U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Appendix C

Engineering Design for the Gulf Intracoastal Waterway Coastal Resilience Study

January 2022

DRAFT

CONTENTS

LIST OF TABLES AND FIGURES

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ATR	Agency Technical Review
BEG	Bureau of Economic Geology
BUDM	Beneficial Use of Dredged Material
CSRM	Coastal Storm Risk Management Plan
CStorm-MS	Coastal Storm Modeling System
DIFR-EIS	Draft Integrated Feasibility Report-Environmental Impact Statement
ER	Ecosystem Restoration
ER (in reference to document title prefix)	Engineering Regulation
ERDC-CHL	Engineering Research and Development Center–Coastal Hydraulics Laboratory
FEMA	Federal Emergency Management Agency
FR	Feasibility Report
FWP	Future With-Project
FWOP	Future Without-Project
GIWW	Gulf Intracoastal Waterway
GLO	General Land Office
GoM	Gulf of Mexico
GICA	Gulf Intercoastal Canal Association
ITR	Independent Technical Review
JPM-OS	Joint Probability Method of Optimum Sampling
LiDAR	Light Detection and Ranging
LMSL	Local Mean Sea Level
MHHW	Mean Higher-High Water Level
MLLW	Mean Lower-Low Water Level
MSL	Mean Sea Level
NAD	North American Datum
NCF	National Channel Framework
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NWR	National Wildlife Refuge
O&M	Operation and Maintenance
OMRR&R	Operation, Maintenance, Repair, Rehabilitation, and Replacement
PED	Project Engineering and Design
PWOP	Present Without-Project
PWP	Present With-Project

RSLC .... Relative Sea-Level Change
RSM .... Regional Sediment Management
SLR .... Sea Level Rise
SMART .... Specific, Measurable, Attainable, Risk-Informed, and Timely
SWL .... Still Water Level
TCOON .... Texas Coastal Oceanic Observation Network
TNRIS .... Texas Natural Resources Information System
TPCS .... Total Project Cost Summary
TSP .... Tentatively Selected Plan
TWDB .... Texas Water Development Board
TxDOT .... Texas Department of Transportation
USACE .... United States Army Corps of Engineers
USDA .... United States Department of Agriculture
USGS .... United States Geological Survey
WRDA .... Water Resources Reform and Development Act
WIS .... Wave Information Studies

1. GENERAL

1.1. PURPOSE AND CONTEXT

This Engineering Appendix documents the preliminary engineering and conceptual designs for the features of the Gulf Intracoastal Waterway Coastal Resilience (GIWW-CR) Study. It supports the viability of the Tentatively Selected Plan (TSP), which is presented in the GIWW-CR Study Draft Integrated Feasibility Report–Environmental Impact Statement (DIFR-EIS). The GIWW-CR Study is comprised of two counties, Matagorda and Brazoria, along the Texas coast as shown in Figure 1-1. Present and future conditions, together with long-term climate conditions, were used to determine the recommended features.

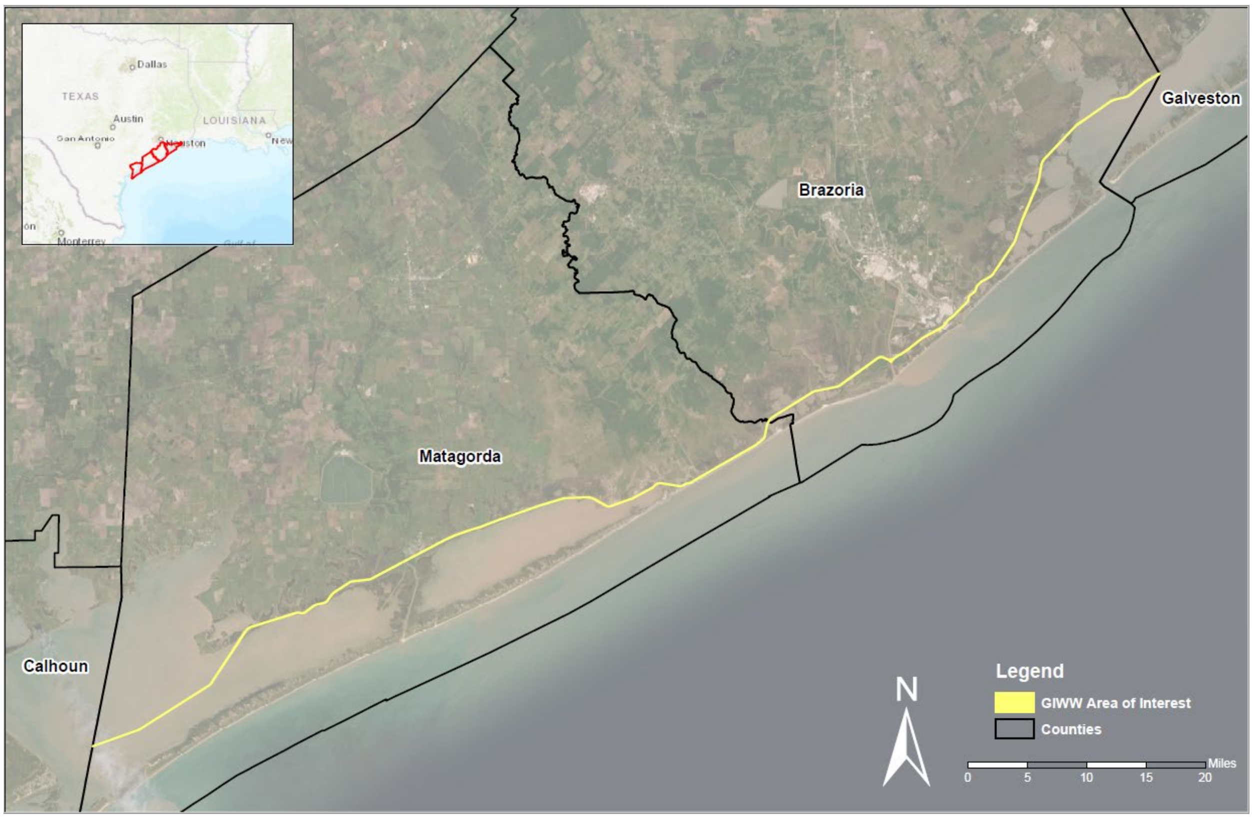


Figure 1-1: Coastal Texas Study Area

The U.S. Army Corps of Engineers (USACE) received Congressional authorization under the Water Resources Development Act (WRDA) 2016, Section 1201, to initiate a 3 by 3 by 3 feasibility study, with the Texas Department of Transportation (TxDOT) as a non-federal sponsor, to analyze the portion of the Gulf Intracoastal Waterway (GIWW) within Matagorda and Brazoria counties, Texas. This section of the GIWW extends from roughly station 434+000 near the Galveston/Brazoria county line to the north east down to roughly station 954+000 near the Matagorda/Calhoun county line to the south west for an approximate total length of 100 miles.

> Water Resources Development Act 2016
>
> SEC. 1201. AUTHORIZATION OF PROPOSED FEASIBILITY STUDIES. The Secretary is authorized to conduct a feasibility study for the following projects for water resources development and conservation and other purposes, as identified in the reports titled ''Report to Congress on Future Water Resources Development'' submitted to Congress on January 29, 2015, and January 29, 2016, respectively, pursuant to section 7001 of the Water Resources Reform and Development Act of 2014 (33 U.S.C. 2282d) or otherwise reviewed by Congress:
>
> (25) GULF INTRACOASTAL WATERWAY, BRAZORIA AND MATAGORDA COUNTIES, TEXAS.—Project for navigation and hurricane and storm damage reduction, Gulf Intracoastal Waterway, Brazoria and Matagorda Counties, Texas.

From the Water Resources Reform and Development Act (WRRDA) proposal:

"It is proposed to modify the Gulf Intracoastal Waterway (GIWW) in Texas, pursuant to Sec 216 of the Flood Control Act of 1970, to address the impacts of relative sea level rise, coastal storm forces, and historical losses to adjacent coastal features, on waterway conditions and functions, with the purposes that adjacent coastal features provide: (1) shelter for resilient transit of commercial vessels on the waterway against waves and currents of the open Gulf of Mexico (GoM), and (2) a reduction to channel sedimentation from GoM open seas for sustainable maintenance into the future. The study would involve: describing waterway reaches that are most vulnerable to losses in GIWW resiliency and sustainability, identifying sediment resources regionally, with emphasis on renewable sources, for harvesting and restoration of degraded adjacent coastal features, with periodic maintenance of these features over the project life cycle on the intended purposes. Strategically, the recommended project modifications will also inform the comprehensive component of the Coastal Texas Protection and Restoration Study."

The GIWW is an invaluable resource for the transportation of commercial goods along the Texas coast and is subject to shoaling of sediment and inclement weather conditions. If not dredged frequently, the accumulation of sediment can become problematic to the navigability of the channel by causing some vessels to run aground or restrict certain vessel to operate only at specific tide levels. The sediment accumulating in the GIWW can come from a range of sources including riverine discharge, shoreline erosion, and suspended sediment transported by wind driven waves and tidal currents. Additional concerns to navigability of the GIWW are above average wind speeds, wind driven waves, and cross currents from tides. These issues are most noticeable in areas where the channel is adjacent to open bay systems without the protection of barrier islands and intersecting water ways such as the Brazos and Colorado Rivers.

The focus of this study is to identify methods of improving the GIWW's resiliency with respect to navigation, hurricane and storm damage reduction, and regional sediment management (RSM) practices throughout the entirety of the GIWW.

1.1.1. Scope of Effort

The engineering work performed in this study is feasibility level, consistent with the Specific, Measurable, Attainable, Risk-Informed, and Timely (SMART) planning process necessary to substantiate the TSP. Available existing information was used to develop project features which are combined to form alternative plans. Sources of information are documented in this report.

The preliminary engineering and conceptual design conducted during this study are of sufficient detail to substantiate the TSP and baseline estimate. This includes the project alignment, type of measure and sufficient measure detail to estimate cost; but do not include final design criteria or detail project features. Further investigation, engineering, and design analysis will be needed in future phases.

1.2. DESCRIPTION OF ALTERNATIVES

This project includes the GIWW within Matagorda and Brazoria Counties as shown on Figure 1-2. Alternatives were formulated to address Navigation (NAV). The following are the alternatives that were investigated past the AMM:

- Alternative 1: No Action
- Alternative 3: Stabilization
- Alternative 6: Stabilization and Sediment Placement

The AMM presents two alternatives besides the no-action plan, a Stabilization Alternative and a Stabilization plus Sediment Placement Alternative. The primary difference between Alternative 3 and Alternative 6 is the addition of sediment placement, both as an initial feature and as a new O&M policy throughout the project design life. The primary components of Alternatives 3 and 6 include:

ALTERNATIVE 3: Stabilization	ALTERNATIVE 6: Stabilization and Sediment Placement
• Breakwaters along interior and bay side of GIWW barrier features at select locations. • Breakwaters/Revetment along sides of Caney Creek / Mitchell's Cut • Terminal Groins / Jetties at mouth of Mitchell's Cut • Sediment Traps / Advance Maintenance at GIWW intersection of Caney Creek / Mitchell's Cut	• ALTERNATIVE 3 features (with different design elevations) • Barrier creation along bay side of GIWW at select locations. • Marsh creation along bay side of GIWW at select locations for BUDM.

Annex 1: Engineering Plates shows the general layout of the NAV features that have been carried forth as TSP and are discussed in detail in the current Appendix. The feasibility level design and analyses are performed to meet the engineering requirements detailed in ER 1110-2-1150, Engineering and Design for Civil Works Projects.

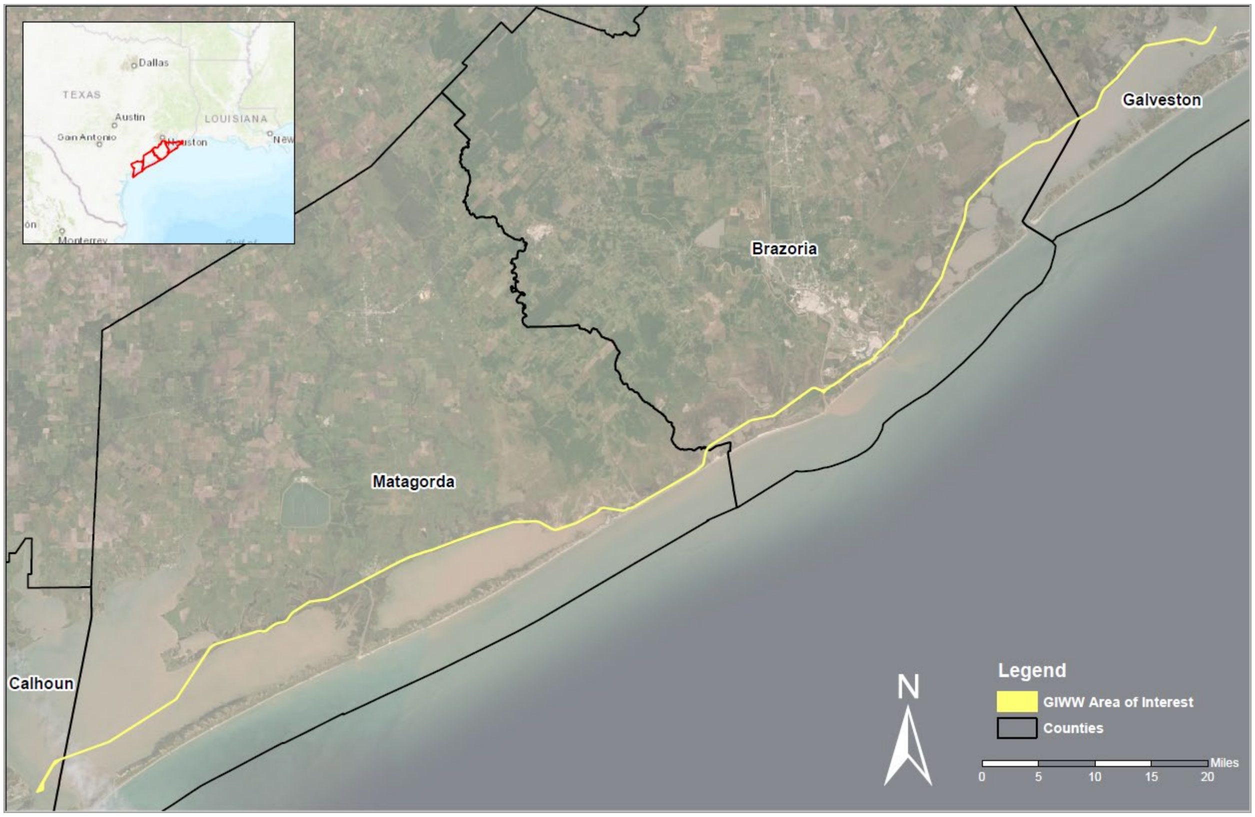


Figure 1-2: General Layout of the Tentatively Selected Plan

1.3. SELECTED TSP ALTERNATIVE- INCREMENTS

The Resilience Plan and the NED Plan are both viable plans, but the Resilience Plan is recommended as the TSP because it is more effective at meeting the evaluation criteria, achieving the study objectives, and addressing the study problems. They are described in more detail in section 1.4.

1.4. RECOMMENDED PLAN

The recommend plan is Alternative 6 - Resilience Plan which includes the following increments:

- Increment 12.3.2 - combination of shoreline stabilization using breakwaters and channel widening in zone 12 protecting 16 acres of barrier island and 951 linear feet of channel. This increment also addresses a grounding hotspot which has posed safety risks to navigation.

- Increment 13.6.1 - a combination of shoreline stabilization using breakwaters and sediment placement in zone 13 protecting/restoring 438 acres of barrier island and protecting 19,000 linear feet of channel.

- Increment 14.6.1 – a combination of shoreline stabilization using breakwaters and sediment placement in zone 14 protecting/restoring 114 acres of barrier island and protecting 4,329 linear feet of channel.

- Increment 16.6.1 - a combination of shoreline stabilization using breakwaters and sediment placement in zone 16 protecting/restoring 376 acres of barrier island and protecting 7,704 linear feet of channel.

- Increment 18.6.1 - a combination of shoreline stabilization using breakwaters and sediment placement in zone 18 protecting/restoring 1161 acres of barrier.

1.5. ORGANIZATION OF THE REPORT

Technical narratives of the NAV features presented in this report are broken into technical disciplines such as: Hydraulics and Hydrology, Geotechnical, Civil & Structural, and Cost, in accordance with the guidance in Engineering Regulation (ER) 1110-2-1150. The preliminary engineering and conceptual design conducted during this study support the project alignment and configuration of structure using different models with assumptions; but do not finalize design criteria or detail project feature design. This report is organized as follows:

- Hydrology and Hydraulics — Section 2.0
- Geotechnical — Section 3.0
- Cost — Section 4.0
- Risk and Uncertainties – Section 5.0
- Tentative Construction Schedule – Section 6.0

1.6. PROJECT COORDINATION

The Texas Department of Transportation (TxDOT) is the Local Sponsor and an active part of the study team. Coordination with the Gulf Intracoastal Canal Association (GICA) and state and governmental agencies were vital for this study. The interdisciplinary Project Delivery Team (PDT) collaborated with subject matter experts and engaged the Vertical Team (VT) throughout the plan formulation process. Agency Technical Reviews (ATRs) and In-Progress Reviews were conducted at key development stages.

1.7. PROJECT DATUM

The horizontal and vertical datum used in the engineering analyses and models conform to the current Federal standard. Horizontal coordinates are referenced to North American Datum (NAD) of 1983. Elevations of features related to Navigation (NAV) are referenced to the North American Vertical Datum of 1988 (MLLW), unless otherwise stated. For QA/QC, engineering PDT team coordinated with the District's datum coordinator to review relevant documents referenced in this Appendix to make sure that the team are in compliance with the ER 1110-2-8160 guidance. More information on project datum is available in Section 2.4.

1.8. DESIGN CONSIDERATIONS

The feasibility level design and analyses are performed to meet the engineering requirements detailed in ER 1110-2-1150, Engineering and Design for Civil Works Projects. For geotechnical evaluation, primarily Engineer Regulation 1110-2-1806 has been followed to guide design processes. Additional details are available in Section 3.0. Sufficient Civil and Structural designs were performed to meet the engineering requirements specified for a feasibility study detailed in ER 1110-2-1150, Engineering and Design for Civil Works Projects. Additional details are available in Section 5.0 and 6.0. For hydrology and hydraulics, ER 1110-2-1150, EM 1100-2-1000, ER 1100-2-8162, Engineering Technical Letter (ETL) 111 2 1, and other regulations are followed. Details can be found in Section 2.0. USACE ETL 1100-2-1, 2014 recommends an expansive approach to considering and incorporating Relative Sea Level Change (RSLC) into civil works projects which has been followed here.

1.9. DESCRIPTION OF EXISTING FEATURES RELEVANT TO THE PROJECT

The following sections describe the major existing features relevant to the resiliency study of the GIWW.

1.9.1. **Gulf Intracoastal Waterway and Cross-Channels**

A total of six authorized federal channels cross the GIWW in the project area. Starting from left to right, they are the Channel to Palacios, Colorado River, San Bernard River, Freeport Ship Channel, and

Chocolate Bayou Channel. The Rivers and Harbors Act (RHA) of 1970 authorized the Freeport Harbor Project commonly referred to as the 45-Foot-Project.

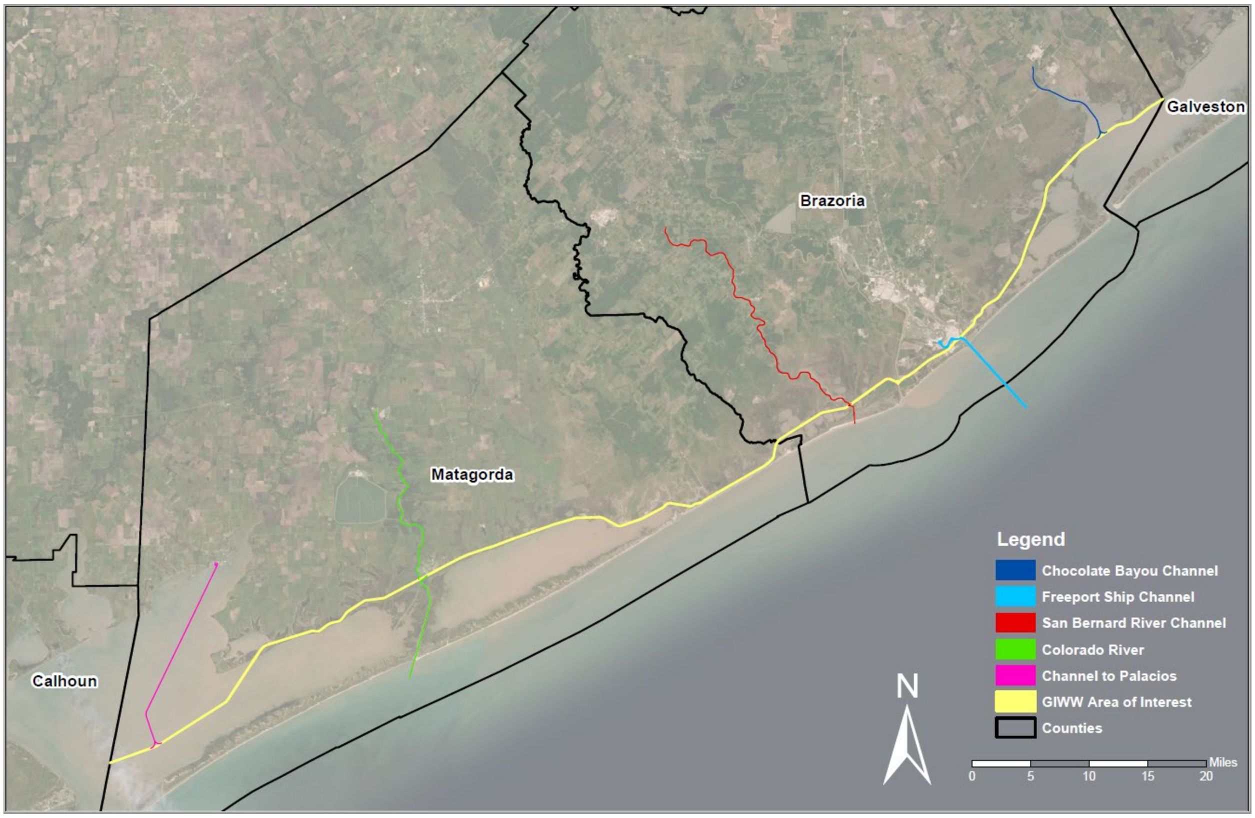


Figure 1-3: Authorized Federal Navigation Channels within Project Area

1.9.1. **Placement Areas**

Along the GIWW, there are numerous confined placement areas constructed of dikes with hydraulic outlet structures. There are also several semi-confined beneficial use sites. Many but not all of the perimeters of the confined placement areas along the GIWW have shoreline protection either in the form of Articulated Concrete Block (ACB) mats or riprap.

1.9.2. **Sargent Beach Revetment**

Sargent Beach (See Figure 1-4) was authorized under P.L. 102-580, Sec. 101(20) 31 Oct 1992, "Provide 8 miles of erosion protection for the existing GIWW waterway in the vicinity of Sargent, Tx." Located along the barrier islands of the Texas Gulf Coast in the highest erosion rate area, the Gulf of Mexico began to threaten the GIWW by breaching the island at Sargent Beach. After erosion studies in the 1970s and 1980s, a reconnaissance and feasibility study concluded in 1992 recommending a revetment structure to prevent the Gulf of Mexico from breaching the island and eliminating transportation along the GIWW. The revetment was designed and constructed "in the dry" with the intent that the Gulf beach would erode up to the structure but prevent future erosion preventing a breach into the GIWW. The project was constructed from May 1995 to Feb 1998 at a final cost of $45 million.

The structure consists of a block revetment (Figure 1-5) along a 42,000-foot stretch of Sargent Beach. Both structures are built at a continuous elevation of 7.0 feet MLT to prevent erosion and the eventual breaching of the GIWW. The revetment consists of 4 to 6-ton granite blocks on top of 2 feet of bedding and core stone with back-side and toe protection rock. The concrete sheet-pile wall sections are placed in areas where the soil conditions proved inadequate to support the revetment and contain back-side and toe protection rock. Toe protection extends down to -10.0 feet MLT to prevent undermining of the revetment and sheet piles. It was placed with a rough uniform offset of 300 feet. Currently, Sargent Beach Revetment is a navigation feature under the Operations and Maintenance authorization (96X3123 O&M General funds) of the GIWW. Inspections and maintenance fall under this authorization.

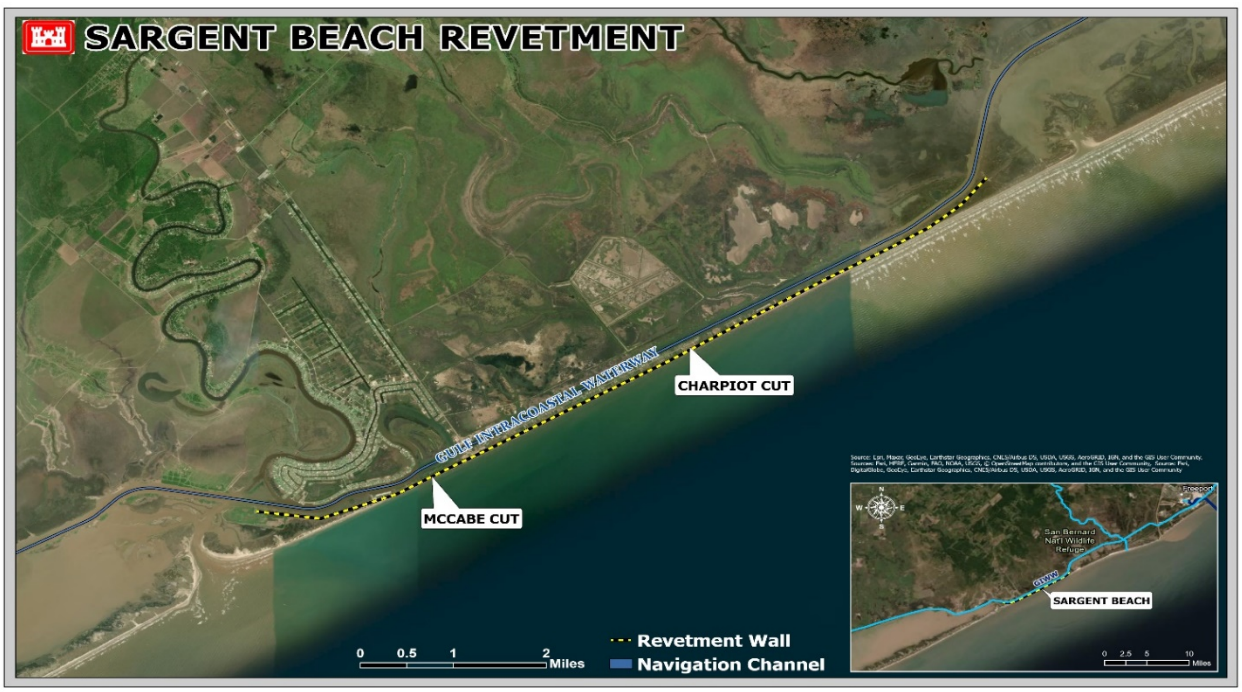


Figure 1-4: Sargent Beach Site Plan

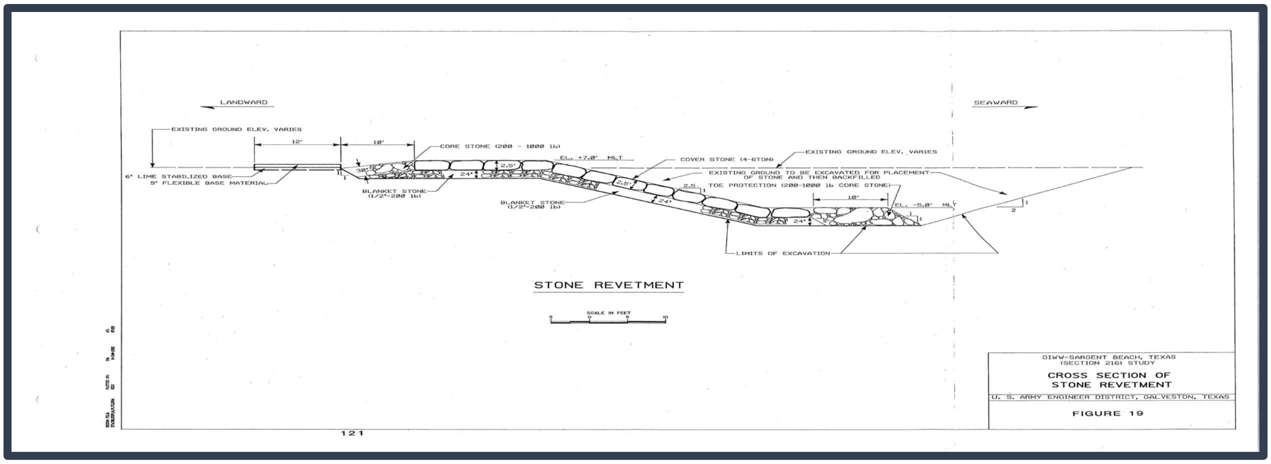


Figure 1-5: Sargent Beach Stone Revetment Section

1.9.3. **Brazos River Floodgates and Colorado River Locks**

The history of the BRFG began in 1941 when Congress authorized the initial construction of the floodgates, which were later completed in September of 1943. Major rehabilitation of the east floodgate guidewalls was completed in 1997. An additional recon study was completed in 2000 which proposed measures to modify the floodgates.

The history of the CRL began in 1941 when Congress authorized the initial construction of the floodgates, which were completed three years later in 1944. Almost six years after the construction of these floodgates Congress authorized the conversion of the floodgates into locks in 1950. This conversion took approximately five years to complete and was finished in 1955. An additional recon study was completed in 2000 which proposed measures to modify the locks.

1.10. DESCRIPTION OF PROPOSED FEATURES RELEVANT TO THE PROJECT

The following sections describe proposed features relevant to the resiliency study of the GIWW.

1.10.1. **Brazos River Floodgate and Colorado River Locks**

In 2014 TXDOT conducted an assessment of Navigation on the Texas portion of the GIWW and proposed a study request to the USACE. The project received funding approval in 2015 for FY 2016. Two years later the draft IFR/EIS was released for Public review of and completed on 11 April 2018. The FIFR-EIS was signed the following year in June of 2019. The Chief's Report for this project was signed on October 23, 2019 and the Record of Decision was signed on March 2, 2020.

This project is tasked with addressing modifications to the BRFG and CRL that are capable of alleviating navigational difficulties, delays, and accidents as vessels transit through the floodgates and locks and across the Brazos and Colorado Rivers. The reduction of navigation delays, increase of navigational efficiency, minimization of vessel allisions, management of sediment shoaling from the Brazos and Colorado Rivers into the GIWW, and overall improvement of operations and functions of the facilities over the 50-year period of analysis were the key planning objectives governing the selection of the recommended alternative plan.

The recommended alternative for the BRFG includes the removal of the existing 75-foot gates on both sides of the Brazos river, construction of a new 125-foot sector gate structure approximately 1,000 feet from the Brazos River on the east side, and construction of a minimum 125-foot open channel on the west side of the Brazos River, with a bottom depth of -12 feet NAVD88 with a bank-to-bank width of approximately 500 feet.

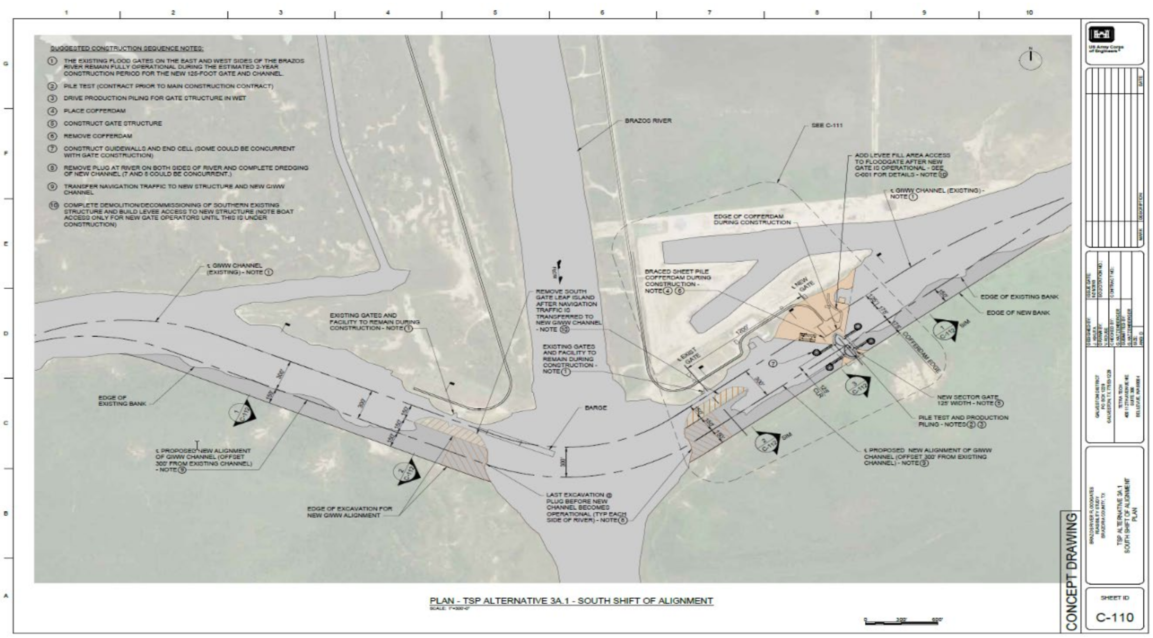


Figure 1-6: Brazos River Floodgates TSP Site Plan

The recommended alternative for the CRL includes the removal of the existing 75-foot gates on both sides of the Colorado River and construction of a new 125-foot sector gate structure on the east and west sides of the Colorado River crossing.

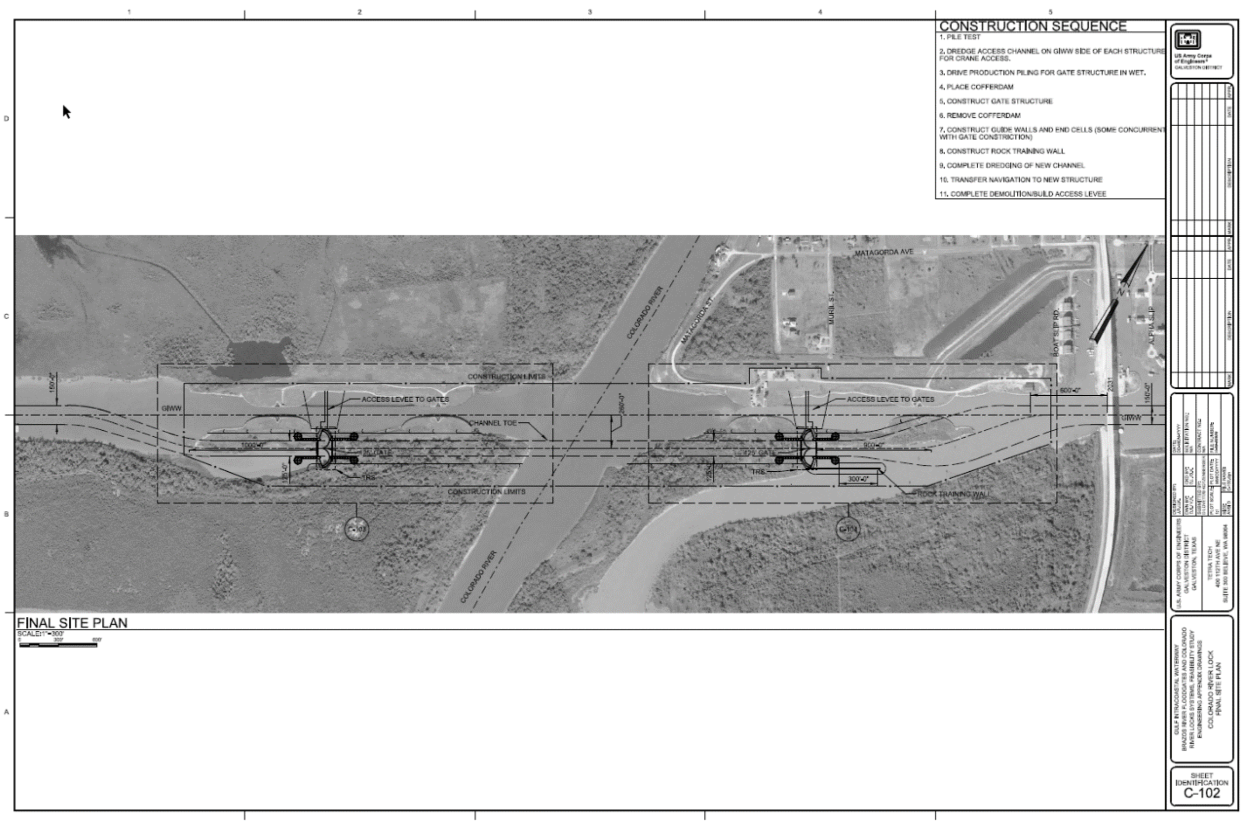


Figure 1-7: Colorado River Locks TSP Site Plan

Additionally, the project will include the Implementation of the environmental compensatory mitigation and associated monitoring and mitigation area adaptive management plan.

1.10.2. Freeport Harbor Channel Improvement Project (FHCIP)

As of the draft of this report, the FHCIP is in the preliminary engineering and design phase. This Final Integrated General Reevaluation Report and Environmental Assessment (FIGRR-EA) was completed in 2018, which documented the formulation and evaluation of plans to modify the recommended plan from the Freeport Harbor Channel Improvement Project Final Feasibility Report (2012 Feasibility Report) and Environmental Impact Statement (2012 FEIS), dated September 2012 (2012 Feasibility Report/FEIS). The 2012 Feasibility Report Recommended Plan was authorized for construction in Section 7002 of the Water Resources Reform and Development Act of 2014 (WRRDA 2014). The 2012 FEIS provided National Environmental Policy Act (NEPA) compliance for the 2012 Feasibility Report. The overall purpose of the 2018 reevaluation study and report was to address modifications to the project authorized in WRRDA 2014, that are necessary to facilitate the safe and efficient navigation of the Panamax design vessel around the Dow Thumb and to and from the Velasco Container Terminal, and determine whether those modifications are economically justified as a separable element. Additionally, an economic update of the overall project authorized in WRRDA 2014 was performed to determine whether the project is still in the Federal Interest. In general, the FHCIP is a deepening of the Outer Bar and Main Channels from the 45 Foot project to 51/56/58 Foot depths and channel widening and is evaluated by 4 reaches as shown in Figure 1-8. A new placement area is planned to be constructed to handle the new work material.

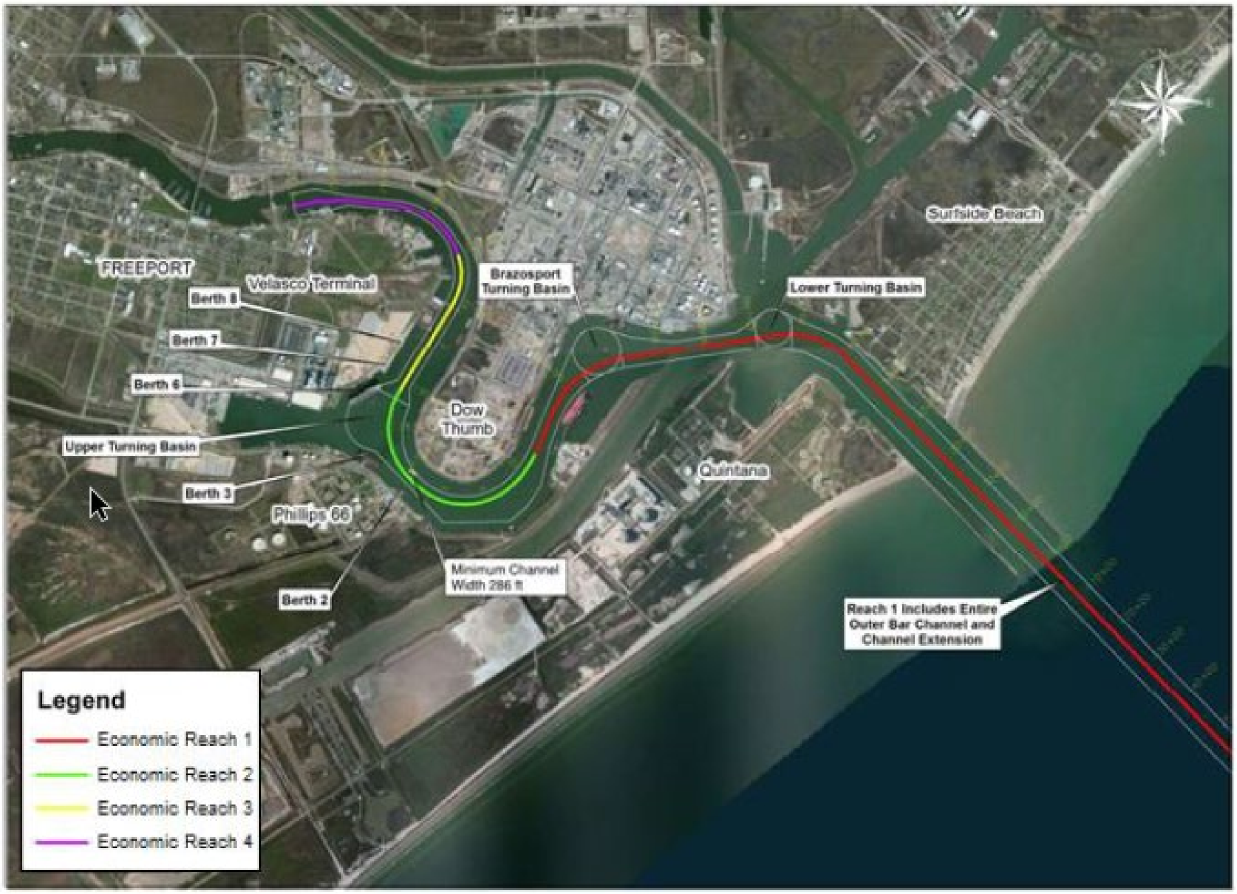


Figure 1-8: Proposed Plan for the Freeport Harbor Channel Improvement Project (2018)

1.10.3. **Sabine Pass to Galveston Bay Study (S2G)**

The Flood Control Act (FCA) of 1962 authorized the Freeport Hurricane Flood Protection Project (HFPP). Many existing features were adopted into the HFPP as is. S2G developed recommendations to reduce the risk of coastal storm surge impacts in the Freeport area such as modifying the Old River North Levee, which is located around the Dow Thumb (2017). The Chief's Report was signed on December 7, 2017. Significant borrow material will be needed for levee construction and it is anticipated that existing placement areas will be used for source material.

