion and Maintenance (Texas Barge and Boat)	Freeport	PP	1, 2, 3, 4, 10, 11, 16	3 – Water and Sediment Quality 16 – Navigation	
Houston Ship Channel Barge Fleeting Expansion (Port of Houston Authority)	Galveston Bay	RF	2, 3, 16	3 – Water and Sediment Quality 16 – Navigation	
Bayport Turning Basin (USACE)	Galveston Bay	RF	1, 2, 3, 4, 11, 16	3 – Water and Sediment Quality 11 – Aquatic Resources 16 – Navigation	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
Texas City Turning Basin Improvements (Texas City Terminal Railway Company)	Galveston Bay	RF	2, 3, 16	3 – Water and Sediment Quality 16 – Navigation	
Harbor of Refuge Bulkhead (City of Port Lavaca)	Matagorda Bay	RF	2, 3, 11	3 – Water and Sediment Quality 16 – Navigation	
LaQuinta - Ingleside Dredging (OXY Ingleside Energy Center)	Corpus Christi Bay	RF	2, 3, 16	3 – Water and Sediment Quality 16 – Navigation	
OXY Ingleside Energy Pier Dredging Activities (OXY Ingleside Energy Center)	Corpus Christi Bay	RF	2, 3, 16	3 – Water and Sediment Quality 16 – Navigation	
Port Mansfield, Texas Maintenance (USACE)	Laguna Madre	RF	2, 3, 16	3 – Water and Sediment Quality 16 – Navigation	
Brazos Island Harbor Improvement Project (Port of Brownsville)	Laguna Madre	RF	1, 2, 3, 4, 6, 10, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	
East Wye Channel Widening (Port Isabel – San Benito Navigation District)	Laguna Madre	RF	1, 2, 3, 4, 6, 10, 11, 12, 13, 15, 16	3 – Water and Sediment Quality 4 – Hydrology 11 – Aquatic Resources 16 – Navigation	
Petrochemical and Industrial Actions					
Houston Ship Channel Dredging and Bulkhead Construction (Kinder Morgan)	Galveston Bay	PP	1, 2, 3, 4, 9, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	Investment and expansion of existing infrastructure within the study area has potential to impact air, water and sediment quality, HTRW, and noise levels. There could be short-term impacts with the construction of TSP as other facilities operate within the study area at the same time. The combined impacts could be reduced through coordination and phased implementation. Investments into hardening infrastructure and facilities against coastal risk and damage may support the resiliency of the area targeted through TSP. Navigation improvements can affect localized flow and salinity. BU of sediment may support a broad systems approach to coastwide restoration and protection. No potential cumulative effect identified.
Barbours Cut Ethane Terminal Improvements (Enterprise Products)	Galveston Bay	PP	2, 3, 9, 10, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Formosa Plastics Plant (Formosa Plastics Corporation)	Matagorda Bay	PP	2, 3, 8, 9, 11, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Alcoa Alumina Plant (Alcoa)	Matagorda Bay	PP	2, 3, 7, 8, 9, 11, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Ingleside Ethylene Cracking Plant (Occidental Chemical Corporation)	Corpus Christi Bay	PP	2, 3, 8, 9, 11, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
OXY Ingleside Energy Center (Occidental Petroleum)	Corpus Christi Bay	PP	2, 3, 8, 9, 11, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Corpus Christi Liquefaction Project (Cheniere Energy)	Corpus Christi Bay	PP	2, 3, 8, 9, 11, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
Buffalo Bayou Petroleum Storage and Marine Terminal (Magellan Terminal Holdings)	Galveston Bay	RF	1, 2, 3, 4, 8, 16	3 – Water and Sediment Quality 8 – Air Quality	
Corpus Christi Channel Marine Terminal Expansion (Plains All American Pipeline)	Corpus Christi Bay	RF	1, 2, 3, 4, 8, 16	3 – Water and Sediment Quality 8 – Air Quality	
Magelland Crude and Hydrocarbon Bulk Storage Terminal (Magellan Terminal Holdings)	Corpus Christi Bay	RF	3, 4, 8, 16	3 – Water and Sediment Quality 8 – Air Quality	
Port of Brownsville LNC Terminal #1 (Texas LNG Brownsville)	Laguna Madre	RF	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Port of Brownsville LNC Terminal #2 (Rio Grande LNG)	Laguna Madre	RF	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Port of Brownsville LNC Terminal #3 (Annova LNG)	Laguna Madre	RF	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Port of Brownsville Subsea 7 Spool Base Facility (Brownsville Navigation District)	Laguna Madre	RF	1, 2, 3, 4, 8, 9, 10, 11, 12, 13, 16	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise	
Private Developments and Roadway Transportation Actions					
Spoonbill Bay Mixed Use Development (Spoonbill Holdings)	Galveston Bay	RF	1, 2, 3, 4, 5,10, 11, 12	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise 10 – Wetlands 11 – Aquatic Resources	Investment and expansion of existing Private Developments and public infrastructure within the study area has potential to impact air, water and sediment quality, and noise levels. There could be short-term impacts with the construction of the TSP as other roads and private developments are constructed concurrently. The combined impacts could be reduced through coordination and phased implementation.
SH 87 Improvements (Rollover Pass to SH 124) (TXDOT)	Bolivar Peninsula	RF	1, 4, 5, 10, 11, 13, 17	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise 10 – Wetlands 11 – Aquatic Resources 17 – Flood Risk Reduction	
The Sanctuary at Costa Grande Mitigation Plan (DH Texas Development)	Espirtu Santo Bay	PP	1, 2, 3, 4, 10, 11, 12	3 – Water and Sediment Quality 8 – Air Quality 9 – Noise 10 – Wetlands 11 – Aquatic Resources	
Corpus Christi New Harbor Bridge (Corpus Christi)	Corpus Christi	PP/RF	4, 9, 11	9 – Noise 11 – Aquatic Resources	
Lake Padres Subdivision Canal (Gulf Shores Joint Venture)	Laguna Madre	PP	1, 2, 3, 4, 10, 11, 12	3 – Water and Sediment Quality 10 – Wetlands 11 – Aquatic Resources	

Project or Action (Responsible Entity)	Location	Past or Present (PP) or Reasonably Foreseeable (RF)	Resource* Considered	Environmental Resource Issues that could be Cumulative	Interaction with the TSP and Potential Cumulative Impacts
Long Island Village Residential Development (John Freeland)	Laguna Madre	PP	1, 2, 3, 4, 10, 11, 12	3 – Water and Sediment Quality 10 – Wetlands 11 – Aquatic Resources	
South Padre Island Second Access (Cameron County Regional Mobility Authority)	Laguna Madre	PP	4, 9, 10, 11, 12, 13	10 – Wetlands 11 – Aquatic Resources	
Residential Piers and Improvements	Coastwide	PP/RF	1, 2, 3, 4, 5,10, 11, 12	3 – Water and Sediment Quality 9 – Noise 10 – Wetlands 11 – Aquatic Resources	Shoreline vegetation change 8,965 permitting actions: riprap, shoreline work, restoration, piers, pipeline. These efforts have occurred in the past and are reasonably expected into the future. The permitting process is an opportunity to restrict efforts that create unnecessary impacts.

*1 – Geomorphology and Coastal Processes; 2 – Physical Oceanography; 3 – Water and Sediment Quality; 4 – Hydrology; 5 – Soils; 6 – Energy and Mineral Resources; 7 – HTRW; 8 – Air Quality; 9 – Noise; 10 – Wetlands; 11 – Aquatic Resources; 12 – Wildlife Resources; 13 – Protected Resources; 14 – Cultural Resources; 15 – Socioeconomics; 16 – Navigation; 17 – Flood Risk Reduction

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which restrict the flow of water between the bay and the Gulf. It is anticipated that flood risk management actions would contribute to the TSP's purpose of CSRM and ER and would yield positive cumulative impacts (see Table 5-12).

Navigation and Dredging Actions. Projects or actions involving navigation and dredging are common along the Texas coast. Some of these actions have the potential to contribute to the TSP's impacts, where many others may not result in any identified synergy with the TSP. One of the largest actions considered in this analysis is the Houston Ship Channel Expansion Channel Improvement Project. That project has not been authorized for construction at this time, but it is reasonable to expect that this or future investments will include deepening of entrance channels and interior harbor features at various ports in the area. Although the TSP would result in a tidal constriction at the Galveston Bay entrance due to the Coastal Barrier Alternative, a deeper and wider Houston Ship Channel may at times reduce impacts resulting from the TSP's tidal constriction. Many of the other larger channel deepening and widening projects, such as the Sabine-Neches Waterway Channel Improvement Project, Matagorda Ship Channel Expansion, Corpus Christi Channel Improvement Project, GIWW maintenance, GIWW Coastal Resilience Study, Brazos Island Harbor Improvement Project, and other shallow draft navigation channel maintenance, in conjunction with the TSP, may not have a direct negative or positive cumulative impact; however, BU opportunities arise from these projects (including marsh restoration, beach nourishment, bird islands, and shoreline protection) when sediment is used in the TSP restoration features (see Table 5-12).

Petrochemical and Industrial Actions. A major component of the Texas economy and coastal setting includes petrochemical and industrial actions and activities. Many of these actions include facilities, terminals, bulkhead construction, and dredging. Investment and expansion of existing infrastructure within the study area has potential to impact air, water and sediment quality, HTRW, and noise levels. Combination with the TSP could be short-term impacts of TSP construction as other facilities operate within the study area. The combined impacts could be reduced through coordination and phased implementation (see Table 5-12).

Private Developments and Roadway Transportation Projects. Investment and expansion of existing Private Developments and public infrastructure within the study area has potential to impact air, water and sediment quality, and noise levels. There could be short term impacts with the construction of the TSP as other roads and private developments are constructed concurrently. The combined impacts could be reduced through coordination and phased implementation.

SH 87 Improvements (Rollover Pass to SH 124). TxDOT will be raising SH 87 to 7.5 feet above sea level from Rollover Pass to SH 124 on Bolivar Peninsula. Efforts to increase the roadbed elevation will include the use of asphalt, beach nourishment, dune restoration, and roadway alignment reconfiguration. This increase in elevation should prevent roadway flooding during high tides and some storm events. Realignment would allow for more area for beach restoration and maintenance; 15.9 acres of wetlands would be filled because of the roadway improvement. The project will be constructed entirely within existing right-of-way, which is typically between 120 and 398 feet wide. Wetland impacts would be mitigated with credits from the Gulf Coastal Plains Mitigation Bank (SWG-2017-00359).

When considering some of the past, present, and reasonably foreseeable actions, TSP features may yield cumulative benefits to coastal resources. The potential for positive cumulative impacts is particularly likely for coastal restoration actions and flood and coastal storm risk management actions. For navigation and dredging actions, there may be opportunities for BU that would contribute to coastwide restoration and protection. Since the TSP is intended to provide long-term benefits to coastal resources, cumulative impacts that may result from the TSP are likely to be positive or beneficial.

5.11 ANY ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED SHOULD THE TSP BE IMPLEMENTED

The TSP will result in minor adverse impacts to benthic organisms and plankton assemblages during construction activities, but these impacts would be temporary. Estuarine faunal productivity could be reduced with the TSP. Potential long-term direct impacts to fish and shellfish with larval and juvenile life stages that depend largely on passive transport could result from the cumulative impacts of the Coastal Barrier.

The ecological effects that the gate structures will have on Galveston Bay were modeled based on a 27.5 percent constriction. This would cause changes in the volume of flow being exchanged through the inlets, known as the tidal prism. The change in tidal prism with the project in place is a 13.5 and 16.5 percent reduction for the present and future conditions, respectively. The tidal amplitudes were also reduced at all bayside locations between 9 and 22 percent. The impacts may be reduced as barrier designs are refined. The reductions in tidal amplitude will cause indirect impacts to tidal wetlands in the Galveston Bay area. These impacts have been accounted for in the mitigation plan and are described in Appendix C-9. As presented in Section 4.0, approximately 850.5 acres of wetlands would be lost as a direct result of construction of the TSP, which is also included in the Mitigation Plan and described in Appendix C-9. Potential indirect tidal marsh acre loss is estimated to be 3,375, and to date 4,547 acres of potential marsh mitigation sites have been identified to account for this loss. A total of 25.2 acres of prime farmland will be impacted and no longer available for agricultural use.

While there would be unavoidable impacts to EFH the ecosystem restoration measures will protect and create marshes, seagrass beds, and oyster reefs, increasing the amount of nursing areas, protective habitat, and food sources along the Texas coast. Mitigation of tidal wetlands will also create improved habitat areas for fish.

5.12 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE TSP

The labor, capital, and material resources expended in the planning and construction of this project are irreversible and irretrievable commitments of human, economic, and natural resources. The loss of 850.5 acres of wetlands during construction is irreversible; however, restoration and mitigation activities create and restore wetlands on a landscape scale. Loss of 25.2 acres of prime farmland is another resource that would no longer be available following construction of the TSP. A total of 2,154 acres of open water and bay bottom habitat would be irretrievably lost from construction of the surge barrier gates at Bolivar Roads, GIWW, Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall).

5.13 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Pursuant to NEPA regulations (40 CFR 1502.16) an EIS must consider the relationship between the short-term uses of the environment and the maintenance and enhancement of long-term productivity. The primary goal of the Coastal Texas Study is to evaluate the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration along the Texas coast.

The construction of the TSP would result in the loss of 850.5 acres of wetlands. These impacts would be fully mitigated in the same general area, resulting in no net loss of wetlands and preservation of the area's long-term productivity. Mitigation and ER measures for wetland and marsh restoration activities compensate for this short-term impact to wetlands. Since there would be a time lag before the restored marshes become established and ecologically functional, there would be a temporary loss of productivity during the interim period. Construction would remove 25.2 acres of prime farmland from future agricultural use.

The TSP is expected to support long-term productivity of Texas, estuaries particularly in the Galveston Bay system, by protecting Gulf shorelines from breaching to the Gulf on Bolivar Peninsula and Follets Island and protecting bay shorelines and restoring marshes from West Bay to East Matagorda Bay. Shoreline protection of Keller Bay, Powderhorn Lake, and Redfish Bay will prevent opening of these systems to greater erosive forces expected to accompany sea level change. Restoration of sediment transport across the Port Mansfield Channel jetties will help protect the North Padre Island shore. The cumulative long-term benefits of these efforts are intended to increase and strengthen multiple lines of defense to tropical storms and hurricanes which threaten to create openings between the Gulf and estuaries. They will tend to maintain existing long-term salinity regimes and the ecological productivity associated with the protected and expanded marshes. Short-term uses will be impacted as these projects are constructed; however, those impacts are expected to last months to a few years and will likely be localized. Some of these ER measures will also benefit navigation over the long-term by strengthening protection of critical reaches of the GIWW.

There will be substantial costs associated with construction of the Coastal Barrier Alternative and although it will take years to construct, the period of construction will be short-term compared to long-term benefits to citizens, local governments, agriculture, and nationally-critical petrochemical industry in the area. The reduced height and inland extent of storm surge will decrease long-term, repeated damage and loss of life caused by multiple storms expected to impact this area over the decades of protection provided by the barrier.

There are expected to be ecological impacts from implementation of the Coastal Barrier Alternative with generally reduced salinity, increased water retention time, decreased migration of larval fish and shellfish, and reduced width of the intertidal zone. Some of these impacts will be offset by implementation of the TSP's ER measures and required mitigation. There is a considerable ecological footprint associated with the generating raw materials, manufacturing and transporting materials needed for reconstruction following storms, combined with efforts responding to and cleaning up hazardous chemical spills caused by storms. The Coastal Barrier Alternative is expected to reduce the long-term and wide ecological footprint associated with response to and reconstruction following major storms striking the area in the future

5.14 ENERGY AND NATURAL OR DEPLETABLE RESOURCES REQUIREMENTS AND CONSERVATION POTENTIAL OF VARIOUS ALTERNATIVES AND MITIGATION MEASURES

NEPA regulations in 40 CFR 1502.16 (e) and (f) require a discussion of project energy requirements and natural or depletable resource requirements, along with conservation potential of alternatives and mitigation measures in an EIS. Energy (fuel) will be required to construct the Coastal Barrier, South Padre Island, and ER measures, but would only have a short-term impact and would not result in a major depletion of depletable energy or natural resources. The construction of the TSP would, however, reduce the risk of serious disruptions in the Nation's energy and petrochemical supplies by reducing storm surge impacts on areas with a high density of large petrochemical facilities.

6.0 TENTATIVELY SELECTED PLAN

As discussed in Section 4.0, the TSP includes three major components to address the immediate needs along the Texas Gulf Coast for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence. The plan includes an overall coastwide ER plan, "Alternative 1-Scale 2," which maintains a robust coastal ecosystem in light of RSLR changes and also provides for resilience from coastal storm surge to the existing and proposed risk reduction systems. The plan includes two CSRM recommendations: a "Coastal Barrier with complementary system of nonstructural measures (Alternative A)" in the upper Texas coast and a long-term construction and renourishment of beach and dune measures along two areas of South Padre Island in the lower Texas coast.