1.10.4. Sargent Breakwater and Beach Nourishment Project

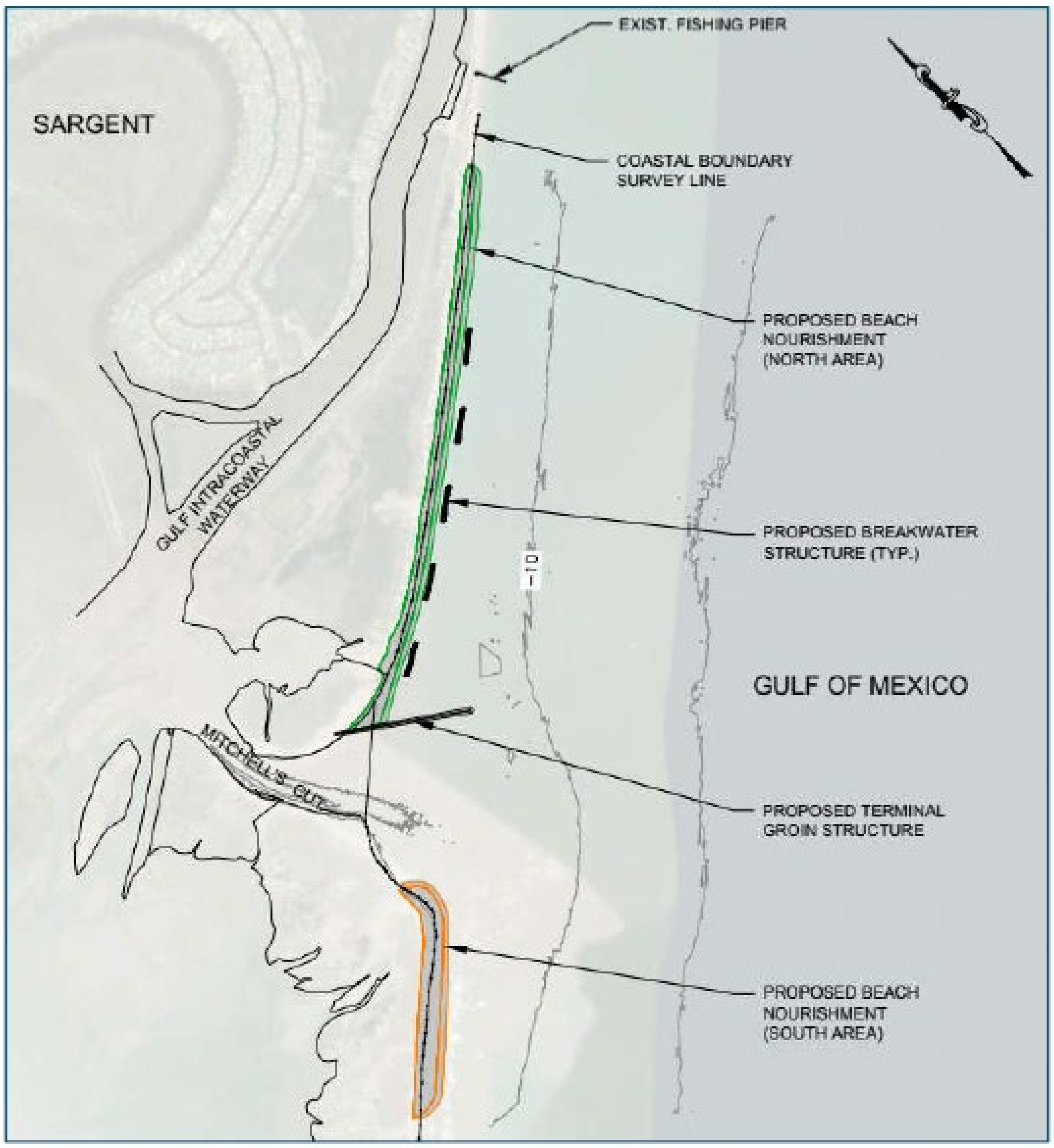


Figure 1-9: Proposed Plan for Sargent Breakwaters and Nourishment Project (2020)

The segmented breakwaters would be five granite rubble mound structures nearly 440 feet long each, spaced 660 feet apart, and along with the angled groin have a post-settlement design crest elevation of 5.0 feet and 3:1 side slope. The anticipated nourishment is 215,000 cubic yards on the north and 185,000 cubic yards on the south, with the south anticipating a 3-year nourishment cycle to address the downdrift interruption due to the terminal groin. The anticipated design life of the breakwater and groin structures is 25 years.

The next steps for this project are to proceed to final design and construction. Post-construction, this project is part of a long-term plan to stabilize and reduce erosion along the entirety of Sargent Beach.

1.10.5. Coastal Texas Feasibility Study

This section describes the ecosystem restoration (ER) measures included in the Recommended Plan of the Coastal Texas Feasibility Study located within the GIWW-CR study area. These measures are described below

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

This measure consists of shoreline protection and restoration utilizing rock breakwaters, oyster cultch creation, marsh restoration, and island restoration as shown along with sediment sources on Figure 1-10.

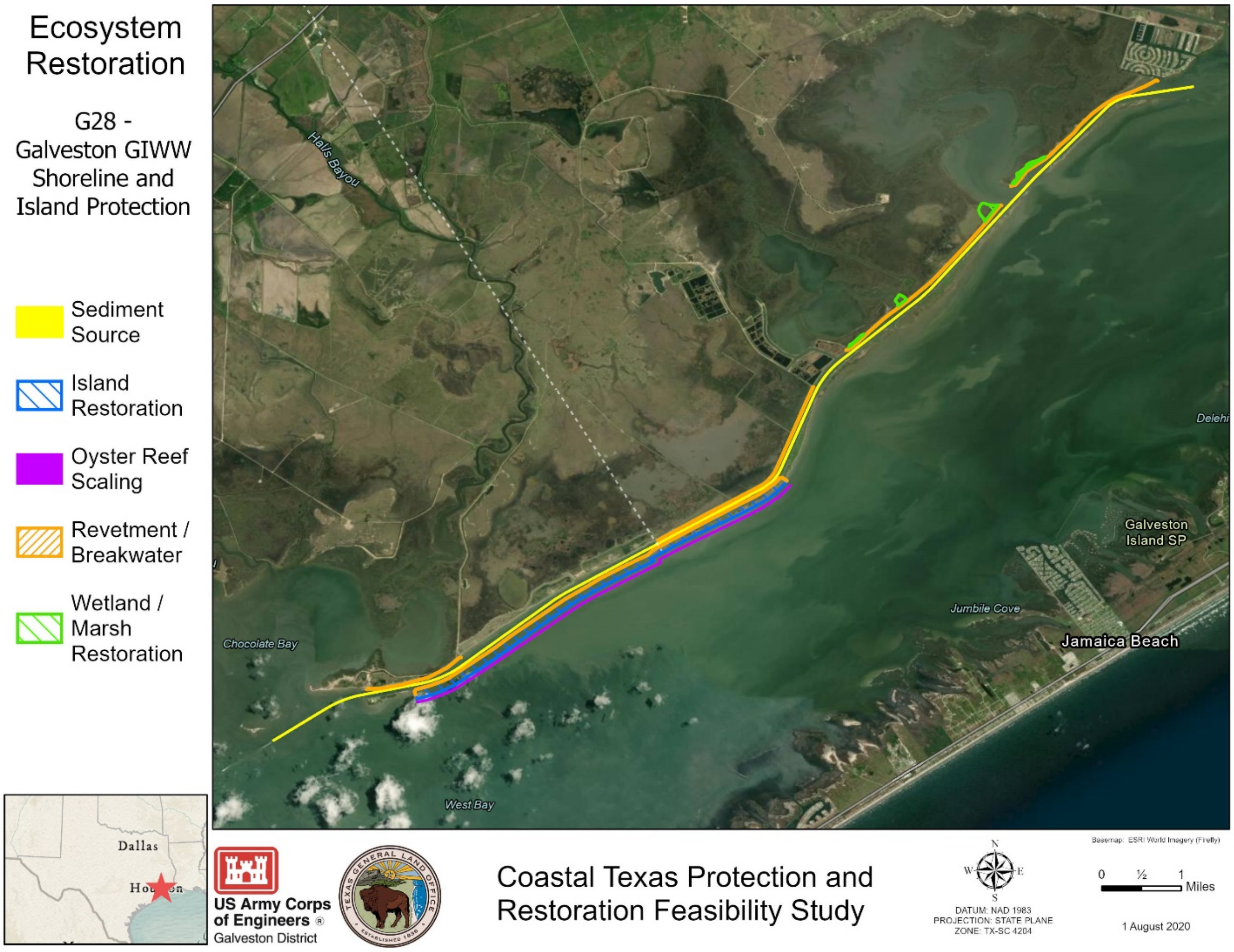


Figure 1-10: G-28 Bolivar and West Bay GIWW Shoreline and Island Protection West

The construction of the rock breakwaters will reduce erosion, and preserve marsh habitat, along unprotected segments of shoreline along north shore of West Bay. No breakwaters would be constructed where the GIWW shoreline is a dredged material placement area.

As seen in Figure 1-11, a degraded island extending approximately 5 miles and covering 251 acres will be restored in West Bay using sediment dredged is association with construction of the CSRM gate features at Bolivar Roads. The island will be protected on the GIWW side using rock breakwaters similar to those on the opposite side of the GIWW. On the bay side of the restored island, 18 acres of oyster cultch will provide natural protection. In addition to the habitat benefit associated with this feature, the island will enhance navigation and vessel safety in the GIWW by reducing the existing uninterrupted fetch in West Bay. As shown on Figure 1-12, the rock breakwaters are planned to have a crest height of 7 feet with 2H:1V side slopes and a base width of 46 feet.

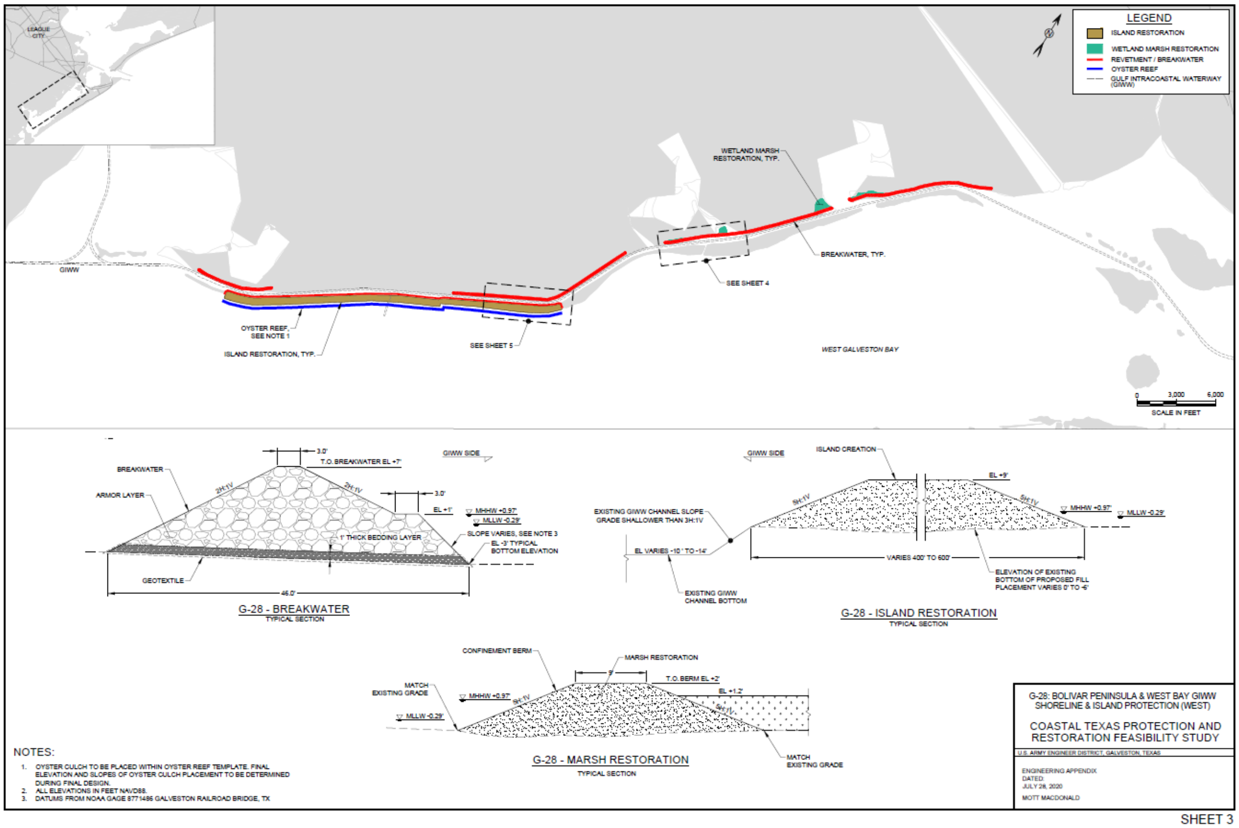


Figure 1-11: G-28 Bolivar and West Bay GIWW Shoreline and Island Protection West

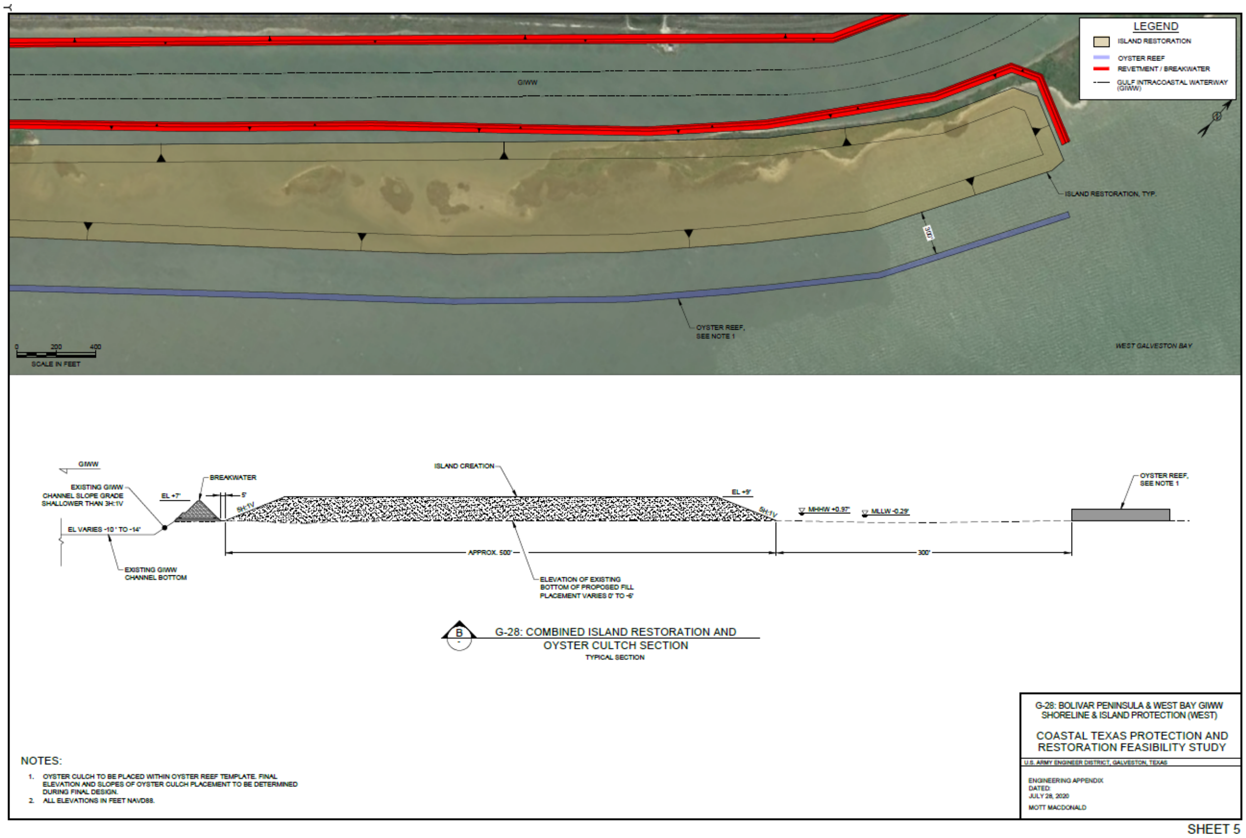


Figure 1-12: G-28 Bolivar and West Bay GIWW Shoreline and Island Protection West

1.10.5.2. B-12 – West Bay and Brazoria GIWW Shoreline Protection

This measure consists of shoreline protection and restoration utilizing 43 miles of rock breakwater at a crest height of 7 feet with 2H:1V side slopes and a base width of 46 feet, 0.17 acre of oyster cultch creation, 551 acres of marsh nourishment (See Figure 1-13). The construction of the rock breakwaters will reduce erosion of critical reaches of shorelines on the western side of West Bay and Cowtrap Lakes, and about 40 miles along selected segments of the GIWW in Brazoria County. The measure will protect critical reaches in Oyster Lake from breaching into West Bay by adding about 0.7 mile of oyster cultch to encourage the creation of oyster reef.

The measure would restore habitat and protect critical reaches of shoreline in this bay complex from breaching and impacting marsh, oysters, colonial waterbird rookeries and other habitats in the complex through erosion and changes in circulation. It would also reduce shoreline breaches and marsh erosion during storm events and erosive effects of vessel wakes, creating a more sustainable marsh with future RSLC. Sediment from GIWW BUDM (one O&M cycle) will be used for the marsh restoration and nourishment. The sediment borrow volume for the marsh effort is 639,105 cy.

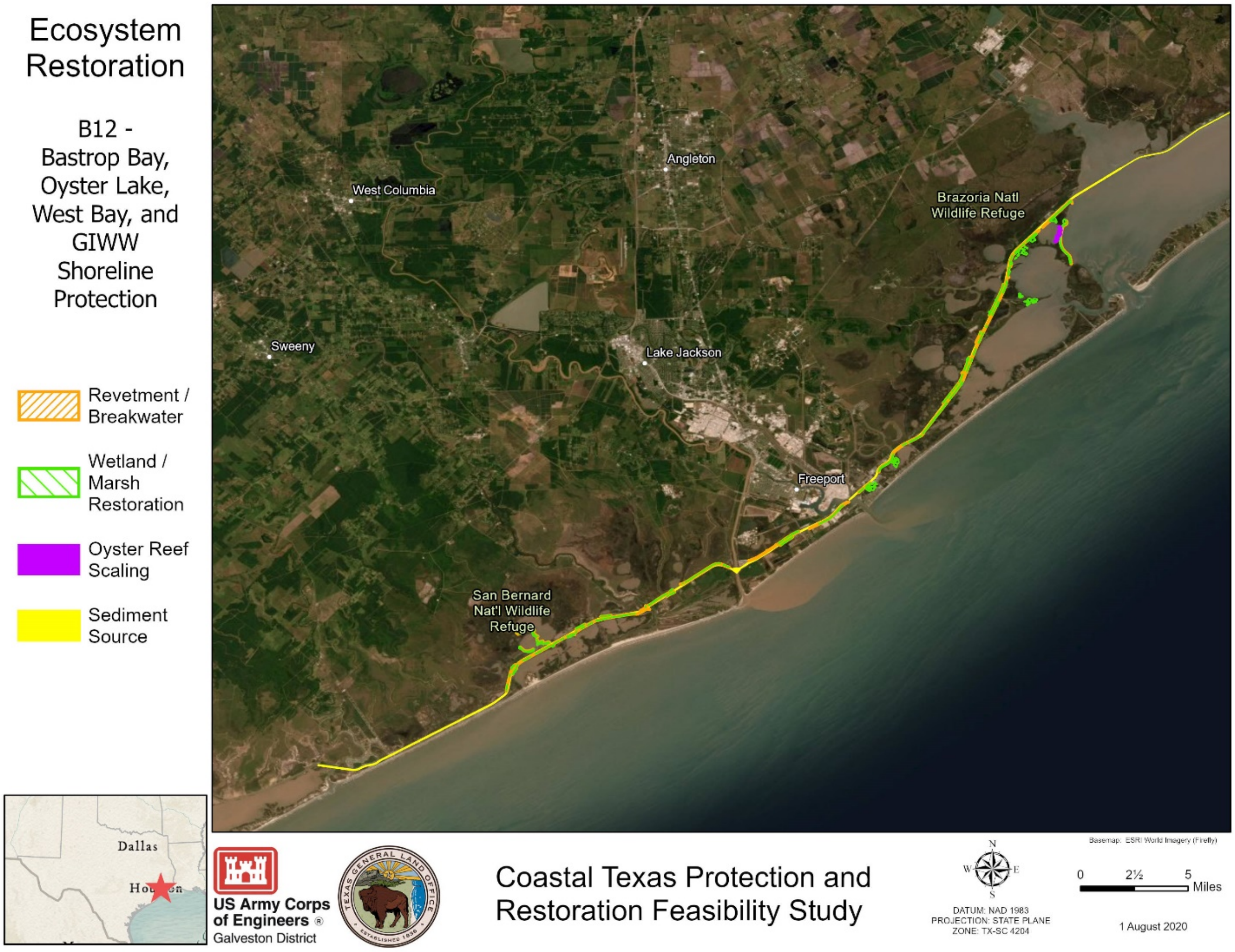


Figure 1-13: B-12 –West Bay and Brazoria GIWW Shoreline Protection

1.10.5.3. M-8 – East Matagorda Bay Shoreline Protection

This measure consists of shoreline protection and restoration utilizing 9.0 miles of rock breakwater at a crest height of 7 feet with 2H:1V side slopes and a base width of 46 feet. The measure provides for 96.1 acres of island restoration, 236 acres of wetland and marsh restoration, and 14.6 acres of oyster reef creation (See Figure 1-14). The construction of the rock breakwater will reduce erosion of 12 miles of unprotected segments of the GIWW shoreline and associated marsh along the Big Boggy National Wildlife Refuge shoreline and eastward to the end of East Matagorda Bay. No breakwaters would be constructed where portions of the GIWW shoreline are stabilized by adjacent dredged material placement areas.

GIWW BUDM will be used for the marsh nourishment features; mining of the upland confined placement area will provide sediment for the island restoration. Breakwaters will also be constructed as the erosion protection for the island feature on the GIWW side, an additional 3.5 miles. Oyster cultch will be placed on the bayside of the island. The sediment borrow volume for the marsh creation and restoration is 247,778 cy and for the island creation and restoration is 1,195,299 cy.

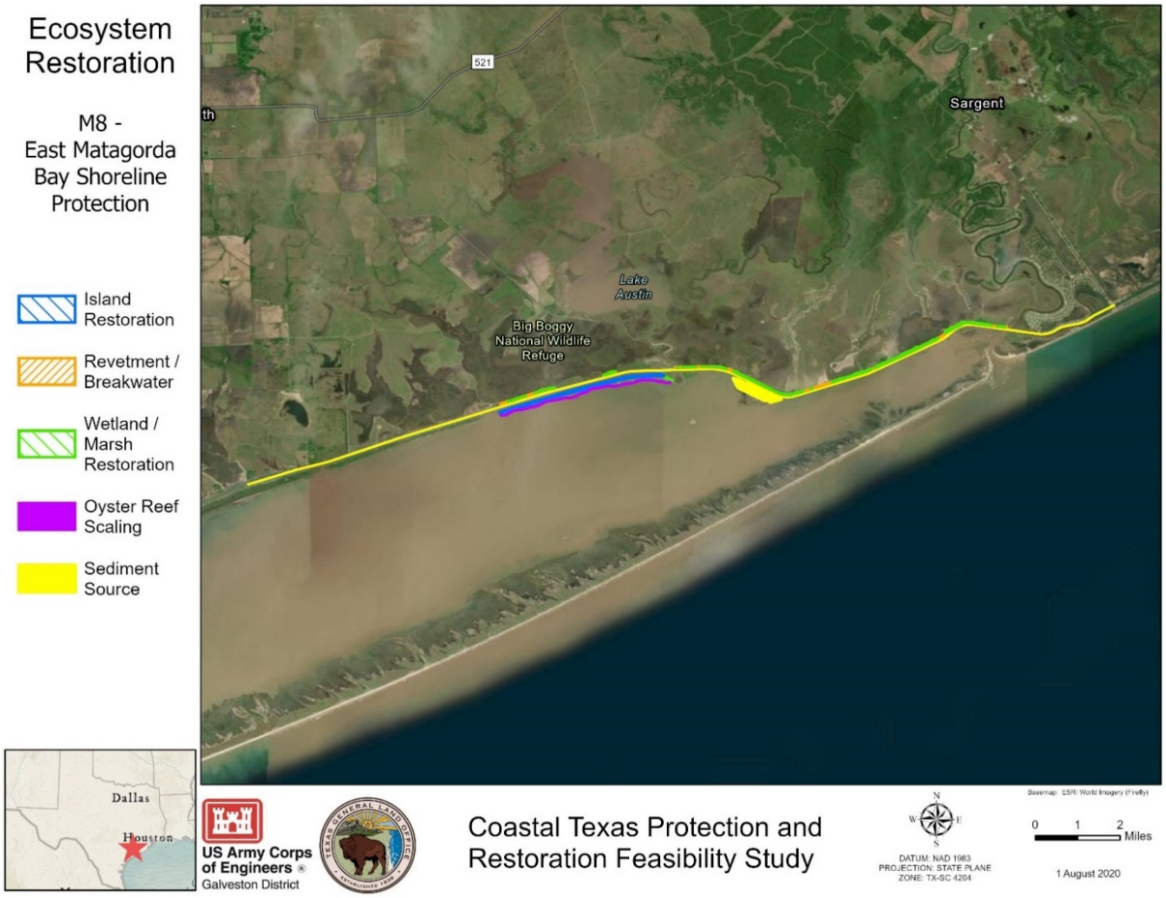


Figure 1-14: M-8 – East Matagorda Bay Shoreline Protection

1.11. DATA MANAGEMENT PLAN

The Data Management Plan (DMP) provides process and procedures for management of data for the GIWW-CR Study. These procedures and policies are consistent with USACE regulations and Galveston District processes and includes management of both existing and new data.

While all personnel working on the GIWW-CR Study have a role in data quality control, the Galveston District Geospatial Program Manager and CADD Manager has primary responsibility for ensuring that accurate, efficient data management procedures are implemented and used. A GIS technical lead is assigned for gathering, managing, and updating data. The geospatial data is managed in accordance with Engineering and Construction Bulletin (ECB) No. SWG 2016-01 Geospatial Data Management Plan (GDMP) for Projects. A fillable GDMP form is located on the EC SharePoint site for PDT utilization.

2. HYDROLOGY AND HYDRAULICS

2.1. INTRODUCTION

A SMART planning feasibility-level analysis of the coastal resiliency of the GIWW is conducted to provide preliminary design guidance for the tentatively selected plan. Additionally, RSLC and impacts are assessed in accordance with ER 1100-2-8162 and Engineering Technical Letter ETL 111-2-1.

H&H analyses are key components in identifying the tentatively selected plan (TSP). This section of the engineering appendix presents an overview of the H&H efforts performed to inform, evaluate, and support the identification of the TSP and an evaluation of its impacts. Analyses were conducted to support design of the resiliency features.

2.2. DESIGN CRITERIA

The section of GIWW within the study area is currently subject to reoccurring sediment shoaling, shoreline erosion, and navigational safety due to coastal storms and tidal flows. To address these concerns this study will look at structural alternatives that include the use of breakwaters, barrier islands, and marsh systems.

The following list identifies all engineering regulations and manuals and additional design documents referenced when establishing the design criteria for the mitigation features:

- EC 11-2-220: Civil Works Direct Program Development Policy Guidance (31 March 2019)
- EP 1130-2-520: Navigation and Dredging Operations and Maintenance Guidance and Procedures (22 Nov 96)
- ER 1130-2-520: Navigation and Dredging Operations and Maintenance Policies (22 Nov 96)
- ER 1110-2-1150: Engineering and Design for Civil Works Projects (31 Aug 99)
- ER 1100-2-8162: Incorporating Sea Level Change In Civil Works Programs (15 June 2019)
- ER 1110-2-1407: Hydraulic Design for Coastal Shore Protection Projects (30 Nov 1997)
- ER 1110-2-8153: Sedimentation Investigations (30 September 1995)
- ER 1110-2-1403: Studies by Coastal, Hydraulic, and Hydrologic Facilities and Others (1 January 1998)
- EM 1110-2-1100: Coastal Engineering Manual USACE. (1997).
- EM 1110-2-1204: Environmental Engineering for Coastal Shore Protection.
- EM 1110-2-1607: Tidal Hydraulics (15 March 1991)
- EM 1110-2-5025: Dredging and Dredged Material Management. (2015)
- EM 1110-2-1614: Design of Coastal Revetments, Seawalls, and Bulkheads (30 June 1995)
- EM 1110-2-8159: Life Cycle Design and Performance (31 October 1997)

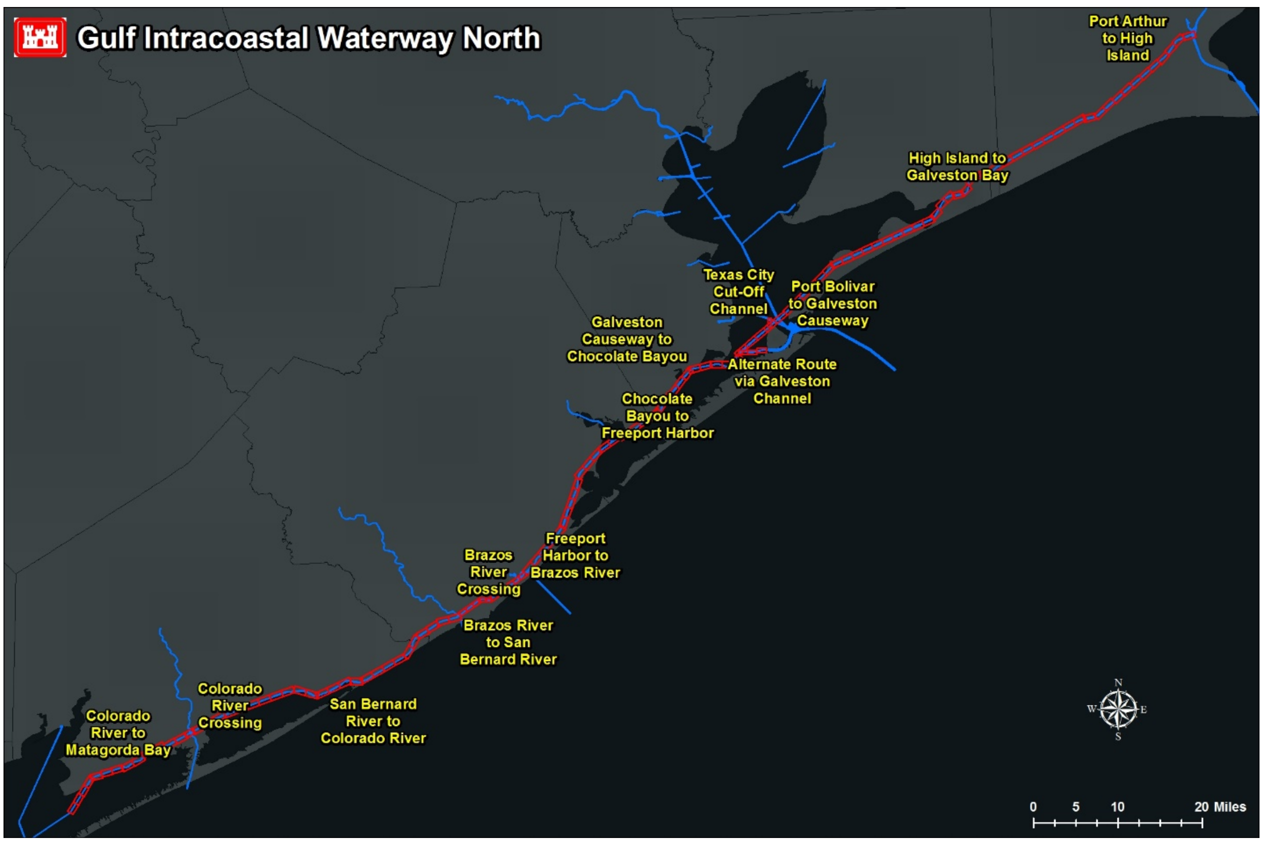
2.3. EXISTING DATA

2.3.1. **Bathymetry / Topography**

This section covers the data sources that were identified and collected to assist with the characterization of the study area's bathymetry and topography. Bathymetric maps and survey are the graphic delineation of bed elevation or depth below the water line or sea level that is collected by hydrographic survey, and then converted to Digital Elevation Models (DEM), which applies to both the GIWW channel and surrounding bays, inlets, nearshore, and other adjacent waterbodies. Topographic maps and survey show the elevation of landforms above sea level that is modernly collected through the use of LiDAR (Light Detection And Ranging), and then converted to DEMs.

2.3.1.1. **USACE eHYDRO Surveys**

The USACE Navigation Branch performs routine hydrographic surveys of SWG federal channels. The Galveston district hydrographic survey webpage[1] provides the latest hydrographic survey products and raw survey data for download. The data is organized by reach(See Figure 2-1)



[1] https://www.swg.usace.army.mil/Missions/Navigation/Hydrographic-Surveys/

and by Sheet (Figure 2-2). As shown in the example of Sheet 101 at the Intersection of Caney Creek (See

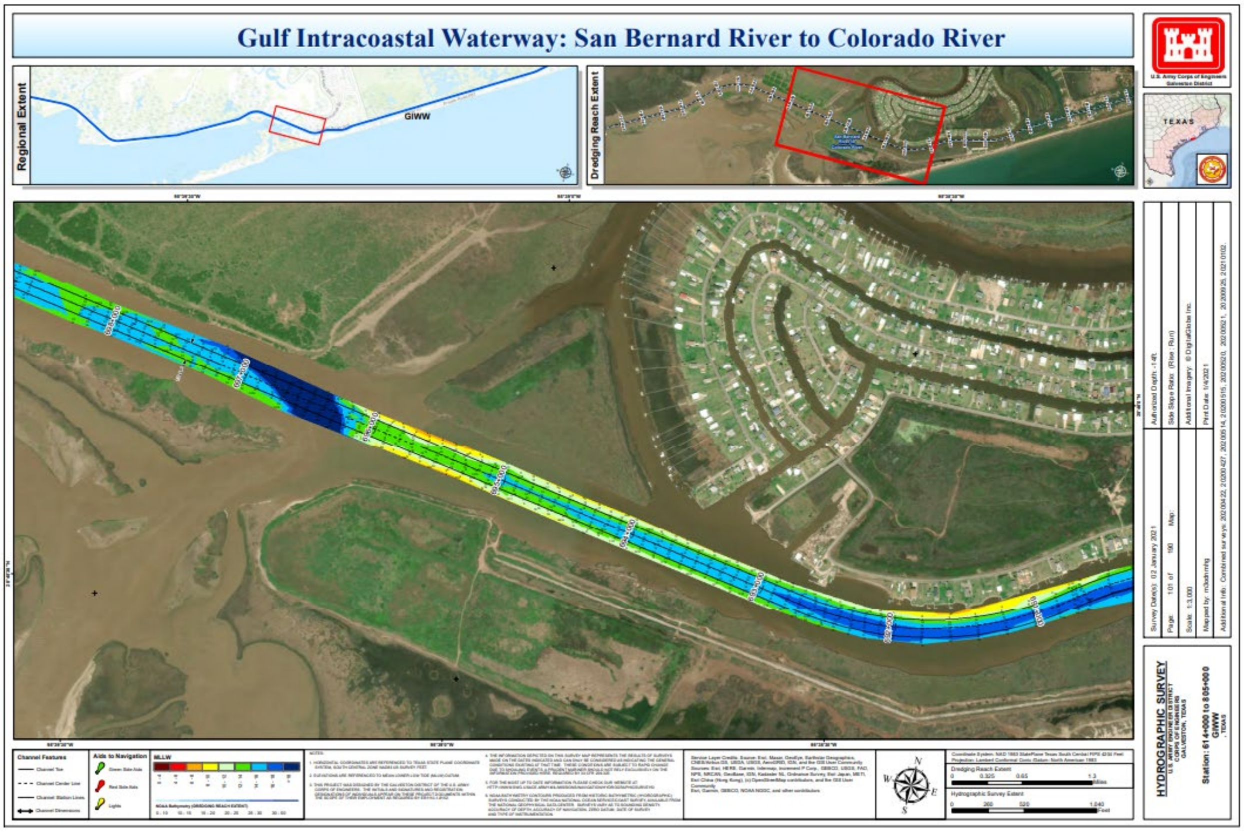


Figure 2-3), the cooler colors represent deeper water and warmer colors represent shallower water, which when examined show a scour hole to the west of the intersection of Mitchell’s Cut and shoaling to the east.

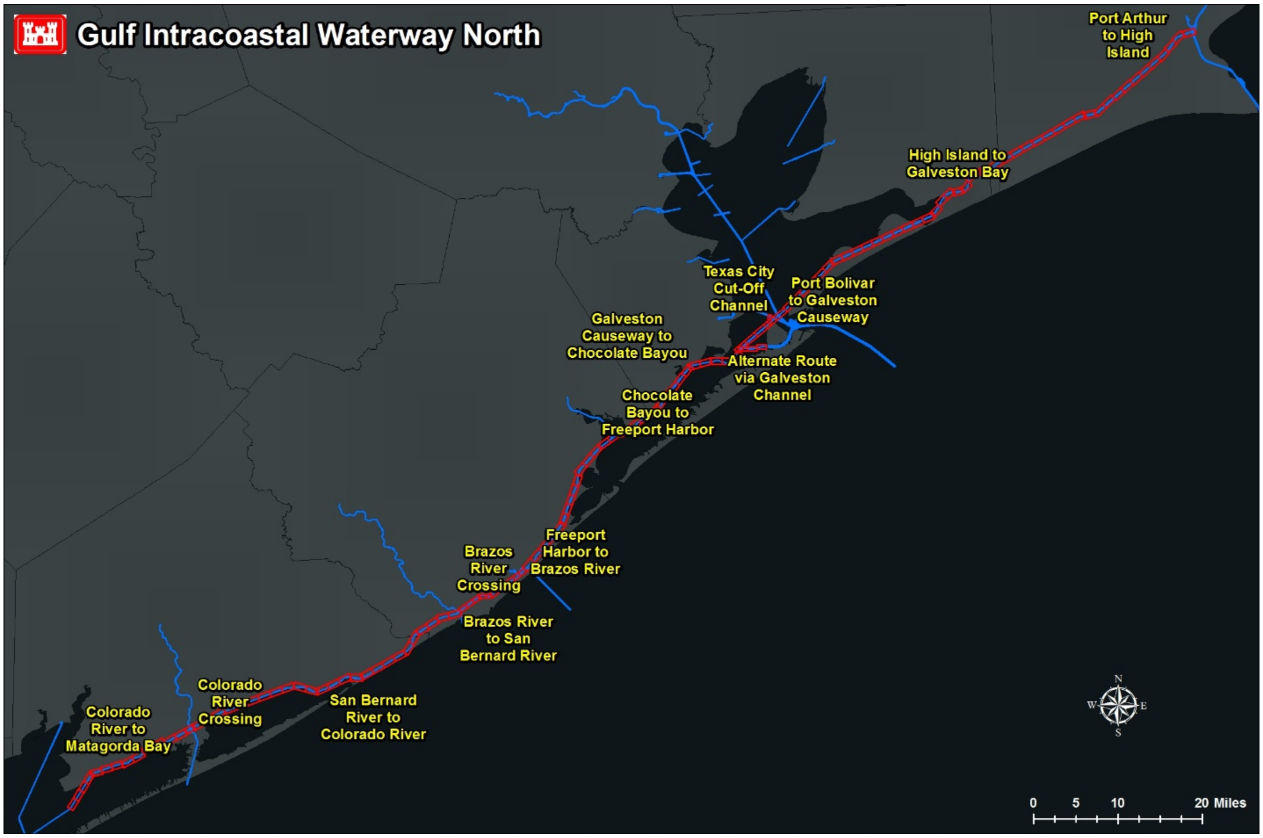


Figure 2-1: Gulf Intracoastal Waterway North Hydrographic Survey Reaches

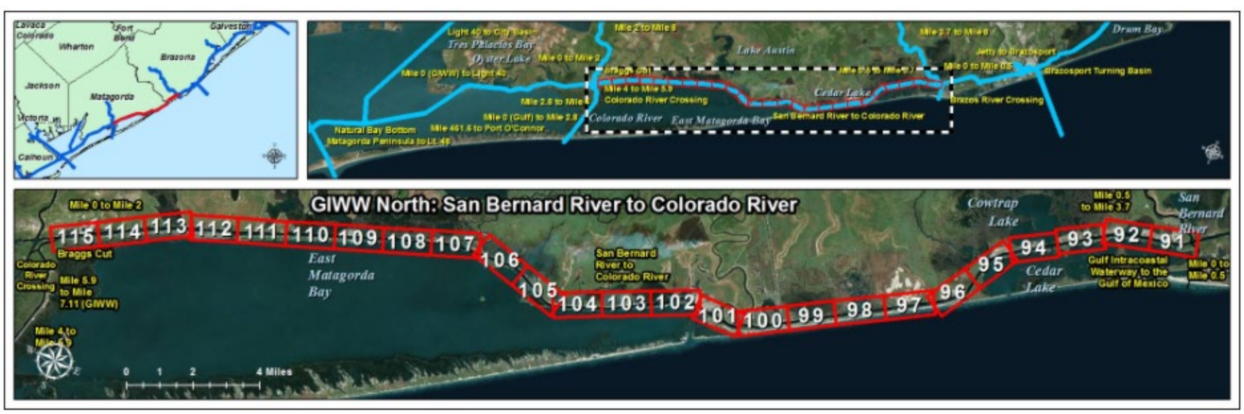


Figure 2-2: San Bernard River to Colorado River Hydrographic Survey Maps

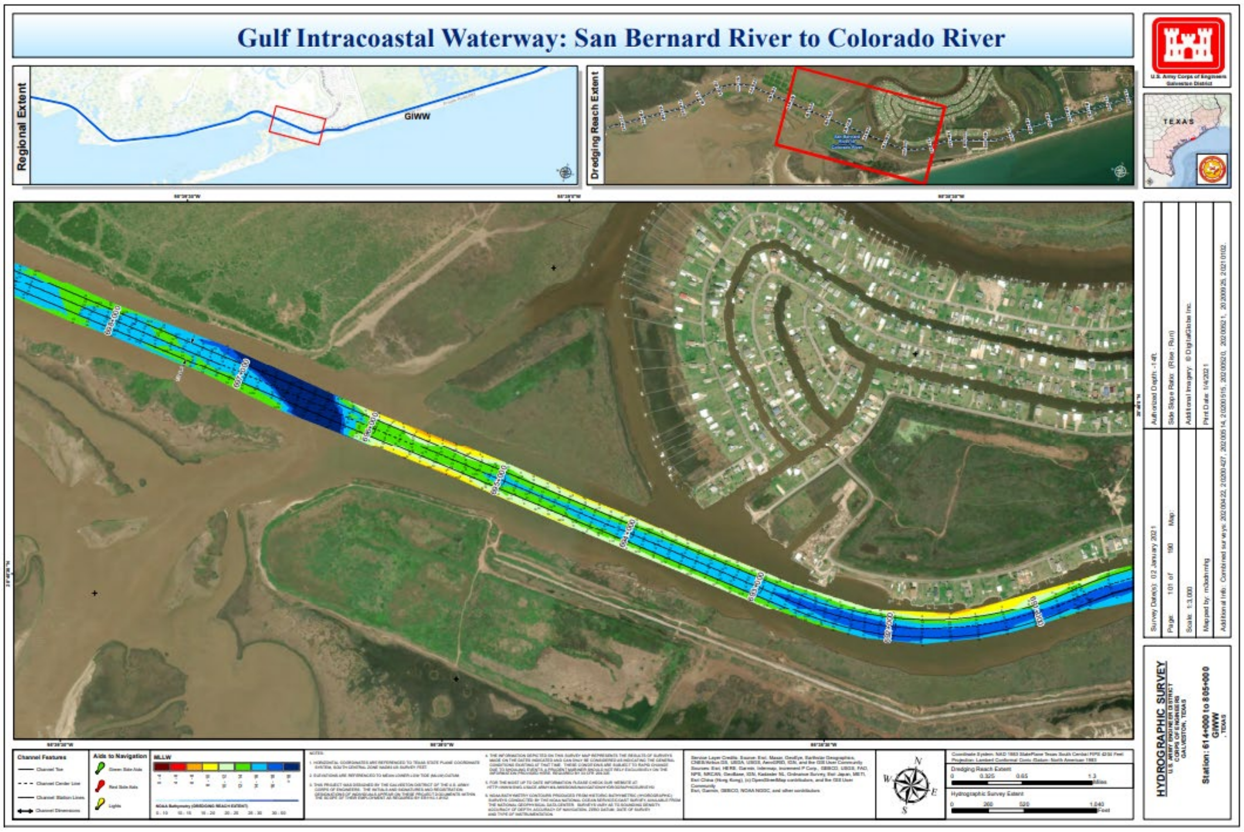


Figure 2-3: Hydrographic Survey (Sheet 101) of Caney Creek/Mitchell Cut Intersection

The U.S. Army Corps of Engineers developed eHydro to provide enterprise performance-based analyses and budgeting for coastal navigation channels through geospatial data to be used for, uniform method of data dissemination and comparison of latest conditions on coastal navigation channels. The Galveston district processes and reports channel condition data through the eHydro reporting process for all high and moderate commercial use channels, followed by low use channels. This eHydro data will be used in shoaling analyses, described later.

2.3.1.2. **Bathymetry**

The following data was collected from NOAA's Bathymetry & Relief website[2] and NOAA's NCEI Bathymetric Data Viewer[3], which collects data from a variety of sources (Map shown in Figure 2-4).

- NCEI 2001 Vol. 5 – Western Gulf of Mexico Coastal Relief Model 3 arc second[4]

[2] https://www.ngdc.noaa.gov/mgg/bathymetry/relief.html

[3] https://maps.ngdc.noaa.gov/viewers/bathymetry/

[4] https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:286/html

- NCEI 2005 Matagorda Bay, TX (G280) [5] Bathymetric Digital Elevation Model (30-meter resolution) Derived From Source Hydrographic Survey Soundings Collected by NOAA

- NCEI 2007 Galveston Coastal Elevation Model - 1/3 arc-second[6]

- NCEI 2018 Galveston Bay (G260) [7] Bathymetric Digital Elevation Model - NOAA/NOS Estuarine Bathymetry. A 1/3 arc-second Mean Lower Low Water bathymetric DEM of NOS hydrographic survey data in Galveston Bay.

- NCEI 2020 Houston/Galveston Continuously Updated Digital Elevation Model (CUDEM) – 1/9 arc-second tiles[8]

NCEI builds and distributes high-resolution, coastal digital elevation models (DEMs) that integrate ocean bathymetry and land topography. This data is often a mosaic of multiple year's data, so the data may not be current. For example, the most recent hydrographic survey found on NCEI in East Matagorda Bay is from 1935, so it is likely that is the most recent bathymetric data in that area. In addition to the variation in source data, some bathymetric data has gaps and overlaps between the models, so the smoothing routines that are applied to merge datasets may artificially create inaccurate bathymetry in these regions, which is very common in the nearshore and very shallow areas where hydrographic survey is limited.

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[5] https://www.ngdc.noaa.gov/thredds/catalog/regional/catalog.html?dataset=regionalDatasetScan/matagorda_bay_g280_30m.nc

[6] https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:403/html

[7] https://www.ngdc.noaa.gov/thredds/catalog/regional/catalog.html?dataset=regionalDatasetScan/galveston_bay_G260_2018.nc

[8] https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:999919/html

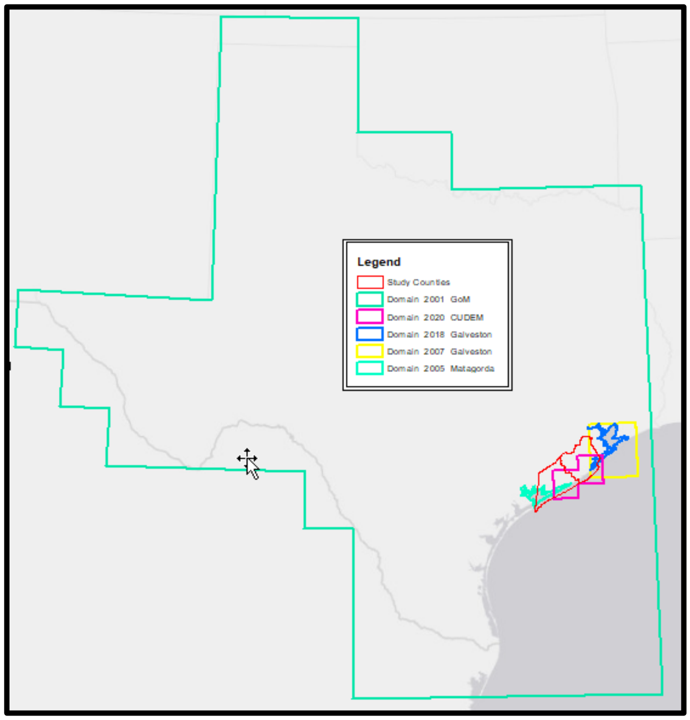

Figure 2-4: Map of Bathymetric Data Set Domains

2.3.1.3. **Topography**

The following data was collected from NOAA's Data Access Viewer[9], which collects data from a variety of sources:

(A) 2018 TWDB Lidar: Coastal Texas (Source: TNRIS, TX Water Development Board)[10]

(B) 2018-2019 NOAA NGS Topobathy Lidar Post Hurricane Harvey: Galveston to Corpus Christi (Source: NOAA NGS)[11]

(C) 2016 USACE NCMP Topbathy Lidar: Gulf Coast (AL, FL, MS, TX) (Source: USACE)[12]

(D) 2009 USACE NCMP Lidar: Post-Ike & Gustav (Source: USACE)[13]

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[9] https://coast.noaa.gov/dataviewer/#/lidar/search/

[10] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/lidar3_z/geoid12b/data/8898

[11] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/lidar4_z/geoid18/data/9215

[12] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/raster2/elevation/USACE_Gulf_Topobathy_DEM_2016_6371/

[13] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/lidar4_z/geoid18/data/1061

(E) 2006 TWDB Lidar: Matagorda County (Source: FEMA, TWDB)[14]

(F) 2006 TWDB Lidar: Brazoria County (Source: FEMA, TWDB)[15]

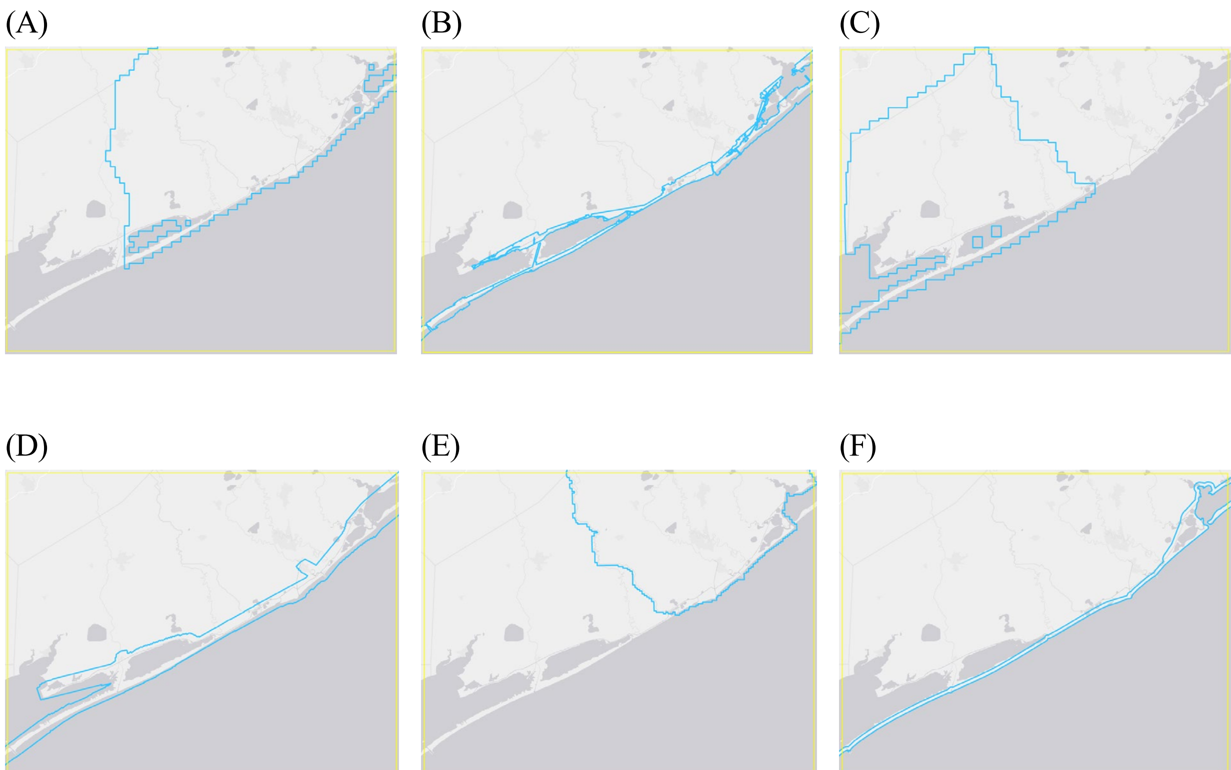

Figure 2-5: Map of Topographic Data Domains

2.3.2. **Sediment and Geology**

The USACE Sediment Analysis & Geo-App (SAGA) database documents sediment samples within the project area.

[14] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/lidar1_z/geoid12a/data/94

[15] ftp://ftp.coast.noaa.gov/pub/DigitalCoast/lidar1_z/geoid12a/data/95

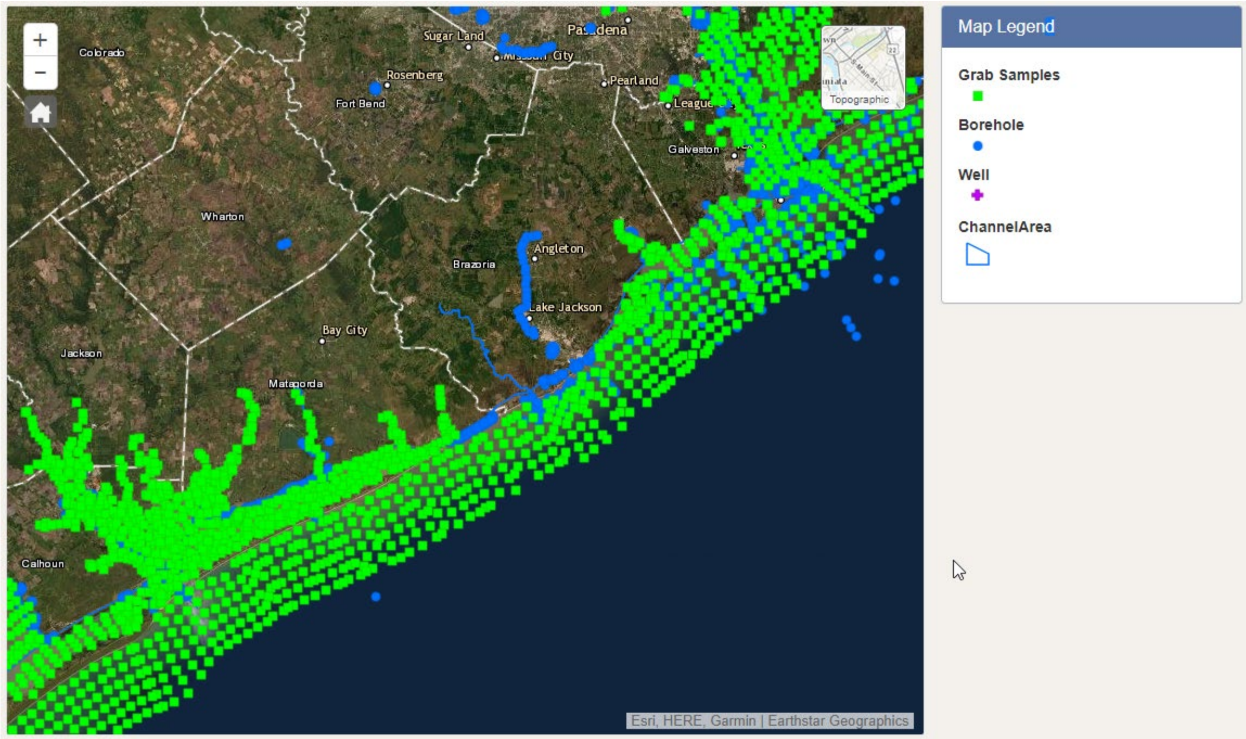

Figure 2-6: SAGA Data near the Study Area

Table 2-1 outlines the sediment composition of the GIWW from the Galveston Causeway to the Matagorda Bay and is broken into smaller sections identified by their respective start and end station numbers. The average grain size ranges from a minimum of 0.016 mm to a maximum of 0.190 mm, which occurs near the intersection of Caney Creek and Mitchell's Cut. Material that shoals in the GIWW comes from one of three sources: (1) channel side erosion, (2) watershed runoff yield, or (3) circulation due to tides or winds. Most of the GIWW project area is sheltered and has an average grain size classified as silt, so it can be assumed that the majority of the average channel side material can also be classified as silt. The areas with the higher average grain size occur where circulation due to tides or winds are stronger. The higher grain size at the Caney Creek and Mitchell's Cut intersection suggests that a significant portion of the material depositing in the GIWW there may be sourced from Sargent Beach, which means cutting off this supply may reduce shoaling in that area.

Table 2-1: Sediment Grain Size Analysis Results

Reach	Sta. Start	Sta. End	% Sand	% Silt	% Clay	Avg. Grain Size (mm)
Galveston Causeway to Freeport Harbor	360+000	495+000	31.8	45.3	22.9	0.046
Freeport Harbor to Brazos River	565+000	593+000	11.5	42.6	45.9	0.012
Greens Lake Vicinity	373+917	493+918	31.5	44.0	24.4	0.047
Channel to Port Bolivar	5+000		37.7	40.5	21.8	0.081
Brazos River to Caney Creek	595+000	660+000	12.5	46.4	41.1	0.103
Caney Creek to Colorado River	665+000	805+000	28.4	36.1	35.5	0.037
Sargent Beach	655+000	690+000	41.6	30.6	27.8	0.190
Colorado River to Matagorda Bay	810+000	905+000	14.7	41.0	44.3	0.016
Across Matagorda Bay	945+000	960+000	53.7	27.0	19.3	0.104

Figure 2-7 is a screen shot of the CESWG Geospatial Data Portal showing the current sediment budget from Freeport, TX to Bolivar Peninsula, TX. This online tool allows for detailed analysis of sediment transport along the upper Texas coast. This tool can still serve as a quality control check for the new sediment budget analysis.

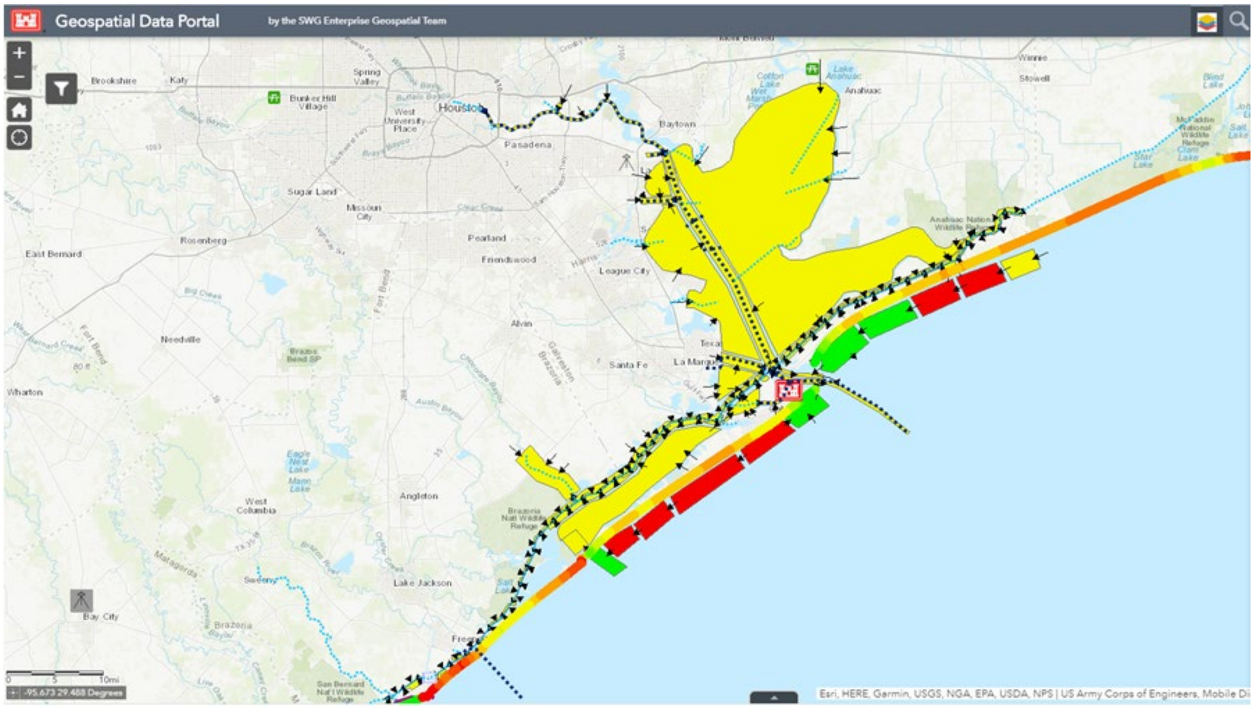

Figure 2-7: Geospatial Data Portal Sediment Budget

2.3.3. **Historical Shoreline Changes**

The Texas coast is generally erosive except for areas on the updrift side of navigation jetties. Shoreline change has been monitored by the Bureau of Economic Geology (BEG) at 50-meter intervals through remote sensing techniques and is reported by Paine et al. (2014). Figure 2-8 shows the long-term averaged shoreline change rates throughout Texas; the rates are summarized by geomorphic region in

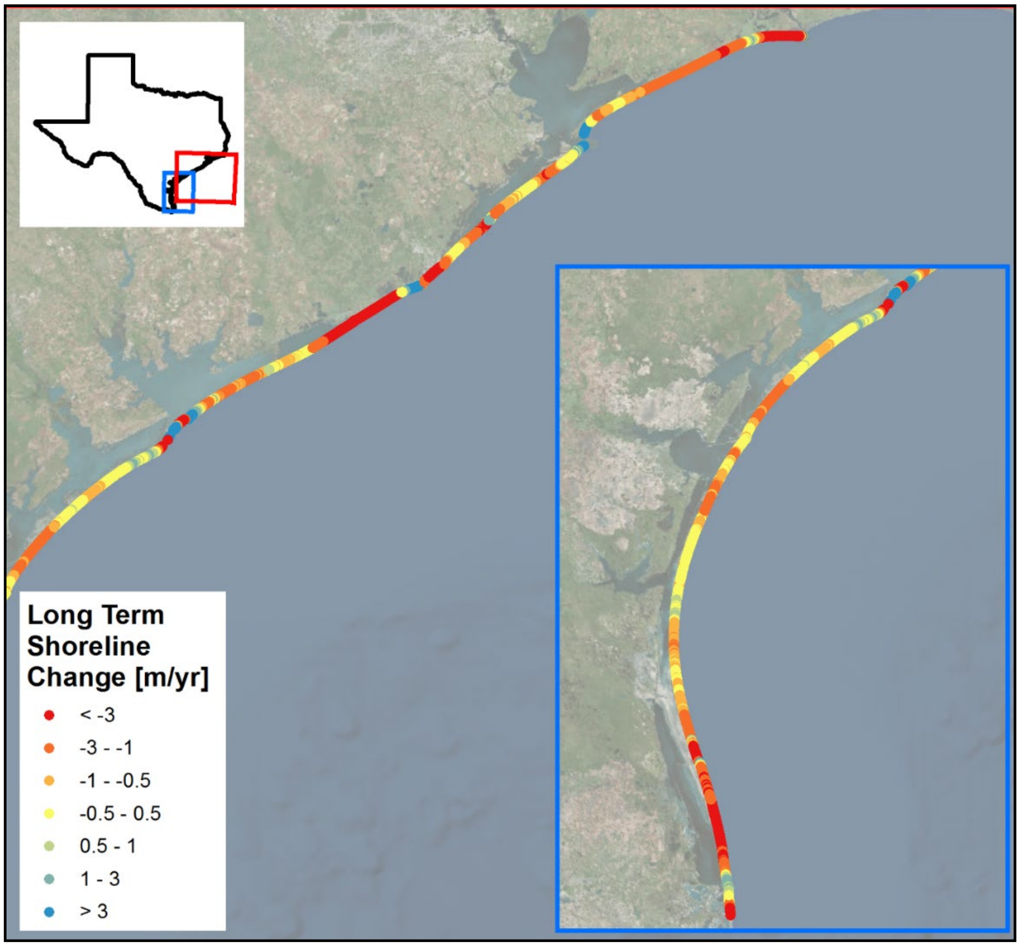

Figure 2-8: Long-term Shoreline Change along the Texas Coast (Paine et al., 2014)

Table 2-2: Long-term and Recent Shoreline Change Rates through Various Geomorphological Regions along the Texas Coast

	Long Term (1930s - 2012)			Recent (2000 - 2012)		
Region	Net Rate (m/yr.)	Standard Deviation (m/yr.)	Range (m/yr.)	Net Rate (m/yr.)	Standard Deviation (m/yr.)	Range (m/yr.)
Sabine Pass to Rollover Pass	–2.94	2.66	–11.7 to 9.3	–4.66	3.52	–15.9 to 2.8
Bolivar Peninsula	0.41	2.72	–1.8 to 14.6	–0.66	1.57	–10.5 to 4.5
Galveston Island	–0.27	1.85	–2.7 to 6.5	0.98	2.8	–5.1 to 24.9
Brazos/Colorado Headland	–2.08	5.48	–13.0 to 20.5	–1.34	5.12	–38.9 to 16.5
Matagorda Peninsula	–1.00	2.83	–10.3 to 20.1	–0.57	3.85	–11.7 to 19.4
Matagorda Island	–0.74	3.80	–16.8 to 16.1	–1.24	4.91	–15.9 to 4.8
San Jose Island	–0.74	0.47	–1.6 to 0.4	1.08	1.48	–4.0 to 12.7
Mustang Island	–0.34	0.61	–1.9 to 0.4	0.08	1.87	–4.0 to 30.4
North Padre Island	–0.82	0.98	–4.5 to 1.1	–1.14	1.19	–5.0 to 11.0

Region	Long Term (1930s - 2012)			Recent (2000 - 2012)		
	Net Rate (m/yr.)	Standard Deviation (m/yr.)	Range (m/yr.)	Net Rate (m/yr.)	Standard Deviation (m/yr.)	Range (m/yr.)
South Padre Island	–2.27	1.91	–7.5 to 3.4	–1.57	1.61	–6.6 to 2.9

m/yr. = meters per year

As reflected in the table, the range of shoreline change rates can be highly variable even within a geomorphological region. This variability is typically associated with interrupted longshore transport at navigation jetties, where sediment accumulates on the updrift side and leaves a deficit on the downdrift side. Given the long-term monitoring, impacts associated with a singular tropical event that could induce large impacts on the landscape are averaged out. Given this, the Texas coast shows a consistent trend of shoreline erosion. Erosion persists, or accretion is minimal, even though the longshore convergence zone which indicates a degree of sediment loss from the littoral system through a variety of mechanisms including navigation channel dredging, eolian transport to the bays, and cross-shore transport.

2.3.4. **Vegetation and Land Use**

The Texas Parks and Wildlife Department's website[16] categorizes the marshes of Texas into the following four subtypes:

- Subtype 1: Maidencane-Alligator Weed (fresh) Marsh
  - Commonly Associated Plants: Water hyacinth, cattail, water-pennywort, pickerelweed, arrowhead, white waterlily, cabomba, coontail, duckweed.
  - Distribution: Hydric lowlands landward of brackish marsh, Coastal Prairies and Marshes.
- Subtype 2: Marshay Cordgrass-Olneyi Three-Square-Leafy Three-Square (brackish) Marsh
  - Commonly Associated Plants: Big cordgrass, widgeongrass, California bulrush, seashore paspalum, sacahuista, common reed.
  - Distribution: Generally landward of normal tidelands to storm tide, Coastal Prairies and Marshes.
- Subtype 3: Smooth Cordgrass-Marsh Saltgrass-Sea Ox-eye (saline) Marsh

[16] https://tpwd.texas.gov/publications/pwdpubs/pwd_bn_w7000_0120/marsh/

- Commonly Associated Plants: Black rush, vidrillos, black mangrove, glasswort, seashore paspalum, shoalgrass.
- Distribution: Tidally-inundated shores of bays, Gulf Coast.

• Subtype 4: Seaoats-Seacoast Bluestem Grassland

- Commonly Associated Plants: Croton, single-spike paspalum, Pan American balsamscale, flat sedge, sea purslane, cenicilla, bulrush, beach morningglory, goatfoot morningglory, sea rocket, lime pricklyash.
- Distribution: Sandy coastal barrier islands from high tide mark to leeward marshes.

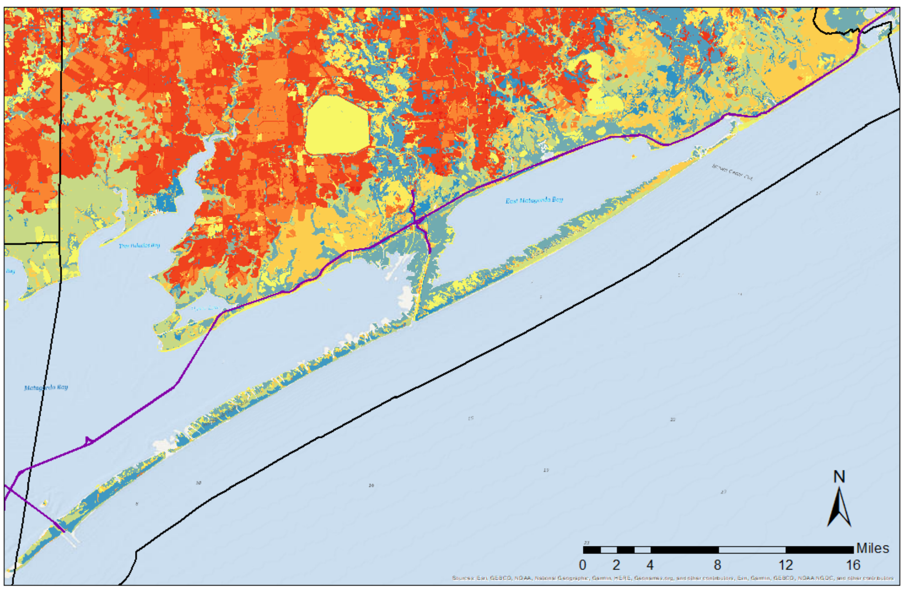

Figure 2-11: West Gulf Coast Plains Ecosystems within Matagorda and Brazoria Counties.

There are no cataloged seagrass beds[17] present within or adjacent to the GIWW within Matagorda and Brazoria Counties. While there are no cataloged seagrass beds present; it should be noted that there has been no field survey to confirm or assess the presence of any seagrass beds. The majority of the GIWW within the study area is flanked by wetlands and wildlife refuges.

[17] https://tpwd.maps.arcgis.com/apps/webappviewer/index.html?id=af7ff35381144b97b38fe553f2e7b562

2.3.5. **Salinity and Water Temperature**

From NOAA's National Oceanographic Data Center website[18], the average monthly water temperatures for various coastal cities along the Texas coast are displayed in Table 2-3.

Table 2-3: Coastal Texas Average Monthly Water Temperature (˚F)

Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corpus Christi Point, TX	59	60	65	72	79	83	84	85	84	79	70	62
Freeport, TX	53	56	62	71	77	82	84	85	82	75	66	59
Galveston Pleasure Pier, TX	54	55	61	71	78	83	86	86	83	75	67	59
Port Aransas, TX	59	61	67	71	80	85	86	86	86	77	72	63
Rockport, TX	59	63	68	75	81	87	88	89	85	79	70	61

The minimum average water temperatures occur between December and January with the lowest temperature range occurring in the northern two locations of Galveston and Freeport. The average maximum temperatures occur between June and September with the highest temperature range occurring in Rockport, one of the most southern locations.

Salinity varies along the GIWW in Matagorda and Brazoria Counties from negligible (<0.5ppt) where freshwater inputs like the Colorado River intersect to hyper-saline (+35 ppt), like in back bay areas of East Matagorda where tidal exchange is weak, freshwater input is low, and evaporation accentuates saline concentrations. In general, most salinity falls between 10 to 30 ppt, but concentrations are heavily dependent on freshwater input and seasonality. Figure 2-9 is a map of several continuous water quality data stations in the East Arm of Matagorda Bay and East Matagorda Bay. As shown in Figure 2-10, the sonde in East Matagorda Bay has captured several hyper saline periods, and as shown in Figure 2-11, the sonde in the East Arm of Matagorda Bay has captured fairly lower salinity ranges. This difference is even more readily apparent in Figure 2-12. The East Arm of Matagorda Bay captures freshwater from the Colorado River on its east end; whereas East Matagorda Bay has limited freshwater input on its western end.

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[18] https://www.nodc.noaa.gov/dsdt/cwtg/all_meanT.html

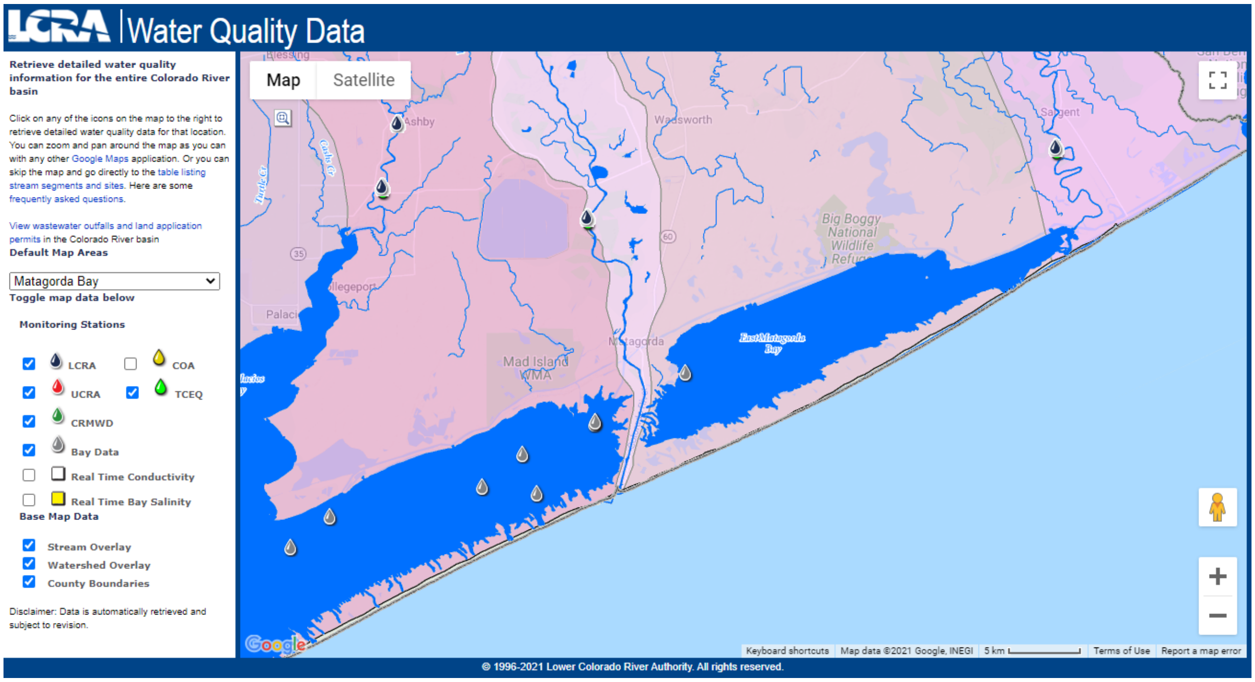

Figure 2-9: Lower Colorado River Authority Data Portal (https://waterquality.lcra.org/)

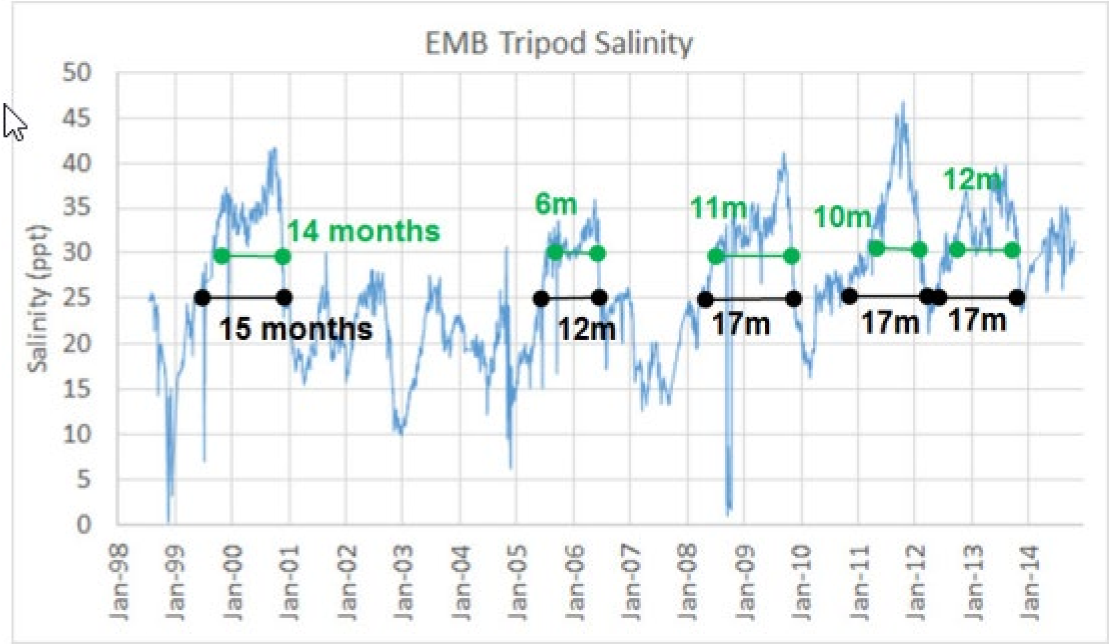

Figure 2-10: Historical observed salinity data at East Matagorda Bay "Tripod" sonde, with duration of events exceeding 25 ppt and 30 ppt. Invalid source specified.

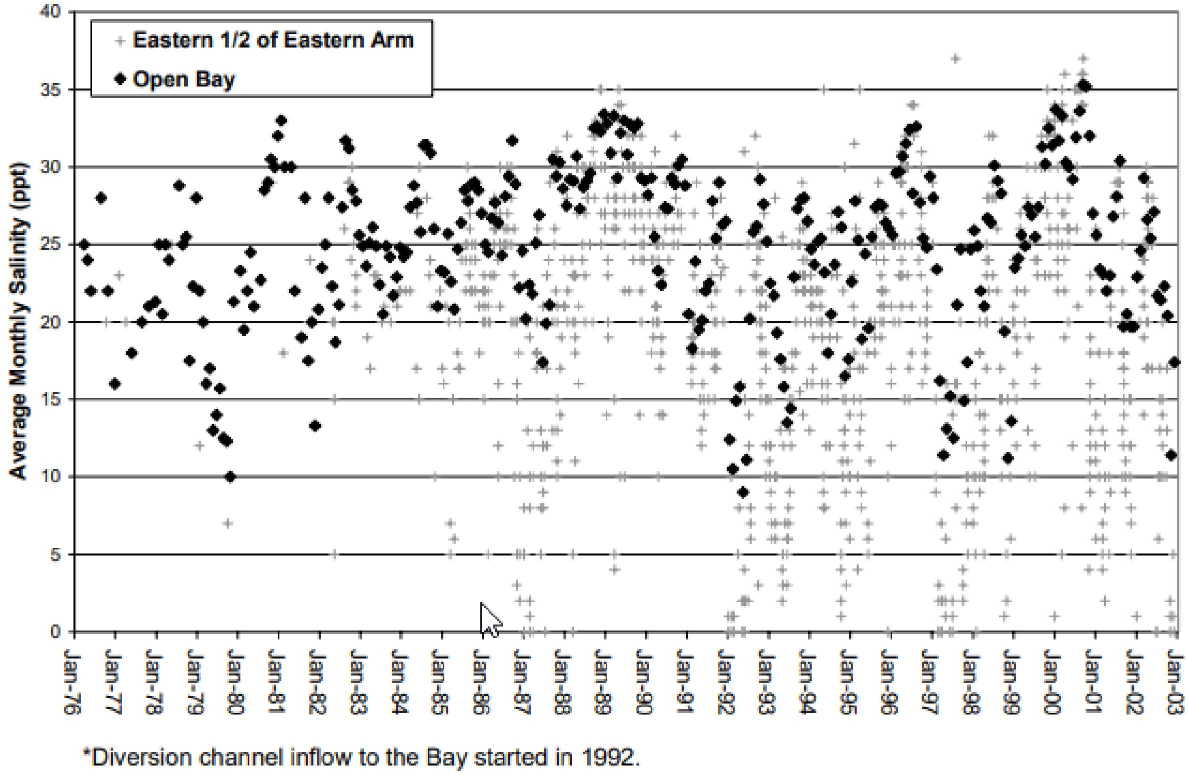

Figure 2-11: Monthly Salinity in the Eastern Half of the Eastern Arm and Open Bay of Matagorda Bay – TWPD Coastal Fisheries Data Invalid source specified.