The sections below provide a project description of the TSP to date and include detailed cost estimates, benefits, impacts, and implementation requirements. Additional details on the plan can also be found in the technical appendices. It should be noted that once the DIFR-EIS has undergone a public review, policy review, ATR, and IEPR, the details of the TSP could be refined in the FIFR-EIS; however, the changes will be limited to optimizing the design, such as level of risk reduction, design details, construction sequence details, and proposed construction methods. An overview of the entire risk reduction system is shown on Figure 6-1.

6.1 DESCRIPTION OF THE TENTATIVELY SELECTED PLAN

Comprehensive restoration features were combined in the multiple lines of defense strategy to support and maintain a variety of species and natural functions in several important estuaries along the coast. The coastwide CSRM and ER risk reduction is shown on Figure 6-2. Biodiversity influences ecosystem functions across terrestrial, freshwater, and marine systems.

6.1.1 Ecosystem Restoration Measures

Table 6-1 lists the nine coastwide ER measures that are included as part of the TSP.

Table 6-1
Ecosystem Restoration Measures

ER Measure	Name
G-5	Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration
G-28	Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection
B-2	Follets Island Gulf Beach and Dune Restoration
B-12	Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection
M-8	East Matagorda Bay Shoreline Protection
CA-5	Keller Bay Restoration
CA-6	Powderhorn Shoreline Protection and Wetland Restoration
SP-1	Redfish Bay Protection and Enhancement
W-3	Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

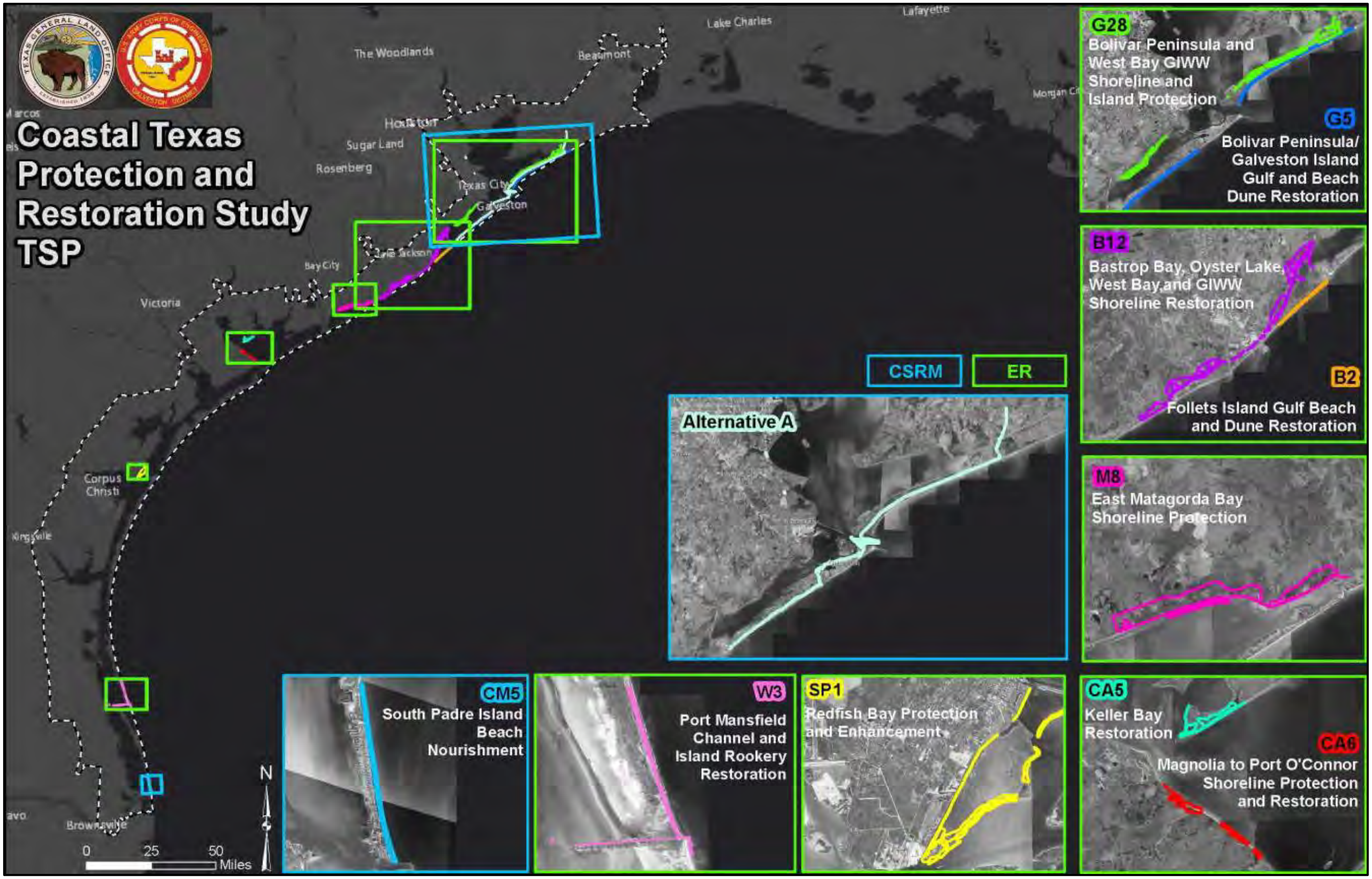

Figure 6-1: Coastwide Risk Reduction System

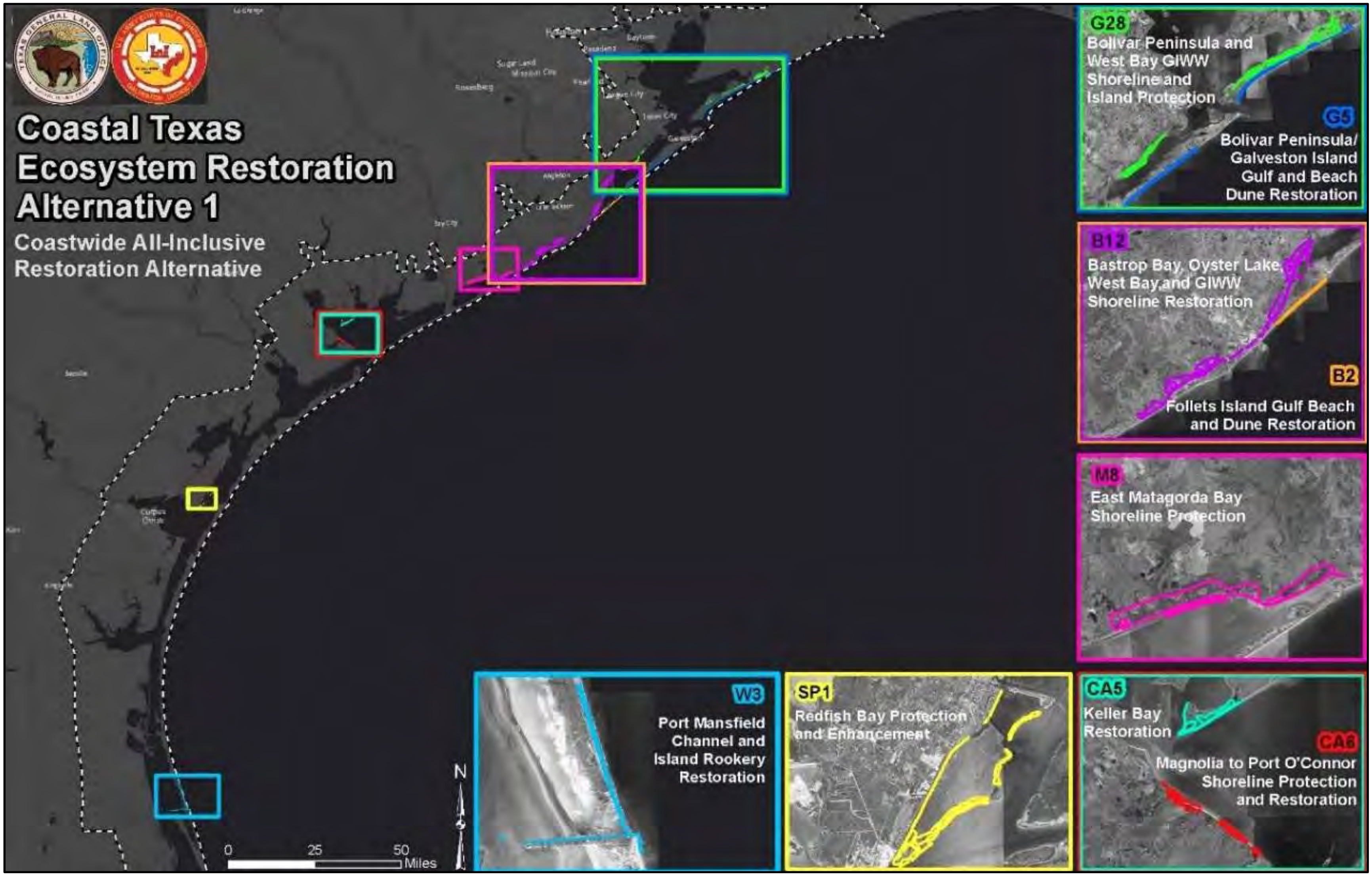

Figure 6-2: Ecosystem Restoration Measures

Multiple sediment sources for each measure were identified to ensure adequate sediment is available to construct all measures (see Table 4-14). In several instances, a portion of the necessary sediment will be available from closer sources, but the cost estimate reflects the cost of dredging and transporting from the largest and possibly farthest source. This approach recognized that certain cost savings may be achieved at the time of construction by using closer sources, but ensured that the cost estimate adequately reflected the highest cost source.

The PDT also identified vulnerable areas at different points in time for the low, intermediate, and high rates of RSLC to evaluate the performance and cost effectiveness across different sea level change scenarios. The comparison confirmed that RSLC threatens critical geomorphic ecosystem features and habitat in coastal Texas under all RSLC scenarios, with variation across the curves only in how quickly the water level reaches that height. A “tipping point”/break point, at which estuarine environments in coastal Texas evolve into open water or unconsolidated shoreline, is evident when the water level increases by 2.7 feet.

Given the coast-wide scale of the intervention necessary to restore marsh and estuarine environments along the Texas coast, the PDT considered it more conservative to plan with higher impacts than lower impacts. Underestimating the quantities, time of intervention, or cost of the measures could negate the value of the effort. The NFS expressed concern that the planning effort and the budget decisions should not underestimate the scale and the budget implications of a meaningful action to restore the coastal environment. As a result, several measures were formulated to include an out-year nourishment or “continuing construction” component to adapt the measure over changing physical conditions in the study area.

A description of the ER measures in the TSP is described below. The plan recognizes that the out-year nourishment can be implemented only when necessary. Under lower rates of RSLC, the tipping point will occur later, and the out-year nourishment may not be necessary or may occur later. An Adaptive Management Plan will address the data collection and thresholds that will trigger the implementation of out-year nourishments.

The TSP would restore, create, protect, and/or enhance approximately 26.6 miles of Gulf shoreline from High Island on Bolivar Peninsula to the Galveston East Jetty and 18.6 miles of Galveston Island shoreline west of the Galveston seawall (G-5). An initial 33 to 66 mcy of beach and dune fill for environmental restoration purposes would be placed over the area. A total of five nourishment cycles would place 27.6 mcy over a 50-year period or a one-time renourishment (27.6 mcy) in year 10 with a sand engine placement that would be used to reduce the dune and beach shaping needed by land equipment. A total of 5,057 acres would be restored, created, protected, and/or enhanced.

The plan would also install breakwaters and restore marsh habitat to protect 27 miles of marsh habitat along the GIWW on Bolivar Peninsula and 9 miles of shoreline along the north shore of West Bay (G-28); however, no breakwaters would be constructed where portions of the GIWW shoreline are already stabilized by adjacent dredged material placement areas. This would be accomplished by restoring 664 acres of marsh using 482,000 cy of fill. The plan would also use 5.8 mcy of sediment to restore, create, and/or enhance 326 acres of islands adjacent to the GIWW along a 5-mile stretch of shoreline habitat along the north shore of West Bay. A 26,280-linear foot oyster reef would be created on the bayside of the restored islands for a creation of 18 acres of oyster reefs. Also, subsequently in the future, the plan would, through future construction activities along the Galveston Bay portions of the GIWW, nourish 6,891 acres of marsh expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be needed in 2065, are expected to require 10.1 mcy of fill material.

The plan would also restore, protect, and/or enhance beach and dune complexes on approximately 10 miles of Gulf shoreline on Follets Island in Brazoria County (B-2). A total of 1,113.8 acres would be restored, created, protected, and/or enhanced by placing 8.7 mcy of beach fill for environmental restoration purposes. In order to maintain the habitat, a total of 11.6 mcy would be placed over five nourishment cycles over a 50-year period, or a one-time renourishment (11.6 mcy) in year 10 with a Sand Engine placement that would be used to reduce the dune and beach shaping needed by land equipment.

In Bastrop Bay, Oyster Lake, Cow Trap Lake, and the western side of West Bay, the plan would restore, create, and/or enhance critical areas of shoreline (B-12). A total of 551 acres of estuarine marsh would be restored using an estimated 400,000 cy of fill material. A total of 43.2 miles of breakwaters would be placed on the western side of West Bay and Cow Trap Lake, and along selected segments of the GIWW in Brazoria County. In the area of Oyster Lake, 3,708 linear feet of oyster reef or 0.17 acre of oyster reef would be created to prevent the lake from joining with West Bay. Also, the plan would, through future construction activities, nourish 19,794 acres of marsh along the GIWW that is expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be needed in 2065, is expected to require 29 mcy of fill material to address losses from RSLR impacts.

The plan includes the use of breakwaters to restore, protect, create, and/or enhance approximately 12.4 miles of shoreline and associated marsh along the Big Boggy NWR shoreline and eastward to the end of East Matagorda Bay (M-8); however, no breakwaters would be constructed where portions of the GIWW shoreline are already stabilized by adjacent dredged material placement areas. This would be accomplished by restoring 239 acres of estuarine marsh restoration using 173,696 cy of fill along these areas. The plan would also restore 92.7 acres/3.5 miles of islands adjacent to the Big Boggy NWR along the GIWW, using 1.1 mcy of fill. In addition, 31,355 linear feet of oyster reef on the bayside of the islands would be created. Subsequently in the future, the plan would, through future construction activities, nourish 6,034 acres of marsh along the GIWW that are expected to be lost based on RSLR impacts. The out-year construction activities, estimated to be need in 2065, is expected to require 8.8 mcy of fill material.

Along the Matagorda Bay shoreline between Matagorda Bay and Keller Bay, the plan would use breakwaters to restore, protect, create, and/or enhance approximately 6 miles of shoreline (CA-5). A total of 3.8 miles of breakwaters would be placed along the southern reach of the project area, while 2.3 miles of oyster reef would be created on the western reaches of the project area. The plan would also, through future construction activities, nourish 623 acres of marsh directly behind the breakwaters. The out-year construction activities, estimated to be needed in 2065, is expected to require 914,647 cy of fill material.

Near the Powderhorn Lake area, along Matagorda Bay, the plan would restore, create, and/or enhance critical areas of shoreline (CA-6). A total of 5 miles of breakwaters would be used for shoreline stabilization, fronting the portions of Indianola, the Powderhorn Lake estuary, and TPWD's Powderhorn Ranch. In addition, 531 acres of estuarine marsh restoration would be created using 385,760 cy of fill material in areas near the Powderhorn Lake estuary, which has converted to unconsolidated shorelines.

The plan includes using breakwaters and/or living shorelines, BU material, and oyster reef balls to restore, create, and/or enhance the island complex of Dagger, Ransom, and Stedman islands in Redfish Bay (SP-1). The plan would include creating 391 acres of island habitat in the complex and would require 6.7 mcy of fill material. Also, along the unprotected GIWW shorelines, along the backside of Redfish Bay, and the bayside of the restored islands, the plan would place 7.4 miles of breakwaters around the system. In the interior of the system 7,392 linear feet of oyster reef would be created to enhance SAV growth.

In order to maintain the geomorphic function of the Gulf shoreline north of the Port Mansfield Channel and restore and maintain the hydrologic connection between the Laguna Madre and the Gulf, the plan would dredge 6.9 miles of the Port Mansfield Channel (W-3). The material would be used to nourish 9.5 miles of beach north of the channel. The plan would also include a bird island restoration using the dredge material to restore 27.8 acres of an existing rookery island. A 0.7-mile breakwater would also be placed around the island to maintain the system. The action of restoring and maintaining the hydrologic connection between the Laguna Madre and the Gulf would hydrologically restore over 112,864 acres in the Lower Laguna Madre.

The ER plan contains features that are located partially on existing Federal lands such as the USFWS refuge lands. Many of these features make up an important and integral component of the overall restoration plan; however, many of the individual Federal agencies are ultimately responsible for managing their own lands. As the study progresses in to future planning and design phases, the USACE will categorize these areas and report on the individual cost and benefits for these separable features in the TSP. The USACE would not seek authorization and funds for the separate features. Rather, the USACE would support other Federal agencies seeking its own authorization and appropriation to construct these features and offers other Federal agencies the information that the USACE developed under this study effort as a starting point for those efforts.