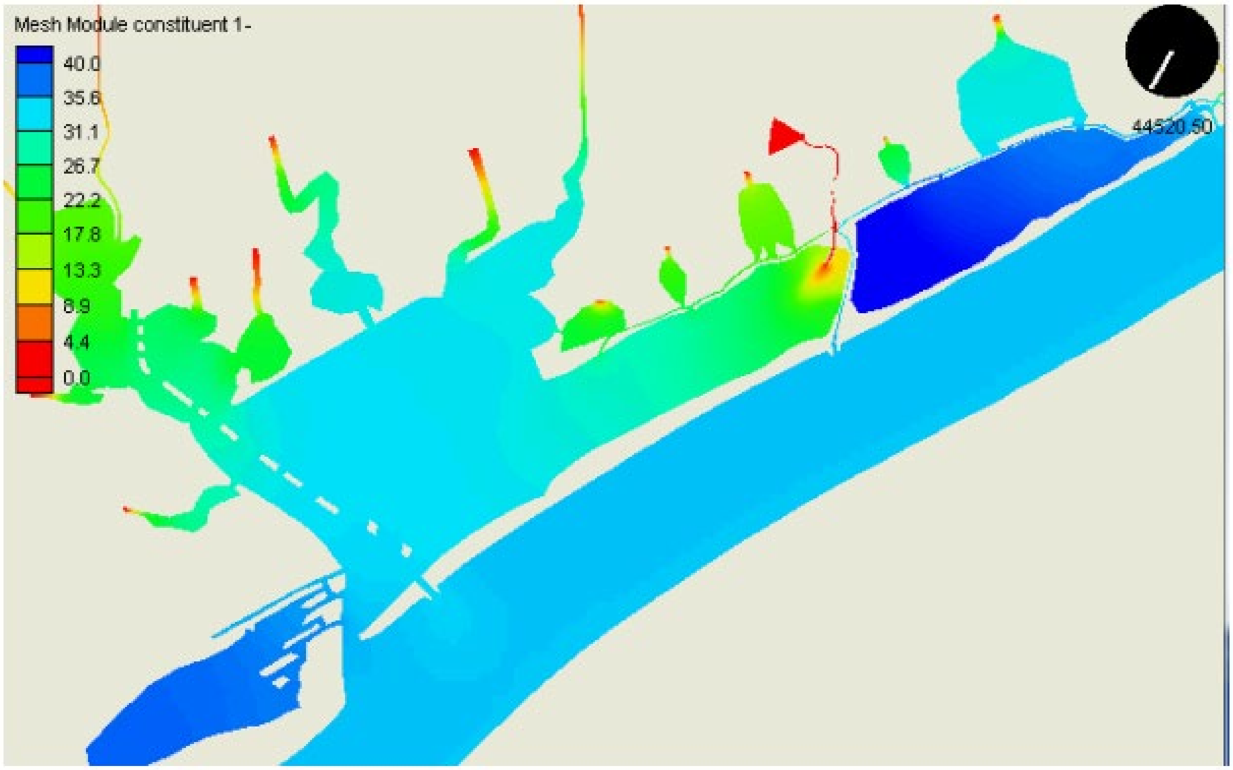

Figure 2-12: MBHE RMA2/RMA4 Salinity Model year July 2000. Salinity in parts per thousand. Invalid source specified.

2.3.6. **Tides**

There are five NOAA gages within the project study area. They are shown in Figure 2-13 and listed in Table 2-4.

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Figure 2-13: Location of NOAA Tide Stations

Table 2-4: NOAA Tide Stations

Station Name	Station ID
San Luis Pass	8771972
Freeport Harbor	8772471
Sargent Beach	8772985
Matagorda City	8773146
Matagorda Bay Entrance Channel	8773767

2.3.6.1. **Datums**

The project area spans two counties and over 100 miles of the GIWW. The tidal datums for the five nearby NOAA gages vary depending on proximity to Gulf, tidal prism, and riverine contribution. In general, the further or less influence from the Gulf, the narrower the tidal range and the higher the datums. An illustration for the datums at gage 8773145 is shown in Figure 2-14 and datums for each of the five gages are tabulated in Table 2-5.

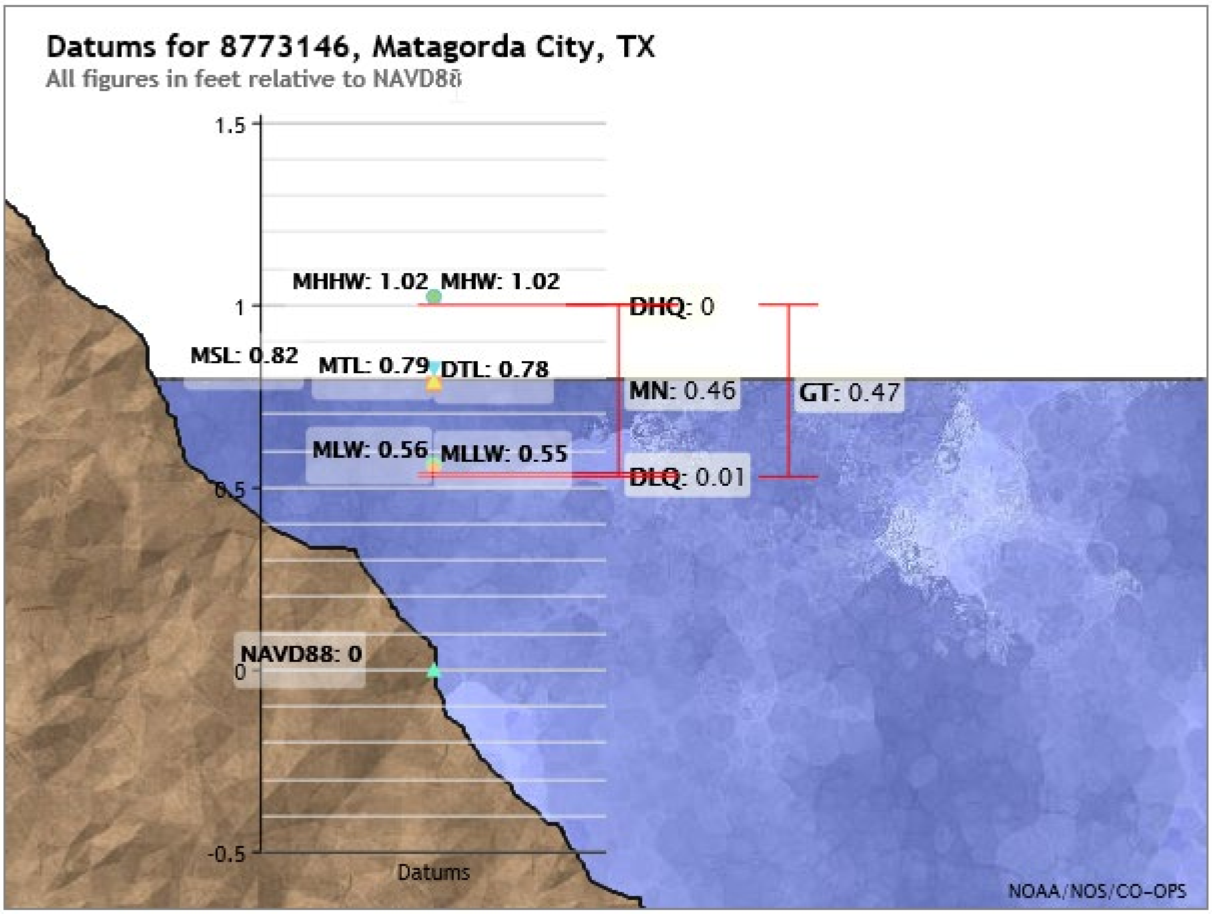


Figure 2-14: Datums for 8773145, Matagorda City, TX (NAVD88)

Table 2-5: Datum

Datum	8773767, Matagorda Bay Entrance Channel TX	8771972, San Luis Pass, TX	8772471, Freeport Harbor, TX	8772985, Sargent Beach, TX	8773146, Matagorda City, TX
MHHW	0.88	0.92	1.02	1.05	1.02
MHW	0.84	086	.88	1.01	1.02
MTL	0.29	0.41	0.26	0.71	0.79
MSL	0.37	0.44	0.26	0.75	0.82
MLW	-0.26	-0.04	-0.37	0.40	0.56
MLLW	-0.37	-0.25	-0.65	0.36	0.55
GT	1.25	1.17	1.67	0.69	0.47
MN	1.10	0.90	1.25	0.61	0.46
Tidal Datum Analysis Period	09/01/2017 - 08/31/2019	04/01/2019 - 03/31/2020	01/01/2019 - 12/31/2019	01/01/2016 - 12/31/2019	10/01/2016 - 09/30/2019

2.3.7. **Historical Storms**

Historical hurricane data is available from NOAA's National Hurricane Center (NHC) and NCEI databases. Shown in Figure 2-15 from NOAA's Hurricane Track Visualizer[19] is every storm to have hit Texas within 150 miles of the Study Area including category 1-5 hurricanes, tropical storms and depressions, and extratropical storms. Figure 2-16 displays only the major hurricanes of category 3 or higher to have hit Texas, and as can be seen from this figure, the only CAT 3+ storms to have made landfall in the study area were unnamed; Hurricane Harvey (2017) did double back through the area.

[19] https://coast.noaa.gov/hurricanes/#map=4/32/-80

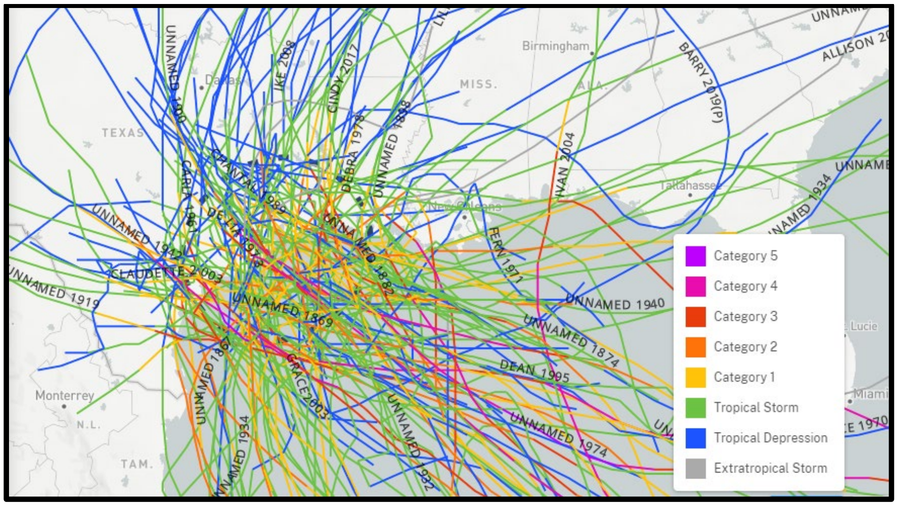


Figure 2-15: Historical Storms within 150 miles of Study Area

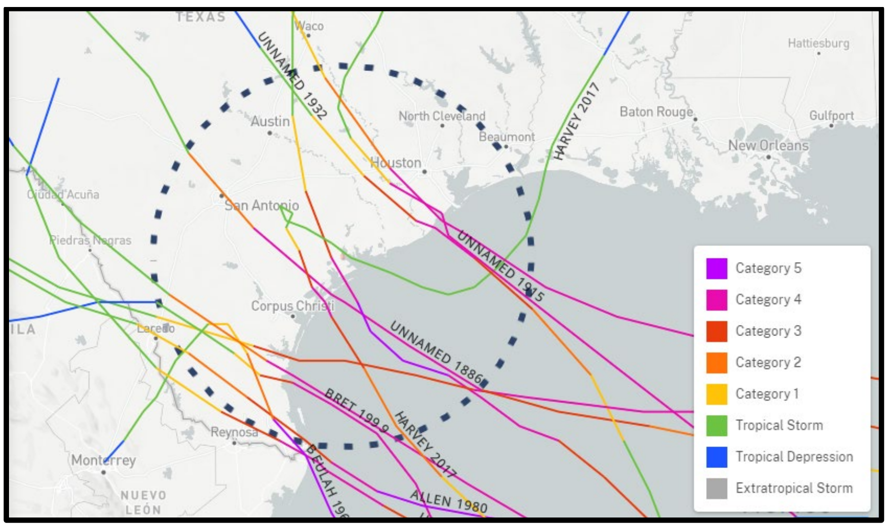
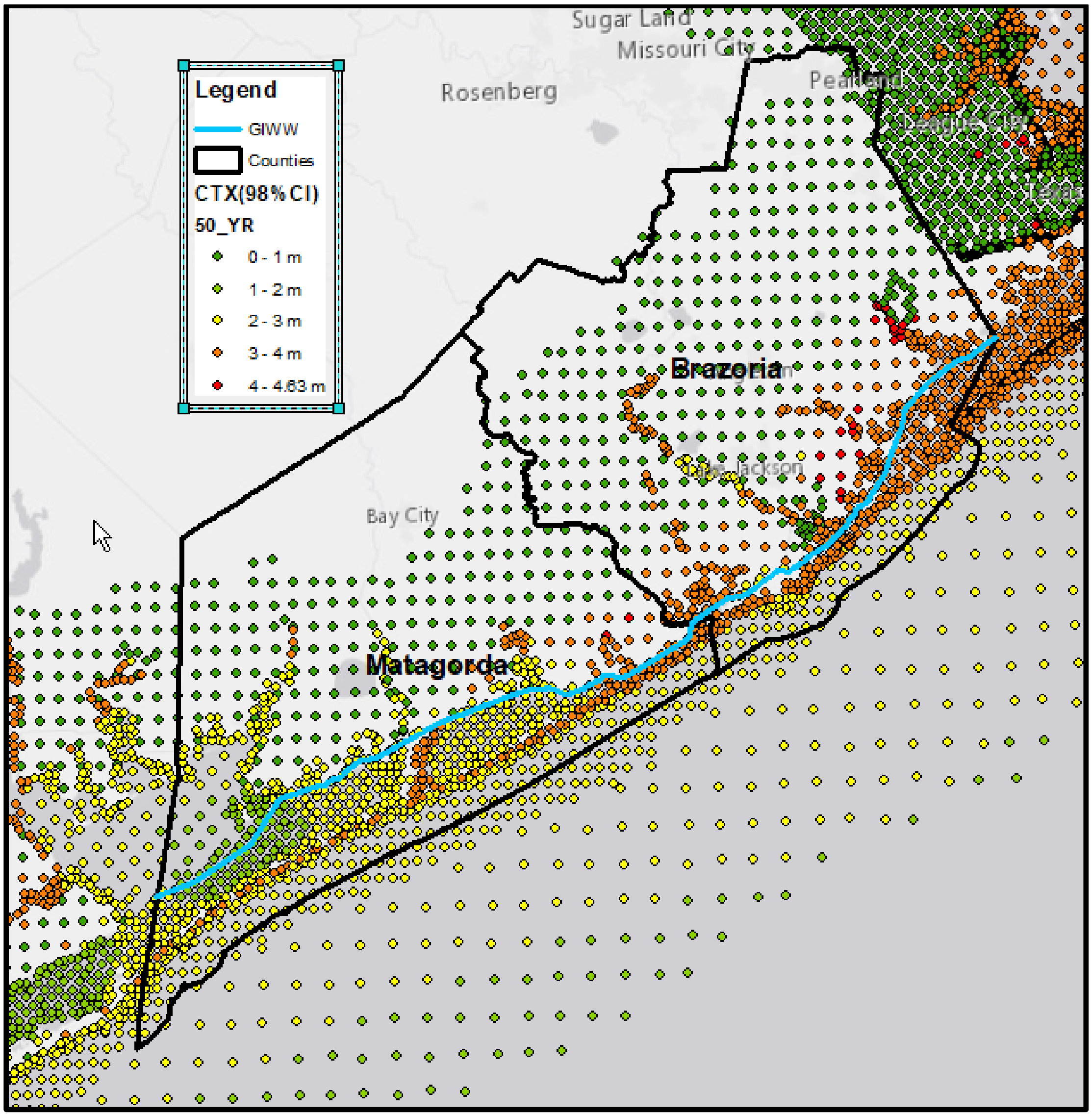


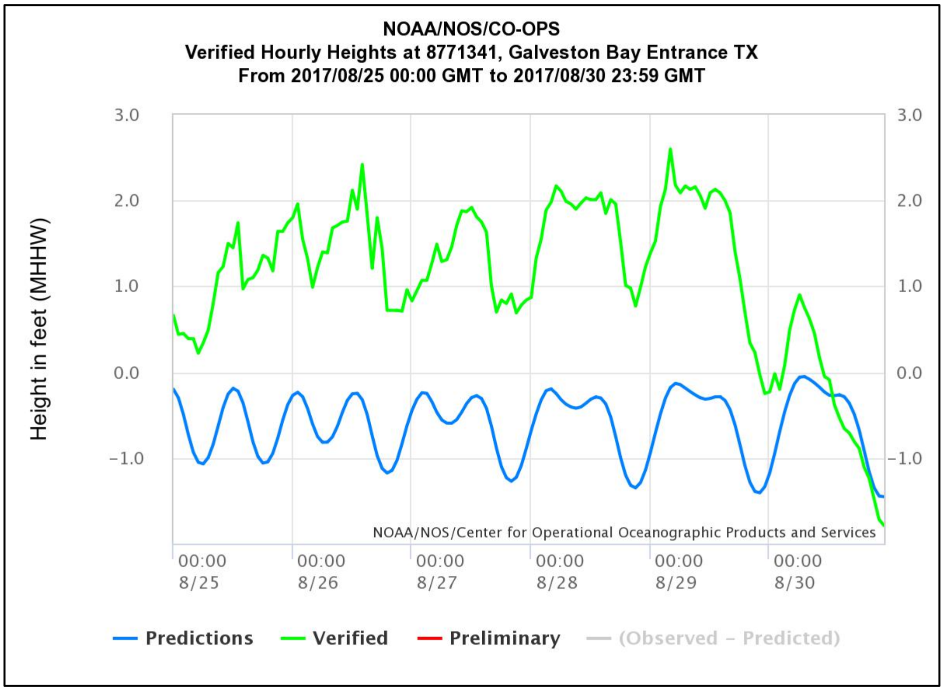
Figure 2-16: Historical Major Hurricanes (Category 3, 4, 5) in Texas

2.3.8. **Water Levels**

For statistical water levels, there are FEMA Flood Insurance Studies that cover the project area; however USACE recently performed an in-depth probabilistic analysis of water level and wave hazards for the Texas Coast. See Figure 2-17 for the locations of observation points and the computed 50-YR stillwater levels from that study.



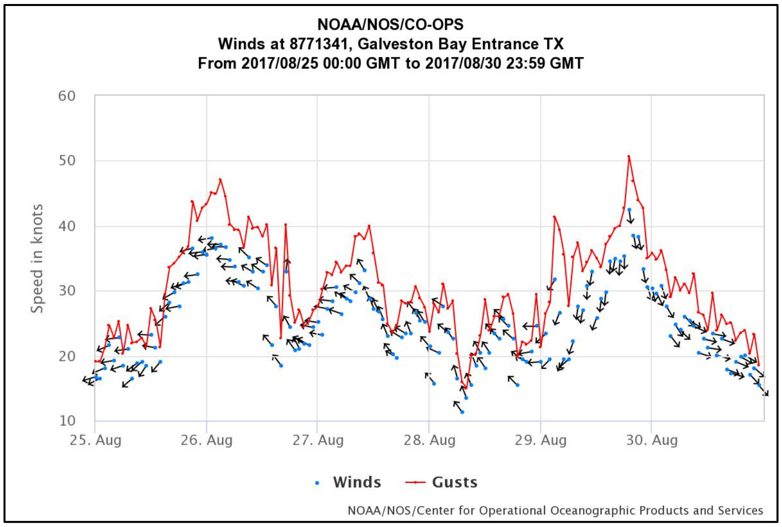
Historical water levels can be obtained from nearby gages. In NOAA station 877134120 recorded the hourly water level heights and wind speeds for Hurricane Harvey. The water levels from August 25 – 30 in 2017 are displayed in Figure 2-18 and the wind speeds are displayed in Figure 2-19.



21

20 https://co-ops.nos.noaa.gov/stationhome.html?id=8771341

21 https://co-ops.nos.noaa.gov/stationhome.html?id=8771341



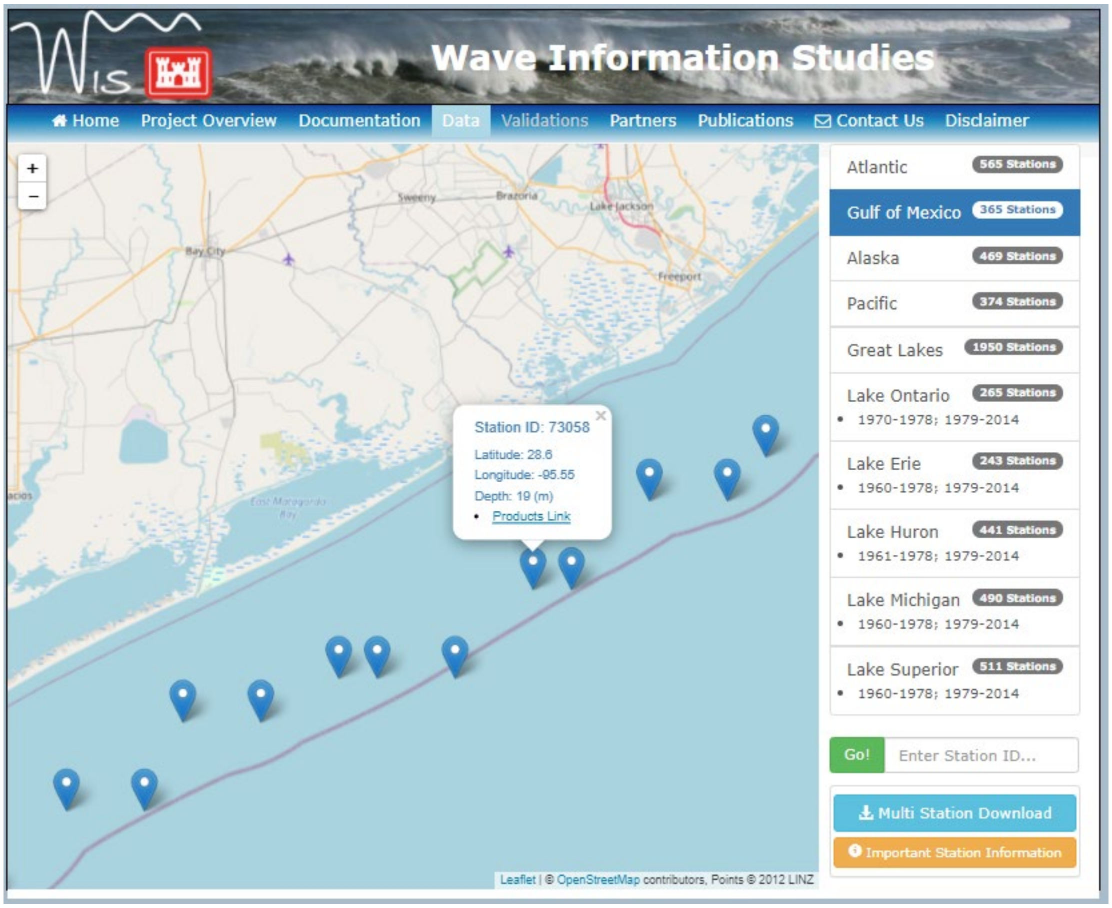
[22]

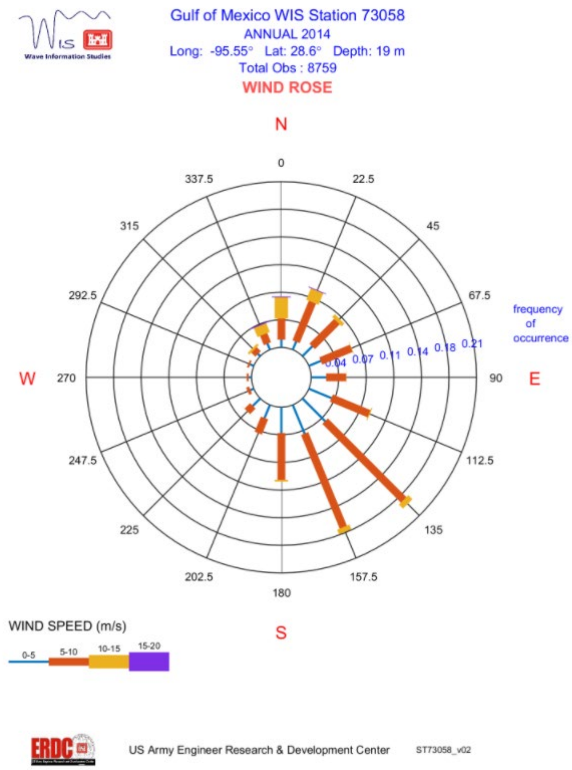
2.3.9. **Winds**

The wind rose displayed in Figure 2-21 was found on the USACE Wave Information Studies website[23]. Station 73058, displayed in Figure 2-20 was determined to be most representative of offshore conditions to the project location, and the most recent data provided by this station is from 2014. The dominant wind direction for 0-5 m/s and 5-10 m/s wind speeds comes predominantly from the southeast, while winds of 10-15 m/s came mainly from the north. The least frequent wind directions for all wind speeds comes from the west.

[22] https://co-ops.nos.noaa.gov/stationhome.html?id=8771341

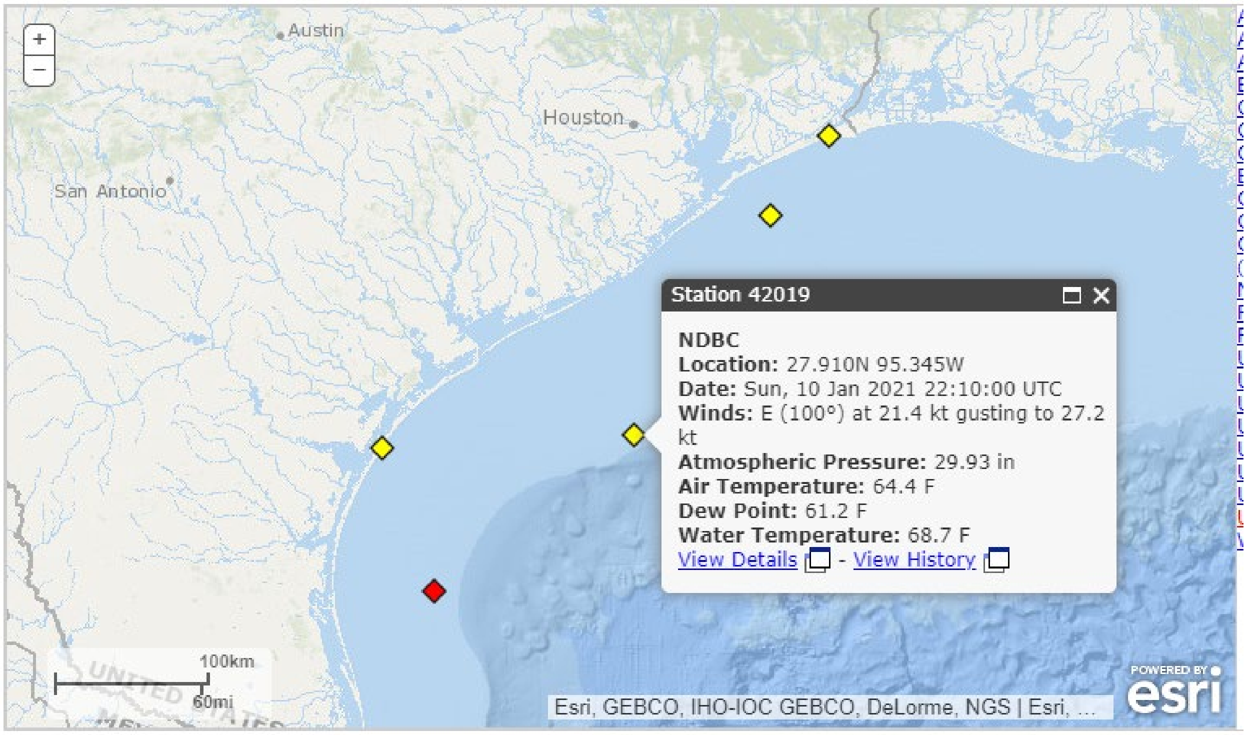
[23] http://wis.usace.army.mil/wis_products.html?dmn=gulf&staid=73058&lat=28.6&lon=-95.55&dep=-19

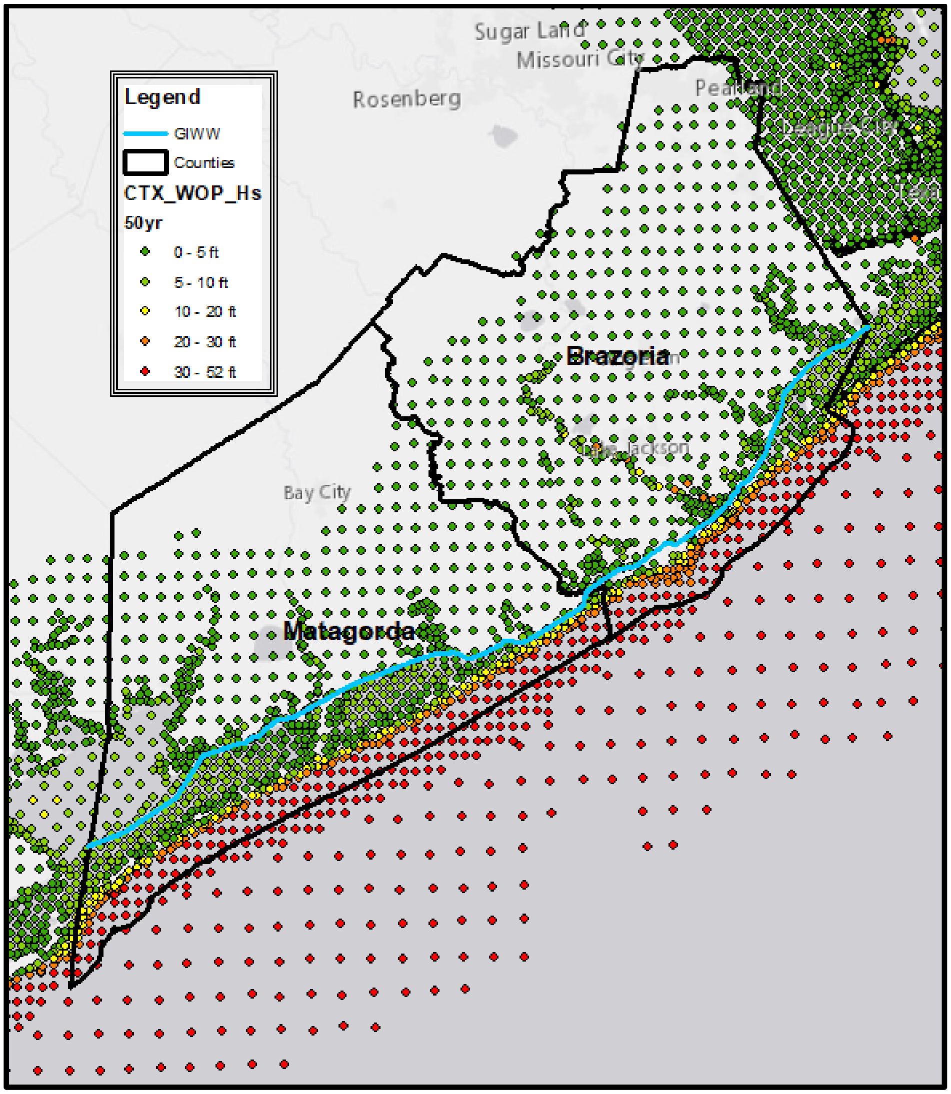

Wave Information Studies
Home
Project Overview
Documentation
Data
Validations
Partners
Publications
Contact Us
Disclaimer
Station ID: 73058
Latitude: 28.6
Longitude: -95.55
Depth: 19 (m)
Products Link
Atlantic 565 Stations
Gulf of Mexico 365 Stations
Alaska 469 Stations
Pacific 374 Stations
Great Lakes 1950 Stations
Lake Ontario 265 Stations
1970-1978; 1979-2014
Lake Erie 243 Stations
1960-1978; 1979-2014
Lake Huron 441 Stations
1961-1978; 1979-2014
Lake Michigan 490 Stations
1960-1978; 1979-2014
Lake Superior 511 Stations
1960-1978; 1979-2014
Go!
Enter Station ID...
Multi Station Download
Important Station Information
Leaflet | © OpenStreetMap contributors, Points © 2012 LINZ



2.3.10. **Waves**

The GIWW is predominantly sheltered and even though there are multiple offshore wave gages (See Figure 2-20 and Figure 2-22), there are no known wave gages directly along the GIWW. For purposes of this study, the probabilistic wave hazard data computed during CTX is more relative. See Figure 2-23 for locations of observation points and 50-yr significant wave heights.


Austin
Houston
San Antonio
Station 42019
NDBC
Location: 27.910N 95.345W
Date: Sun, 10 Jan 2021 22:10:00 UTC
Winds: E (100°) at 21.4 kt gusting to 27.2 kt
Atmospheric Pressure: 29.93 in
Air Temperature: 64.4 F
Dew Point: 61.2 F
Water Temperature: 68.7 F
View Details - View History
100km
60mi
Esri, GEBCO, IHO-IOC GEBCO, DeLorme, NGS | Esri, ...
POWERED BY esri



2.4. FUTURE WITHOUT PROJECT ANALYSES

2.4.1. **H&H Plan**

The following objectives were identified for the H&H Future Without Project analyses.

- Project FWOP/FWP Channel Shoaling Rate along length of channel and dredged material volume annually

- Project FWOP/FWP Barrier and Shoreline Geomorphology to delineate channel subject to Open Water Conditions
- Project storm-related impacts
- Project Sea Level Rise and Climate Change Impacts
- Develop FWOP/FWP Dredge Material Management Plans and Evaluate Issues
- Characterize Geophysical Conditions

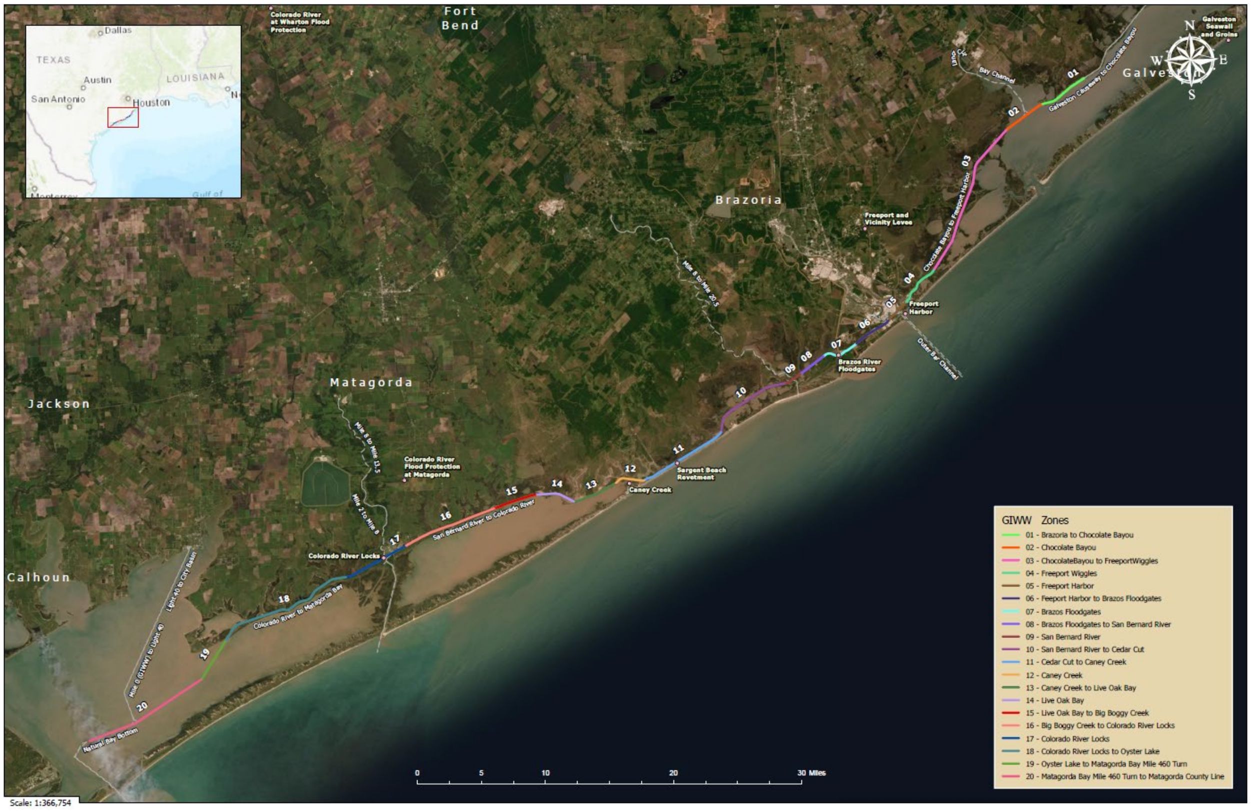
To accomplish these, objectives, the following methodology and modeling plan was developed:

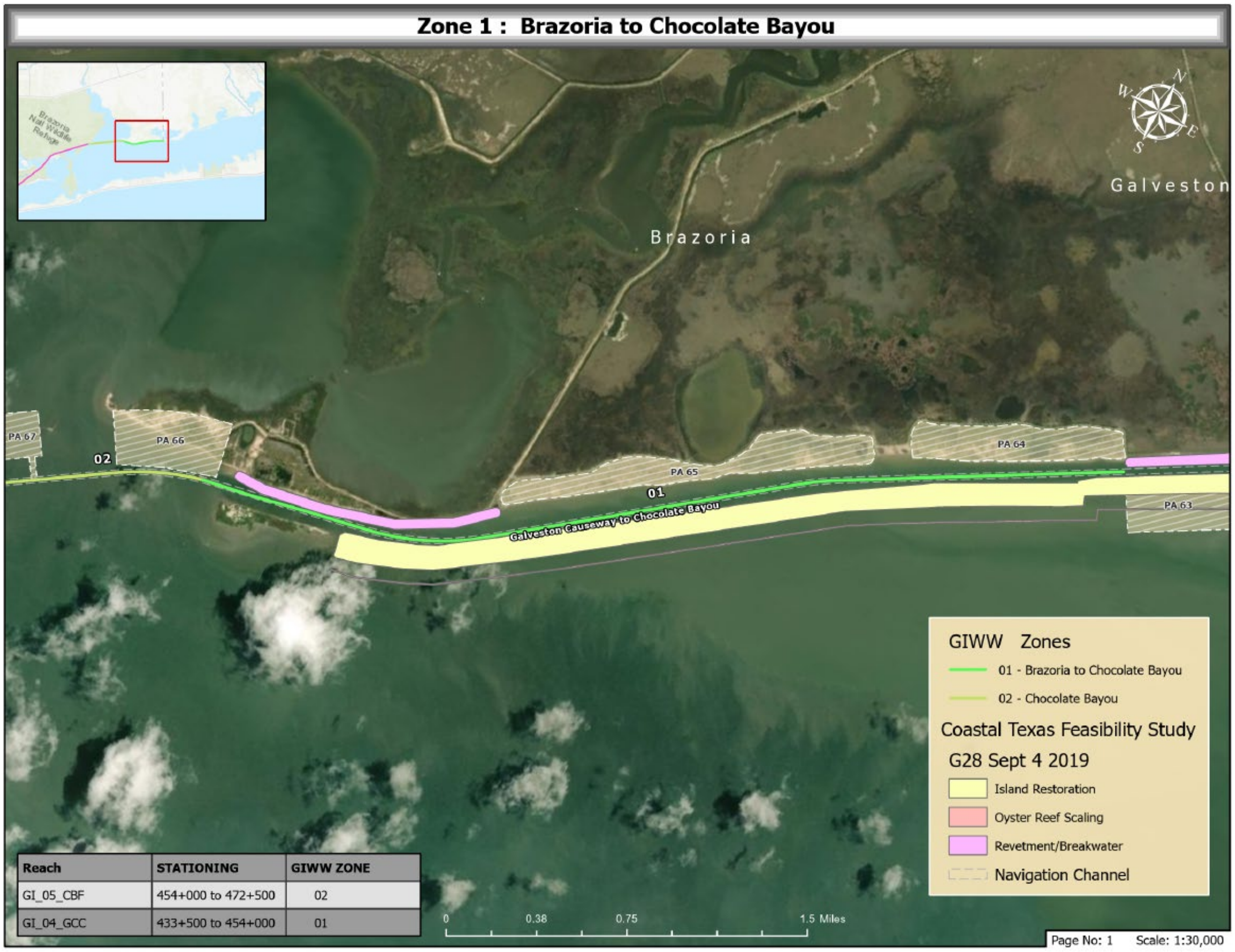
1. Characterize Project Area
2. Project Sea Level Rise
3. Determine Historical Shoaling Analysis using CSAT
4. Geospatial analysis to characterize existing shoreline erosion rates using historical imagery and project future shoreline geomorphology
5. Sediment Transport Modeling using Coastal Modeling System (CMS)
6. Sediment Budget Analysis

2.4.2. Zone Delineation and Initial FWOP Condition Assessments

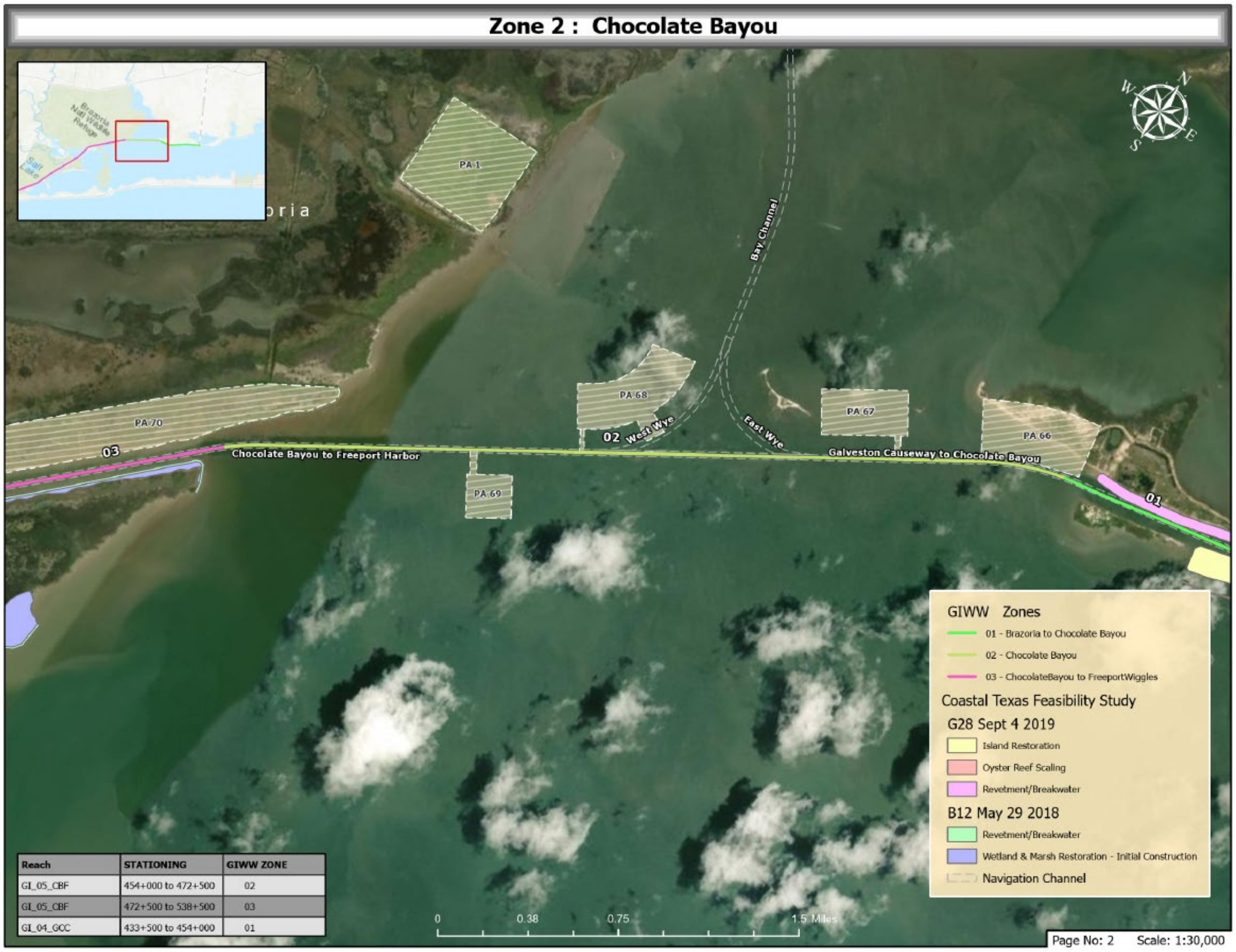
Dynamic changes in habitats, land development, and navigational requirements were observed over the 100-miles of study area. In an effort to focus and organize the analysis of study area the 100-mile stretch was separated into 20 individual zones as shown in , with zones 1 – 10 in Brazoria county and zones 11 – 20 in Matagorda county. After several discussions with stakeholders and careful deliberation amongst the project delivery team (PDT) members it was decided the most crucial zones requiring attention were zones 12, 13, 14, 16, and 18. The root cause of several of the identified concerns within these zones is the lack or degradation of barrier islands separating the GIWW from adjacent bay systems. Without the presence of barrier islands, the GIWW is susceptible to increased sediment shoaling, harsher wind and wave conditions, and an overall decrease in navigation safety.

Each of these zones are outlined in more detail in the following figures.

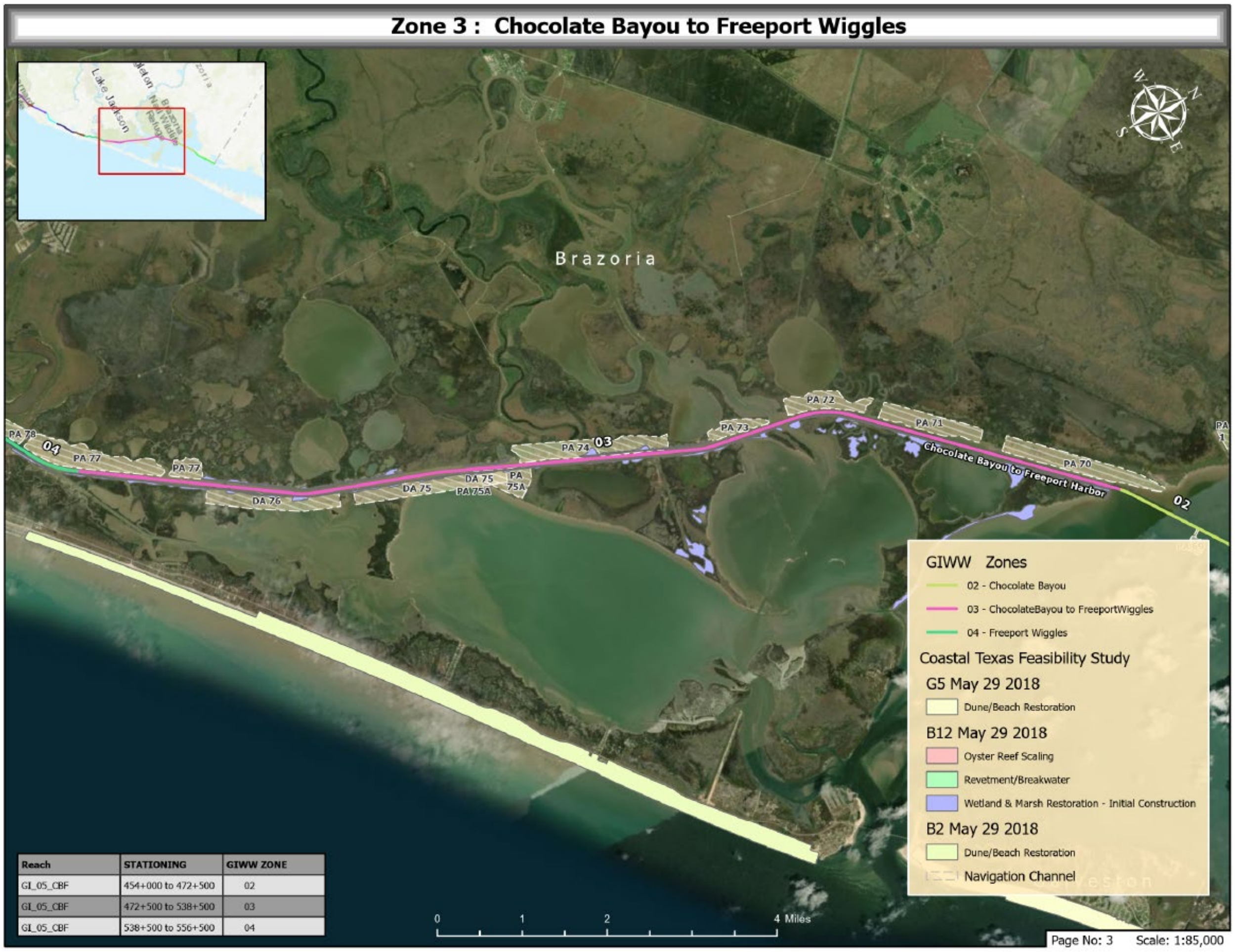




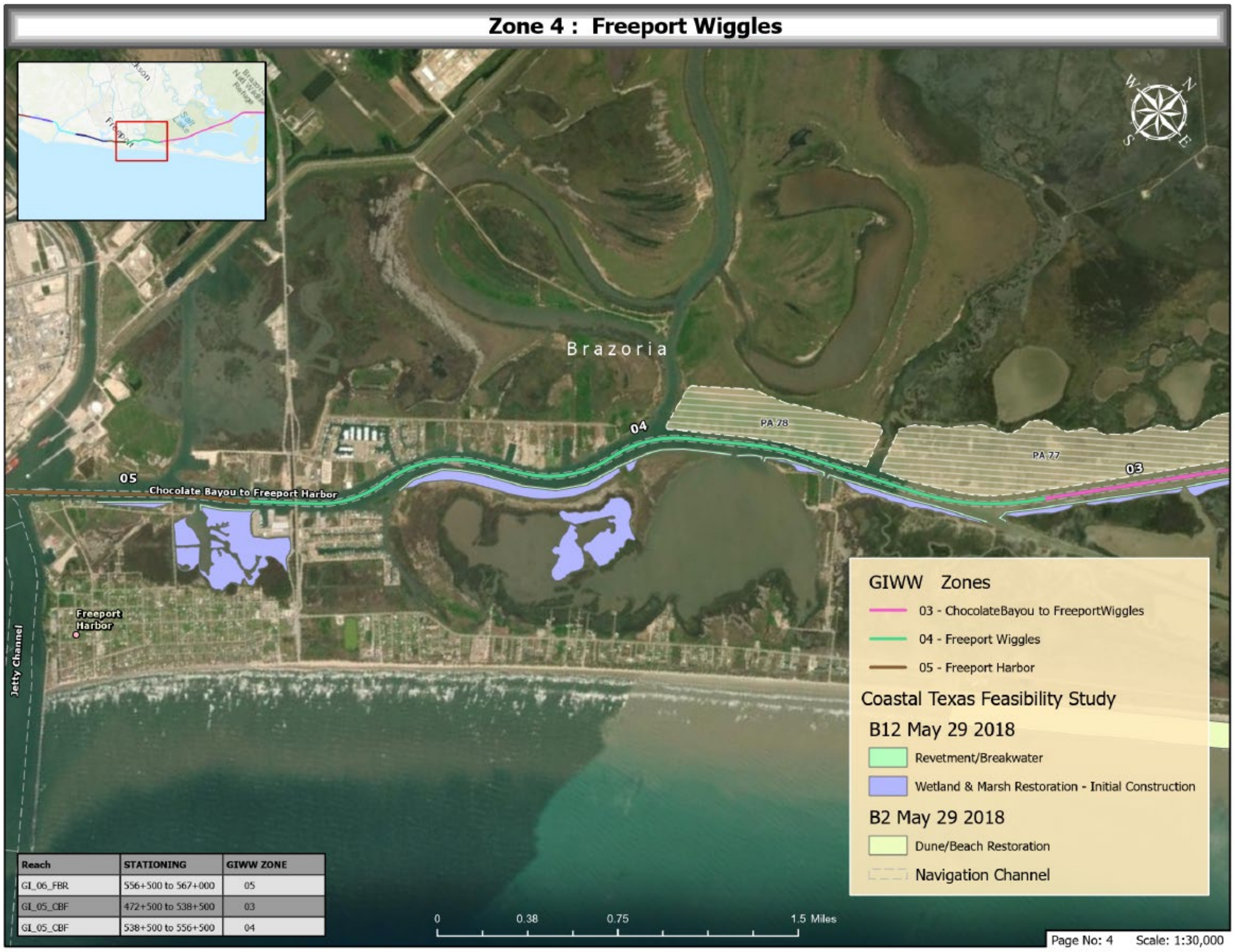
After initial analysis of Zone 1 it was determined that problems associated with this location include light shoaling. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan partially identified problems within this location to include barrier loss, upland Placement Areas (PAs) exposed to wind waves due to barrier loss, moderate shoreline erosion on the upland side of the GIWW, and exposed channel to wind waves due to barrier loss.



After initial analysis of Zone 2 it was determined that problems associated with this location include moderate shoaling, upland island loss, submerged PAs exposed to currents and waves with sea level rise, exposed channel to wind waves, and issues with turning at Chocolate Bayou Wye. Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.



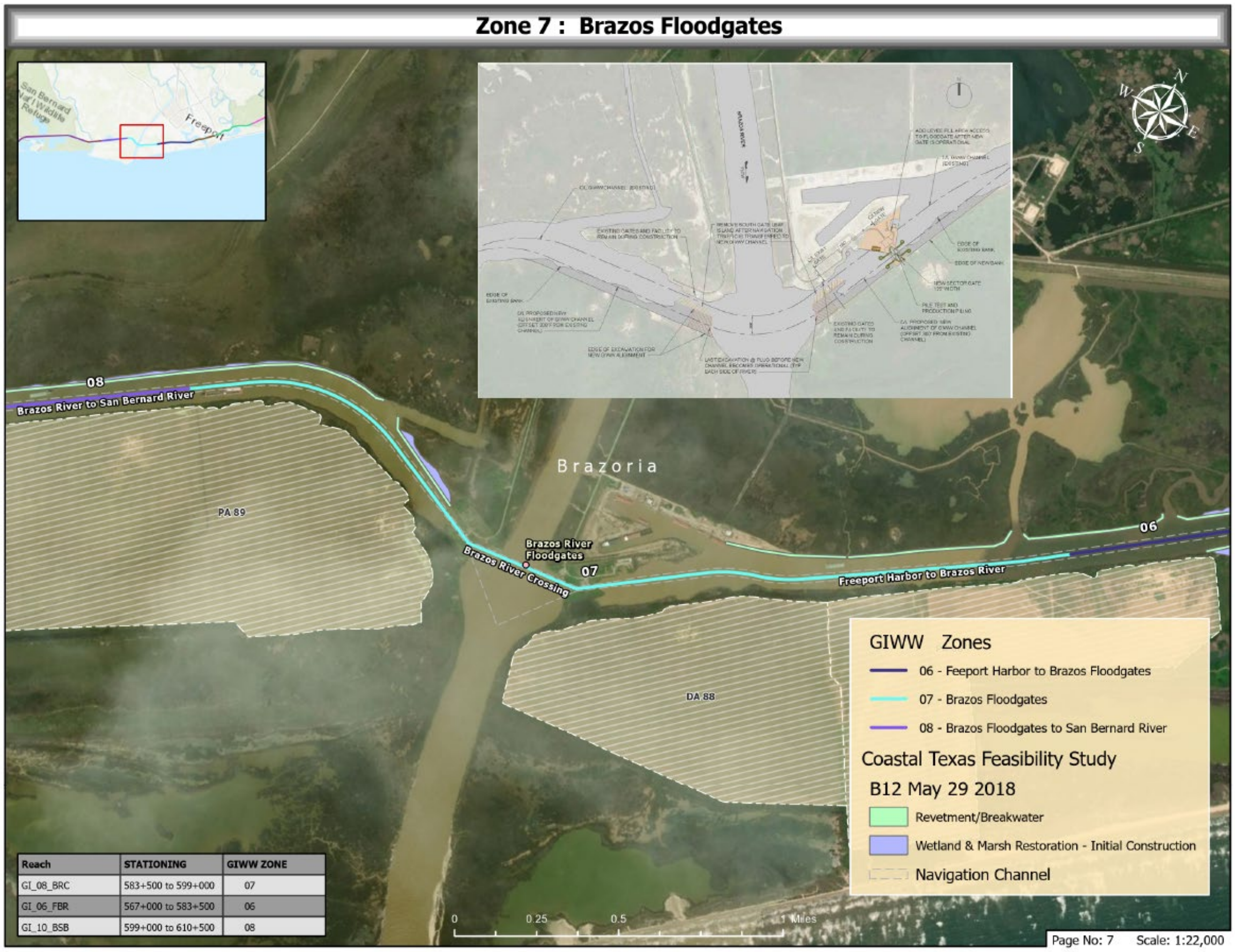
After initial analysis of Zone 3 it was determined that problems associated with this location include moderate shoaling and barrier end loss at Chocolate Bayou. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on upland side, light shoreline erosion on barrier channel side, and barrier loss at Bastrop Bayou (where additional breaches were discovered) and at Oyster Lake (where breach was determined to be imminent).



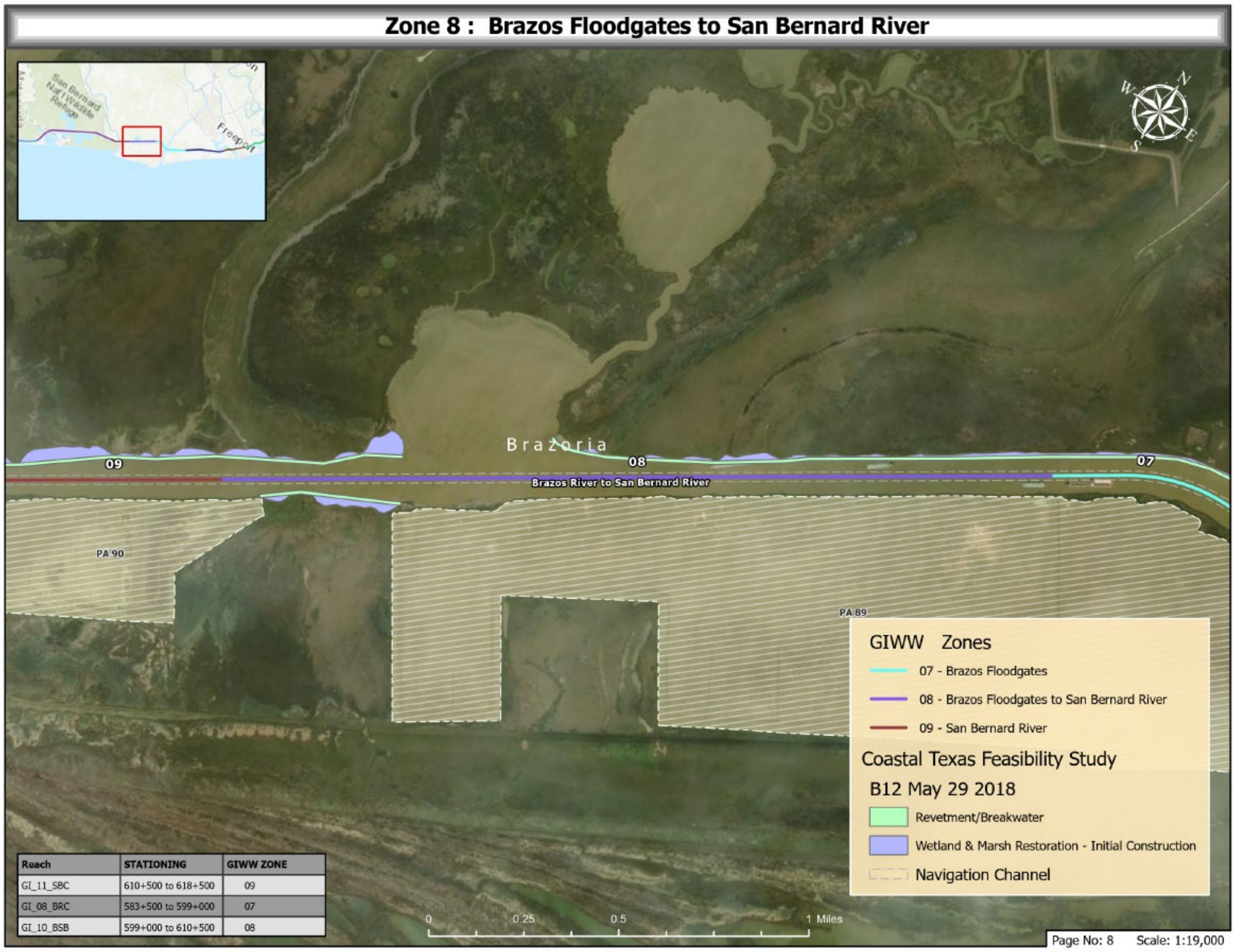
After initial analysis of Zone 4 it was determined that problems associated with this location include difficult negotiation of curves and passing issues. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoaling adjacent to Swan Lake.

After initial analysis of Zone 5 it was determined that problems associated with this location include moderate shoaling, the need to dredge every 1.5 years, and no adjacent placement areas for placement of material. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include light shoreline erosion on barrier channel side.

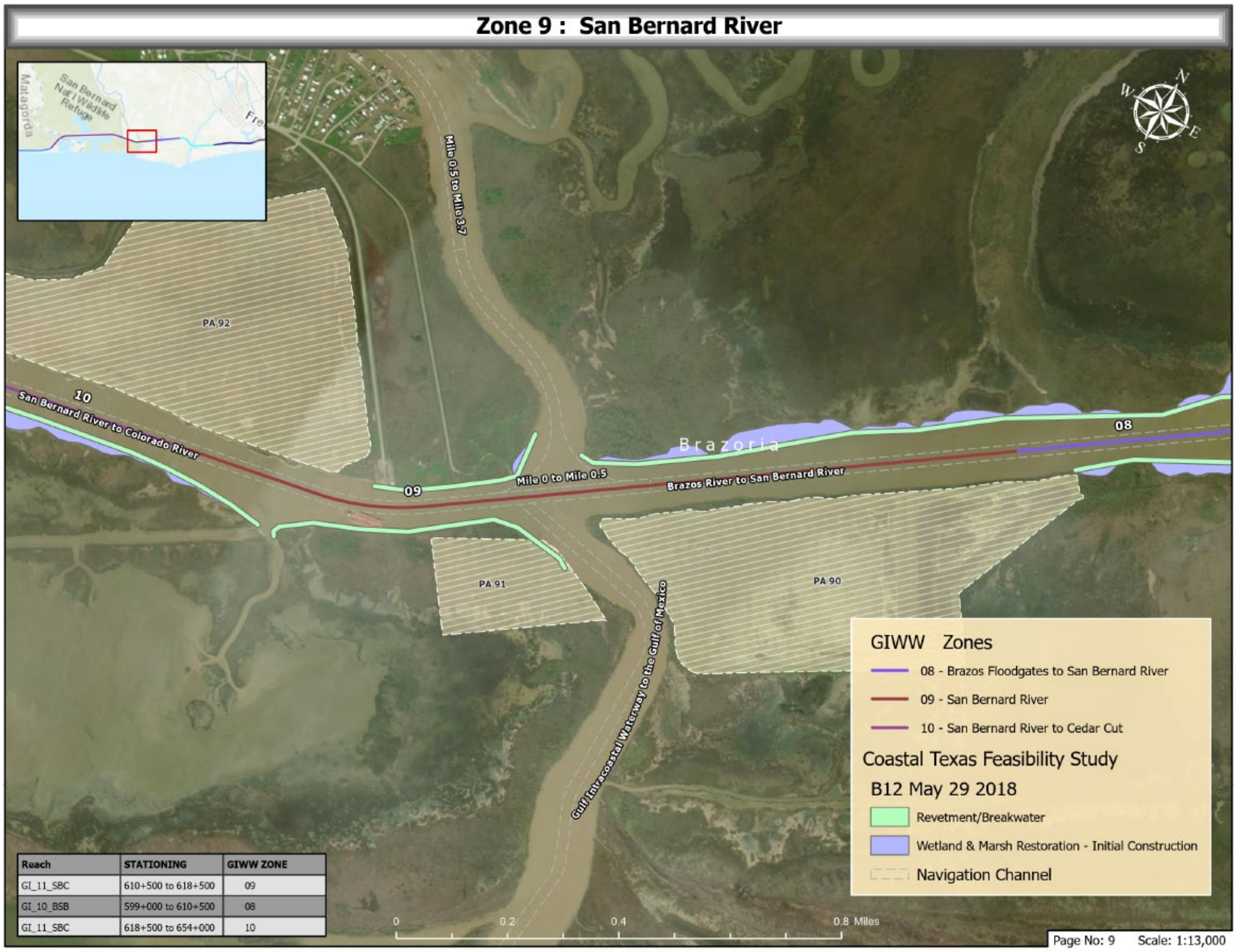
After initial analysis of Zone 6 it was determined that problems associated with this location include high shoaling. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side and light shoreline erosion on the barrier channel side.



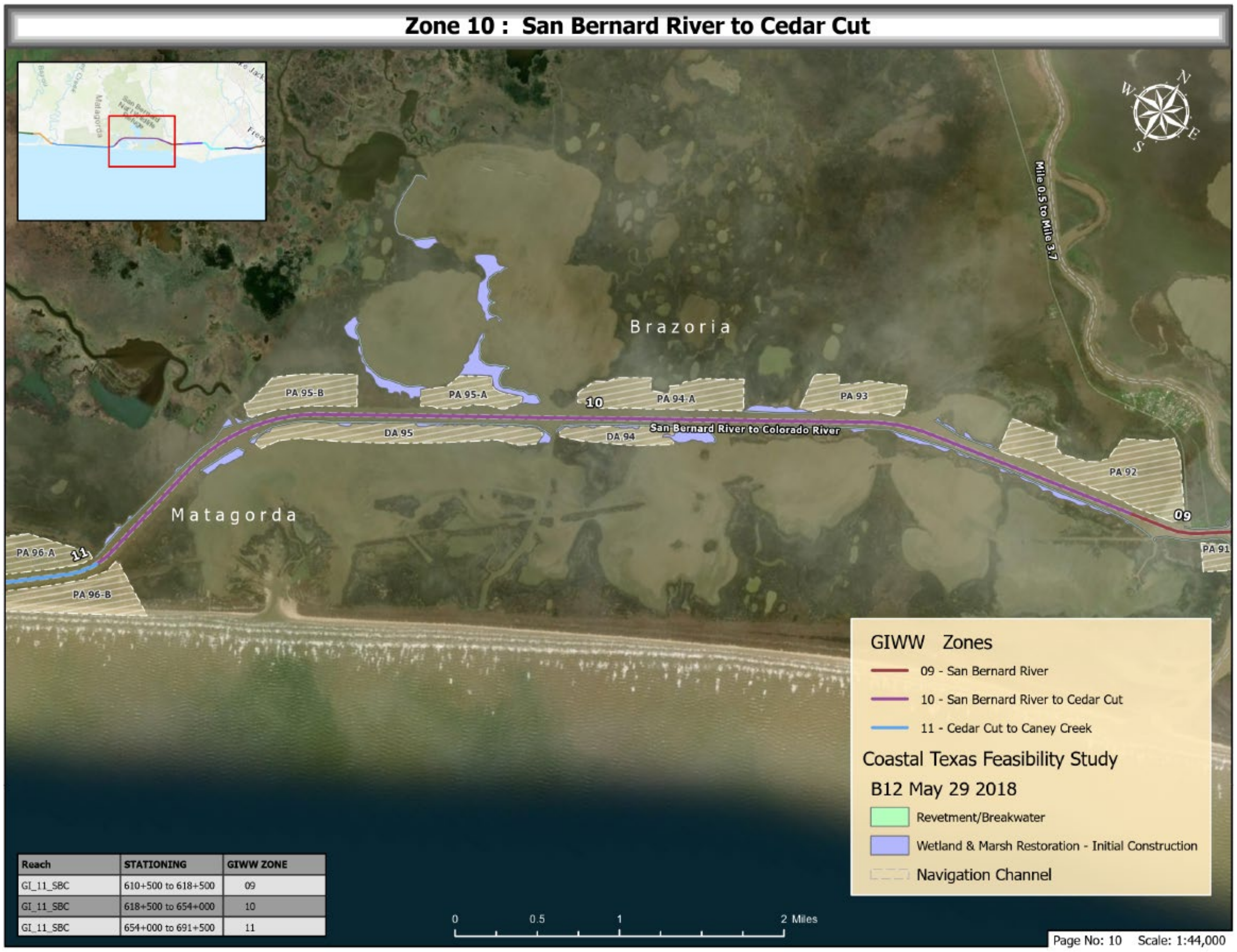
After initial analysis of Zone 7 it was determined that problems associated with this location include high shoaling (most episodic), channel exposed to cross currents (tidal and riverine), dwindling PA capacity, and traffic jams due to wait times and insufficient moorings. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on upland side and navigation safety specifically regarding accidents at gates being addressed in BRFG-CRL Project.



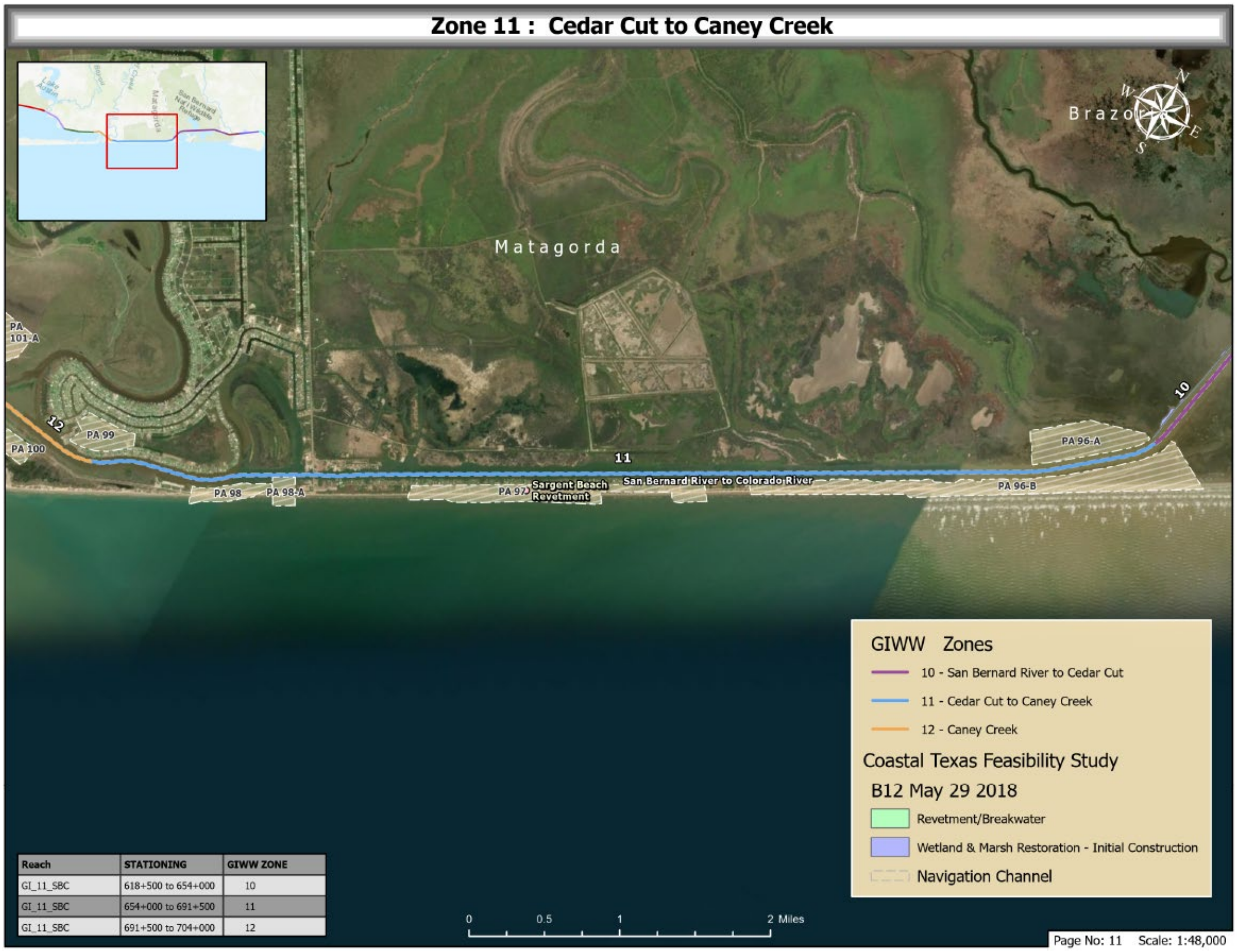
After initial analysis of Zone 8 it was determined that problems associated with this location include moderate shoaling. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side.



After initial analysis of Zone 9 it was determined that problems associated with this location include high shoaling and channel exposed to cross currents from tidal and riverine influences. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side and PA 2 at risk due to channel erosion.



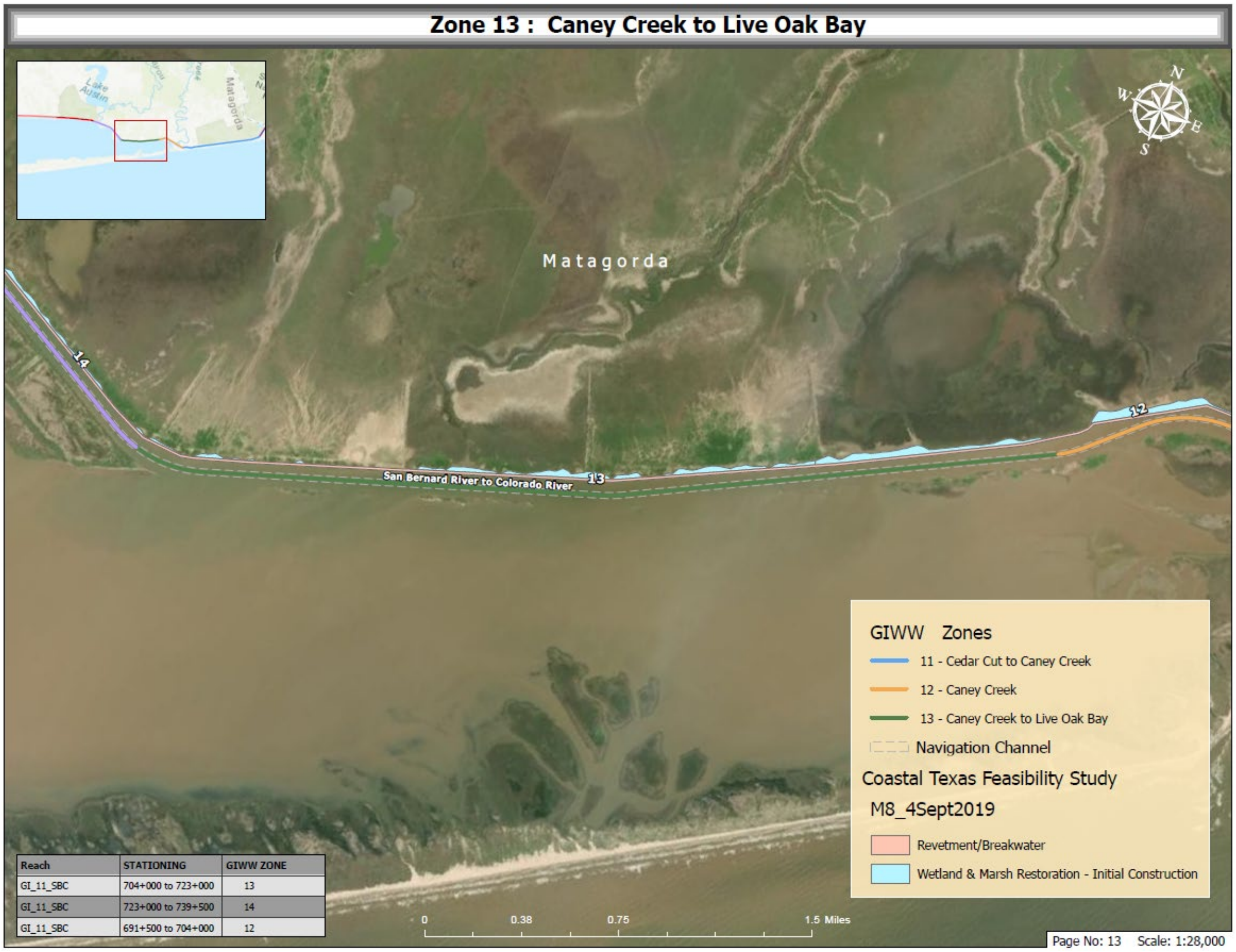
After initial analysis of Zone 10 it was determined that problems associated with this location include moderate episodic shoaling. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side and light shoreline erosion on the barrier channel side.



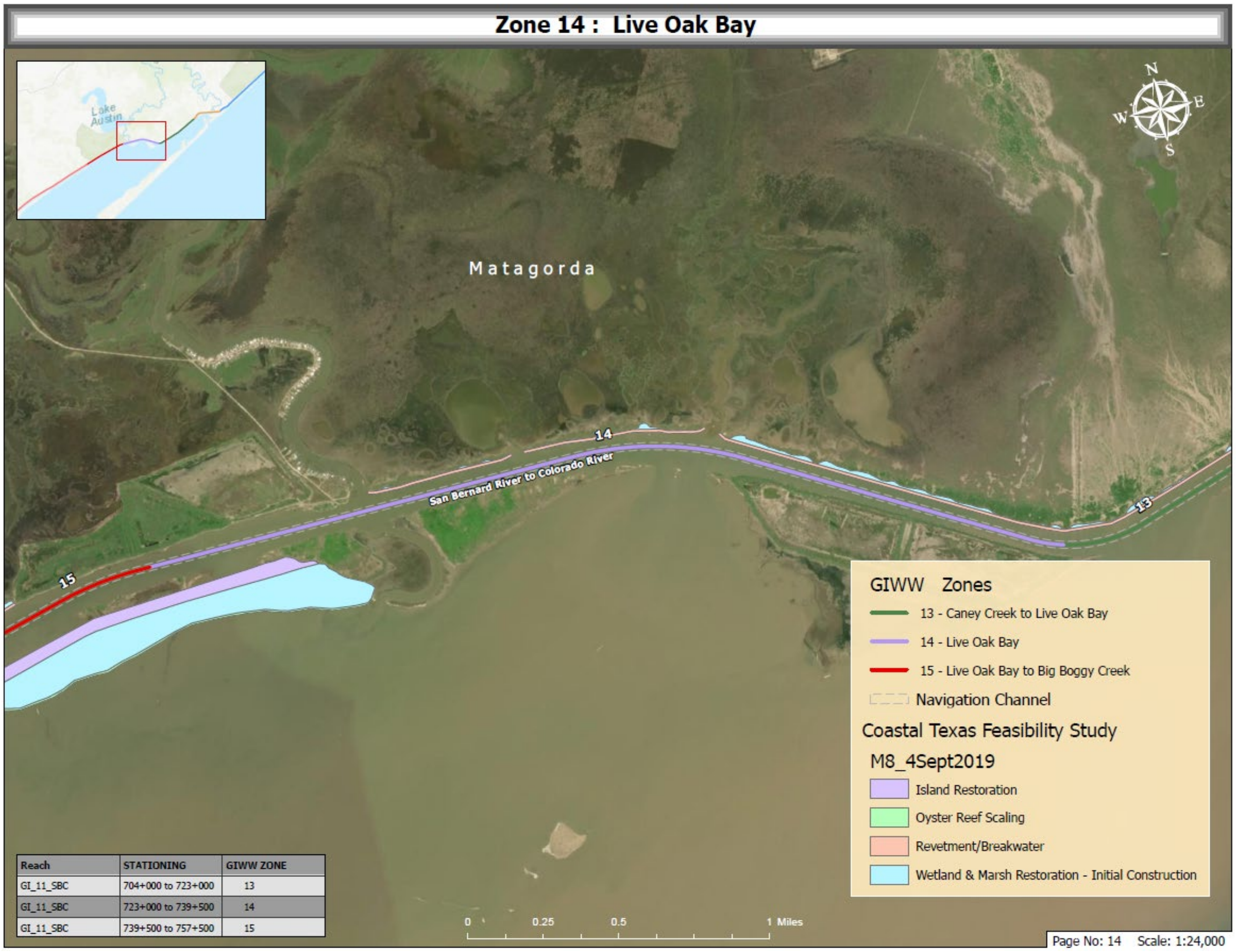
Reach	STATIONING	GIWW ZONE
GI_11_SBC	618+500 to 654+000	10
GI_11_SBC	654+000 to 691+500	11
GI_11_SBC	691+500 to 704+000	12

After initial analysis of Zone 11 it was determined that problems associated with this location include light shoaling, moderate shoreline erosion on the upland side, light shoreline erosion on the barrier channel side, high shoreline erosion on the barrier Gulf side (PA loss), and the channel being too narrow for at-speed passing. HTRW locations have also been identified within this zone and there is an increased likelihood of disturbing these areas as the project footprint increases. Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.