6.1.2 Coastal Barrier CSRM System

The Coastal Barrier CSRM System in the upper Texas coast focuses on addressing or blocking coastal storm surge at the Gulf interface (previously designated as Alternative A during the alternatives analysis, see detailed discussion in Section 4.3.4). It includes a complementary system of nonstructural measures that consists mainly of a barrier system across Bolivar Peninsula, a closure at the pass at Bolivar Roads, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. For planning purposes for the DIFR-EIS, the PDT evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island; however, the PDT recognizes that there are opportunities to optimize the design and alignment to minimize impacts to existing structures and the environment on the peninsula and island. For example, ER measures G-5 and G-28 could be modified in future designs to serve the same function as the levee/floodwall system currently proposed. The current design consists of 54 miles of levee, 20 miles of floodwall, 93 highway gates, 4 railroad gates, 80 drainage closure structures, and 5 pump stations.

The current design includes a raised roadway/levee/floodwall that would start near Mud Bayou, south of Stowell. This reach called the eastern Tie-in would follow the existing SH 124 and attempt to avoid impacts to the Anahuac NWR and continue until reaching the GIWW just north of High Island. The estimated elevation for planning purposes for this reach was 20.0 feet. The system would then transition to a combi-wall and cross the GIWW on the west side of SH 124 with a sector gate. The sector gate would accommodate navigation traffic in the 125-foot-wide authorized channel with a sill elevation at –16.0 feet MLLW. The sector gate would tie into a combi-wall on the south side of the GIWW and then transition to a levee that would continue southward on the west side SH 124 until tying into natural high ground north of Hatcher Avenue in High Island.

The next reach, the Bolivar Peninsula Reach, consists of 25 miles of levee, 2 miles of floodwall, and 20 two-lane highway gates. For planning purposes, the elevation for the Bolivar Peninsula Reach was set at 18.0 feet. The reach starts at High Island, about 0.60 mile southward of the end of the eastern Tie-in, with a levee on the east side of SH 124. This levee runs south for 0.5 mile until just south of Oilfield Road southeast of where it turns westward and crosses SH 124. From that point the system turns southwestward and would include a system of levees and floodwalls to reach the vicinity of Port Bolivar and the SH 87 ferry landing. In areas where there are existing facilities in the direct alignment of the levee, the system would transition into floodwalls to minimize impacts. The Bolivar Peninsula Reach would end with a combi-wall transition into the next reach, the Galveston Harbor Entrance Channel crossing.

The 2.08-mile Galveston Harbor Entrance Channel crossing consists of 0.6 mile of combi-wall, thirty-eight 100-foot vertical lift gates for tidal exchange, one 100-foot recreational gate, and a 1,200-foot floating sector gate across the Inner Bar segment of the Galveston Harbor Entrance Channel. For planning purposes, the elevation for the Galveston Harbor Entrance Channel crossing was set at 18.0 feet. The first part of the crossing consists of seventeen 100-foot-wide vertical lift gates with sill elevation at –15.0 feet, followed by twenty-one 100-foot-wide vertical lift gates and one recreational gate with sill elevation at –30.0 feet. The combination vertical lift gates and combi-wall tie into a 1,200-foot, two-leaf floating sector gate with a sill elevation set at –60.0 feet. This sill elevation allows for future deepening of the Galveston Harbor Entrance Channel, which is currently maintained at a depth of –48.0 MLLW with advanced maintenance at this location. The sector gate is anchored and housed in man-made “islands” on either side of the Entrance Channel. Construction of the sector gate across the Galveston Harbor Entrance Channel would require a temporary bypass for navigation. The bypass channel will be north of the existing channel, through existing anchorage areas and would be maintained at 800-foot toe-to-toe wide and depth of –48.0 MLLW, which is consistent with the existing channel. The crossing continues south of the sector gate with combi-wall that ties into the existing San Jacinto Placement Area on Galveston Island, which would serve as an existing high ground tie-in point.

In order to address Gulf and bay surges, the next reach ties into the east side of the existing San Jacinto Placement Area on Galveston Island and forms a ring levee around the highly developed and low-lying portions of the city of Galveston. The Galveston Ring Levee/Floodwall Reach consists of 5.0 miles of levee, 46 two-lane highway gates, 6 four-lane highway gates, 4 railroad gates, 13.0 miles of floodwall, a 2,400-foot crossing of Offatts Bayou with a vertical gate, a series of 100-foot environmental gates, combi-wall, 3 pump stations, 8 miles of existing seawall raising with 7 two-lane highway gates. For planning purposes, the top elevations ranged from 18.0 to 18.5 feet on the west side of the system to 11 to 17 feet along Harborside Drive and 21 feet along the seawall. The reach would include a floodwall/levee system on the backside of Galveston Island and would continue until meeting the existing end of the seawall near 7-Mile Road and FM 3005. Improvements to 7.9 miles of the existing Galveston seawall would equate to an increase in the height of approximately 4.0 feet above the existing ground elevations. It is important to understand the current design of the Galveston seawall initially provided a fronting protection (the upward and outward curved section to the wall) elevation of about 17.0 feet; however, subsequent modifications to the embankment behind the fronting protection places the risk reduction level at an elevation range between about 19 to 26 feet. This would be an important consideration when considering the 4 feet of additional risk reduction in the final design.

Due to the fact that Galveston Island currently operates on a gravity drainage system, the plan would include a forced drainage system for when the ring levee is closed off during storm events. Interior drainage within the risk reduction system would require three pump stations: one at Offatts Bayou (4,386 cubic feet per second) and two near Harborside Drive (1,645 and 1,243 cubic feet per second). An interior drainage analysis could refine pump station requirements and locations.

The entire Galveston Ring Levee/Floodwall Reach would tie-into a levee/floodwall system that follows the west end of Galveston Island. The West Galveston Reach consists of 13.5 miles of levee, 1.5 miles of floodwall, 14 two-lane highway gates, 35 drainage closure structures, and 3.5 miles of elevated highway and ends at a tie-in point at San Luis Pass Bridge abutment. For planning purposes, the West Galveston Reach was set at an elevation of 17.0 feet. Similar to the Bolivar Peninsula Reach, areas where there are existing facilities in the direct alignment of the levee system would transition into floodwalls to minimize impacts.

The system also includes two closures at Clear Creek Channel and Dickinson Bayou to address wind-driven surges in the bay. The features at both areas consists of sector gates across the channel, associated barrier walls, and pump stations. For planning purposes, the elevation of the walls and gates were set at an elevation of 17.0 feet.

The plan would also include nonstructural measures along the west side of Galveston Bay to address residual damages from wind-driven bay surges. As discussed above, elevating is a common approach already being undertaken by residents and businesses in the study area. Due to the general uncertainty associated with structures' first-floor elevations and locations in the floodplain, additional structure inventory investigations would be undertaken to evaluate which structures are at risk if this alternative moves forward. The focus would be on the approximately 10,000 structures between SH 146 and the bay rim.

Hydrologic connectivity at the Galveston Harbor Entrance Channel crossing, in the Galveston Ring Levee/ Floodwall Reach, and in the closures at Clear Creek Channel and Dickinson Bayou would be maintained to the extent practicable through water control structures except during closures for hurricanes or tropical storms. Closure criteria has not been developed at this point, but based on other large surge barriers worldwide (e.g., Eastern Scheldt, Maeslant, Venice, Thames), the system would operate on an average of 1 to 3 days per year when including storm surge frequencies and operation and maintenance activities. The closure criteria would be revisited over the life of the project, as the closure of the system will be tied to tropical storm events and the elevation trigger would be adjusted over time as RSLR impact occurs. The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in RSLR. Rainfall events and high tides could still cause substantial flooding of the areas surrounding Galveston Bay. All drainage features through the Galveston Ring Levee/Floodwall system were sized to match the existing gravity drainage system and would mimic the existing drainage patterns when the system is not closed. Any operational changes, including increasing of the closure frequency of the Galveston Harbor Entrance Channel crossing, to address changing RSLR conditions or for any other non-project-related purpose would be considered a separate project purpose requiring separate authorization, new NEPA documentation, and/or permit approvals.

As stated above, the closure structures associated the Galveston Ring Levee/Floodwall Reach and the closures at Clear Creek Channel and Dickinson Bayou would only operate on average 1 to 3 days per year, but the NFS also has an obligation relating to the operation of the project, specifically pump station capacities, to prevent encroachments that would impact the utility of the project when the pump station is operating. The NFS will be required to comply with floodplain management requirements and ensure that project features such as pump stations would not be impacted by developments in the areas behind the risk reduction system. The pump system is designed to match the existing gravity drainage capacity when the system is closed. The NFS would have a responsibility to ensure that this operation of the project features is maintained.

All of the impacts from the constructed features for the Coastal Barrier CSRM system would be to either palustrine (freshwater) emergent wetland or estuarine (saline and brackish) emergent wetland habitats. There would be a direct removal of 850.5 acres of combined palustrine and estuarine marsh habitats. Using HEP under the intermediate sea level scenario, the project would be required to mitigate for a direct loss of 279.5 AAHUs of wetland habit.

In addition to the direct removal of acres of habitat due to construction, the project would potential indirectly impact 3,375 acres of tidal marsh. The system is designed to maintain hydrologic connectivity to the extent practicable. In order to minimize changes in tidal flows and changes in tidal amplitude, the system includes environmental control structures. To investigate potential impacts, the team developed an AdH model to predict hydrological impacts, changes in tidal prism, and tidal amplitude that may occur from the proposed CSRM gates. A change in tidal amplitude was predicted to create a situation where high tides are lower and low tides are higher than in a without-project condition. It was assumed that a change in tidal amplitude would affect tidal marsh since the potential would exist for marsh at the upper bounds of the cover type to experience less inundation, while marsh at the lower bounds of the area would experience potentially constant inundation.

To generate an estimate of indirect tidal marsh impacts due to the presence of CSRM structures across Bolivar Roads, a spatial analysis was developed using the NOAA Marsh Migration viewer outputs associated with a projected 1 foot of RSLR. It was assumed that 2035 would represent the condition to apply potential effects from the CSRM structure on tidal marsh, which corresponds to approximately 1 foot of RSLR based on USACE RSLR curves. For the analysis, only tidally influenced cover types, which included estuarine and brackish wetlands, were included. Preliminary AdH modeling of Galveston Bay determined that 0.5 foot would be eliminated from the tidal amplitude if a CSRM structure was placed across Bolivar Roads (Appendix D). The reduction was assumed to be symmetric about the high and low tide. The reduction of 0.5 foot resulted in a FWP tidal range of 0.0 to +1.5 feet. Using GIS, marsh acres were calculated. FWOP tidal marsh acres were estimated to be 38,696 acres. FWP tidal marsh acres were estimated at 35,321 acres. Subtracting the FWP acre estimate from the FWOP acre estimate resulted in a total of 3,375 acres of tidal marsh indirectly impacted by a CSRM structure or storm surge barrier across Bolivar Roads. This equates to an overall reduction of 4,738 AAHU throughout Galveston Bay.

Using HEP under the intermediate sea level scenario, the project would be required to mitigate for an indirect loss of 4,738 AAHUs due to the changes in tidal prism and tidal amplitude. The total required mitigation for both the direct and indirect impacts from the construction of the risk reduction levee system is 5,018.5 AAHUs.

6.1.3 South Padre Island CSRM Measure

The TSP would provide risk reduction to South Padre Island (previously designated as lower Texas coast South Padre Island CSRM) as discussed in Section 4.3.2. Under the TSP, approximately 2.2 miles of CSRM dune and beach system (Reaches 3 and 4) would be aligned parallel to the existing beach and dune system and would start 2 miles from the Brazos Santiago Pass North Jetty system and end 4.2 miles from the Brazos Santiago Pass North Jetty system. Based on the nourishment volumes and intervals, the most-cost-effective scale was shown to be a 12.5-foot dune and 100-foot-wide berm with a 10-year renourishment cycle. Based on this design, an initial 23,558 cy of beach fill would be placed in Reaches 3 and 4, with a total of 1.4 mcy of beach fill placed over a 50-year nourishment cycle. This is the minimal amount of beach fill expected with the TSP. The local sponsor is interested in exploring a larger extent of beach fill along the entire South Padre Island reaches from the Brazos Santiago Pass North Jetty system to 5.8 miles north of the jetty (Reaches 1, 2, 5, 6A, and 6).

6.2 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

The USACE is obligated under Engineering Regulation 1165-2-132 to assume responsibility for the reasonable identification and evaluation of all HTRW contamination within the vicinity of proposed actions during the feasibility phase. It identifies that HTRW policy is to avoid the use of project funds for HTRW removal and remediation activities. Potential HTRW concerns were identified for the TSP. A Draft HTRW Assessment was conducted to identify the existence of, and potential for, HTRW contamination, which could impact or be impacted by the TSP (Appendix C-7). This assessment followed guidance provided by Engineer Regulation 1165-2-132 and consists of a review of recent and historic aerial photographs and a review of Federal, State, and local regulatory agency database information.

If a recognized environmental condition is identified in relation to the project site in the future, the USACE would take the necessary measures to avoid the recognized environmental condition so that the probability of encountering or disturbing HTRW would continue to be low.

6.3 MONITORING AND ADAPTIVE MANAGEMENT

In accordance with the WRDA of 2007 Section 2039 and subsequent implementation guidance (CECW-PB Memorandum dated August 31, 2009), Monitoring and Adaptive Management Plans (MAMPs) are required for ER project components of feasibility studies. The implementation guidance for Section 2039 specifies that ER projects include plans to track and improve restoration success through monitoring and adaptive management. Guidance stipulates that the monitoring plan include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring. It also specifies that monitoring will be performed until restoration success is achieved.

In consultation with the interagency team, the USACE will develop a full MAMP for the comprehensive coastwide ER plan. The MAMP will establish a framework for decision making that utilizes monitoring results and other information, as it becomes available, to update project knowledge and adjust management actions through adaptive management. Having a MAMP ensures success under a wide range of conditions and enables implementing corrective actions in cases where monitoring demonstrates that the measures are not achieving ecological success. Monitoring and adaptive management provides an iterative approach to achieve restoration project goals and objectives by promoting flexible decision making where uncertainties are present. Uncertainties remain concerning exact project features for the ER measures, monitoring elements, and adaptive management opportunities. These uncertainties will be developed further under future planning and design phases; plans will be revised to incorporate more-detailed MAMPs and cost breakdowns.

During further development under future planning and design phases or as implementation planning occurs, Adaptive Management Teams (AMTs) consisting of USACE, NFS, and resource agencies will be formed to develop MAMPs specific to each ER measure. Establishing location specific, or ER measure specific, AMTs will allow the USACE to employ the technical knowledge of local experts to guide the adaptive management decision-making process. The AMTs will review monitoring results, advise on, and recommend actions that reflect the needs of the habitats and the species they support. AMTs will focus on achieving restoration outcomes in the face of uncertainties, which are inherent with any large-scale restoration project. Uncertainties include ER measure implementation timing, RSLC, climate change, sediment dynamics, and natural variability in ecological and physical processes. Individual teams will develop a monitoring plan to identify performance standards, desired outcomes, and monitoring design, as well as designate the monitoring period to achieve ecological success.

Monitoring results will be documented in reports to be used to evaluate adaptive management needs and inform decision making. Decision criteria, or adaptive management triggers that will be addressed in future planning and design phases by the AMTs are used to determine any implementation of adaptive management opportunities. Triggers or thresholds are defined and tied to individual performance standards for ER measures. ER measures proposed for the coastwide project include beach/dune restoration, marsh restoration, breakwaters, island restoration, oyster reef construction, and out-year marsh nourishment.

Potential adaptive management actions that may be considered for ER measures include:

- **Beach/Dune Restoration.** Renourishment with additional material to correct elevation or topography to target; replanting to increase vegetative cover of dunes.
- **Marsh Restoration.** Renourishment with additional material to correct elevation or topography to target; erosion control measures; berm construction, removal, or modification to affect tidal exchange; replanting to increase vegetative cover; changes in invasive species control and management.
- **Breakwater Construction.** Maintenance of shoreline stabilization features to include repair, height or width increase, or complete redesign.
- **Island Restoration.** Placement of additional sediment to maintain or correct elevation and topography to target; invasive species control; replanting to increase vegetative cover; predation control; repair or replacement of Interlocking Concrete Block; breakwater additions for increased erosion control.
- **Oyster Reef Construction:** Addition of cultch material.
- **Out-Year Marsh Nourishment.** Several of the ER measures include out-year nourishments, which will require adaptive implementation. The action was proposed for a specific year based on the intermediate rate of RSLC to offset the anticipated impacts of RSLC. Since the intervention may be required earlier or later, depending upon when the water level reaches the "tipping point"/break point, where the rate at which estuarine environments in Texas evolve into open water or unconsolidated shoreline, is evident when the water level increases by 2.7 feet.

Initial monitoring and adaptive management cost estimates were estimated as a percent of the total construction cost and based on the complexity of the proposed ER activity and the estimated level of effort and frequency of need. Section 2039 of the WRDA of 2007 allows monitoring to be cost-shared for up to 10 years post-construction; however, monitoring may continue beyond that point, funded by the local NFS, if success criteria are not yet met. Monitoring and adaptive management costs will be refined as project design evolves.