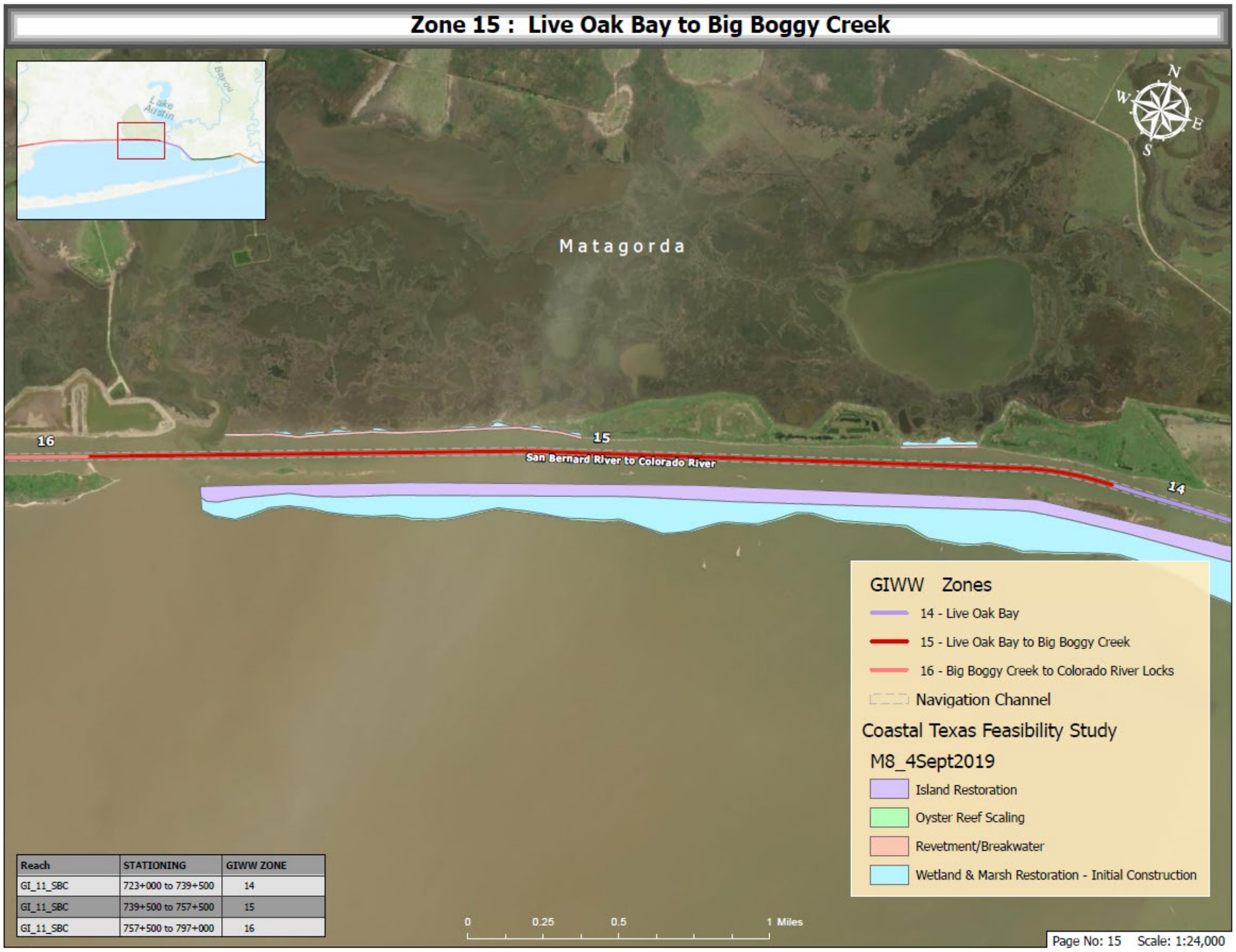
After initial analysis of Zone 12 it was determined that problems associated with this location include high shoaling, the channel being exposed to high cross currents from tidal and riverine influences, moderate shoreline erosion on the barrier channel side, moderate shoreline erosion on the barrier Gulf side, and the channel being too narrow for at-speed passing. HTRW locations have also been identified within this zone and there is an increased likelihood of disturbing these areas as the project footprint increases. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side.



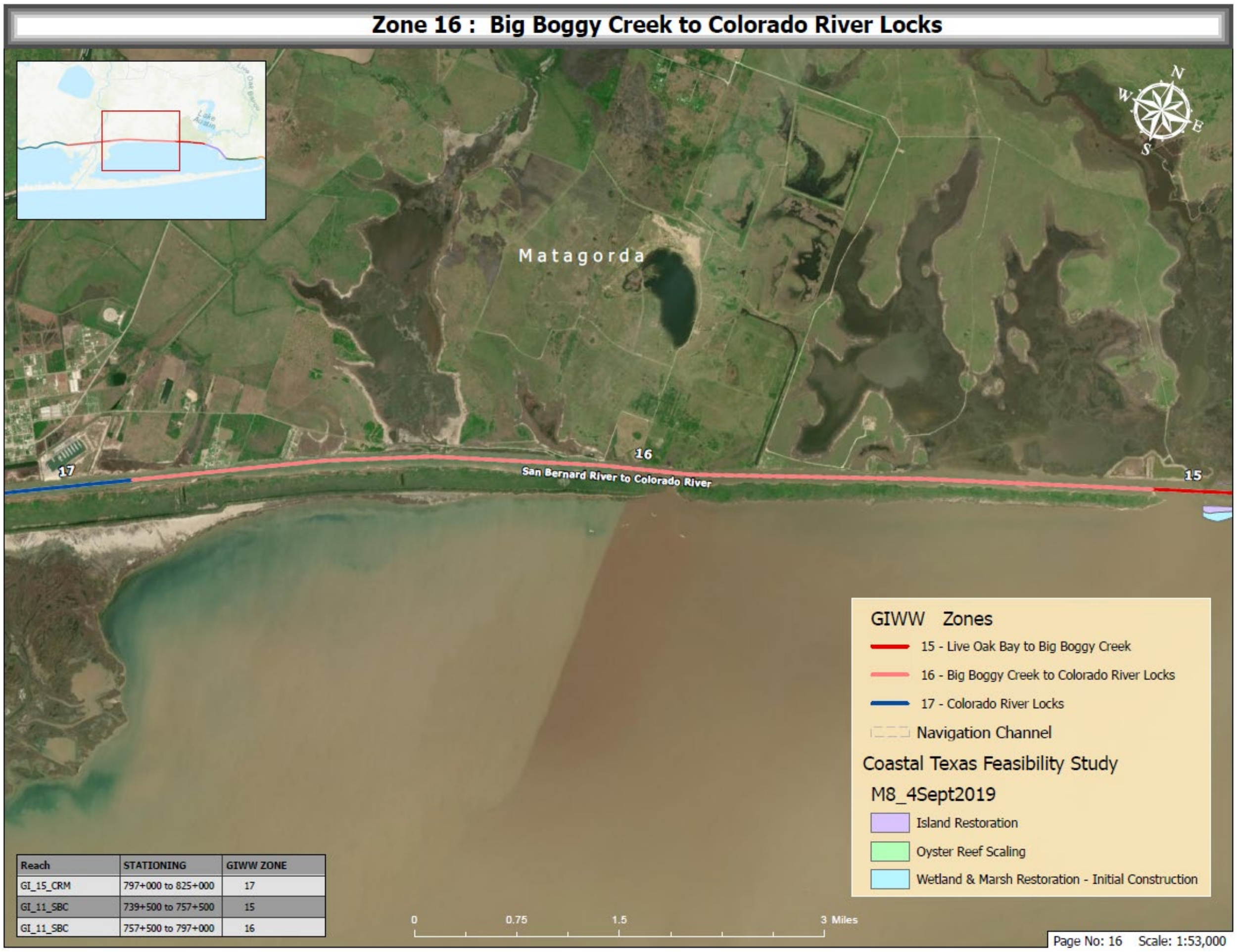
After initial analysis of Zone 13 it was determined that problems associated with this location include moderate shoaling, barrier island loss (PA loss), Gulf-side PAs being exposed, and the channel being exposed to wind waves. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side and upland PAs being exposed to wind waves.



After initial analysis of Zone 14 it was determined that problems associated with this location include shoaling. Cross referencing this information against other projects in the area revealed that the Coastal Texas Plan identified problems within this location to include moderate shoreline erosion on the upland side (light erosion at the PAs), upland PAs being exposed to wind waves, barrier island loss (PA loss), Gulf-side PAs being exposed, and the channel being exposed to wind waves.

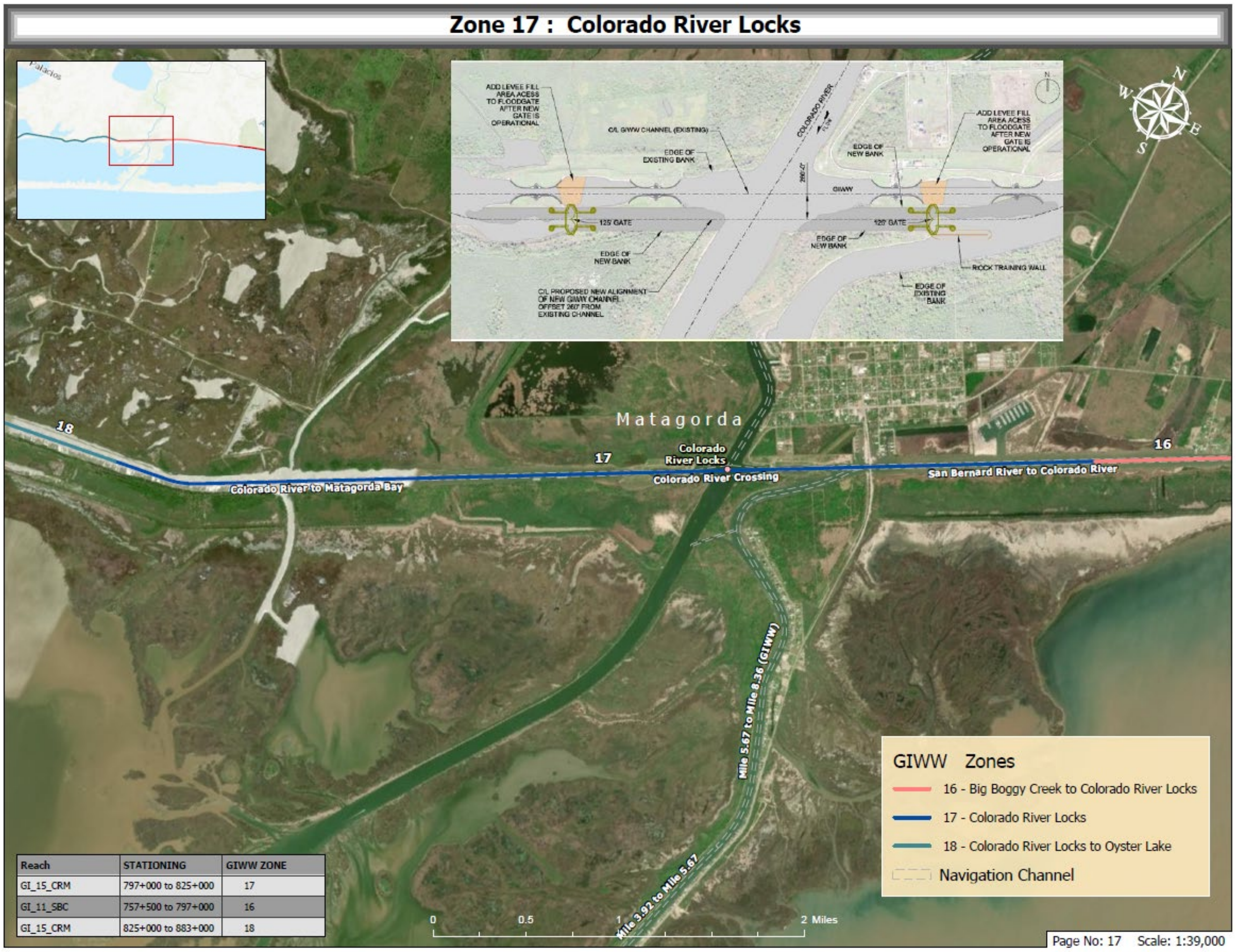


After initial analysis of Zone 15 it was determined that problems associated with this location include moderate shoaling, moderate shoreline erosion on the upland side (light erosion at the PAs), upland PAs being exposed to wind waves, barrier island loss (PA loss), Gulf-side PAs being exposed, and channel exposure to wind waves. Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.



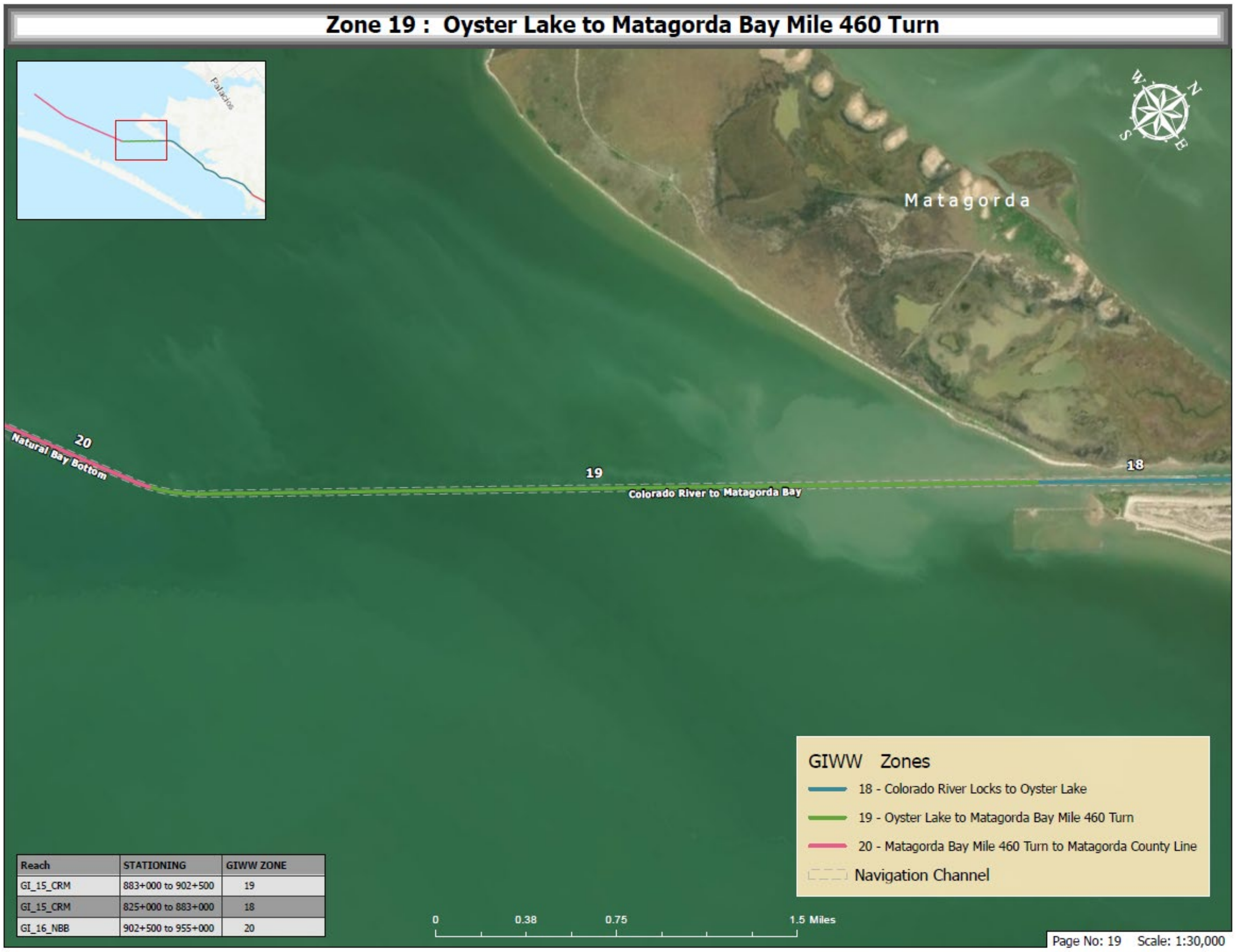
Reach	STATIONING	GIWW ZONE
GI_15_CRM	797+000 to 825+000	17
GI_11_SBC	739+500 to 757+500	15
GI_11_SBC	757+500 to 797+000	16

After initial analysis of Zone 16 it was determined that problems associated with this location include light shoaling at Mile 435, moderate shoaling at the east end, moderate shoreline erosion on the upland side, light shoreline erosion on the barrier channel side, and high shoreline erosion on the barrier gulf side (PA loss). Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.



After initial analysis of Zone 17 it was determined that problems associated with this location include moderate shoaling, light shoreline erosion on the barrier channel side, moderate shoreline erosion on the upland side, and the channel being exposed to cross currents from tidal and riverine influences. Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.

After initial analysis of Zone 18 it was determined that problems associated with this location include high shoaling at Oyster Lake and Mad Island, light shoreline erosion on the barrier channel side, moderate shoreline erosion on the upland side, and high shoreline erosion on the barrier Gulf side (PA loss). Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.



After initial analysis of Zone 19 it was determined that problems associated with this location include moderate shoaling at the west end, high shoaling at Oyster Lake, the channel being exposed to wind waves along the open bay, and adjacent submerged PAs being exposed to currents and waves with sea level rise (SLR). Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.

After initial analysis of Zone 20 it was determined that problems associated with this location include moderate shoaling west of the Mile 465 turn, the channel being exposed to wind waves along the open bay, and there are no adjacent PAs. Cross referencing this information against other projects in the area revealed that no other projects addressed issues in this location.

2.4.3. Sea Level Rise

The USACE Sea Level Change Curve Calculator (Version 2019.21) website[24] is an online tool which provides low, intermediate, and high projections to regional sea level rise (RSLR) based on select gages along the United States coastline. This tool is the USACE authorized method of analyzing RSLR and utilizes Equation 2 from EC 1165-2-212 to establish the three SLC scenarios.

[24] http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html

$$E(t) = 0.0017t + bt^2 \qquad \text{Eq. (2)}$$

The bt^2 term on the right-hand side of Eq. (2) is the acceleration term and is calculated separately for the intermediate and high scenario curves relative to the low scenario curve. The current National Tidal Datum Epoch (NTDE) is 1983-2001 with a mid-epoch of 1992. Thus 1992 is used as the base year for most gages. However, a few gages follow a 5-year epoch and require the base year to be changed from 1992 to 2004 when analyzing these special gages. Furthermore, it is recommended to use only gages that contain at least 40 years of recorded data regardless of their base year.

After reviewing the assortment of available gages along the Texas coast it was found that the Galveston Pier 21 gage (8771450) was the closet northernmost gage and the Rockport, Texas gage (8774770) was the closet southernmost gage in proximity to the study area with at least 40 years of recorded data. It was also determined that the Galveston Pier 21 gage (8771450) followed the current epoch with the 1992 base year while the Rockport, TX gage (8774770) followed the 5-year epoch with the 2004 base year.

The SLC calculator utilizes a SLC Rate specific for each gage and provides both a "NOAA 2006" SLC rate and a "Regional" SLC rate. A plot of relative sea level trends for Rockport, TX (8774770) was collected from NOAA's Tides and Currents website and is displayed in Figure 2-45. The temporal extent of the data present for each station is equivalent to the time the gage was in use.

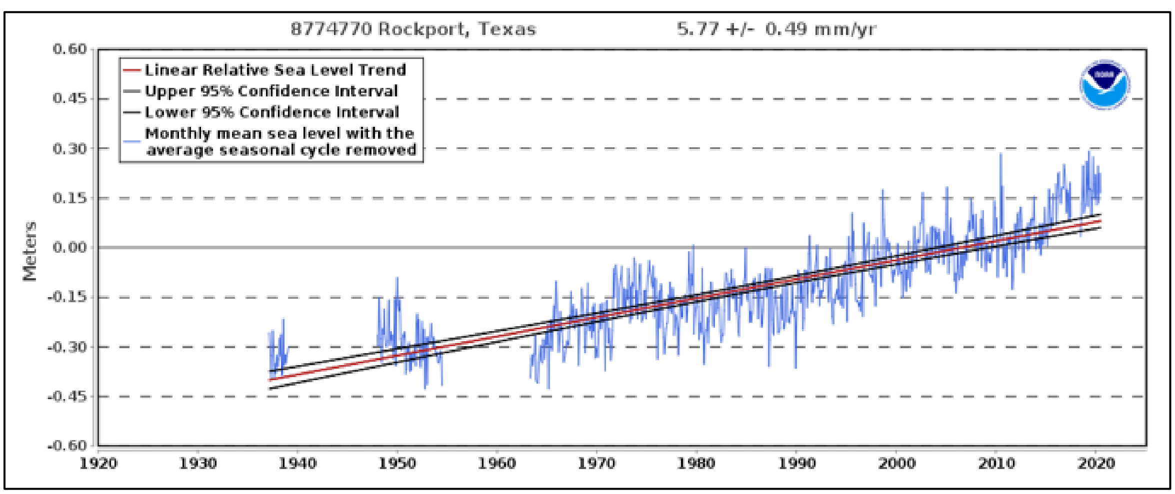


Figure 2-45: Relative Sea Level Trend for Rockport, TX (8774770)

The USACE Climate Preparedness and Resilience (CPR) has further analyzed SLC rates and their recommendation is listed in Tale 2-8 along with the "NOAA 2006" and "Regional" SLC rates for these two gages.

Table 2-6: Summary of Gage Stations Data for This Study

Gage Location	Gage Number	Sea Level Change Rates (mm/yr.)		
		NOAA 2006	Regional	CPR (Recommended)
Galveston, TX	8771450	6.39	6.42	6.55
Rockport, TX	8774770	5.16	5.35	5.77

Of the two gages, the Rockport, TX gage (8774770) with the SLC Rate of 5.77 (mm/yr.) was chosen as the representative SLC data for this project based on proximity and similar geologic setting. Table 2-7 outlines the process of converting the USACE Sea Level Change Curve Calculator (Version 2019.21) output from the base year of 1992 to 2004 and from MSL to NAVD88. It is important to note that the left side of each "Acceleration (bt^2)" column within Table 2-7 corresponds to the respective "USACE Int" column while the right side of each "Acceleration (bt^2)" column corresponds to the respective "USACE High" column. In the 1992 base year "Acceleration (bt^2)" term is calculated by subtracting the "USACE Low" column from the "USACE Int" column and again from the "USACE High" column. These calculated "Acceleration (bt^2)" values were then transferred to their respective years in the 2004 base year starting with year 2005 and the year 2004 being zeroed out. The new "USACE Low" value was then calculated by multiplying the SLC Rate (5.77 mm/yr. converted to m/yr.) by the change in years (i.e. 2005 – 2004 = 1 year) by the factor of 3.281. Each consecutive time step (i.e. 5yrs) adds to the previously calculated "USACE Low" value. The "USACE Int" and "USACE High" values were recalculated by adding the respective "Acceleration (bt^2)" value to the respective "USACE Low" value.

Table 2-7: Calculator Output 2019 RSLR 5.77 mm/yr. for Rockport, TX gage (8774770)

RSLR (ft, MSL) - 1992 Base Year

Year	USACE Low	Acceleration (bt^2)		USACE Int	USACE High
1992	0	0	0	0	0
1995	0.06	0	0	0.06	0.06
2000	0.15	0.01	0.03	0.16	0.18
2005	0.25	0.01	0.06	0.26	0.31
2010	0.34	0.03	0.12	0.37	0.46
2015	0.44	0.04	0.19	0.48	0.63
2020	0.53	0.07	0.29	0.6	0.82
2025	0.63	0.09	0.4	0.72	1.03
2030	0.72	0.13	0.53	0.85	1.25
2035	0.81	0.17	0.69	0.98	1.5
2040	0.91	0.2	0.85	1.11	1.76
2045	1	0.25	1.05	1.25	2.05
2050	1.1	0.3	1.25	1.4	2.35
2055	1.19	0.36	1.47	1.55	2.66
2060	1.29	0.41	1.71	1.7	3
2065	1.38	0.48	1.98	1.86	3.36
2070	1.48	0.54	2.25	2.02	3.73
2075	1.57	0.61	2.56	2.18	4.13
2080	1.67	0.68	2.87	2.35	4.54
2085	1.76	0.77	3.21	2.53	4.97
2090	1.86	0.85	3.56	2.71	5.42
2095	1.95	0.94	3.93	2.89	5.88
100	2.04	1.04	4.33	3.08	6.37

RSLR (ft, MSL) - 2004 Base Year

Year	USACE Low	Acceleration (bt^2)		USACE Int	USACE High
2004	0	0	0	0.00	0.00
2005	0.02	0.01	0.06	0.03	0.08
2010	0.11	0.03	0.12	0.14	0.23
2015	0.21	0.04	0.19	0.25	0.40
2020	0.30	0.07	0.29	0.37	0.59
2025	0.40	0.09	0.4	0.49	0.80
2030	0.49	0.13	0.53	0.62	1.02
2035	0.59	0.17	0.69	0.76	1.28
2040	0.68	0.2	0.85	0.88	1.53
2045	0.78	0.25	1.05	1.03	1.83
2050	0.87	0.3	1.25	1.17	2.12
2055	0.97	0.36	1.47	1.33	2.44
2060	1.06	0.41	1.71	1.47	2.77
2065	1.15	0.48	1.98	1.63	3.13
2070	1.25	0.54	2.25	1.79	3.50
2075	1.34	0.61	2.56	1.95	3.90
2080	1.44	0.68	2.87	2.12	4.31
2085	1.53	0.77	3.21	2.30	4.74
2090	1.63	0.85	3.56	2.48	5.19
2095	1.72	0.94	3.93	2.66	5.65
2100	1.82	1.04	4.33	2.86	6.15

MSL to NAVD88 Conversion

USACE Low	USACE Int	USACE High
1.13	1.13	1.13
1.15	1.16	1.21
1.24	1.27	1.36
1.34	1.38	1.53
1.43	1.50	1.72
1.53	1.62	1.93
1.62	1.75	2.15
1.72	1.89	2.41
1.81	2.01	2.66
1.91	2.16	2.96
2.00	2.30	3.25
2.10	2.46	3.57
2.19	2.60	3.90
2.28	2.76	4.26
2.38	2.92	4.63
2.47	3.08	5.03
2.57	3.25	5.44
2.66	3.43	5.87
2.76	3.61	6.32
2.85	3.79	6.78
2.95	3.99	7.28

Figure 2-28 displays the low, intermediate, and high estimated relative SLC projections for the Rockport, TX (8774770) in feet, MLLW.

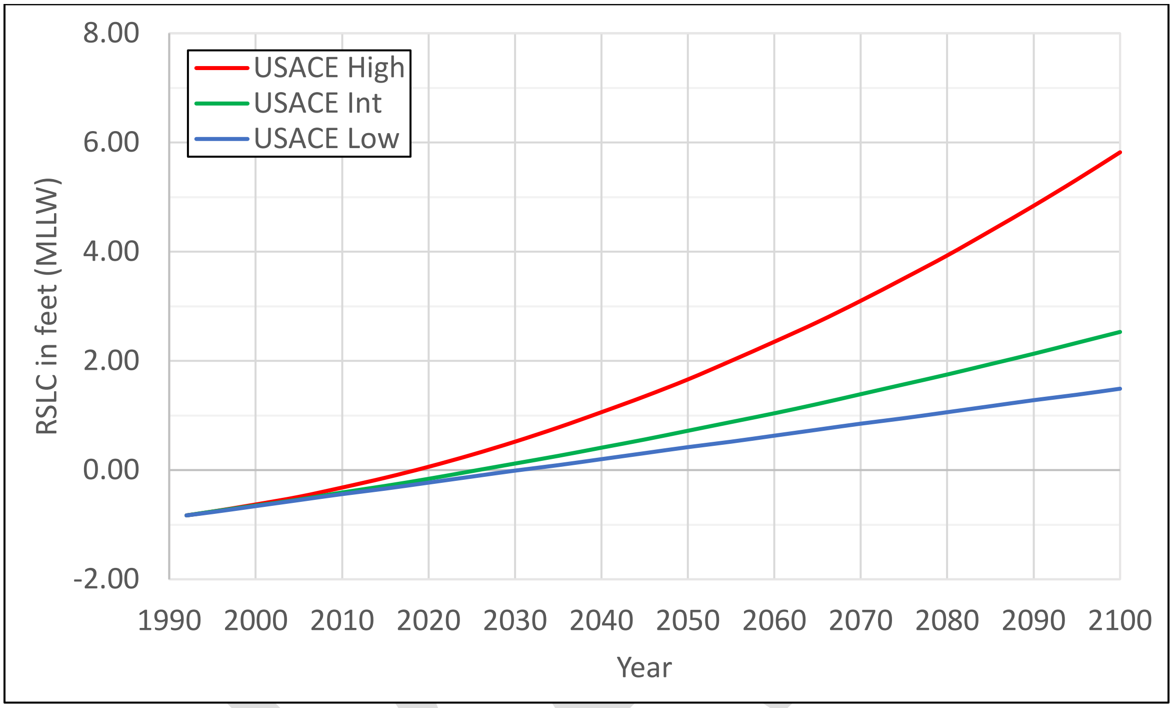


Figure 2-46: Regional Sea Level Change Based on Rockport, Texas (Gage 8774770)

The USACE Intermediate curve was chosen as a conservative RSLR Scenario for this study and a summary of the data is provided in Table 2-8. Also summarized in Table 2-9 for comparison purposes is the RSLR defined in other recent nearby projects.

Table 2-8: Summary of RSLR Estimation for this Study

NOAA Gauge	Mid Epoch Year	Tidal Datum (MSL, MLLW)	Year	Intermediate RSLR (ft, NAVD88)	Change from 2020 (ft, NAVD88)
8774770, Rockport, TX	2004	MSL	2020	1.50	0.00
			2030	1.75	0.25
			2080	3.25	1.75

Table 2-9: Summary of RSLR Estimations for Previous Projects

Project	Gage Location	Gage Number	Project Start Year	Project End Year	RSLC (ft/yr.)	Relative Sea Level Rise (ft)		
						Low	Intermediate	High
Brazos River Floodgates	Freeport, TX	8772440	2025	2125	N/A	2	3.6	9
Colorado River Floodgates	Unknown	N/A	N/A	N/A	N/A	0	1	2
Coastal Texas	Galveston, TX	8771450	1992	2100	+0.02096	1.7	2.7	5.8
	Galveston, TX	8771510	1992	2100	+0.02244	N/A	N/A	N/A
	Freeport, TX	8772440	1992	2100	+0.01427	N/A	N/A	N/A
	Rockport, TX	8774770	1992	2100	+0.01693	1.4	2.4	5.5
	Port Mansfield, TX	8778490	1992	2100	+0.00633	N/A	N/A	N/A
	Port Isabel, TX	8779770	1992	2100	+0.01194	1.3	2.3	5.6
Freeport Harbor Channel Improvement	Freeport, TX	8772440	2020	2070	+0.00558	0.71	1.18	2.68
Sabine to Galveston	Sabine Pass, TX	8770570	2030	2050	+0.01857	1.08	1.38	2.38
	Freeport, TX	8772440	2030	2050	+0.01427	0.83	1.13	2.07
	Sabine Pass, TX	8770570	2030	2080	+0.01857	1.63	2.32	4.51
	Freeport, TX	8772440	2030	2080	+0.01427	1.26	1.94	4.13
	Sabine Pass, TX	8770570	2030	2130	+0.01857	2.56	4.26	9.62
	Freeport, TX	8772440	2030	2130	+0.01427	1.97	3.66	9.03

2.4.4. CSAT Analysis

The Corps Shoaling Analysis Tool (CSAT version 2.2.0) was applied in this study to estimate annual shoaling rates along all NCF reaches within Matagorda and Brazoria Counties. The NCF was created in 2005 as a means of supporting the USACE Navigation mission to maintain United States waterways for safe and efficient commerce, national security requirements, and recreation. The NCF allows for a Geographical Information System (GIS) representation of the USACE coastal navigation channels, and is divided up into smaller reaches, which for this analysis are significant for pinpointing shoaling hot spots along the GIWW and connected channels. CSAT leverages both e-hydro surveys and the NCF which were developed by the USACE to better manage the large quantities of data associated with navigation channel dredging. These tools are uniquely available to USACE to support its mission for maintaining federal navigation projects. CSAT-generated high-resolution shoaling maps can support easy identification of shoaling and erosion hot spots. However, the CSAT cannot be applied to estimate shoaling rate prior to 2011 due to gaps in historical hydrographic surveys record in the e-hydro database.

Additional detail on the methodology and results of the CSAT analysis can be found in Annex 2 of the Engineering Appendix.

2.4.4.1. **CSAT Assumptions**

CSAT analysis assumes that historical trends will continue unless there are external factors that have been altered. In the case of Navigation Channels, the dimensions of the width and depth are consistent between years and require extensive studies and authorizations for any changes to occur. Any modifications to the channel design need to be identified so that only the surveys after the updates are used in the analysis. Additionally, the analysis should be performed using surveys measured with the same vertical datum and same hydrographic survey techniques. Meteorological events may influence the shoaling predictions, particularly in areas that have a limited number of surveys. Seasonal variations in rainfall totals or extra-tropical storm events that impact the channel may result in changes to the sediment flux in the system. Therefore, fluctuations due to anomalous events should be considered when interpreting the CSAT results. In addition, the user may choose to remove the survey from the analysis and classify the survey as emergency response to avoid skewing the results from those anomalous events.

2.4.4.2. **CSAT Methods**

The following four points provides details on how CSAT computes shoaling rates. Additional detailed information on CSAT computation methods are available in Dunkin et al. (2018).

1. Elevation differences are calculated for the survey pairs between dredging events. Each survey set comparison is then combined to provide an overall channel shoaling prediction.

2. The elevation difference grids created for the survey pairs are then combined to find the average, maximum and minimum change rates at the individual cell.

3. These cell change values are rolled-up to provide a reach value for the average, maximum, and minimum shoaling rates in addition to volume of sediment fluctuations between survey sets.

4. Few other output files are also created for result validation and to assist with any modifications to thresholds or surveys used in the analysis. These files are used primarily for quality control (QC) purposes.

Figure 2-47 shows the location of all NCF reaches (denoted by pink polygons) located within the study locations of Matagorda and Brazoria Counites. More detailed information on each of these reaches is provided within Table 2-10. Since only the portions of the GIWW within the study location are the main focus of this feasibility study, all additional reaches located outside or adjacent to the primary GIWW reaches (identified in Table 2-10 with "GI" at the beginning of the reach ID") are supplementary to the primary GIWW reaches.

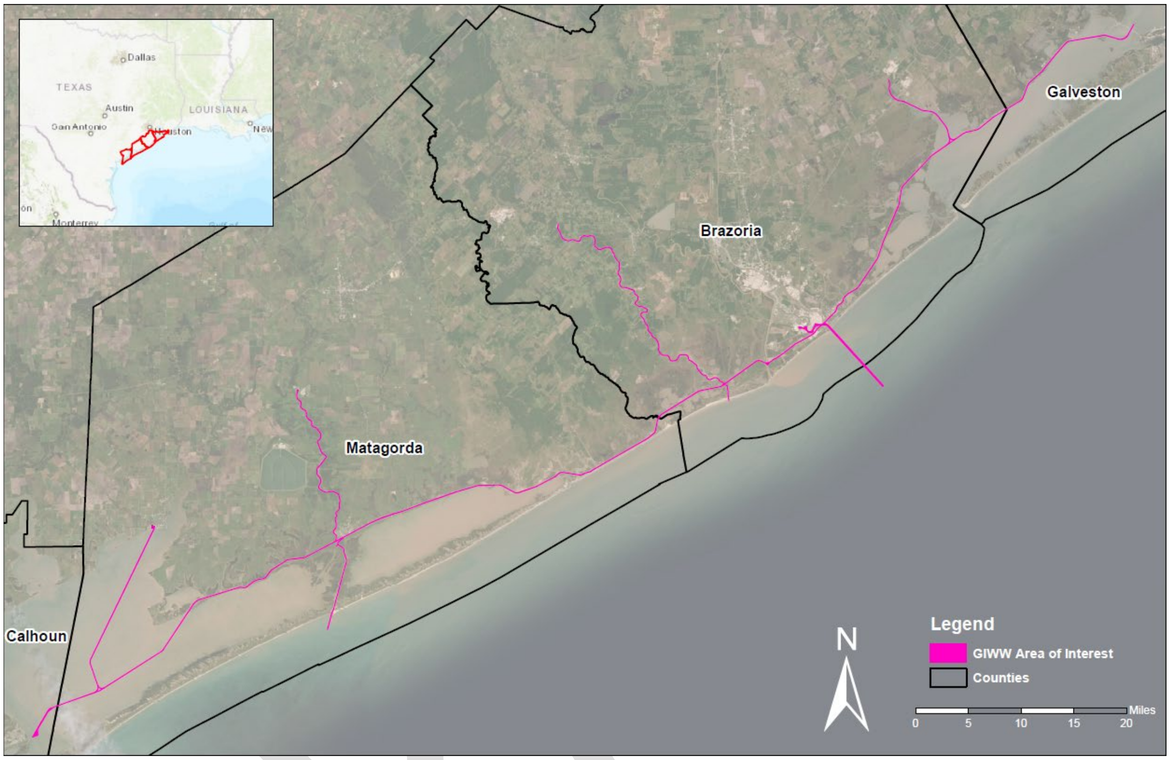


Figure 2-47: NCF Reaches within Matagorda and Brazoria Counties

Table 2-10: NCF Reaches within Matagorda and Brazoria Counties

Reach ID	Reach Name	From Station	To Station
BH_12_BHA	Brazos Harbor Approach Channel	28+00	10+00
BH_13_BHT	Brazos Harbor Turning Basin	10+00	0+75
CB_01_EWY	East Wye	0+000	36+79.72
CB_02_WWY	West Wye	0+000	24+95.30
CB_03_BCL	Bay Channel	36+79.72	290+000
CB_04_LCT	Land Cut	290+000	434+29.46
CO_01_MZT	Mile 0 (Gulf) to Mile 1.4	-75+00	0+00
CO_02_MTF	Mile 1.4 to Mile 3.9	0+00	133+58
CO_03_MFF	Mile 3.9 to Mile 5.7	133+58	226+22
CO_04_MFS	Mile 5.7 to Mile 8.36 (GIWW)	226+22	368+10

CO_05_GZT	Mile 0 (GIWW) to Mile 2	0+00	10+500
CO_06_GTE	Mile 2 to Mile 8	10+500	42+000
CO_07_GET	Mile 8 to Mile 13.5	42+000	71+000
CO_08_GTF	Mile 13.5 to Mile 15.5	71+000	81+746
CO_09_TNB	Turning Basin	81+746	82+991.59
CO_4A_BGC	Braggs Cut	0+00	16+44
FR_01_OBC	Outer Bar	-300+00	0+00
FR_02_JEC	Jetty Channel	0+00	71+52
FR_03_JBR	Jetty to Brazosport	71+52	95+67
FR_04_BTB	Brazosport Turning Basin	95+67	126+85
FR_05_BUT	Brazosport Turning Basin to Upper Turning Basin	126+85	184+13
GI_04_GCC	Galveston Causeway to Chocolate Bayou	360+270.67	465+000
GI_05_CBF	Chocolate Bayou to Freeport Harbor	465+000	564+000
GI_06_FBR	Freeport Harbor to Brazos River	564+000	590+930.03
GI_08_BRC	Brazos River Crossing	590+930.03	593+940
GI_10_BSB	Brazos River to San Bernard River	593+940	614+000
GI_11_SBC	San Bernard River to Colorado River	614+000	805+000
GI_13_CRC	Colorado River Crossing	805+000	810+000
GI_15_CRM	Colorado River to Matagorda Bay (Mile 461.6)	810+000	901+423.55
GI_16_NBB	Natural Bay Bottom	901+423.55	972+939.05
PS_01_EWY	East Wye	0+00	34+41.06
PS_02_WWY	West Wye	(-)3+59.31	34+41.06
PS_03_GLF	Mile 0 (GIWW) to Light 40	34+41.06	480+00
PS_04_LCB	Light 40 to City Basin	480+00	798+00
PS_05_CTY	City Basin	798+00	804+48
PS_06_ENT	Entrance Channel to Municipal Basin	0+00	6+85.15
PS_07_MNB	Municipal Basin	0+00	11+30
SB_01_GTG	Gulf Intracoastal Waterway to the Gulf of Mexico	0+00	82+00
SB_02_MZF	Mile 0 to Mile 0.5	0+00	26+00
SB_03_MOT	Mile 0.5 to Mile 3.75	26+00	196+00
SB_04_MTE	Mile 3.75 to Mile 8	196+00	420+00
SB_05_MET	Mile 8 to Mile 20.5	420+00	1080+00
SB_06_MTT	Mile 20.5 to Mile 25.2	1080+00	1330+00
SB_07_MTS	Mile 25.2 to Mile 26	1330+00	1337+48.98

2.4.4.3. **CSAT Results**

Hydrographic surveys along GIWW CRS reaches are available in e-Hydro from January 2011 to present (i.e., June 2020). However, these survey datasets are not referenced in a consistent vertical datum as Galveston District has changed reference vertical datum from Mean Low Tide (MLT) to Mean Lower Low Water (MLLW) starting 2016. Survey datasets are required to be in a consistent vertical datum for their usages in a CSAT analysis. Therefore, these survey datasets are divided into two survey groups: prior 2016 surveys (i.e., 2011-2015 surveys) and post 2016 surveys (i.e., 2016-2020 surveys). CSAT tools were then applied on the two survey groups separately to estimate average annual shoaling rate along GIWW CRS national channel framework reaches for each survey group time period (i.e., 2011-2015 & 2016-2020).

CSAT-computed average annual shoaling volume (cy/yr.) and shoaling rate (ft/yr.) along different GIWW CRS reaches for both 2011-2015 and 2016-2020 time period are listed in Table 2-11. Total GIWW CRS annual shoaling volumes were 4,526,192 cy/yr. and 4,874,625 cy/yr. for the 2012-2015 and 2016-2020 time periods, respectively.

Table 2-11: CSAT-computed average annual shoaling rate and shoaling volume for time periods of 2011-2015 and 2016-2020

GIWW Reach	From Station to Station	2011-2015		2016-2020	
		Average annual shoaling rate (ft/yr.)	Average annual shoaling volume (cy/yr.)	Average annual shoaling rate (ft/yr.)	Average annual shoaling volume (cy/yr.)
Brazos Harbor Approach Channel	28+00 to 10+00	0.138	2,192.49	0.438	6,962.15
Brazos Harbor Turning Basin	10+00 to 0+75	0.153	4,408.62	0.371	10,711.04
East Wye	0+000 to 36+79.72	-	-	0.333	5,996.02
West Wye	0+000 to 24+95.30	0.501	8,066.83	0.409	6,582.44
Bay Channel	36+79.72 to 290+000	0.317	32,847.26	0.468	53,978.54
Land Cut	290+000 to 434+29.46	0.415	25,835.66	0.207	12,868.83
Mile 0 (Gulf) to Mile 2.8	-75+00 to 0+00	0.651	11,500.13	0.197	3,485.41
Mile 2.8 to Mile 4	0+00 to 133+58	0.689	19,286.72	0.2	10,286.15
Mile 4 to Mile 5.9	133+58 to 226+22	0.236	5,964.71	0.171	5,866.18
Mile 5.9 to Mile 7.11	226+22 to 368+10	1.014	39,081.02	0.479	24,522.51

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GIWW Reach	From Station to Station	2011-2015		2016-2020	
		Average annual shoaling rate (ft/yr.)	Average annual shoaling volume (cy/yr.)	Average annual shoaling rate (ft/yr.)	Average annual shoaling volume (cy/yr.)
Mile 0 (GIWW) to Mile 2	0+00 to 10+500	0.63	24,435.49	0.748	30,225.67
Mile 2 to Mile 8	10+500 to 42+000	0.194	21,218.60	0.906	104,307.89
Mile 8 to Mile 13.5	42+000 to 71+000	0.591	57,849.70	0.541	58,031.73
Mile 13.5 to Mile 15.5	71+000 to 81+746	0.223	9,351.38	1.238	53,033.31
Turning Basin	81+746 to 82+991.59	0.359	3,159.43	0	-528.03
Braggs Cut	0+00 to 16+44	-	-	-	-
Outer Bar	-300+00 to 0+00	1.852	1,208,675.84	1.537	1,025,136.40
Jetty Channel	0+00 to 71+52	3.362	520,732.01	3.927	606,604.71
Jetty to Brazosport	71+52 to 95+67	3.414	153,041.05	3.142	144,527.66
Brazosport Turning Basin	95+67 to 126+85	2.742	204,907.40	2.919	218,101.31
Brazosport Turning Basin to Upper Turning Basin	126+85 to 184+13	1.08	147,114.14	0.9	122,413.19
Galveston Causeway to Chocolate Bayou	360+270.67 to 465+000	0.142	70,307.44	0.748	301,441.71
Chocolate Bayou to Freeport Harbor	465+000 to 564+000	0.292	115,188.34	0.189	86,469.43
Freeport Harbor to Brazos River	564+000 to 590+930.03	2.181	270,969.72	1.566	194,551.62
Brazos River Crossing	590+930.03 to 593+940	0	-9,703.63	2.566	111,943.15
Brazos River to San Bernard River	593+940 to 614+000	0.534	49,401.83	0.479	44,278.77
San Bernard River to Colorado River	614+000 to 805+000	0.246	216,593.02	0.635	560,857.47
Colorado River Crossing	805+000 to 810+000	1.299	18,636.56	1.315	29,445.15

GIWW Reach	From Station to Station	2011-2015		2016-2020	
		Average annual shoaling rate (ft/yr.)	**Average annual shoaling volume (cy/yr.)**	**Average annual shoaling rate (ft/yr.)**	**Average annual shoaling volume (cy/yr.)**
Colorado River to Matagorda Bay (Mile 461.6)	810+000 to 901+423.55	1.085	484,482.92	0.93	420,301.18
Natural Bay Bottom	901+423.55 to 972+939.05	0.6	342,876.75	0.365	208,849.13
East Wye	0+00 to 34+41.06	0.841	2,661.99	0.127	2,033.43
West Wye	(-)3+59.31 to 34+41.06	0.817	2,939.77	0.152	2,686.38
Mile 0 (GIWW) to Light 40	34+41.06 to 480+00	1.148	236,288.25	0.164	33,852.34
Light 40 to City Basin	480+00 to 798+00	1.387	204,166.79	0.816	119,399.04
City Basin	798+00 to 804+48	0.899	3,149.63	0.064	229.33
Entrance Channel to Municipal Basin	0+00 to 6+85.15	0.959	3,574.86	0.154	715.03
Municipal Basin	0+00 to 11+30	0.608	6,111.42	0.221	2,224.55
Gulf Intracoastal Waterway to the Gulf of Mexico	0+00 to 82+00	0.663	9,050.87	0.472	8,400.28
Mile 0 to Mile 0.5	0+00 to 26+00	-	-	0.293	4,508.06
Mile 0.5 to Mile 3.75	26+00 to 196+00	-	-	0.588	37,040.34
Mile 3.75 to Mile 8	196+00 to 420+00	-	-	0.09	7,476.88
Mile 8 to Mile 20.5	420+00 to 1080+00	-	-	0.408	99,675.72
Mile 20.5 to Mile 25.2	1080+00 to 1330+00	-	-	1.007	93,284.11
Mile 25.2 to Mile 26	1330+00 to 1337+48.98	0	- 172.80	0.668	1,849.22
Total			**4,526,192**		**4,874,625**

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Average annual shoaling rate (ft/yr.) and shoaling volume (cy/yr.) of GIWW CRS reaches for 2011-2015 and 2016-2020 time periods are shown in 2-29 and 2-30, respectively. In these figures, blue-colored and orange-color bars denote annual shoaling rate/volume for 2011-2105 and 2016-2020 time period. It is clear from Figure 2-25 that average annual shoaling rates along several of the GIWW reaches from Freeport to the Brazos River Crossing were significantly higher in comparison to other reaches with shoaling rate values exceeding 2.5 ft/yr. for both time periods. Average annual shoaling volumes for the Freeport "Outer Bar" and "Jetty Channel" and "Colorado River to Matagorda Bay (Mile 461.6)" reaches were significantly higher in comparison to the rest of the GIWW CRS reaches with value exceeding 420,000 cy/yr. for 2011-2015 time period. Similarly, annual shoaling volumes for the Freeport "Outer Bar" and "Jetty Channel," "San Bernard River to Colorado River," and "Colorado River to Matagorda Bay (Mile 461.6)" reaches were significantly higher in comparison to the rest of the GIWW CRS for 2016-2020 time period with value exceeding 420,000 cy/yr. It is worth noting the significant increase in average annual shoaling volume for the "Galveston Causeway to Chocolate Bayou," "Brazos River Crossing," and "San Bernard River to Colorado River" reaches from the 2011-2015 to the 2016-2020 time period. Similarly, there as a significant decrease in average annual shoaling volume for the "Mile 0 (GIWW) to Light 40" reach from the 2011-2015 to the 2016-2020 time period. Furthermore, there were an insufficient number of surveys for the "East Wye," "Mile 0 to Mile 0.5," "Mile 0.5 to Mile 3.75," "Mile 3.75 to Mile 8," "Mile 8 to Mile 20.5," "Mile 20.5 to Mile 25.2," and "Mile 25.2 to Mile 26" reaches for the 2011-2015 time period and there were no surveys for the "Braggs Cut" reach for either time periods, as seen in Figure 2-48 and Figure 2-49.

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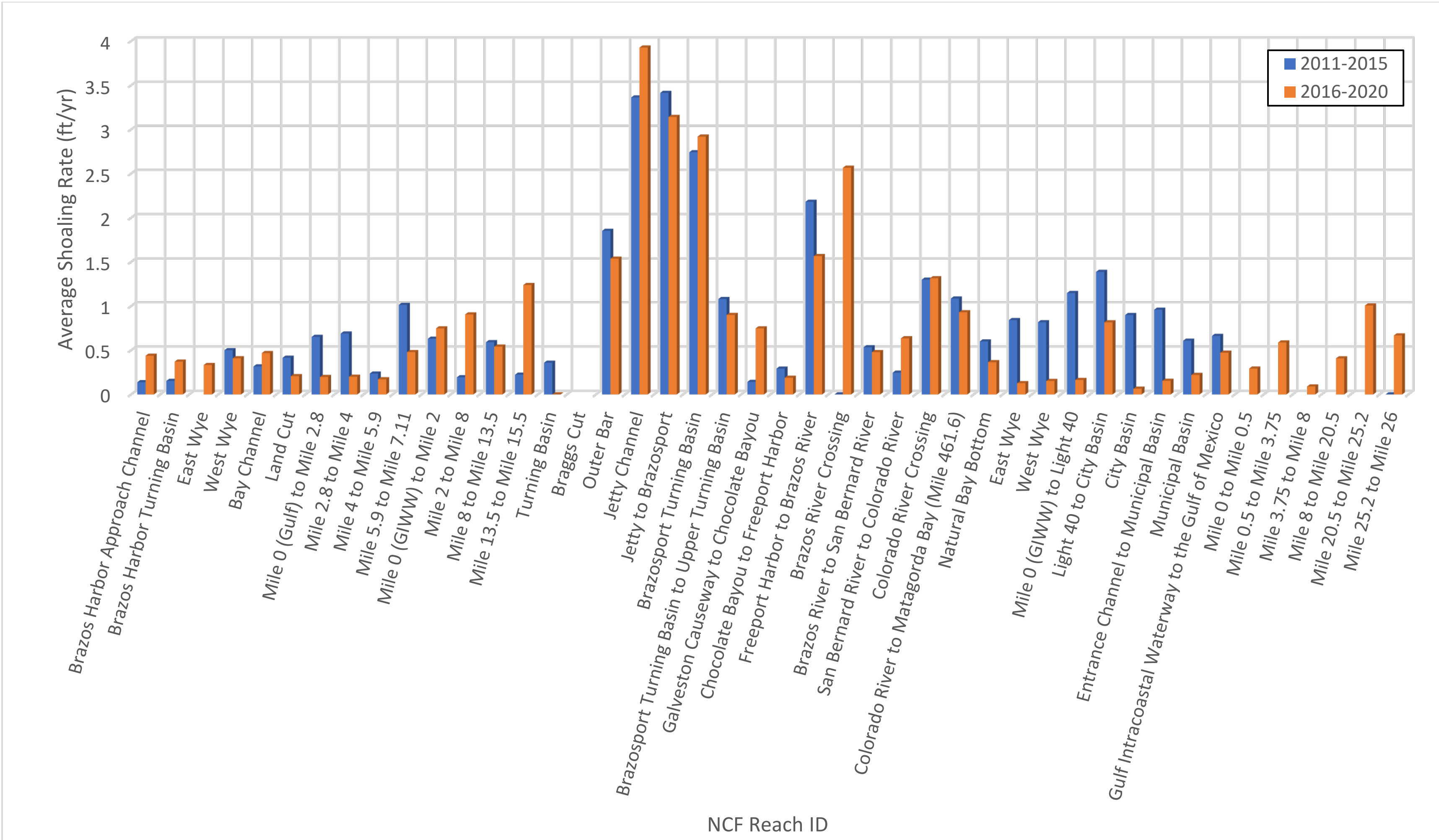

Figure 2-48: Average annual shoaling rate (ft/yr.) comparisons among different GIWW CRS reaches for the time periods of 2011-2015 (blue) and 2016-2020 (orange)

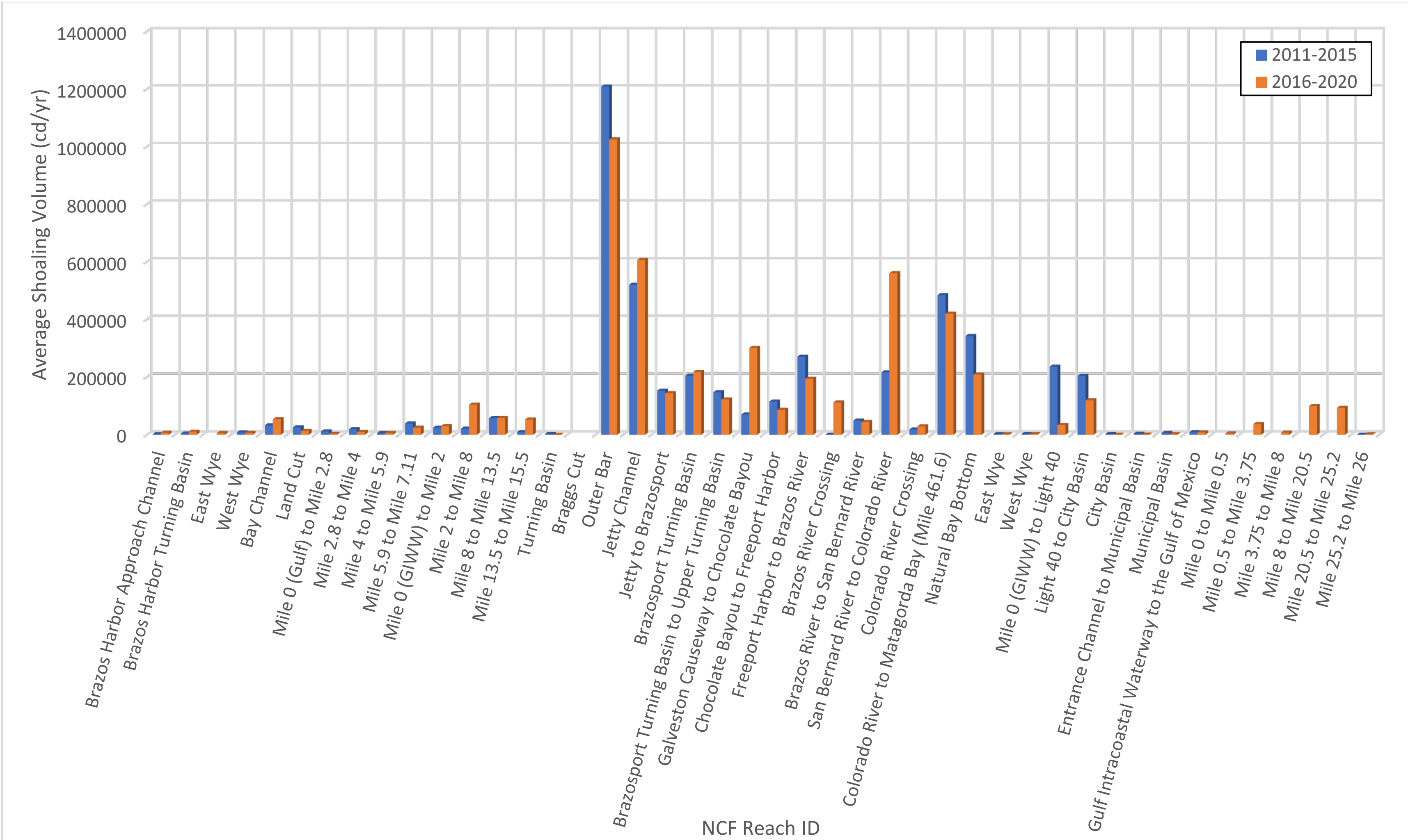

Figure 2-49: Average annual shoaling volume (cy/yr.) comparisons among different GIWW CRS reaches for the time periods of 2011-2015 (blue) and 2016-2020 (orange)

2.4.4.1. **CSAT Conclusion**

Though there were a few select reaches that could be reanalyzed and a few reaches with insufficient survey data sets, CSAT computed reasonable shoaling estimates for the NCF reaches found within Matagorda and Brazoria counties during the 2011-2015 and 2016-2020 time periods. From the CSAT-computed results, the total average annual shoaling volume for the NCF reaches identified within Table 2-11 was 4,526,192 cy/yr. and 4,874,625 cy/yr. for the 2012-2015 and 2016-2020 time periods, respectively. Average annual shoaling rates along the GIWW from Freeport to the Brazos River Crossing ("Jetty Channel," "Jetty to Brazosport," "Brazosport Turning Basin," "Freeport Harbor to Brazos River," and "Brazos River Crossing" reaches) were significantly higher in comparison to other reaches with shoaling rate values exceeding 2 ft/yr. for both time periods. However, this shoaling study did not investigate any potential causes of increased or decreased areas of sedimentation, nor did it evaluate the mechanisms by which shoaling and erosion occurs in the project location. It only provides a summary of findings regarding shoaling rates along the NCF reaches within Matagorda and Brazoria Counties. Numerical sediment transport models can be developed to investigate the potential causes of the shoaling hotspots within the study location.

2.4.5. **Geospatial Analysis**

To estimate the shoreline erosion, a geospatial analysis was performed using aerial imagery from 2018, 2011, 1995, and 1943 (See Figure 2-50). Shoreline shapefiles were created for each year. The shoreline was categorized as either Channel Landward (CL), Channel Bayside (CB), or Barrier Bayside (BB). Shoreline erosion for each of these categorizations were computed from 2018 to 2011 and converted into an annual erosion rate. In addition a weighted smoothing algorithm was performed +/- 500-ft along the channel.

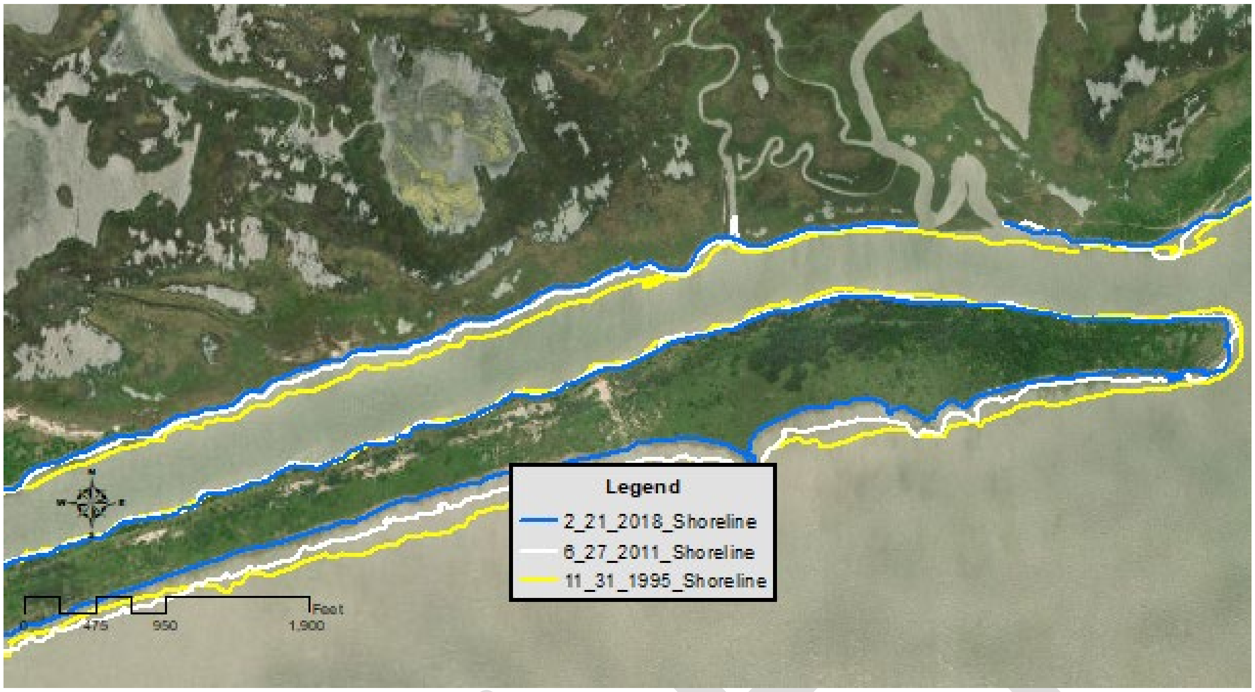

Figure 2-50: Shoreline Delineation along the GIWW

In addition, shapefiles were created for any existing or planned armoring. Existing armoring included existing revetments, breakwaters, and bulkheads, as well as the Sargent Beach revetment. Planned armoring included Coastal Texas and the GIWW-CR measures, all anticipated for 2030. In the analysis, whenever armoring was identified, the erosion rate was set to zero and the shoreline was set to the location of the armoring.

Using these shapefiles, a shoreline morphology was projected from 2018 to 2080. Erosion rates were assumed to be constant for each categorization, except in the case of armoring or if the barrier was eroded away, the BB rate would transfer to the CL. See Figure 2-51, Figure 2-52, Figure 2-54, Figure 2-55, Figure 2-56 and for projected shoreline erosion from 2020 to 2080. The blue hatch represents area protected by CTX and the purple lines represent the shoreline. Note that this analysis is crude and is linear in projection. It assumes erosion rates will continue temporally and spatially in the direction that they were measured, whereas nature is far more complex due to variation in heterogeneity of geologic conditions, trends in storm frequency, intensity, and duration, as well as sea level rise. Despite the uncertainty in using historical shoreline change trends, the advantages are that it already includes variability of storms and sea level rise, it just doesn't include any exponential growth or intensity of those influencers.

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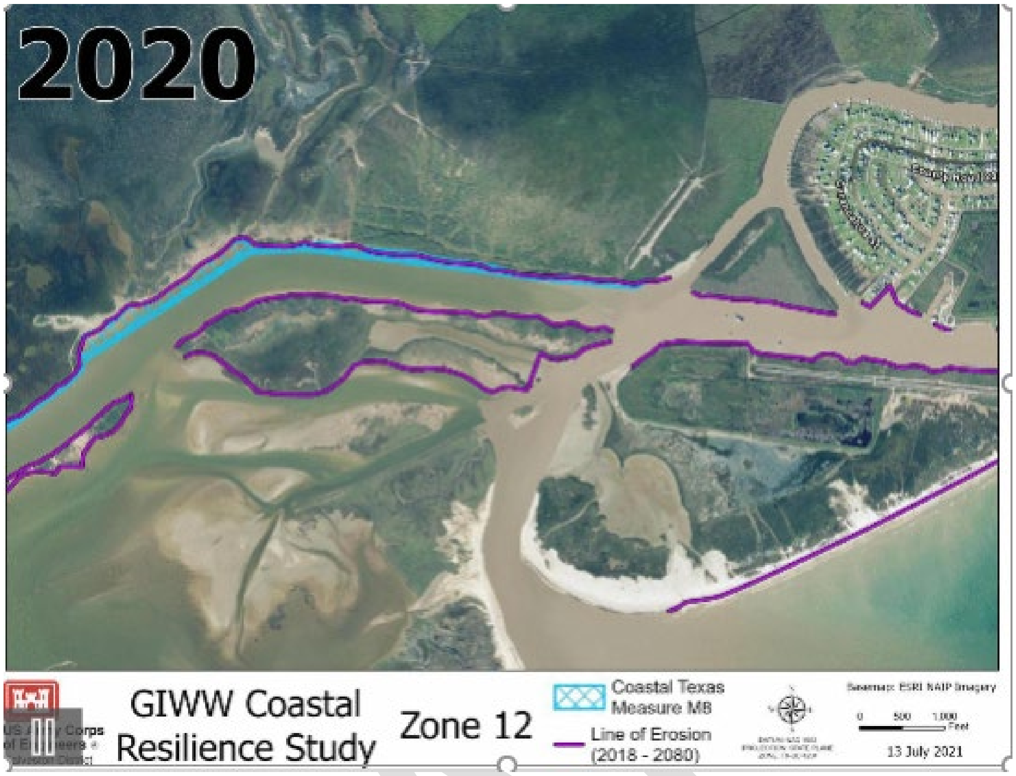
2020
GIWW Coastal
Resilience Study
Zone 12
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
13 July 2021


2040
GIWW Coastal
Resilience Study
Zone 12
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
13 July 2021

Figure 2-51: Projected Shoreline Erosion for Zone 12

Along zone 12, the CL shoreline is not anticipated to change due to the planned construction of a breakwater as part of CTX. In contrast the CB continues to be susceptible to erosion due to vessel induced traffic. The greatest shoreline changes occur on the bay and gulf side of the barrier, particularly at Sargent Beach. Sargent Beach is ranked as one of the highest eroded shorelines in Texas. Along most of Sargent Beach, it has already eroded back to the Sargent Beach Revetment. Along this stretch of Zone 12, without any intervention, it will continue to erode back to PA 100 and the revetment. There are currently plans to make improvements, particularly a groin, breakwaters, and nourishment in this area, which are assumed to address this risk. The greatest remaining risk is therefore the shoreline on the bay side of the barrier to the west of Mitchell's Cut, which is projected to erode considerably, particularly the opening by the intersection.


2020
GIWW Coastal
Resilience Study
Zone 13
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
Basemap: ESRI NAIP Imagery
13 July 2021


2040
US Army Corps
of Engineers
Galveston District
GIWW Coastal
Resilience Study
Zone 13
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
Basemap: ESRI NAIP Imagery
13 July 2021

Figure 2-52: Projected Shoreline Erosion for Zone 13

Along zone 13, the CL shoreline is not anticipated to change due to the planned construction of a breakwater as part of CTX. On the bay side there is very little barrier remaining and what is there will be fully lost by 2050. This is in direct contrast to what has historically existed at this location. Shown in Figure 2-53, is the footprint of the barrier at it is existed in 1995, where it was still intact but had several breaches. The system at one point functioned with a complete barrier system in place, so the condition that is projected is a "changed" condition.

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Figure 2-53: Barrier for Zone 13 in 1995


2040
GIWW Coastal
Resilience Study
Zone 14
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
Basemap: ESRI NAIP Imagery
0 1,000 2,000 Feet
7 July 2021

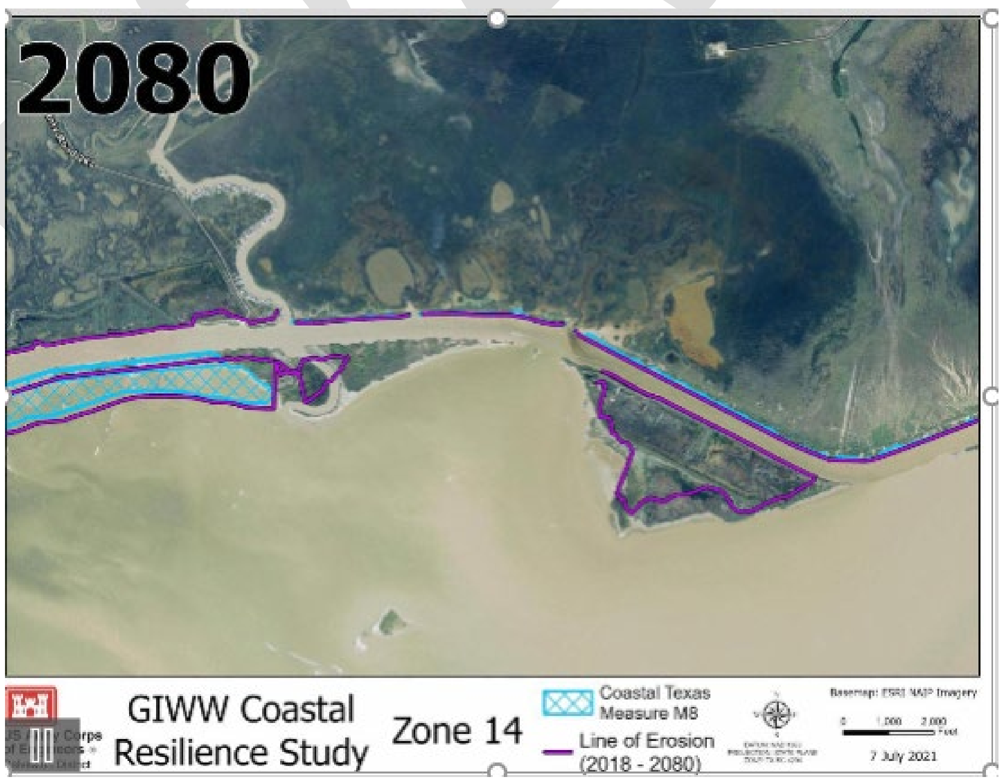

2080
GIWW Coastal
Resilience Study
Zone 14
Coastal Texas
Measure M8
Line of Erosion
(2018 - 2080)
Basemap: ESRI NAIP Imagery
0 1,000 2,000 Feet
7 July 2021

Figure 2-54: Projected Shoreline Erosion for Zone 14

Along zone 14, the CL shoreline is not anticipated to change due to the planned construction of a breakwater as part of CTX. On the bay side the barrier is anticipated to erode, particularly a widening of the opening at Live Oak Bay across from Turkey Run Slough. PA 102C is armored and anticipated to be maintained. To the west of Zone 14, a barrier is planned for Zone 15 as part of CTX.

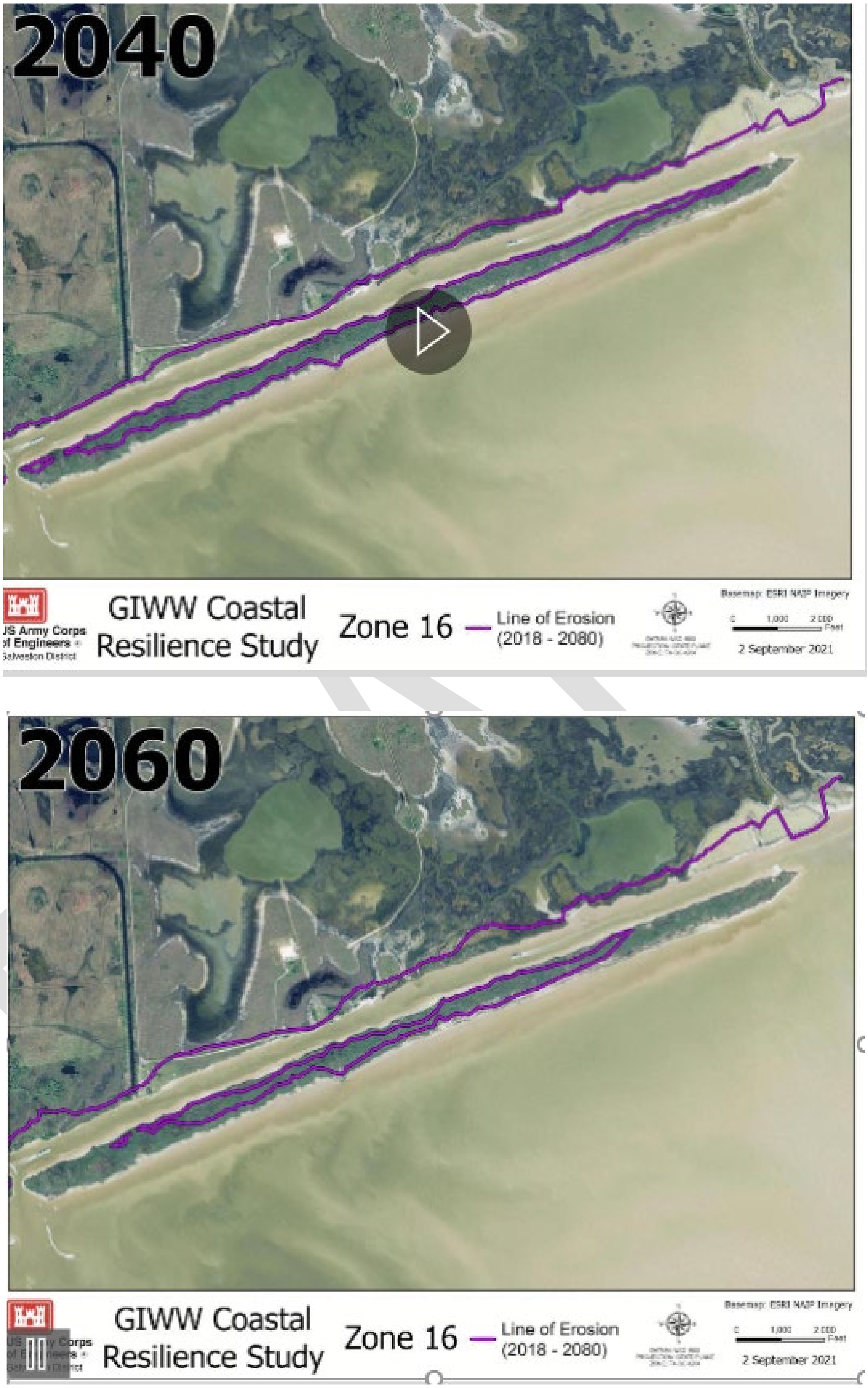
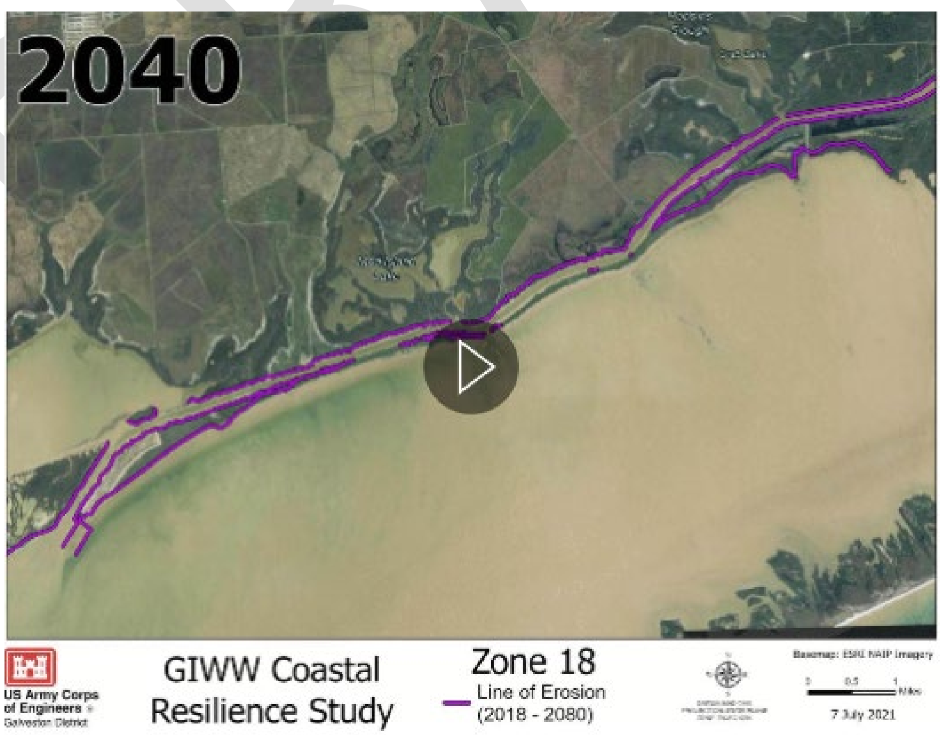


Figure 2-55: Projected Shoreline Erosion for Zone 16

Along zone 16, the CL shoreline is subject to change as there is no armoring except along the PA on east end. The erosion rate increases about 10-fold in areas where the barrier is lost. The barrier erodes the greatest on the Bay side and at its ends. Half the barrier will be lost by 2080, which is a "changed" condition.



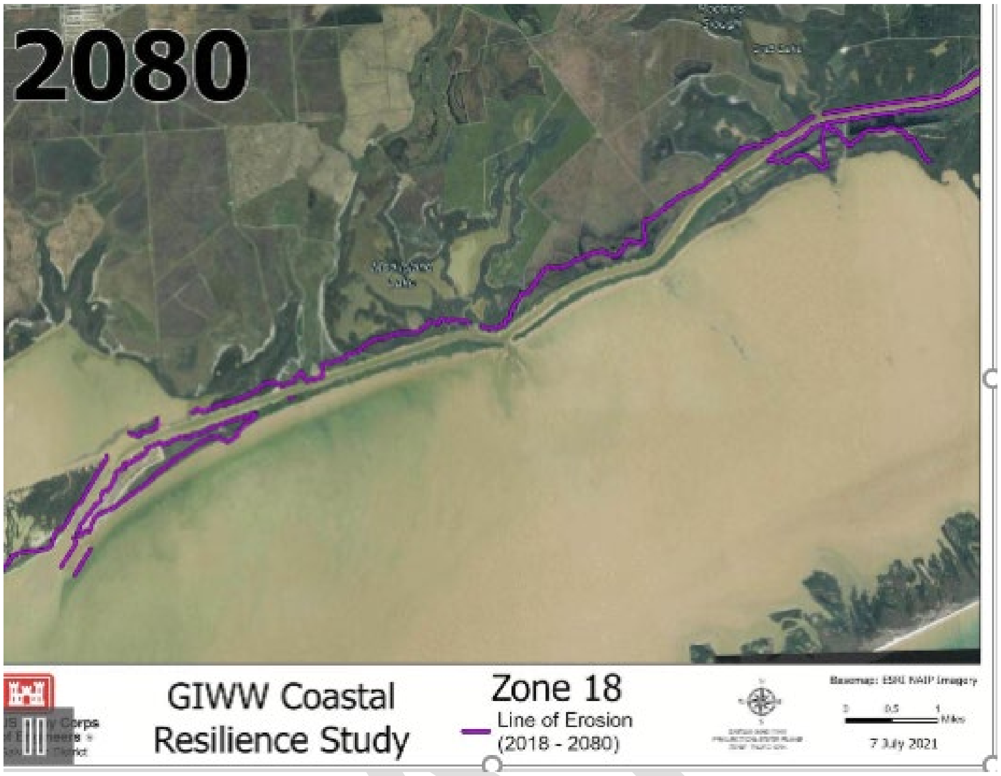


Figure 2-56: Projected Shoreline Erosion for Zone 18

Along zone 18, the CL shoreline is subject to change as there is little armoring except along several isolated stretches. The erosion rate increases about 10-fold in areas where the barrier is lost. The barrier erodes near the Mad Island Cut. By 2050, a significant portion of the barrier will be lost, which is a "changed" condition. This particular shoreline has eroded over 125 ft in less than 7 years. At its current rate, the barrier will be breached in several places in less than 20 years.

2.4.6. Coastal Modeling System (CMS)

The intersection of Caney Creek and Mitchell Cut at the GIWW has been identified as a major area of concern by GICA due shoaling and due to dangerous cross currents during Ebb flow that draw vessels into the Cut. These issues are a result of the dynamic nature of a tidal inlet.

In 2012/2013, a study was performed (Thomas and Dunkin 2012, Rosati et al. 2013) that assessed the erosion at Sargent Beach and recommended improvements; however this study did not evaluate the shoaling or currents at Caney Creek. A numerical model was created for this project that included the study area. In 2020, GLO/Atkins submitted a permit that built off the recommendations by Thomas & Rosati to pilot improvements at the west end of Sargent Beach. This study also did not investigate shoaling in the GIWW. In 2019/2020 a RSM study was performed by Hamilton to investigate alternatives for reducing shoaling in the GIWW and did investigate several options to reduce shoaling at Mitchell's Cut. It included a sediment trap and offshore breakwaters similar to recommendations by

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Thomas & Rosati, but neither naturally reduced shoaling. The sediment traps did provide some relief, but their long-term effectiveness needed to be evaluated. That study did not consider groins, barrier restoration, or channel stabilization.

Existing conditions and the considered alternatives are simulated using the Coastal Modeling System (CMS). The CMS is a depth-averaged hydrodynamic and wave model well suited for the project area (See Figure 2-57 and Figure 2-58 for the flow and wave domains, respectively). In addition to the flow and wave simulations, the CMS calculates sediment transport and morphologic change throughout the simulations. The CMS model covers the East Matagorda Bay. The CMS model was forced at the boundary using water surface elevation from nearest NOAA stations.

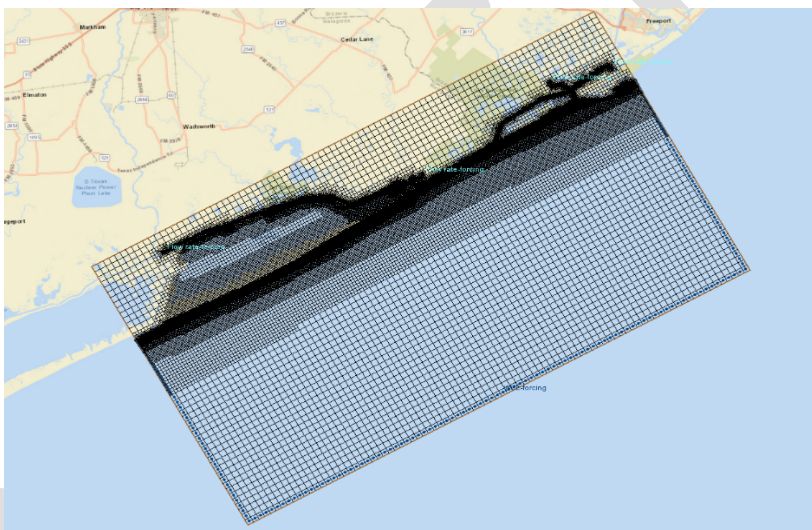

Figure 2-57: Computational domain (CMS-Flow/sediment grid)

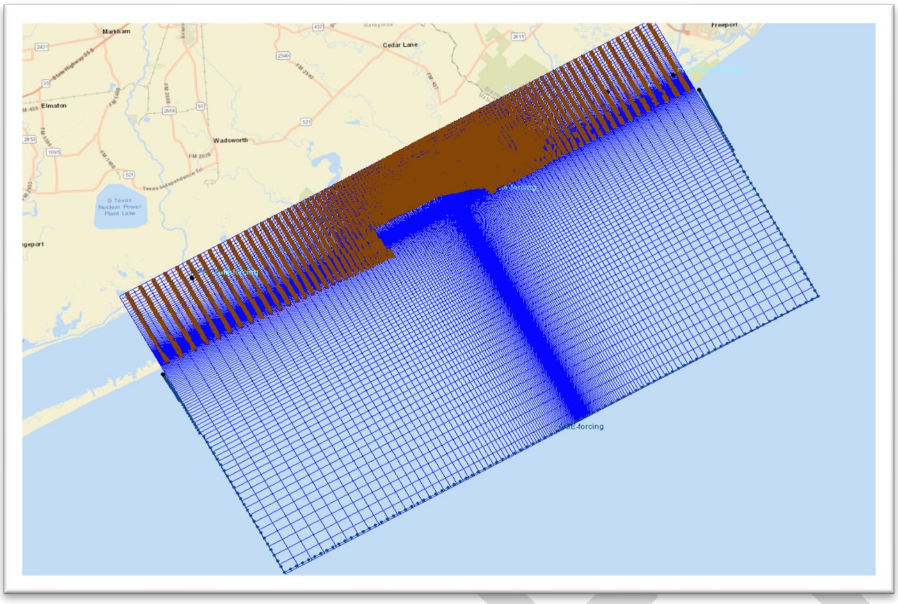

Figure 2-58: Computational domain(CMS-Wave grid)

CMS was simulated with sea level conditions for the months of January and July in the years 2030 and 2080. It was also simulated with and without potential improvements to Sargent Beach, particularly groins on the east and west side of Mitchell's Cut. Qualitatively, the model recreates a flood tidal delta and a deep high velocity cross-channel at the intersection of the GIWW, Caney Creek, and Mitchell's Cut (See Figure 2-59). It also illustrates that the GIWW acts as a major conduit for flow into East Matagorda Bay. Of note for the FWOP condition, is that problematic cross-currents at the intersection appear to increase as the tidal prism increases with SLR. Limitations to this current analysis include not assessing the geomorphic system evolution over 50 years and the shortness of simulation duration. It is recommended that these limitations be addressed either before or during PED. It is also recommended that the contribution of sediment from Sargent Beach and the influence of a potential permitted groin on the east side of Mitchell's Cut be further evaluated as it is likely a high portion of the sediment shoaling in the GIWW is related to material from Sargent Beach.