6.4 REAL ESTATE REQUIREMENTS ASSOCIATED WITH THE TENTATIVELY SELECTED PLAN

A Real Estate Plan describing the real estate requirements and costs for the project can be found in Appendix F. The NFS will have the responsibility of acquiring all necessary real estate interests for the project and for ensuring that relocation of utilities and facilities are accomplished.

The non-Federal contribution of Land, Easements, Rights-of-Way, Relocation, and Disposal Areas (LERRD) for the coastwide ER measures portion of the project is estimated to be $1.7 billion, which includes the costs associated with acquiring lands in fee where restoration projects are not proposed on existing State- or Federal-owned lands.

The non-Federal contribution of LERRD for the Coastal Barrier CSRM System is estimated to be $640 million, which includes the costs associated with acquisition of real estate interests for structural features and potential mitigation sites. A standard perpetual flood protection levee easement will be acquired for the construction of levees and floodwalls. A standard temporary work area easement will be acquired for staging areas. A non-material deviation will be made to the standard road easement to revise the rights necessary for a temporary access easement to be acquired over existing private roads to allow access to the construction area. Location of mitigation lands have yet to be finalized; however, lands will be acquired in fee, excluding minerals (with restrictions on use of the surface). Currently the potential costs of the mitigation LERRD have been captured in the project contingencies. LERRD for the nonstructural features along the westside of Galveston Bay to address residual damages from wind-driven bay surges, would be investigated in future planning and design phases of the study, but are expected to be minimal compared to the overall project LERRD's cost.

The non-Federal contribution of LERRD for the South Padre Island CSRM Measure is estimated to be $1.6 million, which includes the costs associated with an estimated 124 affected property owners that still have an ownership interest on the beach.

6.5 RELOCATIONS WITH THE TENTATIVELY SELECTED PLAN

Levee construction may cause relocations and/or temporary interruptions to pipelines. Relocations are a part of the NFS LERRD's responsibility. The assumption for the TSP was that a pipeline floodwall would be required wherever a pipeline crossed the levee footprint. The pipeline would cross through a cutoff wall under the pipeline floodwall. It was decided that the existing carrier line would remain in operation while a bypass line would be constructed through a sleeve in the T-wall cutoff piles. When the bypass would be completed and in place, the switch over-tie in with the existing line then would follow along with the removal of the abandoned pipeline. These assumptions are consistent with the screening level assumptions. Although no determination of compensability was prepared for purposes of this DIFR-EIS, it is expected that all of the pipeline relocations would be compensable. The total costs for relocations are the responsibility of the NFS. A final determination of compensability and cost for utility/common carrier relocations will be refined during future planning and design phases.

6.6 OPERATION, MAINTENANCE, REPAIR, REHABILITATION, AND REPLACEMENT ASSOCIATED WITH THE TENTATIVELY SELECTED PLAN

The purpose of OMRR&R is to sustain the constructed project. The largest OMRR&R is associated with the Coastal Barrier CSRM System. OMRR&R associated with the South Padre Island CSRM Measure, and the ER measures has been limited to Adaptive Management and Monitoring activities, due to the fact that many of the features have out-year nourishment activities that are considered construction activities and would be cost shared.

The cost estimates for maintenance of the structures with the Coastal Barrier was based on existing expenditures for normal OMRR&R of similar features around the Nation. The main features of work identified based on the cost estimates were levee, floodwall, pump station, drainage structure, surge barrier gates, and the 1,200-foot sector gate complex. The total estimated annual OMRR&R cost is $130,458,000 based on the current Federal FY 18 fiscal year discount rate (2.75 discount rate). The one big driver for the OMRR&R costs was the maintenance of the 1,200-foot sector gate complex. The costs for this feature were developed based on historical information for gates of similar magnitude provided by the Rijkswaterstaat, Netherlands. The assumption that the annual OMRR&R costs for the surge barrier gates is roughly equivalent to 1 percent of the total construction cost of the gate is based upon meeting with Rijkswaterstaat. Ongoing discussions would occur through future planning and design phases with Rijkswaterstaat for further insight into the operation and maintenance of gates of this magnitude. Additionally, ongoing collaboration with the International Network of Storm Surge Barriers (I-Storm) is occurring to gain further knowledge on large storm surge barriers.

The NFS will be required to maintain these features to their initial constructed design height for so long as the project remains authorized. The final design heights would be set in the future planning and design phases of the study. The NFS would not be obligated to address loss of risk reduction due to RSLR. After the District Engineer provides notice of construction completion for the project, or functional portion of the project, the NFS would commence OMRR&R responsibilities associated with the project.

6.7 COST AND BENEFIT ANALYSIS ASSOCIATED WITH THE TENTATIVELY SELECTED PLAN

The sections below provide a summary of TSP’s cost estimates and benefits to date. Additional details on the plan can also be found in the technical appendices. It should be noted that once the DIFR-EIS has undergone a public review, policy review, ATR, and IEPR, the details of the TSP could be refined in the FIFR-EIS; however, the changes will be limited to optimizing the design (i.e., level of risk reduction, design details, construction sequence details, and proposed construction methods).

6.7.1 Cost

The TSP's costs have been broken into an overall coastwide ER plan and also into the two CSRM recommendations. The cost estimates for the CSRM alternatives were developed by incorporating unit costs and quantities from the GCCPRD report and making revisions to their estimates to be consistent with USACE cost practices. A review of GCCPRD estimates determined that their costs were in FY 15 price level, which required escalation to FY 18. Using the current Civil Works Construction Cost Index System tables, they were escalated by 6 percent. The USACE Galveston District also determined that certain features and longer reaches were necessary to ensure project performance over time. The unit costs developed by GCCPRD were found to be consistent with similar costs developed by the USACE Galveston District for comparable features in recent projects and were appropriate for a Class 4 cost estimate. The GCCPRD developed a library of costs for completed Federal studies and projects, for Texas Department of Highways and Transportation costs for heavy construction projects, and for researched academia reports for costs associated with large coastal barriers in the United States and overseas. These historical data were utilized by the USACE to perform parametric estimates for this study. The study team will continue to develop and refine project costs in future planning and design phases of the study; however, risk contingency markups were also included in the estimate to cover unknowns, uncertainties, and/or unanticipated conditions that are not possible to evaluate from the data on hand at the time the estimate is prepared. The USACE Galveston District estimate diverged from the GCCPRD estimate in the amount of contingency used. The GCCPRD included the Engineering and Design and Construction Management cost in their contingency. Instead, the USACE followed ER 1110-2-1302 (June 30, 2016) and developed an Abbreviated Risk Analysis, utilizing the in-house PDT members. Separate contingencies were developed for each alternative by code of account. These contingencies were then applied to the unit cost.

The greatest ranges in estimated costs are associated with design and construction of the 1,200-foot gate complex and floodwall construction along the backside of Galveston. The range for gate design and construction is relatively wide to account for variability in fabrication and transportation estimates. Existing port facilities and infrastructure along the backside of Galveston make construction of a floodwall in that area difficult and account for the range in estimated costs for floodwall construction. When pump station capacity requirements for Clear Creek are determined, a more accurate price estimate can be determined for this feature.

What makes this project unique is the magnitude of the job and the need to transport borrow material for levee construction onto Bolivar Peninsula and Galveston Island. The utilization of commercial sources for borrow and their continued availability in the future presents a risk, particularly if the transportation distance increases. This borrow risk is also associated with the ER and South Padre Island CSRM measures. It was assumed that material required for beach and dune creation or marsh creation features would be obtained from a variety of sources including offshore sand source or navigation channels. Many of these sites have yet to be fully investigated for detailed quantities or suitability. Due to these uncertainties, the costs are currently presented as a range in Table 6-2. More-detailed analyses would continue through the future planning and design phases to refine the technical details of the features within the selected plan. These refinements drive cost uncertainty. For example, the closure

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Table 6-2
Costs for TSP

Description	Coastal Barrier CSRM System Low – High	South Padre Island CSRM Measure Low – High	Coastwide ER Measures Low – High	Grand Total for TSP Low – High
Real Estate Cost:				
01-Lands and Damages	$643,779,000 – $736,112,000	$2,565,000 – $2,565,000	$1,509,564,000 – $1,574,493,000	$2,155,908,000 – $2,313,170,000
02-Relocations	$60,939,000 – $60,939,000			$60,939,000 – $60,939,000
Subtotal Real Estate Cost (100 percent Non-Federal)	*$704,718,000 – $797,051,000*	*$2,565,000 – $2,565,000*	*$1,509,564,000 – $1,574,493,000*	*$2,216,847,000 – $2,374,109,000*
Construction Costs:				
06-Fish and Wildlife	$652,939,000 – $874,013,000		$22,682,000 – $31,753,000	$675,621,000 – $905,766,000
10-Breakwaters & Seawalls - ER Island Restoration			$1,002,774,000 – $1,403,884,000	$1,002,774,000 – $1,403,884,000
11-Levees and Floodwalls CSRM and ER	$2,582,229,000 – $5,005,970,000		$337,764,000 – $472,870,000	$2,919,993,000 – $5,478,840,000
12-Navigation, Ports, and Harbors – ER Marsh			$1,309,815,000 – $1,833,742,000	$1,309,815,000 – $1,833,742,000
13-Pumping Plants	$1,048,097,000 – $1,220,583,000			$1,048,097,000 – $1,220,583,000
15-Flood Control and Div Str	$297,627,000 – $297,627,000			$297,627,000 – $297,627,000
15-Flood Control and Div Str – "Big Gate"	$5,097,492,000 – $6,304,361,000			$5,097,492,000 – $6,304,361,000
17-Beach Replenishment		$58,482,000 – $68,229,000	$3,583,731,000 – $5,017,224,000	$3,642,213,000 – $5,085,453,000
30-Engineering and Design	$2,496,200,000–$3,540,435,000	$5,849,000 – $6,824,000	$571,964,000 – $800,749,000	$3,074,013,000 – $4,348,008,000
31-Construction Management	$1,291,138,000–$1,831,260,000	$4,679,000 – $5,459,000	$526,273,000 – $736,783,000	$1,822,090,000 – $2,573,502,000
Subtotal Design and Construction Costs	$13,465,722,000–$19,074,249,000	$69,010,000 – $80,512,000	$7,355,003,000 – $10,297,005,000	$20,889,735,000 – $29,451,766,000
Total Project Cost (rounded)	**$14,170,440,000–$19,871,300,000**	**$71,575,000 – $83,077,000**	**$8,864,567,000 – $11,871,498,000**	**$23,106,582,000 – $31,825,875,000**

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system has not been designed in detail, which could result in cost savings through application of a different design concept in the same general location. A detailed design must be conducted to determine the most effective way to build the barrier. Another example is the selection between a beach and dune barrier versus a floodwall landward. As the design refines these key features, costs will continue to become more certain.

6.7.2 Net Benefits and Benefit-Cost Ratios

Similar to the TSP's cost, the benefits have been broken into overall coastwide ER plan benefits and also into two CSRM benefit estimates. Benefits compared to the cost for TSP are shown in tables 6-3, 6-4, and 6-5. Due to the wide cost ranges, sea level scenario evaluations, and with the inclusion of indirect economic impacts, discussed in Section 4.3.4., the net benefits and benefit-cost ratios with upper coast CSRM TSP has been presented as a range. Average costs were used for the ER features and SPI, which is why a point estimate is presented in tables 6-3 and 6-4.

Table 6-3
Coastal Barrier CSRM System, Net Benefits and BCRs ($ millions)

RSLR and Cost Scenario	W/O Project Damages[1]	Alt A With-Project Damages[1]	Annual Damage Reductions	Annual Benefits (Damage Reduction plus GDP Impacts*)	Annual Costs	Equivalent Annual Net Benefits (includes GDP Impacts*)	Equivalent Annual Net Benefits (Without GDP Impacts)	BCR (Includes GDP Impacts)	BCR (Without GDP Impacts)
High RSLR & Low Cost	3,106	1,818	1,288	1,908	717	1,192	571	2.7	1.80
High RSLR & High Cost	3,106	1,818	1,288	1,908	956	952	332	2.0	1.35
Intermediate RSLR & Low Cost	2,243	1,464	779	1,141	717	424	62	1.6	1.09
Intermediate RSLR & High Cost	2,243	1,464	779	1,141	956	185	(177)	1.2	0.81
Low RSLR & Low Cost	2,044	1,382	662	970	717	253	(55)	1.4	0.92
Low RSLR & High Cost	2,044	1,382	662	970	956	14	(294)	1.0	0.69

[1] Equivalent Annual Values, 2035-2085 period of analysis and includes future development.
* REMI model developed by Regional Economic Models Inc. was used to quantify the indirect impacts U.S. economy.

Table 6-4
South Padre Island CSRM Measure, Average BCR When Renourishing Separate Reaches (Reaches 3 and 4 Highlighted)

	Template (DH_DW_BW)	R3 and R4	R3, R4, and R5
	10_20_100	0.895	0.752
	10_15_100	0.897	0.780
TSP	**12.5_20_100**	**1.189**	**0.733**
	12.5_15_100	1.167	0.726
	12.5_10_100	1.129	0.734
	12.5_10_150	0.949	0.543
	15_15_100	0.958	0.650
	15_10_100	0.924	0.649

Table 6-5
Cost of AAHUs for Coastwide ER Measures

Output (AAHU)	Cost ($1,000)	Average Cost ($1,000/ AAHU)	Incremental Cost ($1,000)	Incremental Output	Incremental Cost per Output ($1,000)	Total Cost ($1,000)
69,344	378,759	5.46	231,024	32,747	98.99	12,881,299

6.8 RISK AND UNCERTAINTY ANALYSIS ASSOCIATED WITH THE TENTATIVELY SELECTED PLAN

Risk and uncertainty are intrinsic in water resources planning and design. This section describes various categories of risk and uncertainty pertinent to the study.

6.8.1 Residual Damages and Residual Risks

Residential, Commercial, and Industrial Damages. With a project in place to reduce hurricane and tropical storm surge damages, not all surge damages will be prevented, only reduced. It is important to provide information on residual damages to demonstrate project performance and communicate the fact that the project will not eliminate all risks to life and property. Within the system, residual damages can still occur from project exceedance events, rainfall events, wind-driven surges in Galveston Bay, and hurricane winds and windblown debris. The study area is still highly susceptible to rainfall flooding, particularly in upland areas where drainage features are restricted by railway or roadway features. As stated in Section 6.1, the recommended risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in RSLR or by rainfall events outside of hurricane and tropical storm events.

The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Version 1.4.2 certified model was used to calculate the damages for the without-project existing and future conditions. Measurable damage categories from HEC-FDA, including residential and non-residential structures and automobiles, are accounted for in the residual damages.

Currently, as investigated, the levee system will reduce hurricane and tropical storm surge damages (equivalent annual damages) by 60 percent to the existing residential and non-residential structures behind the levee system over a 50-year period using the high SLR scenario. As stated in Section 6.1, the levee system is not authorized to be closed under non-hurricane and tropical storm events. Some damages will still occur from rainfall events and from storms exceeding the systems 1 percent probability storm level of risk reduction.

6.8.2 Risk to Life and Safety

6.8.2.1 Environmental Factors

Relative Sea Level Rise. There is uncertainty about how much RSLR change would occur in the region. An assessment of RSLR was included in plan formulation and alternatives analysis. The evaluation of RSLR is documented in the Engineering Appendix (Appendix D).

The application of storm surge damage scenarios was not based on just global SLR, but based on the application of a RSLR scenario. Subsidence levels predicted in the study area were incorporated into the storm surge model's initial water level parameter to capture the combined effects of subsidence and local SLR into a single RSLR value.

Storms. Risks associated with the TSP are primarily related to the possibility of extreme weather events. The uncertainty of the size or frequency of storms and meteorological events, such as El Niño and La Niña, cannot be predicted over a set period of time. The storm record is constantly being updated, and a large storm such as Hurricane Katrina or a slow-moving storm such as Isaac can alter the expected return period for other storms. To reduce the uncertainties of storm events, storms with varying degrees of size, intensity, and path are included in the modeling. By using a long-term record of different storm scenarios, the effects of such storms are incorporated into the modeling.

6.8.2.2 Engineering Factors

Levee/Structure Failure. The risk associated with the levee/structure system is its stability. Analysis of the earthen levee and associated T-walls and gates are included in the Engineering Appendix (Appendix D). Additional geotechnical investigation will take place after the release of the DIFR-EIS, and the information collected will be used to ensure that levees and other features are constructed to meet USACE standards.

Hydrologic Flows. As discussed in Section 4.0, there is always uncertainty as to whether the system would potentially induce flooding. Additional ADCIRC modeling will be performed in the future planning and design phases to determine whether or not there will be induced flooding and to precisely estimate its magnitude. At this time, the model uncertainty and inclusion of options to shift the final alignment toward the beach adequately address the limited potential for induced damages.

6.8.3 Economic Uncertainty Factors

HEC-FDA was used to calculate the damages and benefits for the Coastal Texas CSRM evaluation. The economic and engineering inputs necessary for the model to calculate damages for the analysis year (2015), the project base year (2035), and the final year in the period of analysis (2085) include the existing condition structure inventory, future development structure inventory, contents-to-structure value ratios, vehicles, first-floor and ground elevations, depth-damage relationships, and without-project and with-project stage-probability relationships.

The uncertainty surrounding each of the economic and engineering variables was also entered into the model. Either a normal probability distribution, with a mean value and a standard deviation, or a triangular probability distribution, with a most likely, a maximum and a minimum value, was entered into the model to quantify the uncertainty associated with the key economic variables. A normal probability distribution was entered into the model to quantify the uncertainty surrounding the ground elevations. The number of years that stages were recorded at a given gauge was entered for each study area reach to quantify the hydrologic uncertainty or error surrounding the stage-probability relationships.

The evaluation incorporated uncertainty surrounding the economic and engineering inputs to generate results that can be used to assess the performance of the TSP. As presented in Table 5-5 of the Economic Appendix (Appendix E-1), there is a greater than a 75 percent chance that the equivalent annual benefits exceed the annual cost and the benefit-to-cost ratio is greater than one.

6.8.4 Engineering Uncertainty Factors

Several engineering uncertainty factors persist at this stage of the planning process. Some are the result of natural conditions. Uncertainties surrounding storm tracks and probabilities are reflected in the engineering models that assess water surface elevations and conditions in the with- and without-project conditions.

SLR creates uncertainty surrounding the time that the rise will occur across the study area. That uncertainty is addressed in accordance with relevant guidance to assess project performance under different scenarios, and to identify potential adaptations.

Identification of sediment sources presents some uncertainty due to the anticipated start date of construction. At present, the study team confirmed that adequate sediment sources exist and are within a feasible distance of the proposed measures. Some structures proposed along the Bolivar Peninsula and the west side of Galveston Island have been scoped under the assumption that a commercial source of sediment will be used. Over time, specific sources may be depleted, and alternative sources may be needed. This uncertainty is reflected in the contingency applied within the cost estimate.

One uncertainty for coastal barrier design is the absence of soil strength parameters along Bolivar Roads. Conceptual design of the barrier considered soil strength data from adjacent onshore sites, and any variations discovered when borings are completed may change design parameters and potentially cost.

Pumping station capacity estimates are conservative at present. Future planning and design phases of the project will include more-detailed evaluation of the combined impacts of storm surge and precipitation.

6.8.5 Implementation Economic Uncertainty Factors

Subject to project authorization, appropriation and availability of funding, full environmental compliance, and execution of a binding agreement with the NFS, construction is currently scheduled to begin in 2025. The schedule assumes a complete risk reduction system in place by 2035. The project requires construction authorization and the appropriation of construction funds. A continuous funding stream is needed to complete this project within the anticipated timeline, which requires continuing appropriations from Congress and the State of Texas in order to fund the detailed design phase and fully fund construction contracts.

Once construction funds are appropriated for this project, the NFS and the Department of the Army would enter into a Project Partnership Agreement (PPA). After the signing of a PPA, the NFS can acquire the necessary land, easements, and rights-of-way to construct the project. Since project features cannot be advertised for construction until the appropriate real estate interests have been acquired, obtaining the necessary real estate in a timely fashion is critical to achieving the project schedule. At the completion of construction, or functional portions thereof, the NFS would be fully responsible for OMRR&R of the project or of the completed functional portion of the project.

6.8.6 Cost Sharing

The State of Texas, acting through the GLO, is the NFS for the feasibility study. Currently, the cost-share during the feasibility phase is 50 percent Federal and 50 percent non-Federal. Following the completion of the FIFR-EIS, the GLO will be the NFS for the planning, design, and construction. The determination of the sponsor of OMRR&R of the project would be identified before initiating construction. At this time, the estimated cost share for the planning, design and construction of the project will be 65 percent Federal and 35 percent non-Federal for both the CSRM and ER features. However, for the South Padre Island CSRM measure, the future renourishments will be subject to the Federal participation rules under Section 934 of PL 99-662.

Also, as described above, the ER measures contains features that are located partially on existing Federal lands such as USFWS refuge lands, which could impact the cost sharing of features. Also, Coastal Barrier Resources System designated units are located on Bolivar Peninsula in the TSP. The designated units were created to minimize loss of human life by discouraging development in high-risk areas, reduce wasteful expenditures of Federal resources, and to preserve the ecological integrity of these areas. The laws prohibit all Federal expenditures or financial assistance, including flood insurance, for residential or commercial development in the designated units. The study team recognizes that in these areas, construction of a levee/floodwall or engineered dunes would be needed to form comprehensive barrier for the upper Texas Coast. With the study sponsors support, the NFS has agreed to fund all costs attributable to the in-unit portions of the barrier system. Currently approximately 12.4 miles of levee/floodwall or engineered dunes are included in the designated units and would be solely funded and constructed by the NFS. A full description of the non-Federal and Federal responsibilities will be included in the FIFR-EIS.

6.9 VIEWS OF THE NON-FEDERAL SPONSOR

The State of Texas and the GLO support and recognize the importance of hurricane risk reduction in Coastal Texas. A letter of intent from the GLO has been received. In the letter, the sponsor also acknowledges the responsibilities and will support the role as such for the design and construction of the recommended project, if authorized.

This study is supported by the Texas Congressional delegation. The USACE has worked with an interagency team and local stakeholders to develop a feasible comprehensive plan to provide hurricane storm surge risk reduction and ER for the entire area. Construction of the proposed system would immediately allow for improved storm surge risk reduction in the project area, which could potentially reduce life, health and safety risk to residents and interruptions to vital transportation routes.

7.0 CONSISTENCY WITH OTHER STATE AND FEDERAL PLANS AND REGULATIONS (*NEPA REQUIRED)

This DIFR-EIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations and has been prepared using the CEQ NEPA regulations (40 CFR Part 1500–1508) and the USACE's Engineering Regulation 200-2-2 – Environmental Quality: Policy and Procedures for Implementing NEPA, 33 CFR 230. In implementing the Preferred Alternative, the USACE would follow provisions of all applicable laws, regulations, and policies related to the proposed actions. The following sections present brief summaries of Federal environmental laws, regulations, and coordination requirements applicable to this DIFR-EIS.

7.1 NATIONAL ENVIRONMENTAL POLICY ACT

NEPA requires that all Federal agencies use a systematic, interdisciplinary approach to protect the human environment. This approach promotes the integrated use of natural and social sciences in planning and decision-making that could have an impact on the environment.

NEPA requires the preparation of an EIS for any major Federal action that could have a significant impact on the environment (42 USC 4321–4347). The EIS must address any adverse environmental effects that cannot be avoided or mitigated, alternatives to the proposed action, the relationship between short-term resources and long-term productivity, and irreversible and irretrievable commitments of resources. According to 40 CFR 1502.9, a supplement to either a DEIS or FEIS must be prepared if an agency makes substantial changes in the proposed action that are relevant to environmental concerns, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

The NEPA regulations provide for the use of the NEPA process to identify and assess reasonable alternatives to proposed actions that avoid or minimize adverse effects of these actions upon the quality of the human environment. "Scoping" is used to identify the range and significance of environmental issues associated with a proposed Federal action through coordination with Federal, State, and local agencies; the general public; and any interested individuals and organizations prior to the development of an EIS. The process also identifies and eliminates, from further detailed study, issues that are not significant or have been addressed by prior environmental review.

This DIFR-EIS has been prepared in accordance with the NEPA process. Specifically, this DIFR-EIS evaluates the likely environmental consequences of the proposed alternatives, as discussed in Section 4.0, and cumulative impacts of the proposed alternatives in Section 5.0. Detailed environmental consequences can be found in the Environmental Supporting Document (Appendix C-1).

7.2 CLEAN WATER ACT

The Federal Water Pollution Control Act of 1972, as amended in 1977 via the Clean Water Act (CWA), authorizes the EPA to regulate activities resulting in a discharge to navigable waters. Section 404 of the CWA normally requires a USACE permit for the discharge or deposition of dredged or fill material and for the building of structures in all waters of the United States, other than incidental fallback (a term that generally refers to material falling back into waters incidentally during an activity designed to remove material, but if in doubt should be clarified during the preparation or review of a permit application). Section 404(r) of the CWA exempts from Section 404 permitting requirements the discharge of dredge or fill material as part of the construction of a Federal project specifically authorized by Congress if information on the effects of such discharge is included in an EIS pursuant to NEPA. However, if the features are constructed by the NFS are in or affect the course, condition, location, or capacity of navigable waters or the discharge of dredge or fill material into waters of the U.S., the NFS would require a USACE Regulatory Permit to comply with the requirements set forth in the Rivers and Harbors Act of 1899 and the CWA.

Pursuant to the provisions of Section 404(r), the process used for completion of this project would be consistent with the guidelines described in Section 404(b)(1) of the CWA. Criteria to be considered in evaluating the alternatives include cost, technology, environmental effects, and logistics. Guidelines prepared for the evaluation of dredge and fill material also indicate that actions subject to NEPA would, in all probability, meet the requirements of the analysis of alternatives specified by Section 404(b)(1) guidelines. As part of its review, the USACE consults with other agencies, including the USFWS and SHPO.

The CWA applies to this study. The USACE is requesting a §401 State Water Quality certification from Texas for the TSP. A draft CWA §404(b)(1) evaluation of the TSP, provided in the DIFR-EIS (Appendix C-2), describes the effects of the proposed discharges.

7.3 CLEAN AIR ACT of 1970

The CAA is the comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources. Air emissions associated with construction of the TSP would impact the air quality of the study area. It is expected that air contaminant emissions from construction activities would result in temporary and localized impacts on air quality in the immediate vicinity of the project site as they are considered one-time activities (i.e., the construction activities would not continue past the date of completion). After construction, temporary impacts to air quality would continue due to maintenance and renourishment activities, e.g., routine dredging would be required to maintain the ER activities. It is anticipated these maintenance activities would be intermittent and of relatively short-term duration for each segment being maintained. It is anticipated that air contaminant emissions from the operation of the surge barrier gates would result in a relatively minor increase in air contaminant emissions above those for existing emissions sources in Galveston County. Essentially, these operating emissions would be from products of combustion of diesel fuel in the proposed emergency generators, which would be operated periodically for maintenance and testing and during an emergency event.

Pursuant to Section 176 of the CAA Amendments of 1990, the USACE will prepare a General Conformity Determination for the TSP. The USACE and GLO coordinated the methods that may be used to demonstrate conformity of the TSP's emissions during construction with the SIP. It was determined that General Conformity Standards are refined over time, therefore any determination regarding general conformity would have to be undertaken closer to construction.

Because of the project scale and duration, it is anticipated by the TCEQ that emissions of NO_X and VOC would exceed the level of emissions anticipated and allotted for growth in any SIP (current and future) emissions inventory for construction emissions. A future SIP revision will be necessary to demonstrate conformity. This method has not been used by the TCEQ for previous conformity determinations but appears to be a method available under the general conformity rules. The process would require coordination with the USACE, TCEQ, and EPA in the development of a detailed emissions inventory for NO_X and VOC emissions from the TSP's construction. Appendix C-1 provides additional discussions on the General Conformity Determination coordination.

7.4 NATIONAL HISTORIC PRESERVATION ACT OF 1966

Compliance with the National Historic Preservation Act of 1966, as amended (54 USC § 306108), requires the consideration of effects of the undertaking on all historic properties in the project area and development of mitigation measures for those adversely affected properties in coordination with the SHPO, Native American Tribes, and the Advisory Council on Historic Preservation. It has been determined that there is a potential for new construction, improvements to existing facilities, and maintenance of existing facilities to cause effects to historic properties. Therefore, in accordance with 36 CFR 800.14, the USACE will execute a Programmatic Agreement among the USACE, the Texas SHPO, and any NFS to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities. The USACE will also invite the Advisory Council on Historic Preservation and Native American tribes to participate as signatories to the Programmatic Agreement. The Programmatic Agreement is currently being coordinated with applicable agencies; once executed, it will be included in the FIFR-EIS.

7.5 ENDANGERED SPECIES ACT

The Endangered Species Act (ESA), as amended, establishes a national policy designed to protect and conserve threatened and endangered species and the ecosystems upon which they depend (16 USC 1531–1543). The ESA is administered by the Department of the Interior, through the USFWS, and by the U.S. Department of Commerce, through the NMFS. Section 7 of the ESA specifies that any agency that proposes a Federal action that could jeopardize the "continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species" (16 USC 1536 Section 7(a)(2)) must participate in the interagency cooperation and consultation process.

A Draft BA was prepared describing the study area, Federally listed threatened and endangered species of potential occurrence in the study area as identified by the NMFS and USFWS, and potential impacts of the TSP on these protected species (Appendix C-3). The Draft BA has been submitted to NMFS and USFWS for review. The USACE has determined that the TSP would have no effect on the following listed species that could potentially occur in the study area: Gulf Coast jaguarundi, ocelot, Attwater's prairie chicken, red-crowned parrot, golden orb, smooth pimpleback, Texas fawnsfoot, Texas pimpleback, slender rush-pea, South Texas ambrosia, and Texas ayenia.

The BA determined that several Federally listed species of sea turtles, the rufa red knot, and wintering populations of piping plover and its critical habitat could potentially be affected by construction activities related to the ER and CSRM measures. There are seven USFWS-designated critical habitats for piping plover within the project area. TX-3B, TX-3C, TX-3E: South Padre Island, TX-4: Lower Laguna Madre Mainland, TX-36: Bolivar Flats, and TX-37: Rollover Pass would be directly affected by construction activities related to the ER and CSRM measures. ER measures are expected to benefit piping plovers and rufa red knots by providing increased habitat and stabilized shorelines due to beach nourishment, breakwaters, dune restoration, and oyster reef creation

Green sea turtles, Kemp's ridley sea turtles, and loggerhead sea turtles are likely to be adversely affected by dredging activity and placement of dredged material. Avoidance, minimization, and conservation measures outlined in the BA would greatly reduce the likelihood of impacting the sea turtles.

Best management practices would be utilized, to the maximum extent practicable, to avoid project construction impacts to any threatened and endangered species or their critical habitat within the project area. The USACE will continue to closely coordinate and consult with the USFWS and the NMFS regarding threatened and endangered species under their jurisdiction that may be potentially impacted by implementing the proposed action. It anticipated that the NMFS/USFWS will issue a Biological Opinion for the Coastal Texas Study that will be included as an appendix in the FIFR-EIS.

7.6 MIGRATORY BIRD TREATY ACT AND MIGRATORY BIRD CONSERVATION ACT AND EXECUTIVE ORDER 13186

The MBTA of 1918 (as amended) extends Federal protection to migratory bird species; among other activities non-regulated "take" of migratory birds is prohibited under this MBTA in a manner similar to the ESA prohibition of "take" of threatened and endangered species. Additionally, EO 13186 "Responsibility of Federal Agencies to Protect Migratory Birds" requires Federal activities to assess and consider potential effects of their actions on migratory birds (including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds). The effect of the TSP on migratory bird species has been assessed. Impacts to migratory birds as a result of the TSP are expected to be temporary and limited to migratory bird species near the CSRM measures. Migratory birds would benefit from the ER measures by protecting and creating foraging, nesting, and roosting habitat. Improved coastal resiliency is expected to improve bird habitat and increase productivity in the project area. The MBTA (16 USC 715–715d, 715e, 715f–715r; 45 Stat. 1222) establishes a Migratory Bird Conservation Commission to approve areas of land or water for acquisition as reservations for migratory birds which is not applicable to the project. Coordination with the USFWS is ongoing.

7.7 FISH AND WILDLIFE COORDINATION ACT OF 1958

The Fish and Wildlife Coordination Act provides for consultation with the USFWS, and in Texas, with the TPWD whenever the waters or channel of a body of water are modified by a department or agency of the United States. The intent of this consultation is to help prevent the loss of and damage to wildlife resources from water development projects.

Pursuant to Fish and Wildlife Coordination Act, the USFWS provided a Planning Aid Letter (PAL), dated November 20, 2017, to assist with the planning of the proposed project by providing comments and recommendations related to impacts on fish and wildlife resources. A copy of the PAL is provided at Appendix C-5, Attachment 1. The PAL provided a list of high action coastal Texas priorities based in the USFWS vision. The PAL only covered the Coastal Texas Study's ER measures.

The USFWS is preparing a Coordination Act Report and it will be included in the FIFR-EIS as Appendix C-5, Attachment 2. The TSP has been coordinated with the USFWS and other State and Federal resource agencies through the interagency team coordination, all of which had input to the potential impacts assessment, mitigation, and BU areas.

7.8 MARINE MAMMAL PROTECTION ACT OF 1972

The Marine Mammal Protection Act of 1972 (16 USC 1361 et seq.) established a national policy to prevent marine mammal species and population stocks from declining beyond the point where they ceased to be significant functioning elements of the ecosystems of which they are a part. The Marine Mammal Protection Act prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States. In the Marine Mammal Protection Act, "take" is defined "as harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect." The Department of Commerce, through the NMFS, is charged with protecting species that are known to occur in the Texas Gulf region such as whales, dolphins, and porpoises. Manatees are protected by the Department of the Interior through the USFWS.

It is expected that construction and operational activities related to the implementation of either alternative may result in the incidental take of marine mammals, as defined under the Marine Mammal Protection Act. Responsible parties conducting any activities under the selected project alternative that would result in the incidental take of marine mammals will require an Incidental Take Authorization issued by NOAA. Incidental Take Authorization applications must include detailed information regarding each discreet project activity, projected environmental impact, potentially affected marine mammal populations, mitigation of negative impacts, and a comprehensive monitoring and reporting plan.

Early engagement with the NOAA Office of Protected Resources, NOAA Fisheries Southeast Regional Office, and the NOAA Marine Mammal Health and Stranding Response Program has been initiated to formulate a scientific plan for addressing impacts to marine mammal populations, including evaluation of data gaps, pre-project data collection, mitigation options, and construction and long-term operational adaptive monitoring plans.

The requirements of the Marine Mammal Protection Act apply to this study. Potential impacts to marine mammals are also considered in Appendix C-1, Section 5.4.4.2 Threatened and Endangered Species of this DIFR-EIS. Incorporation of the safeguards to protect marine mammal species during project implementation will be coordinated with the USFWS and NMFS for concurrence that the project complies with the Marine Mammal Protection Act.

7.9 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The MSFCMA (PL 94-265), as amended, provides for the conservation and management of the Nation's fishery resources through the preparation and implementation of Fishery Management Plans (16 USC 1801 et seq.). The MSFCMA calls for NOAA fisheries to work with regional Fishery Management Councils to develop Fishery Management Plans for each fishery under their jurisdiction.

One of the required provisions of Fishery Management Plan specifies that EFH be identified and described for the fishery, adverse fishing impacts on EFH be minimized to the extent practicable, and other actions to conserve and enhance EFH be identified. The MSFCMA also mandates that NMFS coordinate with and provide information to Federal agencies to further the conservation and enhancement of EFH. Federal agencies must consult with NMFS on any action that may adversely affect EFH. When NMFS finds that a Federal or State action would adversely affect EFH, it is required to provide conservation recommendations.

EFH is designated for the project area in which the TSP is located. Consultation with NMFS will be initiated with the release of the DIFR-EIS and receipt of any comments regarding EFH impacts. A Draft EFH Assessment has been prepared for this project and is being coordinated with NMFS (Appendix C-4).

7.10 FEDERAL WATER PROJECT RECREATION ACT

The Federal Water Project Recreation Act, as amended, declares the intent of Congress that recreation and fish and wildlife enhancement be given full consideration as purposes of Federal water development projects if non-Federal public bodies agree to (1) bear not less than one-half the separable costs allocated for recreational purposes or 25 percent of the cost for fish and wildlife enhancement; (2) administer project land and water areas devoted to these purposes; and (3) bear all costs of operation, maintenance, and replacement (16 USC 460(L)(12)–460(L)(21)). Cost-sharing is not required where Federal lands or authorized Federal programs for fish and wildlife conservation are involved. This Act also authorizes the use of Federal water project funds for land acquisition in order to establish refuges for migratory waterfowl when recommended by the Secretary of the Interior, and authorizes the Secretary to provide facilities for outdoor recreation and fish and wildlife at all reservoirs under his control, except those within NWRs.

The provisions of the Federal Water Recreation Act apply to this study. One of the goals of the TSP is to protect and enhance outdoor recreational opportunities. However, the potential impacts of the CSRM gate structures could alter recreational opportunities, which would need to be further considered by the agencies.

7.11 COASTAL ZONE MANAGEMENT ACT

Under the Texas Coastal Management Program (TCMP), enacted under the Coastal Zone Management Act in 1972, the GLO reviews Federal activities to determine whether they are consistent with the policies of the TCMP. USACE has prepared a Consistency Determination that evaluates the TSP for consistency with the TCMP and has concluded that it is fully consistent to the maximum extent practicable with the enforceable policies of the Texas program (Appendix C-6).

7.12 COASTAL BARRIER RESOURCES ACT AND COASTAL BARRIER IMPROVEMENT ACT OF 1990

The Coastal Barrier Resources Act (16 USC 3501 et seq.) and the Coastal Barrier Improvement Act of 1990 (PL 101-591) are Federal laws that were enacted on October 18, 1982, and November 16, 1990, respectively (FEMA, 2015). The legislation was implemented as part of a Department of Interior initiative to minimize loss of human life by discouraging development in high-risk areas, reduce wasteful expenditures of Federal resources, and to preserve the ecological integrity of areas Congress designates as a Coastal Barrier Resources System and Otherwise Protected Areas. The laws provide this protection by prohibiting all Federal expenditures or financial assistance, including flood insurance, for residential or commercial development in areas so identified.

Coastal Barrier Resources System designated units are located on Bolivar Peninsula in the TSP. The study team recognizes that in these areas construction of a levee/floodwall or engineered dunes would be needed to form a comprehensive barrier for the upper Texas coast (Figure 7-1).

With the study sponsors support, the NFS has agreed to fund all costs attributable to the in-unit portions of the barrier system. Currently, approximately 12.4 miles of levee/floodwall or engineered dunes are included in the designated units and would be solely funded and constructed by the NFS.

If the features constructed by the NFS are in or affect the course, condition, location, or capacity of navigable waters or the discharge of dredge or fill material into waters of the U.S., the NFS would require a USACE Regulatory Permit to comply with the requirements set forth in the Rivers and Harbors Act of 1899 and the CWA. It would be possible for USACE Regulatory to adopt portions of this DIFR-EIS to complement their review. Specifically, if the Biological Assessment covers the entire project area, including the in-unit portions of the barrier system, then it would be possible for the USACE's Regulatory Review to include the adoption of those documents to avoid the duplication of effort. Finally, USACE Regulatory reviews would require separate authorizations from State Agencies (TCEQ and the GLO, respectively) for compliance with Section 401 of the CWA (401 Water Quality Certification) and for authorization under the TCMP and the Federal Coastal Zone Management Act.

Figure 7-1: Coastal Barrier Resources System Designated Units on Bolivar Peninsula within the TSP

The USACE Galveston District will continue to consult with the USFWS to ensure that the proposed project ER features evaluated in this DIFR-EIS are in compliance with Coastal Barrier Resources Act policies. However, for the CSRM features, the study team determined that formal consultation will not be required, because impacts in the units will not involve Federal expenditures or financial assistance within the system, as discussed above.

7.13 FARMLAND PROTECTION POLICY ACT OF 1981 AND THE CEQ MEMORANDUM PRIME AND UNIQUE FARMLANDS

In 1980, the CEQ issued an Environmental Statement Memorandum "Prime and Unique Agricultural Lands" as a supplement to the NEPA procedures. Additionally, the Farmland Protection Policy Act, passed in 1981, requires Federal agencies to evaluate the impacts of Federally funded projects that may convert farmlands to nonagricultural uses and to consider alternative actions that would reduce adverse effects of the conversion.

The Coastal Barrier CSRM measure would convert 2.3 acres of prime farmlands located north of High Island on FM 124 into a levee barrier. Most of this area has been converted from grasslands and wetlands to farmlands and cattle pastures. The South Padre Island CSRM measures is not expected to impact prime farmlands as there are none located on the island. ER measures will directly impact prime farmlands: revetment/breakwaters to impact 1.6 acres adjacent to the GIWW, wetland/marsh restoration 0.9 acre in Brazoria County, and out-year marsh nourishment in 2065 to 20.4 acres in Brazoria County and East Matagorda Bay. Overall the ER measures will benefit productive soils and provide a buffer from erosive wave and wind action. Prior to construction, the NRCS would be consulted to minimize or avoid impacts to prime farmlands.

7.14 EXECUTIVE ORDERS CONCERNING FLOODPLAIN MANAGEMENT

EO 13690 was enacted on January 30, 2015 to amend EO 11988, enacted May 24, 1977, in furtherance of the NEPA of 1969, as amended (42 USC 4321 et seq.), the National Flood Insurance Act of 1968, as amended (42 USC 4001 et seq.), and the Flood Disaster Protection Act of 1973 (PL 93-234, 87 Star.975). The purpose of the EO 11988 was to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. EO 13690 builds on EO 11988 by adding climate change criteria into the analysis. However, EO 13690 was partially repealed by EO 13807, Presidential Executive Order on Establishing Discipline and Accountability in Environmental Review and Permitting Process for Infrastructure as a means to increase infrastructure investment.

The EOs state that each agency shall provide and shall take action to reduce the risk of flood loss, to minimize the impacts of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for:

- Acquiring, managing, and disposing of Federal lands and facilities;
- Providing Federally undertaken, financed, or assisted construction and improvements; and
- Conducting Federal activities and programs affecting land use, including, but not limited to, water and related land resources planning, regulation, and licensing activities.

Federal agencies are required to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE Engineering Regulation 1165-2-26, requires an eight-step process that agencies should carry out as part of their decision-making on projects that have potential impacts to, or are within the floodplain. The eight steps and project-specific responses to them are summarized below.

1. **Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).** The proposed action is within the base floodplain. However, the project is designed to reduce damages to existing infrastructure located landward of the proposed project.

2. **If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.** Section 5.0 of this document presents an analysis of potential alternatives. Practicable measures and alternatives were formulated and evaluated against the USACE's guidance, including nonstructural measures such as retreat, demolition, and land acquisition.

3. **If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments.** There has been extensive coordination with pertinent Federal, State and local agencies. Once the DIFR-EIS is released, public meetings will be scheduled in the study area during the public review period.

4. **Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base floodplain will affect the base floodplain, impacts resulting from these actions should also be identified**. The anticipated impacts associated with the Preferred Alternative are summarized in sections 5.0 and 6.0 of this DIFR-EIS. The project would not alter or impact the natural or beneficial floodplain values. There would still be an economic cost to overcome for developing an area with natural or beneficial flood plain values under both the FWOP and FWP conditions. Many of the existing undeveloped areas are wetlands or other low-lying areas and would still flood under rainfall events. As stated in Section 4.0 and 6.0, the system would only be closed for storm surge events. Existing local building codes would still require developments to be built above the FEMA 100-year stage for rainfall impacts. Also, with an open system, the day to day tidal stage is still going to increase over time because of RSLR impacts. Existing local building codes would require large amounts of fill material for new developments. These areas would still be in jurisdictional wetland and would require compensatory mitigation for impacting these areas. These factors, also with the existing available upland areas for development, at a much lower cost, would limit the development in areas with natural or beneficial floodplain values.

5. **If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists.** The project provides benefits solely for existing and previously approved development and is not likely to induce development. Nonstructural components of the project and real estate requirements required for construction of the project will reduce the level of development that is at risk.

6. **As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for**

which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no-action" alternative. There is no mitigation to be expected for the Preferred Alternative. The project would not induce development in the floodplain and the project will not impact the natural or beneficial floodplain values. Section 6.0 of this DIFR-EIS summarizes the alternative identification, screening, and selection process. The No-Action Alternative was included in the plan formulation phase.

7. **If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.** The DIFR-EIS will be provided for public review and a public hearing will be scheduled during the public review period. Each comment received will be addressed and, if appropriate, incorporated into the FIFR-EIS. A record of all comments received will also be included as an appendix in the FIFR-EIS.

8. **Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the EO.** The TSP is the most responsive to all of the study objectives and the most consistent with the EO.

7.15 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

The purpose of EO 11990 is to "minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands." To meet these objectives, this EO requires Federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. The EO applies to:

- Acquisition, management, and disposition of Federal lands and facilities construction and improvement projects which are undertaken, financed or assisted by Federal agencies; and
- Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities.

EO 11990 applies to this study. All practicable measures have been taken to minimize the loss of wetlands. Alternatives to avoid the loss of wetlands will be evaluated, and the levee alignment will be carefully located to minimize the loss. The alignment will be reviewed to determine if impacts may be minimized further, and these will be presented in the FIFR-EIS. This DIFR-EIS affords the public an opportunity for review prior to completion of the FIFR-EIS and the selection of a TSP. These impacts will be fully compensated by the mitigation plan so that there will be no net loss of wetlands. Furthermore, the TSP is also designed to employ measures that will protect and improve the integrity of wetlands that would otherwise be lost to anthropogenic and natural processes.

7.16 EXECUTIVE ORDER 13112, INVASIVE SPECIES

EO 13112 addresses the prevention of the introduction of invasive species and provides for their control and minimization of the economic, ecological, and human health impacts the invasive species causes. It establishes the Invasive Species Council, which is responsible for the preparation and issuance of the National Invasive Species Management Plan, which details and recommends performance-oriented goals and objectives and specific measures of success for Federal agencies. Construction of measures is expected to be performed by domestic contractors which would help eliminate potential invasive species vectors. Because the Coastal Texas Study is addressing CSRM and ER, no impacts to ballast water are expected.

7.17 EXECUTIVE ORDER 12898, ENVIRONMENTAL JUSTICE

Environmental justice requires agencies to incorporate into NEPA documents an analysis of the environmental effects of their proposed programs on minorities and low-income populations and communities. Environmental justice is defined by EPA as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of Federal, state, local, and tribal programs and policies."

EO 12898 applies to the study and the potential impacts to minority and low-income groups are described in Appendix C-1, Section 2.6 of this DIFR-EIS. Based on a demographic analysis of the study area and findings of an environmental justice review, the TSP would not have a disproportionately high and adverse impact on any low-income or minority population.

7.18 EXECUTIVE ORDER 13045, PROTECTION OF CHILDREN

EO 13045 directs Federal agencies to ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. Examples of risks to children include increased traffic volumes and industrial or production-oriented activities that would generate substances or pollutants that children may come into contact with or ingest. This DIFR-EIS has evaluated the potential for the TSP to increase these risks to children, and it has been determined that children in the project areas would not likely experience any adverse effects from the proposed project.

7.19 FEDERAL AVIATION ADMINISTRATION – HAZARDOUS WILDLIFE ATTRACTANTS ON OR NEAR AIRPORTS

In accordance with Federal Aviation Administration AC 150/5200-33 and the Memorandum of Agreement among the Federal Aviation Administration, the USACE, and other Federal agencies (July 2003), the TSP was evaluated to determine if proposed land uses could increase wildlife hazards to aircraft using public use airports in the study area. The infrastructure associated with the project is not expected to attract wildlife; however, the ER measures could have the potential to attract birds. ER measures are within Perimeter C of the Charles R Johnson Airport near Port Mansfield and Campbell-Porter and Mustang Beach airports near Aransas Pass/Port Aransas.

8.0 IMPLEMENTATION REQUIREMENTS

This section provides a summary of the implementation requirements for the project in the final format.

8.1 DIVISION OF PLAN RESPONSIBILITIES AND COST-SHARING REQUIREMENTS

The TSP to reduce risk and to restore and maintain the habitats along the Texas coast is massive in scale in order to achieve a comprehensive and impactful intervention. The scale of the effort necessitates phasing of the actions and adaptive efforts to ensure the effectiveness of the intervention in the life cycle of the plan. The necessary phasing of construction will be developed in an implementation plan that identifies opportunities to capture cost savings through combined efforts on varying scales and to accelerate benefit flows by prioritizing actions, and pacing financial costs to aid in budgeting, both the Federal budget and the NFS's budget. The implementation plan will be adaptive in nature, to respond to opportunities to leverage resources that improve the cost effectiveness of the completion of construction over time. The implementation plan will initially identify priority goals and objectives of implementation and a preliminary phasing of constructed elements.

Phased construction of CSRM and ER measures over the project life will consider multiple factors:

- Sponsor readiness
- Most productive "bang for the buck," e.g., gate (CSRM) or measure W-3 (ER)
- Synergies
    - Efficiencies in dredging program
    - Complement existing features
    - Combinations to capture mobilization cost savings, e.g., CA-5 and CA-6
- Air Quality Impacts – timing of construction in regions not within compliance
- Prioritize implementation to complement actions of others in proximity

The completion of the DIFR-EIS is the first step toward implementing the design and construction of the Coastal Texas Study. Upon approval by USACE's Assistant Secretary of the Army, Civil Works, the project will be considered for design and construction.

8.2 PROJECT PARTNERSHIP – LOCAL SPONSOR'S RESPONSIBILITIES

The initial project cost of the Coastal Texas Study will be cost shared, with 65 percent of initial cost paid by the Federal government and 35 percent paid by the NFS. A fully coordinated PPA package will be prepared that will be coordinated and executed subsequent to the approval of this document and serves as the agreement for the future planning and design phases of the project. The PPA reflects the current TSP.

As the NFS, the GLO must comply with all applicable Federal laws and policies and other requirements, including but not limited to:

A. In coordination with the Federal government, who shall provide 65 percent of the initial project cost and 50 percent of the costs of periodic nourishment:

    1. Provide all lands, easements, rights-of-way and relocations, including suitable borrow areas, uncontaminated with hazardous and toxic wastes, and perform or ensure performance of any relocations determined by the Federal government to be necessary for the initial construction, operation, and maintenance of this project.

    2. Perform, or cause to be performed, any investigations for hazardous substances as are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), PL 96-510, as amended, 42 USC 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for the construction, operation, and maintenance of the project. However, for lands that the Federal government determines to be subject to the navigational servitude, only the Federal government shall perform such investigations unless the Federal government provides the NFS with prior specific written direction, in which case the NFS shall perform such investigations in accordance with such written direction.

    3. Coordinate all necessary cleanup and response costs of any CERCLA-regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the construction, operation, or maintenance of the project.

    4. Cost-share the cost of mitigation and data recovery activities associated with historic preservation that are in excess of 1 percent of the total amount authorized to be appropriated for the project.

B. For 50 years, operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and any specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

C. Provide the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the NFS, now or hereafter, owns or controls for access to the project for the purpose of inspection, and, if necessary after failure to perform by the NFS, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project. No completion, OMRR&R by the Federal government shall operate to relieve the NFS of responsibility to meet the NFS's obligations, or to preclude the Federal government from pursuing any other remedy at law or equity to ensure faithful performance.

D. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterments, except for damages due to the fault or negligence of the United States or its contractors.

E. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and local governments at 32 CFR Section 33.20.

F. As between the Federal government and the NFS, the NFS shall be considered the operator of the project for the purpose of CERCLA liability. To the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

G. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1790, PL 91-646, as amended by Title IV of the Surface Transportation and Unifom1 Relocation Assistance Act of 1987 (PL 100-17),and the Unifom1 Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for the construction, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

H. Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, PL 88-352 (42 USC 2000d), and Department of Defense directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army."

I. Participate in and comply with applicable Federal floodplain management and flood insurance programs and comply with the requirements in Section 402 of the WRDA of 1986, as amended.

J. Not less than once each year, inform affected interests of the extent of storm risk management afforded by the project.

K. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in preventing unwise future development in the floodplain and in adopting such regulations as may be necessary to prevent unwise future development and to ensure compatibility with the degree of storm risk management provided by the project.

L. Prevent obstructions of or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments), which might hinder its operation and maintenance, or interfere with its proper function, such as any new development on project lands or the addition of facilities that would degrade the benefits of the project.

M. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

N. Comply with Section 221 of PL 91-611, Flood Control Act of 1970, as amended, and Section 103 of the WRDA of 1986, PL 99-662, as amended, which provide that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the NFS has entered into a written agreement to furnish its required cooperation for the project or separable element.

O. Quarterly and after-storm events, perform surveillance of the beach to determine losses or nourishment material from the project design section and provide the results of such surveillance to the Federal government.

9.0 PUBLIC INVOLVEMENT, REVIEW, AND CONSULTATION

9.1 PUBLIC INVOLVEMENT PROGRAM

A proactive approach was taken to engage the public, including residents, resource agencies, industry, local government, and other interested parties in the Coastal Texas Study planning process. Public engagement was recognized as an essential step to identify and consider public and stakeholder concerns. The team conducted meetings required by the NEPA process, and also convened regular working meetings with potential stakeholders and resource agencies to ensure that plan formulation and impact analysis assessed specific technical concerns. Study overviews and progress reports were presented upon request at stakeholder and agency events to maintain awareness of the scope and objectives of the study.

The USACE Galveston District Public Affairs Office, the team, and the GLO prepared a Communications Plan in 2016 to develop a communication strategy to focus on keeping key audiences informed of the study activities and progress. It emphasized communication methods such as news releases, public meetings, and a dedicated web page (http://coastalstudy.texas.gov/). It also anticipated social media and other opportunities to maintain updated information sharing.

Public meetings will be held approximately six weeks after release of the DIFR-EIS to the public. Meetings are being planned from the upper coast to the lower coast of Texas.

9.1.1 Scoping

Two types of public engagement are required by the NEPA process. The study team must hold a NEPA Scoping meeting to obtain public input on the scope of the study and to gather local expertise that can be applied in the study. Once the DIFR-EIS is prepared, a public meeting is required during the public review period.

The GLO developed an overview of issues affecting the Texas coast, entitled “The Texas Coast: Shoring Up Our Future.” This document identified the issues of concern as wetland/habitat loss, water quality and quantity, impact to fish and wildlife, impact to marine resources, Gulf beach/dune erosion, bay shoreline erosion, flooding and storm surge, tourism/local economy, along with other less important issues. This publication was used as a starting point in identifying the scope of issues, problems and opportunities, and alternatives to be examined in the DIFR-EIS.

A Notice of Intent was published in the *Federal Register* at the beginning of the Reconnaissance 905(b) Study and public meetings were held to capture the stakeholder input of all the problems and opportunities along the entire Texas coast. The Notice of Intent indicated that the same scoping meeting input would be used for the feasibility study.

A series of scoping meetings were initially held in February and March 2014 along the upper Texas coast as a part of the Sabine Pass to Galveston Bay Feasibility Study. Meetings in Seabrook, Beaumont, Freeport, and

Galveston, Texas, sought ideas for storm risk reduction and habitat restoration opportunities in the upper Texas coast region of the study area. The study team considered information collected at these meetings in the preparation of the Reconnaissance 905(b) Report (USACE, 2015e).

In August 2014, scoping meetings were held in Palacios, Corpus Christi, and South Padre Island, Texas, to collect similar information for the remainder of the Texas coast to encompass the Coastal Texas Protection and Restoration Feasibility Study efforts. These meetings requested input from the counties identified in mid to lower Texas coast regions of the study area. An additional meeting was held in League City to update the public on the activities in the upper Texas coast.

Scoping input from Federal, State, and local agencies, Tribal Nations, and other interested private organizations and parties was solicited with publication of the Notice of Intent in the *Federal Register* on March 31, 2016 (Appendix G-1). In addition to the request for scoping comments on the Notice of Intent, a separate Scoping Notice announcing the USACE's request for scoping comments was also sent via electronic email to affected and interested parties. Scoping comments were requested, consistent with the Notice of Intent, to be provided between March 31, 2016, and May 9, 2016. Scoping comments were requested to identify:

- Affected public and agency concerns;
- Scope of significant issues to be addressed in the DIFR-EIS;
- Critical problems, needs, and significant resources that should be considered in the DIFR-EIS; and
- Reasonable measures and alternatives that should be considered in the DIFR-EIS.

A total of 2,108 scoping comments, letters, and emails were received during the comment period, with the vast majority of the comments submitted by NGOs, especially the Sierra Club. The top five scoping themes identified from the scoping comments included:

1. Address impacts due to human development and population growth.
2. Significant natural resources that could be negatively impacted by a coastal barrier risk reduction system.
3. Changes to natural resources should focus on nonstructural solutions and disclose biological effects.
4. Solutions must protect the coastal environment and must disclose biological effects.
5. Alternatives should include nature-based solutions that improve access to outdoor recreation and conserves Texas's diverse coastal ecosystems.

A summary of the comments received during scoping can be found in the Scoping Report and the Addendum to Scoping Report (Appendix G-2 and G-3). Additional comments were also received outside the scoping comment period from the Sierra Club and private parties and are included in Appendix G-4).

9.1.2 Agency Coordination

An interagency team of Federal, State, and local agencies and Tribal Nations met monthly to discuss study progress and formulation issues related to the Coastal Texas Study. Team members shared updates on pending decisions and sought comment and approval of methods to assess performance and impacts of features proposed to reduce risk and restore habitat and natural coastal processes. Interagency workshops were held throughout the planning process to consider restoration measure performance metrics, to screen and refine restoration alternatives, and to develop WVA and HEP model assumptions.

All Federal and State agencies were invited to participate as a Cooperating Agency pursuant to CEQ Regulations for Implementing NEPA (40 CFR §1501.6 and §1508.5), and tribes under EO 13175, NEPA, and Section 106 of the National Historic Preservation Act. The purpose of this request was to formalize, via designation as a Cooperating Agency, the continuing coordination and active participation by resource agencies in the Coastal Texas Study. Entities that agreed to serve as a Cooperating Agency included the EPA, NOAA/NMFS, and BOEM (Appendix B-1 and B-2).

Additional individual coordination meetings with resources agencies was held in addition to the monthly interagency team meetings. Informal consultation with NMFS regarding EFH and NMFS fatal flaw review of the draft DIFR-EIS sections occurred in June 2018 and September 2018. An in-person meeting with representatives from USFWS was held in October 2017 where USACE and GLO staff presented on information including the Coastal Barrier Resources Act, critical habitat, beach nourishment, overall project impacts, mitigation needs, ESA concerns for sea turtles and manatees, and BA delivery and Biological Opinion requirements. Additionally, multiple phone conversations were held with USFWS staff to discuss the PAL, BA, and estuarine modeling. Further, multiple phone conversations were held with NOAA representatives from April 2018 through August 2018 to discuss estuarine modeling and marine mammal mitigation options, consultation timeline and assessment needs, and Incidental Take Authorizations and MMPA permitting. Further coordination will continue through the future planning and design phases of the project.

The DIFR-EIS is being provided to all known Federal, State, and local agencies. Interested organizations and individuals are also being sent notice of availability. All comments received and USACE responses will be included in the FIFR-EIS.

9.1.3 Other Coordination

Coordination with stakeholders included attendance at regular interagency meetings, and formal presentations of study scope and status throughout the study process (Table 9-1). Academic and governmental agencies have been advancing complementary or alternative studies to reduce coastal storm risk or habitat loss within the study area. Coordination and data sharing were emphasized early in the study to ensure transparency in the evaluation and screening decisions of the Coastal Texas Study. To expand awareness of the scope and objectives of the study and to review preliminary planning steps, the PDT convened interested NGOs for an overview of the planning process, the measures under consideration, and to discuss concerns in January 2018.

9.2 DISTRIBUTION LIST (*NEPA REQUIRED)

A list of all Federal and State legislative representatives, agencies, organizations, and persons to whom the notice of availability will be sent is presented as Appendix G-6.

Table 9-1
Previous Meetings and Presentations

Date	Event	Discussion Topics	Presenters/Participants
August 4, 2014	Testimony at Texas Joint Committee Hearing on Coastal Surge Barriers	USACE Mission and Coastal Projects	Colonel Richard Pannell (USACE)/Tony Williams (GLO)
August 10-12, 2014	Planning Charette	Discussion on path forward for study	USACE/GLO
September 1, 2014	USACE Coastal Engineering Research Board	Meeting Texas Coast Shoring up our future	Ray Newby (GLO)
September 2, 2014	Civil Engineering Research Board	Presentation on Coastal Texas Study	Sharon Tirpak (USACE)
October 14, 2015	American Shore and Beach Preservation Association, Annual Meeting	Presentation on Coastal Texas and Sabine Pass to Galveston Bay Studies	Sharon Tirpak (USACE)
October 22, 2015	Galveston Historical Foundation’s Living on the Edge Conference	Presentation on Coastal Texas and Sabine Pass to Galveston Bay Studies	Sharon Tirpak (USACE)
December 11, 2015	Texas Chapter American Shore and Beach Preservation Association	Presentation on the Coastal Texas Study	Ray Newby (GLO)
January 14, 2016	State of the Bay Symposium	Meeting GLO Planning	Ray Newby (GLO)
January 19-20, 2016	Coastal Kick-off Meeting and tour of New Orleans barriers	Presentation on the Coastal Texas Study	PDT
February 3, 2016	Texas Wetland Conference	Presentation on the Coastal Texas Study	Tony Williams (GLO)
March 22 and 31, 2016	GCCPRD Public Meeting	Attended public meeting	Sharon Tirpak/Sheri Willey (USACE)
March 23, 2016	University of Texas Geography Society	Meeting Future of the Texas Coast	Ray Newby (GLO)
April 11, 2016	Testimony	USACE Mission and Coastal Projects	Colonel Richard Pannell (USACE)
April 26-27, 2016	SSPEED Center Avoiding Disaster Conference	Presentation on the Coastal Texas Study	Sheri Willey (USACE)
August 5, 2016	American Shore and Beach Preservation Association Texas Chapter Mtg.	Presentation on the Coastal Texas Study	Sheri Willey (USACE)
August 22, 2016	Committee on Land & Resource Management Interim Hearing: Coastal Erosion/Natural Disasters	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)
August 24, 2016	San Antonio Bay Foundation Board of Directors	Presentation on the Coastal Texas Study	Tony Williams (GLO)

Date	Event	Discussion Topics	Presenters/Participants
October 5, 2016	Texas Joint Committee on Coastal Barriers	Presentation on the Coastal Texas Study	Colonel Zetterstrom (USACE)/ Tony Williams (GLO)
October 6, 2016	Texas Chapter of Coast Ocean Ports Rivers Institute	Coastal Texas Initial Planning Meeting	Ray Newby (GLO)
January 19, 2017	NGO Meeting	Presentation on the Coastal Texas Study	Sheri Willey (USACE)
March 7, 2017	Lone Star Harbor Briefing, Houston, Texas	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)/Tony Williams (GLO)
April 12, 2017	Texas Bays and Estuaries Meeting	Presentation on the Coastal Texas Study	Dr. Kelly Burk-Copes (USACE)/ Tony Williams (USACE)
May 1, 2017	Coastal Bend Hurricane Meeting, Corpus Christi, Texas	Presentation on the Coastal Texas Study	Eddie Irigoyen (USACE)
May 5, 2017	Region 1 Communities Meeting (community leaders)	Presented on the Coastal Texas Study	Sheri Willey (USACE)
June 15, 2017	I-Storm Annual Meeting, New Orleans	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)
August 17, 2017	American Shore and Beach Preservation Association Texas Chapter Meeting	Presentation on the Coastal Texas Study	Eddie Irigoyen (USACE)
October 5 2017	Texas Chapter of Coast Ocean Ports and Rivers Institute	Meeting SLR Planning	Ray Newby (GLO)
October 10, 2017	Texas Joint Committee on Coastal Barriers	Presentation on the Coastal Texas Study	Colonel Zetterstrom (USACE)
October 26, 2017	American Shore and Beach Preservation Association National Conference, Fort Lauderdale, Florida	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)
January 8, 2018	Presentation to NGOs	Presentation on the Coastal Texas Study	Travis Creel (USACE)/PDT
February 27, 2018	USACE Galveston Winter Stakeholders Meeting	Presentation on the Coastal Texas Study	Dr. Kelly Burk-Copes (USACE)/ Tony Williams (USACE)
March 20, 2018	Houston Galveston Area Counsel	Presentation on the Coastal Texas Study	Dianna Ramirez (GLO)/Caroline McCabe (USACE)
July 13, 2018	University of Houston Clear Lake, Texas	Presentation, including Coastal Texas Study Ecosystem Restoration	Dianna Ramirez (GLO)

Date	Event	Discussion Topics	Presenters/Participants
August 3, 2018	Texas Hurricane Center for Innovative Technology Conference	Presentation on the Coastal Texas Study	Dianna Ramirez (GLO)/Caroline McCabe (USACE)
August 5, 2018	Galveston Sunday Morning Coffee Club	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)
August 23, 2018	Texas Chapter of the American Shore and Beach Preservation Association	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)
August 23, 2018	Galveston City Council Workshop	Presentation on the Coastal Texas Study	Sharon Tirpak (USACE)/Tony Williams (GLO)
August 29, 2018	National Conference on Ecosystem Restoration	Presentation on the Coastal Texas Study	Tony Williams (GLO)

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10.0 RECOMMENDATIONS (CURRENT TSP)

Information found in this section may be subject to change and further development under future planning and design phases, to include optimization of the TSP, refinement of relocation and real estate requirements, to include additional hydraulic modeling, as well as from review and resolution of comments received from both the public and other agencies; the ATR; and IEPR, all of which will help refine the TSP. These sources of information will assist the USACE Commander in making an informed decision, which will be documented in the FIFR-EIS. The information provided in this chapter is based on the TSP, as currently defined and may be refined and/or changed prior to publication of the FIFR-EIS.

10.1 TENTATIVELY SELECTED PLAN

The TSP is the Coastal Barrier Alternative, which includes a combination of CSRM structural features along the seaward portion of the study area in addition to a Galveston ring levee, a nonstructural feature on the west side of Galveston Bay, beachfill in the lower Texas coast, and ER along the coast.

The Coastal Barrier CSRM System (previously designated as Alternative A during the alternatives analysis) is a risk reduction system made up of the following features: floodwalls (inverted T-walls), floodgates (both highway and railroad floodgates), seawall improvements, drainage structures, pump stations, and surge barrier gates. The largest feature of the Coastal Barrier is the storm surge barrier along Bolivar Roads at the Houston Ship Channel between Bolivar Peninsula and Galveston Island, which includes a floating sector gate, vertical lift gates, and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap. The alignment includes four reaches: Eastern Tie-in Reach, Bolivar Peninsula Reach, Galveston Ring Levee/Floodwall Reach, and West Galveston Island Reach in addition to features located at Clear Creek Channel and Dickinson Bayou. The team will focus on the scale of the level of risk reduction for the TSP in the future planning and design phases. Individual features such as levee heights, flood heights, pump station sizes, nonstructural features, and alignments would be optimized.

The South Padre Island CSRM measure consists of approximately 2.2 miles of dune and beach restoration along the barrier island on the Gulf and includes a renourishment interval of 10 years.

Coastwide ER includes the following nine ER measures:

1. G-5 – Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration
2. G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection
3. B-2 – Follets Island Gulf Beach and Dune Restoration
4. B-12 – West Bay and Brazoria GIWW Shoreline Protection
5. M-8 – East Matagorda Bay Shoreline Protection
6. CA-5 – Keller Bay Restoration
7. CA-6 – Powderhorn Shoreline Protection and Wetland Restoration

8. SP-1 – Redfish Bay Protection and Enhancement
9. W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

The Coastal Barrier and South Padre Island CSRM systems fulfill the focused CSRM planning objectives and maximize net benefits, consistent with protecting the environment in accordance with national environmental studies, applicable EOs, and other Federal planning requirements. Likewise, ER measures include features that would restore the natural features of the Texas coast, including beach and dune complexes, oyster reefs, bird rookery islands, and wetland and marsh complexes, which work to support a diverse array of habitats and conditions necessary for coastal resiliency and mitigation of damages caused by coastal storms and RSLR.

The TSP recommendation is based on findings that the plan constitutes engineering feasibility, economic effects, and environmental acceptability. This TSP, which is subject to modifications, has an estimated initial project cost of $23,106,582,000 – $31,825,875,000. In future planning and design phases, the TSP cost will be refined to present a point estimate for the cost of the final recommendation. The cost will indicate which portion includes contingencies and will also include a fully funded cost. The fully funded cost would be estimated by inflating costs through the midpoint of construction. The final recommendation will also include detailed implementation guidance for non-Federal interests agreeing to execute and comply with the terms of a PPA following approval of the FIFR-EIS. An example of the draft PPA is already included in Section 8.0.

10.2 DISCLAIMER

The TSP recommendation contained herein reflects the information available at this time and current USACE policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of the national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the TSP recommendations may be modified before they are finalized and transmitted to higher authority as proposals for authorization and/or implementation funding.

11.0 LIST OF PREPARERS (*NEPA REQUIRED)

Key personnel responsible for preparation of the document are listed below:

Name/Title	Experience	DIFR-EIS Area of Responsibility
U.S. Army Corps of Engineers, Galveston District		
Sharon Tirpak, Deputy Chief of Project Management Branch	36 years, Programs and Project Management	Program Manager, DQC Level 2
Kelly Burks-Copes, PhD, Project Manager	25 years, Project Management, Landscape Ecology, Ecosystem Response Modeling	Senior Project Manager, HEP/HEAT, DQC Level 2
Eddie Irigoyen, Civil Engineer	12 years, Civil Engineering, Project Management	Project Manager
Andrea Catanzaro, Project Manager	24 years, Project Management, NEPA Compliance, Biology, Regulatory	Project Manager Houston Ship Channel ECIP Feasibility Study
Tricia Campbell, CE, Operations Project Manager	11 years, Operations Management, Project Engineer	Dredging Placement, Beneficial Use Management, DQC Level 2
Robert Thomas, Chief, Engineering and Construction division	17 years, Coastal Engineering, Levee Safety	Coastal Engineering and Design Oversight and Review
Joseph King, RA, Chief, Engineering Branch	21 years, Architecture	Coastal Engineering and Design Oversight and Review, DQC Level 2
Lori Thomas, PE, Chief, General Engineering Section	26 years, Civil and Structural Engineering	Coastal Engineering and Design Oversight and Review
Ismael J. De la Paz-Bonilla, Civil/ Geotechnical Engineer	2 years, Civil and Structural Engineering	Geotechnical Engineering Oversight and Review, DQC Level 2
Corragio Maglio, PE, CFM, Chief, Hydrology and Hydraulics Branch	14 years, Hydrology and Hydraulics, Coastal Engineering	Hydrology and Hydraulics Engineering Oversight and Review, DQC Level 2
Himangshu S. Das, PhD, Civil Engineer	21 years, Hydrology and Hydraulics, Coastal Engineering	Coastal Engineering Lead, Hydraulics and Hydrology
Mike Diaz, PE, Civil Engineer	35 years, Civil Engineering	Coastal Engineering and Design – CSRM
Paul Hamilton, PhD, Civil Engineer	3 years, Hydrology and Hydraulics, Coastal Engineering, Sediment Transport, Geomorphology	Coastal Engineering and Design – ER
Ratnam Tharmendira, PE, GE, Civil/ Geotechnical Engineer	17 years, Geotechnical Engineering	Lead Geotechnical Engineer – CSRM and ER
Islam Mohammed, PE, Civil Engineer	10 years, Numerical and In-situ Modeling, GIS Data Analysis, Flood Risk Management	Geotechnical Engineering Oversight and Review
Willie Joe Honza, PE, Chief, Professional Services Section	30 years, Civil Engineering	Cost Engineering Oversight and Review
Jackie Lockhart, PE, CCE, Cost Engineer	39 years, Cost Engineering	Lead Cost Engineer – CSRM
Adam Tallman, EIT, Cost Engineer	5 years, Cost Engineering	Lead Cost Engineer – ER

Name/Title	Experience	DIFR-EIS Area of Responsibility
Dale Williams	6 years, Cost Engineering	Cost Engineering
Kristen Shivers, Biologist	14 years, Biology, GIS Analysis	GIS Analyst
Joshua Hutchinson, EI, Civil Engineer	8 years, Geotechnical Engineering	Coastal Engineering and Design – CSRM (Matagorda)
Matthew Duke, GISP, Chief of the Hydrographic Survey Section, Galveston District Datum Coordinator	12 years, GIS Analysis	GIS Analyst, Geospatial Datums DQC Level 1
Timothy Nelson, Chief, Real Estate Division	8 years, Real Estate Planning, Management and Property Disposal	Real Estate Analysis Oversight and Review
Brian Murphy, Chief, Support Branch	20 years, Real Estate Planning, Management and Property Disposal	Real Estate Analysis Oversight and Review, DQC Level 2
Kenny Pablo, Realty Specialist	8 years, Real Estate Planning, Management and Property Disposal	Lead Real Estate Analyst – CSRM
Lisa Mairs, Realty Specialist	6 years, Real Estate Planning, Management and Property Disposal	Lead Real Estate Analyst – ER
Tom J. Seymour, Jr., CPT, Realty Appraiser	18 years, Real Estate Planning, Management and Property Disposal	Gross Appraisals
David Mairs, Realty Appraiser	10 years, Real Estate Planning, Management and Property Disposal	Gross Appraisals
Melinda Pullman, Realty Specialist	1-year, Real Estate Planning, Management and Property Disposal	GIS Mapping and Real Estate Analysis for the Gross Appraisals
Nichole Schlund, Realty Specialist	5 years, Real Estate Planning, Management and Property Disposal	GIS Mapping and Real Estate analysis for the Gross Appraisals
Kelsey Ciarrocca, Cartographer	4 years, GIS Analysis	GIS Mapping and Real Estate analysis for the Gross Appraisals
U.S. Army Corps of Engineers, New Orleans District – Regional Planning and Environmental Divisions, South		
Travis Creel, USACE Certified Planner, National Water Resources; Regional Technical Specialist, Plan Formulator	15 years, Plan Formulation and Coastal Storm Risk Reduction	Lead Planner – CSRM and ER
Louise Williams, PhD, Plan Formulation Specialist	25 years, Economics, Program Management, Plan Formulation	Planning Oversight and Review, DQC Level 1
Mark Haab, Chief, Navigation Section	32 years, Navigation	Economics Oversight and Review – CSRM
Ben Logan, Senior Economist	9 years, Flood Risk Management and Ecosystem Restoration	Economics QA/QC – CSRM
Brian Maestri, Regional Economist	33 years, Economics – CSRM	Lead Economist – CSRM
Warren Cashen, Computer Scientist	15 years, GIS Analysis	GIS Analyst for Economics – CSRM
Brittanie Corley, Economist Department of the Army (DA) Intern	1 year, Economics	Economics – CSRM

Name/Title	Experience	DIFR-EIS Area of Responsibility
U.S. Army Corps of Engineers, New Orleans District		
Charlie Brandstetter, PE, Civil Engineer	22 years, Structural Engineering	Coastal Structural Engineering and Designs – CSRM
Rob Dauenhauer, PE, Supervisory Structural Engineer	22 years, Structural Engineering	Coastal Structural Engineering and Design Oversight and Review – CSRM, DQC Level 2
Dustin Smith, Engineering Technician	10 years, Structural Engineering	Coastal Structural Engineering and Designs – CSRM
Kenny Riggs, Engineering Intern	2 years, Structural Engineering	Coastal Engineering Equipment Lists – CSRM
Ben Barcelona, Civil Engineer	2 years, Structural Engineering	Structural Engineering – Navigation Gate Design – CSRM
Jabeen Pasha, Electrical Engineer	20 years, Power Engineering	Electrical Engineering Lead – CSRM
Stefan Miller, Mechanical Engineer	17 years, Structural Engineering	Mechanical Designs – CSRM
U.S. Army Corps of Engineers, Regional Planning and Environmental Center, Southwest Division		
Brian Harper, Chief, Civil Planning Branch	29 years, Economics, Civil Works Planning	Planning Oversight and Review
Nancy Parrish, RPA, Chief, Plan Formulation Section	28 years, Cultural Resources, Civil Works Planning	Plan Formulation Oversight and Review
Carrie McCabe, Plan Formulator	22 years, Economics, Civil Works Planning	Lead Planner – ER
Norm Lewis, Economist	23 years, Regional Economics, Socioeconomic Analysis, Flood Risk Management, Ecosystem Restoration	Lead Economist – ER
Doug Sims, Chief, Environmental Compliance Branch	17 years, Cultural and Environmental Compliance	Environmental Oversight and Review
Amanda McGuire, Chief, Compliance Section	15 years, Environmental Compliance	Environmental Oversight and Review
Janelle Stokes, Archaeologist, Regional Technical Specialist – NEPA and Cultural Resource Specialist	36 years, Planning, Environmental Impact Assessment and Impact Analysis	Lead Environmentalist (Retired)
Jennifer Morgan, Biologist, NEPA Specialist	13 years, Planning, Environmental Impact Assessment and Impact Analysis	Lead Environmentalist
Jeff Pinsky, Biologist, NEPA Specialist	11 years, Regulatory, Fisheries and Marine Biology	Environmental Oversight and Review
Danny Allen, Certified Wildlife Biologist	20 years, Habitat Assessment, Ecosystem Restoration, Ecological Modeling	Environmental Oversight and Review, DQC Level 2
John Campbell, Acting Chief, Technical Section	23 years, Archaeology	Cultural Resources Impacts
David Clark, Environmental Protection Specialist	6 years, NEPA, HTRW, CERCLA	HTRW Impacts Oversight and Review, DQC Level 2

Name/Title	Experience	DIFR-EIS Area of Responsibility
U.S. Army Corps of Engineers, Engineer Research and Development Center		
Thomas C. Massey, PhD, Research Mathematician	16 years, Numerical Hydrodynamic Modeling, Large-Scale Storm Surge and Wave Modeling	Coastal Storm Modeling Lead (ADCIRC)
Jennifer McAlpin, Research Hydraulic Engineer	17 years, Multi-Dimensional Modeling, Sediment and Particle Transport	Coastal Storm Modeling (AdH)
Dylan Sanderson, Research Hydraulic Engineer	2 years, Probabilistic Life-Cycle Analyses	Coastal Modeling (Beach-FX)
Noberto Nadal, PhD, Research Hydraulic Engineer	39 years, Wave Modeling, Wave Measurements, Meteorology, Climate Assessment	Coastal Storm Modeling (Statistical Analyses)
Julie Rosatti, PhD, PE, Technical Director, Flood & Coastal Systems	36 years, Coastal Engineering	Coastal Engineering DQC Level 1
Mary Bryant, Research Hydraulic Engineer	8 years, Nearshore Waves Physics and Processes	Coastal Storm Modeling (ADCIR)
Yan Ding, PhD, Research Civil Engineer (Hydraulics)	30 years, River and Coastal Engineering, Hydraulics and River Dynamics, Wave Dynamics, Numerical Analysis/Modeling	Coastal Storm Modeling (ADCIR)
Alan Cialone, Civil Engineering Technician	31 years, Wave Hindcasting	Coastal Storm Modeling (ADCIR)
Amanda Lewis, Research Physical Scientist	5 years, Climatology, Meteorology, Coastal Hazards, Statistics	Coastal Storm Modeling (ADCIR)
U.S. Army Corps of Engineers, Hydrologic Engineering Center		
Robert Carl, PE, Hydraulic Engineer	46 years, Civil Eflood Risk Management, Prescriptive Reservoir Modeling	Beach-FX Modeling DQC Level 1
U.S. Army Corps of Engineers, Southwest Division		
Mark Shafer, Environmental Engineer	27 years, Environmental Engineering, Hydrology	Habitat Evaluation, DQC Level 1
U.S. Army Corps of Engineers, Philadelphia District		
Preston Oakley, Economist	4 years, Economics	Beach-FX Modeling DQC Level 1
Texas General Land Office		
Ray Newby, P.G., Coastal Geologist	28 years, Geology	Project Coordination, QA/QC
Tony Williams, Environmental Review Coordinator	24 years, Coastal Resources	Project Manager and Coordination, QA/QC
Dianna Ramirez, Coastal Biologist	11 years, Environmental Assessment and Impact Analysis	Environmental Lead, Conceptual Mitigation, HEP/WVA, QA/QC
Carla Kartman, Environmental Scientist	22 years, Environmental Scientist, NEPA Compliance, Environmental Impact Assessment and Impact Analysis	Project Manager, Project Coordination, NEPA Specialist, QA/QC

Name/Title	Experience	DIFR-EIS Area of Responsibility
Freese and Nichols, Inc.		
Tony Risko, P.E., Coastal Engineer	32 years, Coastal Engineering	Project Manager, Commercial and Recreational Navigation
Lisa Vitale, FP-C, Marine Biologist/Project Manager	21 years, Marine Biology, NEPA Compliance and Coordination	Project Manager, NEPA Document Manager, Marine Fisheries/EFH, Document Coordination, QA/QC
Tom Dixon, Senior Scientist/Project Manager	14 years, Wildlife and Protected Species	Section 404(b) and TCMP preparation, Wetlands and SAV, T&E, HEP/WVA, QA/QC
Dave Buzan, Aquatic Biologist	40 years, Aquatic Biology, Vegetation Analysis and Impacts	Water and Sediment Quality, Freshwater Inflow, Climate, SLR, Oyster Reef Restoration, HEP/WVA, QA/QC
Juan Moya, PhD, P.G., Geomorphologist	31 years, Geologist, Ports and Coastal Engineering	Coastal Geomorphology, GLO Technical Advisor
Andrew Labay, FP-C, Aquatic Biologist	24 years, Aquatic Biology, Freshwater Fisheries	HEP, QA/QC
Kelsey Calvez, Biologist	3 years, Biology and Geology	HEP/WVA, GIS Data
Aaron Petty, Aquatic Biologist	8 years, Environmental Assessment and Impact Analysis	T&E, Wildlife, Cumulative Impacts, Hazardous Wildlife Attractants
Tam Tran, Wildlife Biologist	7 years, Environmental Assessment and Impact Analysis	Wetlands, T&E, Wildlife, Soils, Hydrology, Migratory Birds, Cumulative Impacts
Ryan Deal,	6 years, HTRW	HTRW Analysis, Energy and Mineral Resources
Ben Hagood	11 years, Biologist	Noise
Dan Gise	38 years, Biologist	Noise, QA/QC
Kim Buckley, Geomorphologist	17 years, Environmental Geology	Geology, QA/QC
Sabrina Joplin, GIS Analyst	12 years, GIS	GIS Data/Figures
Brian King, GIS Analyst	17 years, GIS	GIS Data
Christine Vidrick, Word Processor	31 years, Word Processing	Word Processing, Document Formatting and Review
Linda Nance, Technical Editor	35 years, Editing	Technical Editing
Mott MacDonald		
Hugo Bermúdez, P.E., Country Manager	25 years, Coastal Engineering	Project Manager
Patrick McLaughlin, P.E., Coastal Engineer	4 years, Coastal Engineering	Assistant Project Manager
Josh Carter, P.E., Principal Engineer	18 years, Coastal Engineering	Project director
Atkins		
Ruben Velasquez, P.E., Senior Engineer	35 years, Air Quality	Air Quality, General Conformity

Name/Title	Experience	DIFR-EIS Area of Responsibility
Environmental Institute of Houston		
George Guillen, Executive Director	7 years, Marine Mammals; 43 years, Estuarine Ecology	Marine Mammal Protection Act
Kristi Fazioli, Research Associate	23 years, Marine Mammals	Marine Mammal Protection Act
Jenny Oakley, Environmental Scientist	6 years, Marine Mammals, 12 years, Estuarine Ecology	Marine Mammal Protection Act
Crouch Environmental		
Leslie Hollaway, President	13 years, Public Communications	Public Involvement
Greg Sevcik, Project Manager/Creative Director	12 years, Graphic Designer	Public Involvement
Conner Stokes, Editor/ Communications Specialist	4 years, Editor and Communications	Public Involvement

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13.0 INDEX (*NEPA REQUIRED)

To be included in the Final IFR-EIS.

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