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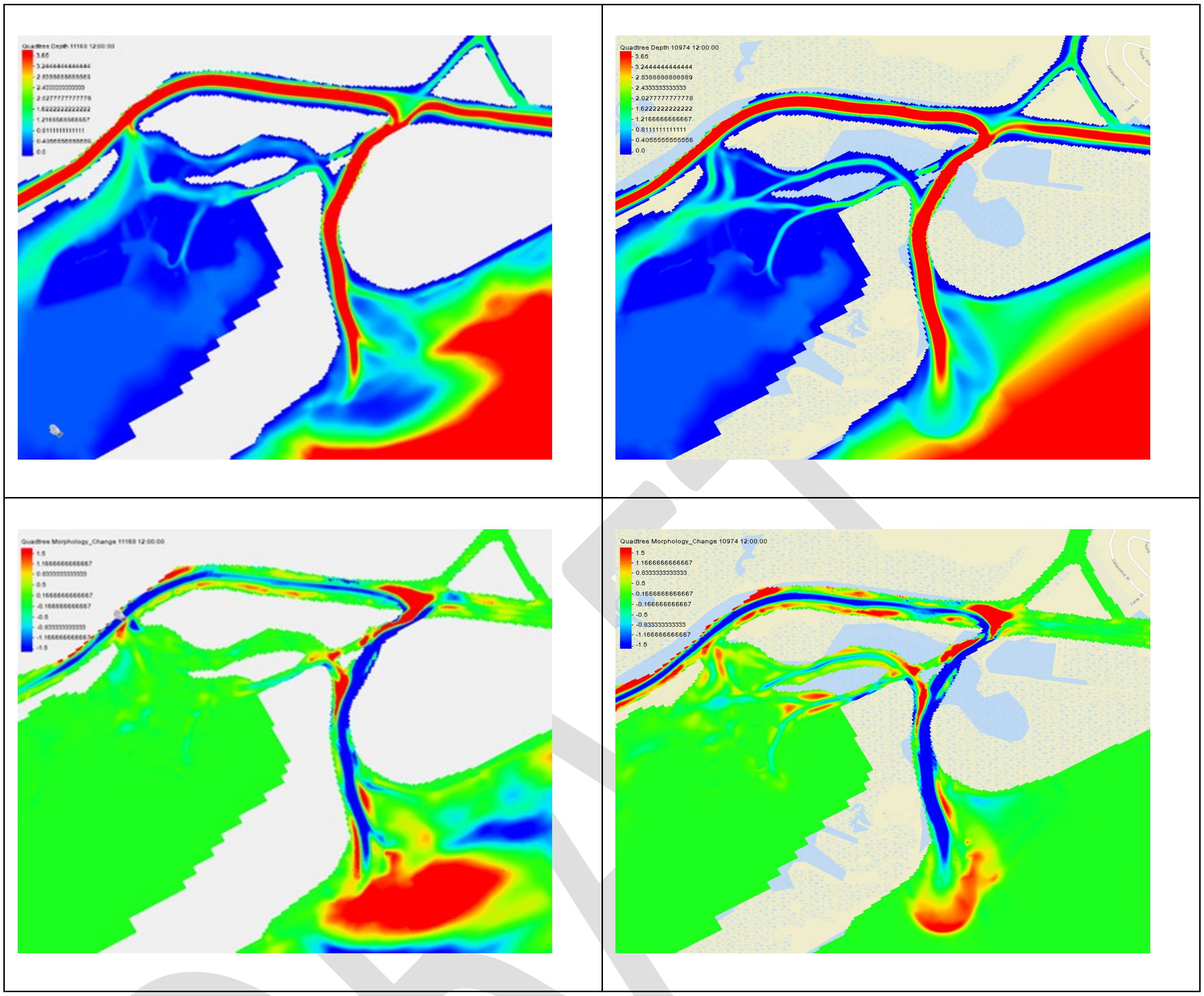

Figure 2-59: CMS Results (Top: Depth (m), Bottom: Morphological Change (m); Left: January 2030; Right: January 2080)

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2.4.7. **Sediment Budget Analysis**

The objective of the sediment budget analysis was to develop an annual shoaling rate (ft) for each year of the project at 100-ft increments along the channel. This information would then be used to evaluate the impacts to the Dredge Material Management Plan (DMMP) which will be developed in the future.

To develop the annual shoaling rate for the Future Without Project (FWOP) and Future With Project (FWP) conditions, a baseline first needed to be established, so the historical shoaling rate was estimated using the Corps Shoaling Analysis Tool (CSAT) based on historical survey and dredging history. Data was processed from 2011-2015 and 2016-2020 and then averaged. This was performed for both Brazoria and Matagorda Counties to establish a baseline historical shoaling rate in the channel.

To project shoaling changes over time and by plan, the factors influencing the shoaling rate needed to be assessed. The three primary sedimentary inputs to the system are shoreline erosion, watershed runoff, and open-water circulation. Sediment that enters the system either shoals in the channel or is deposited in the bay or is released out into the Gulf through inlets.

To estimate the shoreline erosion, a geospatial analysis was performed using aerial imagery from 2018, 2011, 1995, and 1943. Shoreline shapefiles were created for each year. The shoreline was categorized as either Channel Landward (CL), Channel Bayside (CB), or Barrier Bayside (BB). Shoreline erosion for each of these categorizations were computed from 2018 to 2011 and converted into an annual erosion rate. In addition a weighted smoothing algorithm was performed +/- 500-ft along the channel (See Figure 2-60).

In addition, shapefiles were created for any existing or planned armoring. Existing armoring included existing revetments, breakwaters, and bulkheads, as well as the Sargent Beach revetment. Planned armoring included Coastal Texas and the GIWW-CR measures, all anticipated for 2030. In the analysis, whenever armoring was identified, the erosion rate was set to zero and the shoreline was set to the location of the armoring.

Using these shapefiles, a shoreline morphology was projected from 2018 to 2080 (See Figure 2-61). Erosion rates were assumed to be constant for each categorization, except in the case of armoring or if the barrier was eroded away, the BB rate would transfer to the CL. Each year, the location of the shoreline was tracked based on the erosion rate, and an erosion loss was tracked. The erosion loss was computed by multiplying the erosion rate by the height of the shoreline, which based on topo data was uniformly assigned to be 6-ft for the CL, and 10-ft for the CB and BB. This height includes the anticipated submerged land loss, which would be greater on the Bayside of the Channel. This erosion loss was then converted to shoaling rate by assuming a 1.0 bulking factor.

Based on an initial analysis of the overall Matagorda County from zone 7 to 18, shoreline erosion was estimated to represent 60% of the overall shoaling in the channel. Watershed runoff was estimated to be 17%, which means that at minimum 23% is either from bulking or open-water. Considering open-water only represents 13% of the channel length, the percentage contribution per channel foot could be relatively high. In addition, this assume a 100% sediment budget; where it is likely that 20 to 50% of the system's sediment passes through the GIWW and is deposited in the Bay or Gulf, suggesting that this analysis is underestimating as much as 50% of the overall material movement and source of shoaling in the channel by not understanding the overall system circulation effects using a numerical model, which would better capture the deposition from watershed runoff, and the movement of wind-driven and tidally-driven circulation of sediment. Shoaling is assumed to be linearly additive. It is not influenced by SLR, because SLR is assumed to be inherently built into the shoreline analysis.

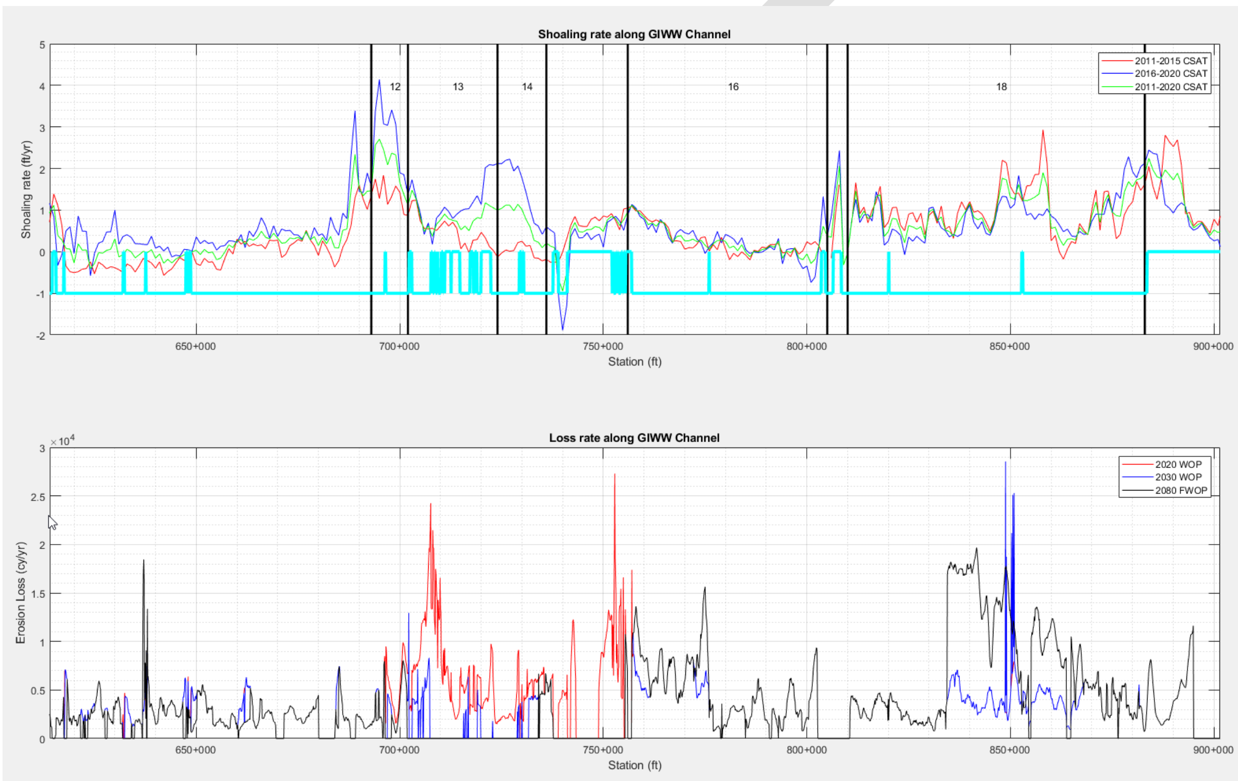

Figure 2-60: Historical Shoaling Rate in ft/yr. (Top) and Erosion Loss in cy/yr. (Bottom)

From the shoaling analysis, the existing highest area of concern is Zone 12, but is followed closely by the transition between Zone 18 and Zone 19. It is interesting to see in the historical CSAT the changes between the 2011-2015 and 2016-2019 rates, particularly zone 13, where the rates have gone up as a result of the barrier being heavily breached. In terms of future shoaling changes, the area of greatest concern is zone 18, followed by zone 16 as these are two areas that will have barrier breached.

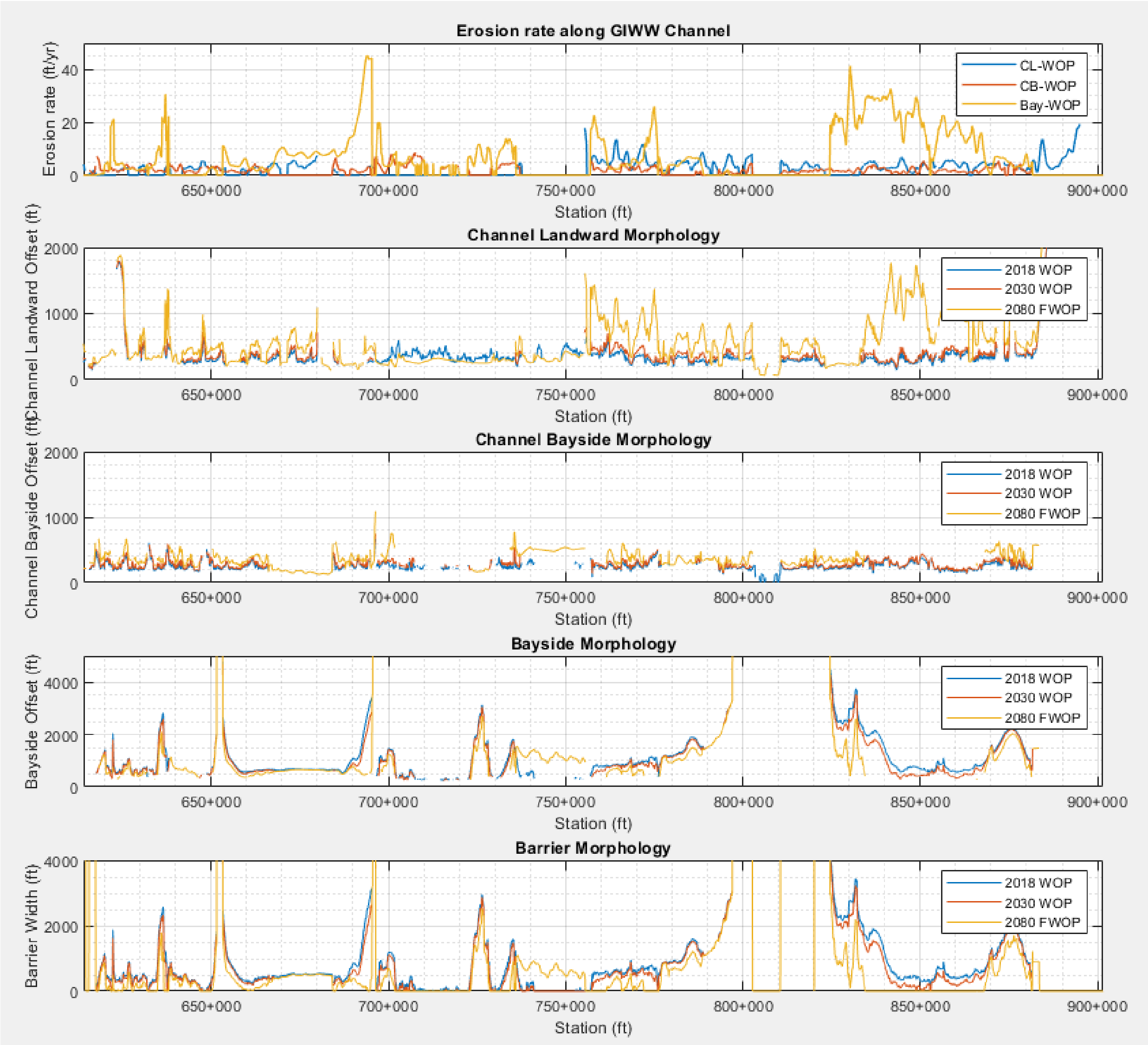

Figure 2-61: Comparison of Erosion Rates and Morphology between CL, CB, and BB

2.4.8. **FWOP Conditions Assessment**

Intermediate projections of relative sea level rise from year 2020 are estimated at 0.25-ft for the 2030 project design year and 1.75-ft by year 2080, 50-year design consideration. This rise in water will inundate and submerge much of the barrier between the GIWW and the Gulf. In addition, coastal storms are predicted to become more frequent and intense due to climate change. This is important because under coastal storms, the remaining emergent barrier system, which will become smaller under SLR, will be more susceptible to inundation and erosion from coastal storms because it will be more frequently overtopped. Essentially, sea level rise and coastal storms due to climate change will accelerate barrier loss faster than existing loss rates.

The NOAA SLR viewer was used to visualize the MHWW inundation for the 2030 construction year (Figure 2-62) and 2080 design life year (Figure 2-63). As seen in the viewer, many of the barriers while partially inundated are not completely submerged. The land most at risk due to inundation is the low-lying marshland inland of the GIWW. The additional SLR does increase the water depth in the shallow bays which will lead to greater wave action, sediment movement, adjacent barrier loss, and shoaling in the GIWW.

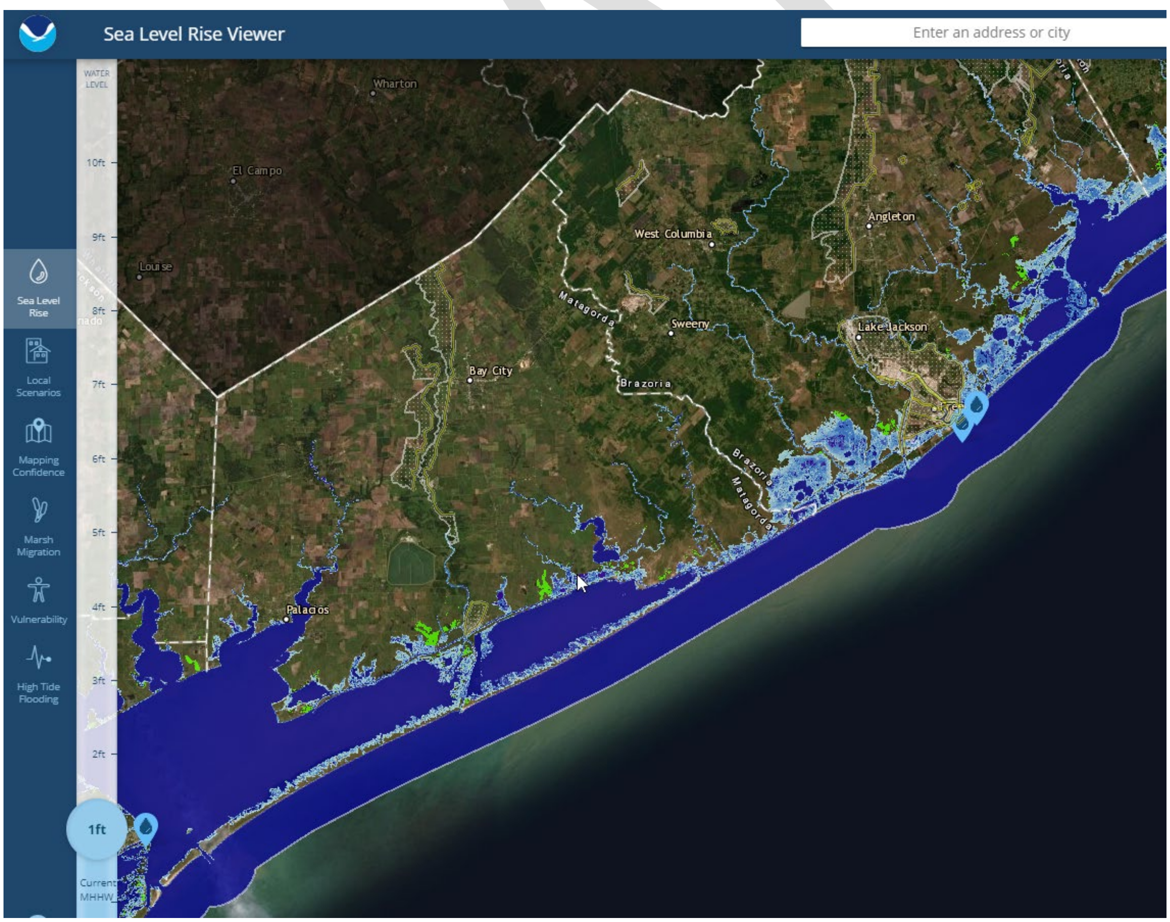

Figure 2-62: MHWW Inundation for 1-ft representation 2030 Construction Year[25]

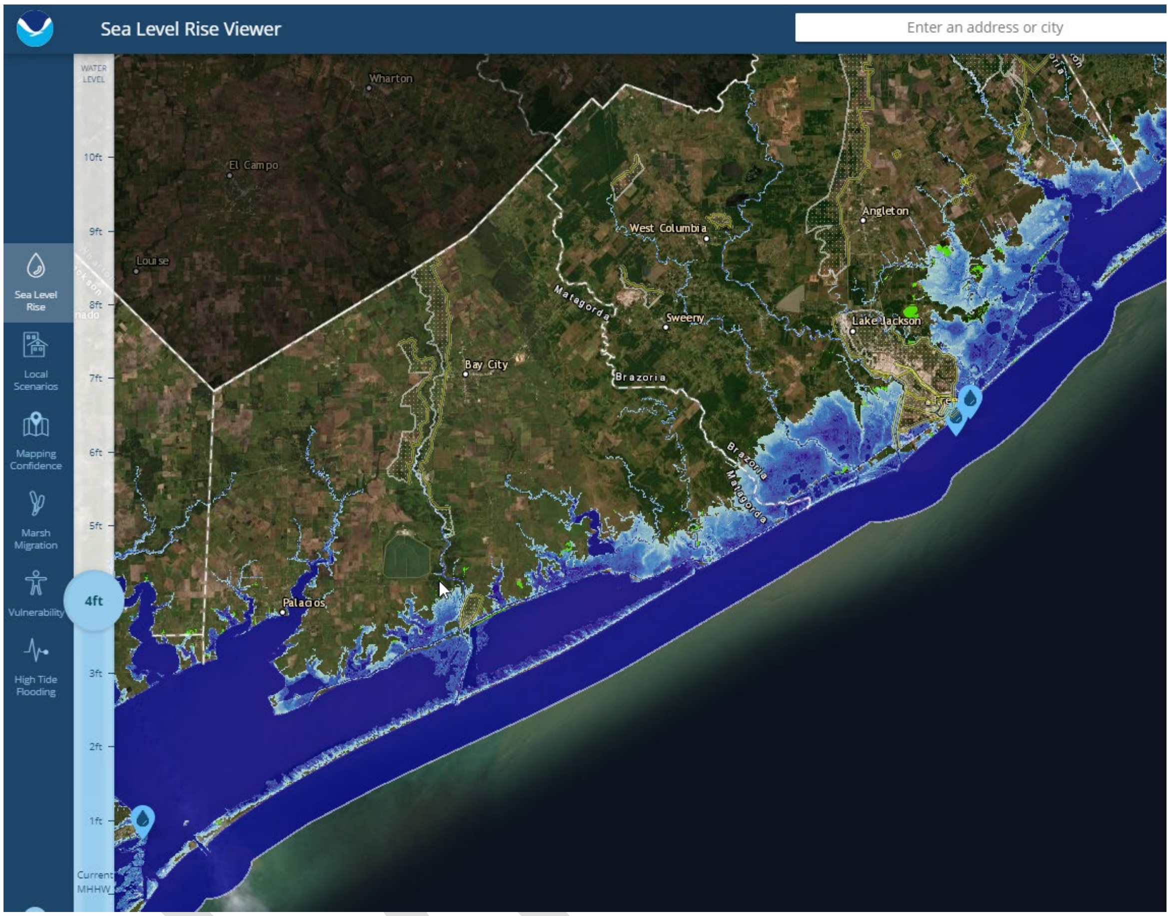

Figure 2-63: MHWW Inundation for 4-ft representation 2080 Design Life Year

Loss of barriers is important because they provide shelter for resilient transit of commercial vessels on the GIWW against waves and currents of the open Gulf of Mexico and to a lesser degree the Bay systems. The most vulnerable section of the GIWW within Matagorda and Brazoria county is Sargent Beach (Zone 11), which is the only section of the GIWW that only has a single line of defense between the Gulf and the GIWW. All other sections, except for the open water stretch of Matagorda Bay (Zones 19 and 20) , East Matagorda Bay (Zone 15,14,13), Chocolate Bay (Zone 2), and West Galveston Bay (Zone 1) have a Gulf-Barrier that separates the Gulf from the Bay systems and a Bay-barrier which separates the Bay from the

[25] https://coast.noaa.gov/slr/

GIWW. These latter zones are not immediately next to the Gulf shoreline and are already open water, so are less vulnerable than Sargent Beach, which is less than 250 ft at its narrowest. The next most vulnerable zones besides the ones previously listed are those where the Bay barrier is intact but is eroding quickly includes Zones 18 and 16. Because the Gulf barriers at 19,20, and 2 are fairly sizeable and zones 1,15 are being addressed as part of CTX, the next most important and vulnerable sections of the GIWW due to barrier loss after Sargent Beach are Zones 13,14,16, and 18.

Erosion of the coastal barriers are caused naturally, by coastal storms and seasonal winds, waves, and currents, and anthropogenically, by vessel induced waves. In general, erosion caused by natural processes occur mostly on the Gulf side of the GIWW either at the Gulf-barrier or the Bay Barrier, whereas anthropogenic erosion, occurs along the shorelines of the interior of navigation channels such as the GIWW. Both natural and anthropogenic erosion cause an influx of sediment material into the system, but based on examination of shoreline erosion rates, natural processes are producing higher erosion rates. In areas where the barrier is intact, this sediment material that is eroded is generally blocked from entering the GIWW system; however in places where there are no barriers or there are cuts or breaches, sediment material is able to cycle into the system, especially as these cuts or breaches widen due to erosion. Once a barrier is eroded, wind-driven waves will accelerate erosion of the shoreline on the other side of the GIWW. In addition, material also enters the system through the watershed runoff and river systems. This is important because sediment influx into the GIWW system results in shoaling which both reduces system reliability and increases system maintenance costs, both negative economic consequences. To reduce shoaling, either the source of the material must be stabilized so it is less erosive or the pathways by which material enters the GIWW be reduced.

Between a barrier that has fully eroded (Zones 1 and 15), and a barrier that is eroding but has not fully breached (Zones 11, 16 and 18), it is the current barrier that is the most vulnerable because it is still a resource and a potential vulnerability to its mass of material it can erode into the system. As a result, the barriers at Zones 11, 16, and 18 are of significant importance, because they represent an existing resource that should it be lost would be more detrimental to lose than the impacts of the ones already lost. If existing barriers, such as along Zone 18 are not stabilized, then within 20 years, that barrier is expected to completely be lost. Currently that section of the GIWW is protected, but if the barrier is lost, the material from that barrier will erode into the GIWW along with the wind driven material from the Bay. In addition, eroded barriers not addressed in the Coastal Texas Plan (Zones 13 and parts of Zone 14) are a vulnerability that should be addressed due to erosion of sediment material caused by winds driven across the Bay that bring material into the channel and erode the unprotected interior shoreline.

The greatest contributors of sediment material into the system that cause shoaling besides barrier losses are the Colorado River (Zone 17), Brazos River (Zone 7), and Caney Creek (Zone 12) crossings. Because the Colorado and Brazos River are part of another USACE study, Caney Creek / Mitchel's Cut crossing is by default the most vulnerable section of the GIWW due to shoaling caused by a river crossing; however the role of the Brazos and Colorado as regional sediment resources should not be neglected. The Caney Creek / Mitchell's Cut crossing is also significant because currents at that intersection have been documented to cause navigation hazards. Shoaling in that area is also linked to erosion at Sargent Beach, so this is area is opportune for synergistic solutions.

As described above, the most vulnerable segments of the GIWW not addressed by other studies, are Zones 11-14, 16, and 18. This includes Sargent Beach (Zone 11), Caney Creek intersection (Zone 12), the unprotected stretches of Zones 13-14, and the eroding barriers of Zones 16 and 18. Despite acknowledgement that these are the vulnerable stretches, this study must also identify sediment resources regionally, with emphasis on renewable sources, for harvesting and restoration of these degraded adjacent coastal features, with periodic maintenance of these features over the project life cycle on the intended purposes. It is important to tie this study into the dredging and operation maintenance plan for this region in order to facilitate solutions that are resilient.

In conclusion, the existing conditions are described by:

- Highest shoaling occurs at river crossings and where barriers are breached by cuts.
- Complete loss or high erosion of the GIWW barriers at the Open Bays.
- Planned shoreline protection of the GIWW along critical areas through most of Brazoria County and select locations within Matagorda County.
- Higher shoreline erosion rates on the bay sides of barrier islands than along the channel. Loss of terrestrial habitat.
- Narrow barrier protection along the GIWW at Sargent Beach, with high susceptibility to breaches due to coastal storms.
- High cross-currents during Ebb Flow at Mitchell's Cut and GIWW intersection which is a navigation safety issue.

In conclusion, the FWOP conditions are described by:

- Reduced sheltering, increased erosion, and higher shoaling due to sea level rise. Loss of terrestrial habitat.
- Increased erosion and higher shoaling due to more frequent and stronger coastal storms, and less barrier protection to attenuate them.
- Complete loss of barriers due to erosion and inundation due to SLR where no protection is planned or existing.

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- Increased shoaling due to sediment influx from Open Bays and GoM.
- An increase in cross-current velocity at Mitchell's Cut and GIWW intersection which will exacerbate a current navigation safety issue.

2.5. ALTERNATIVE DEVELOPMENT

The AMM presented two alternatives besides the no-action plan, a Stabilization Alternative (No. 3) and a Stabilization plus Sediment Placement Alternative (No. 6). The primary difference between Alternative 3 and Alternative 6 is the addition of sediment placement, both as an initial feature and as a new O&M policy throughout the project design life.

Both alternatives focus on the priority zones established during the AMM which includes zones 12, 13, 14, 16, and 18. Alternative 3 proposes the implementation of a breakwater along the GIWW shoreline of the barrier islands and another breakwater along the bay shoreline of the barrier islands. Alternative 6 is identical to Alternative 3 but includes the design of additional barrier islands between the two breakwaters proposed in Alternative 3.

The intention of this study is to develop alternatives that improve the resiliency of a system, which is namely its toughness or ability of the system to recover quickly and efficiently, whether it is from sea level rise, coastal storms, or operational and maintenance dredging and placement challenges. While both alternatives improve resiliency of the navigation channel by developing a reinforced coastal barrier, the difference of sediment placement in Alternative 6, increases the level of resiliency to coastal storms and operational and maintenance challenges by instituting recovery and resiliency into the barrier itself and operational and maintenance placement practices.

2.5.1. **Development of Alternatives for TSP Selection**

The following sections summarize the design methodology of the measures considered for Alternative 3 and Alternative 6, respectively.

2.5.2. **Alternative 3: Stabilization**

The intent of Alternative 3 is to create a stable coastal barrier by constructing breakwaters along the channel and bay sides, that will 1) reduce erosion of the existing coastal barrier, 2) naturally capture sediment from overtopping waves, and 3) reduce erosion of the interior shoreline by attenuating waves from the bay. Numerous measures were considered, but after screening and evaluation, breakwaters were selected over revetment and other options. The intent of the breakwater to protect the shoreline of the barrier islands along the GIWW from erosion. A secondary objective of the interior breakwater is to promote sediment accretion between the structure and the barrier islands, as well as prevent any eroded sediment from the barrier islands entering the GIWW.

2.5.2.1. **Interior Breakwater Design with Barrier**

The purposes of the interior breakwater will be to 1) reduce erosion of the coastal barrier by breaking vessel induced waves from the GIWW prior to hitting the barrier 2) capturing sediment from overtopping waves from the GIWW, and 3) limiting transport of material during coastal storms from the barrier into the GIWW. For this particular measure, the barrier will be assuming to be existent; therefore, waves from the Bay and Gulf will be attenuated by the natural barrier.

The interior breakwater will follow the same concept of a rubble-mound berm breakwater design. This design consists of a thin layer of bedding stone atop geotextile cloth as the foundation and the remainder of the structure consists of a uniform gradation of stone.

The primary erosive force will vessel-induced waves. The optimal breakwater crest elevation is slightly above MHHW, because:

1) it will be emergent and thereby visible to boat traffic for navigation safety,

2) vessels will rarely traffic under storm conditions, so it doesn't need to be higher, and

3) some overtopping is encouraged to allow for movement of water and channel sediments behind the breakwater.

The MHHW at NOAA station 8773146 on the GIWW is 1.02-ft and it's mid-epoch is 2018, so with 1.75-ft of SLR, the 2080 MHHW would be 2.77-ft NAVD88. Rounding up, the post-settlement design crest elevation of 3-ft was chosen.

The following design considerations were made when examining the placement of the interior breakwater:

1) The breakwater needs to be far enough from the barrier island to account for barrier migration. A 50-ft offset was assumed based on engineering judgement; although an overtopping analysis should be performed in PED to investigate this assumption.

2) The breakwater needs to be far enough from the channel to reduce risk of vessel damage, as well as far enough to ensure that the breakwater does not fall into the channel.

3) The toe of the breakwater should be deep enough to reduce immediate toe scour due to wave breaking.

Based on review of existing bathymetry, an average bed elevation of -2.0-ft at 200-ft offset from the channel centerline was selected. As shown in Figure 2-64, the following feasibility level design was estimated:

- Stone Size: R-300
- Toe Elevation = -2.0 ft
- Crest Elevation = 3.0 ft
- Crest Width = 5.0 ft
- Side Slopes = 2:1
- Bottom Width = 25 ft

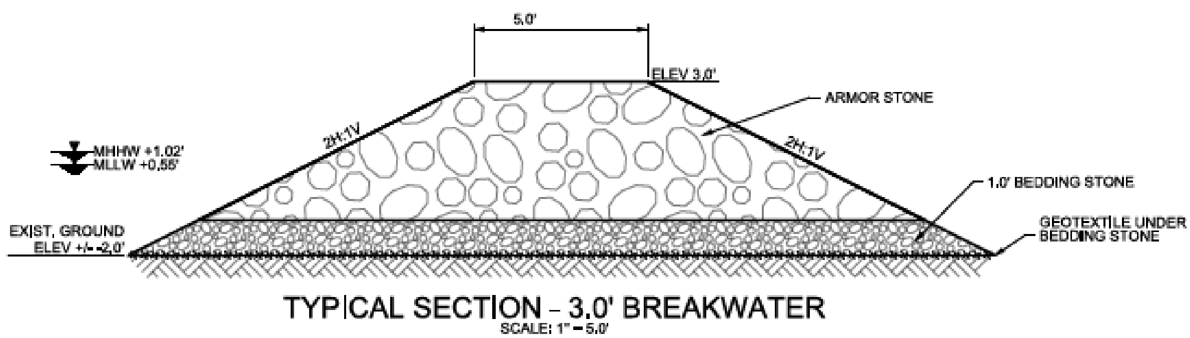

Figure 2-64: Typical Section for 3-FT Breakwater

2.5.2.2. Interior Breakwater without Barrier

Similar to the Interior Breakwater with Barrier in all aspects except that it must withstand wave forces from the open bay and Gulf. As a result, it needs a higher stone gradation and a higher crest elevation. The higher crest elevation is necessary to attenuate seasonal waves that would disrupt navigation traffic. Because this area is susceptible to high stillwater levels due to coastal storm surge, it is not feasible to construct a breakwater that can't be overtopped. As shown in Figure 2-65, the following feasibility level design was estimated:

- Stone Size: R-700
- Crest Elevation = 5.0 ft

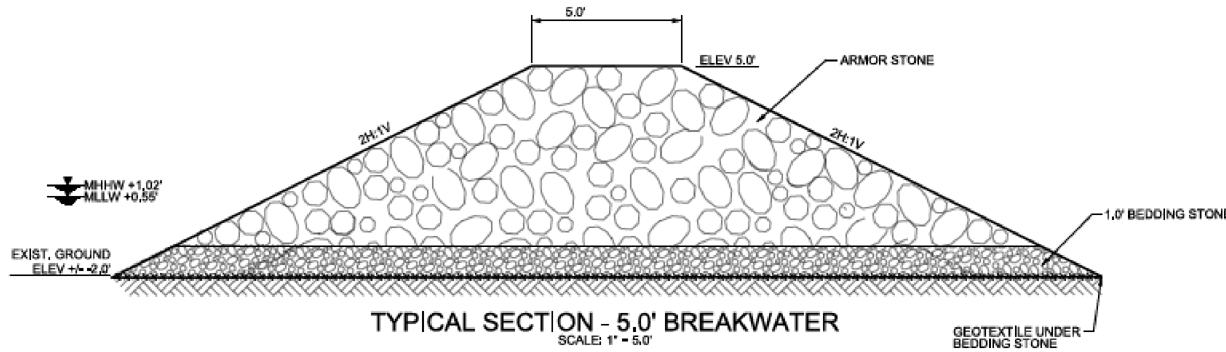

Figure 2-65: Typical Section for 5-FT Breakwater

2.5.2.3. **Bayside Breakwater**

The intent of the bay breakwater is similar to the interior breakwater, except that it is intended to reduce erosion due to wind waves as opposed to vessel-induced waves. In addition, the bayside breakwater has potential to also serve as an oyster cultch and provide a sheltered location which is capable of supporting marsh habitat between the structure and the barrier islands.

To serve the 50-year design life, the structure stability was estimated to be designed for the 50-yr storm which identified from the CTX study resulted in a design stone of R-700. With regard to crest elevation, a design post-settlement crest elevation of 5.0-ft was selected (See Figure 2-65), as that represented the higher end of the spectrum for ground elevations on the landward side of the channel. This was selected as opposed to a design stillwater or sea level rise calculation, because ultimately, if the bayside breakwater is higher than the natural ground on the opposite bank, waves that would break on that ground will break on the breakwater instead. It is understood that some of the existing barrier may erode, but the eroded material will be contained within the interior and bayside breakwater encirclement, and it will only erode under low-recurrent storm events. The channel offset of the bayside breakwater will vary based on bathymetry on the bayside, but in general will range from 600 ft to 1200 ft when combined with an interior breakwater.

2.5.2.3.1. Breakwater Nesting Habitat Adaption

The emergent breakwater may include improving parts of it for nesting habitat. Under this scenario, the top may be lined with a geofabric and then a DF blend to provide bare ground-shell hash nesting habitat. If improving the breakwater to include avian nesting habitat cannot be accomplished, it will be considered designing the breakwaters to be adaptable for nesting habitat features so that another entity can complete the work in the future.

2.5.2.3.2. Oyster Reef Adaption

The bayside breakwater is envisioned and designed to be a rock breakwater; however there is potential consideration for portions of the bayside breakwater to be constructed as intertidal oyster reefs instead. Under that consideration, the water depth and wave height will determine its required width, but this feature should be a low broad feature with gentle slopes (nothing steeper than 5:1 but gentler would be better). It is recommended that down the lateral length of the structure, that the middle (backbone) be a slightly higher elevation than MHHW so that it is slightly emergent for a longer duration of time and that the backbone be approximate 10' width. This higher elevation will obviously help with wave tripping but also create reef diversity and roosting habitat.

2.5.2.3.3. Hydrologic Breaks

To address circulation and tidal interchange through the breakwater system, the elevations will be segmented, meaning that the breakwater will include intermittent breaks. For purposes of cost estimation, the design proposes it will include single row reefball sections with a lower crest elevation for 100 ft in length and alternate every 900 ft. See Figure 2-66 for an example of a Goliath Reef Ball. The spacing and design of the hydrologic breaks will be optimized in PED. Alternate designs could include oyster castles or submerged crests.

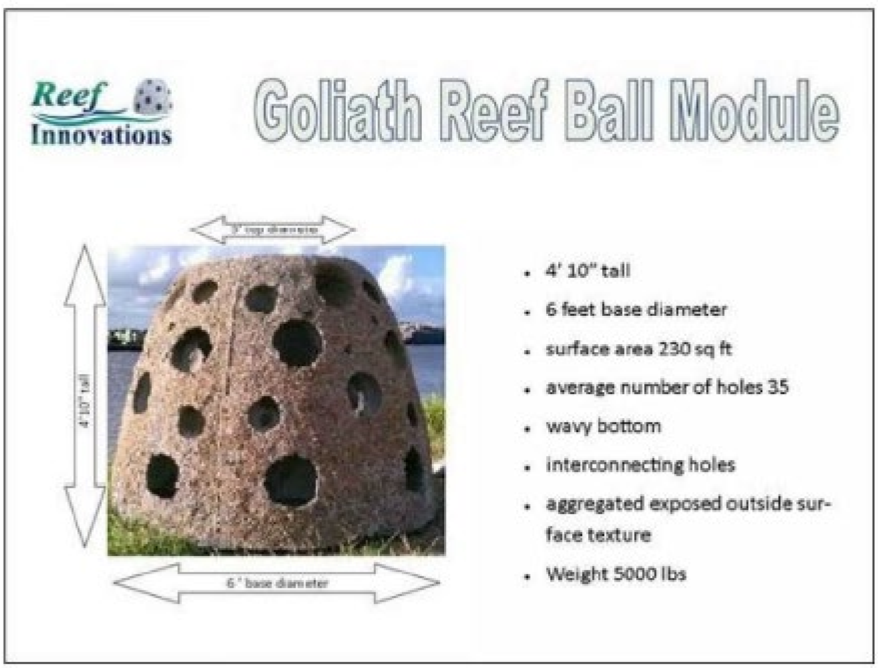

Figure 2-66: Example of a Reef Ball

2.5.3. **Alternative 6: Stabilization with Sediment Placement**

This alternative is similar to Alternative 3, except that an earthen barrier is maintained through beneficial use nourishment. The interior breakwater remains the same as in Alternative 3, with some minor changes to the alignment; whereas the bayside breakwater's crest elevation changes from 5 ft to 3 ft (See Figure 2-64), as the barrier is allowed to erode, because it will be renourished. The additional feature is the earthen berm and nourishment.

2.5.3.1. **Earthen Berm**

The primary goals of the berm are to 1) protect the GIWW from wind and wave attack from the bay(s) and the Gulf of Mexico, 2) reduce sediment shoaling within the GIWW, and 3) provide a sustainable and reusable beneficial use (BU) site for O&M dredged material from adjacent portions of the GIWW. The secondary goal of the barrier island is to provide suitable conditions for marsh development.

The earthen berm was designed to mimic natural coastal barrier elevations, so a crest elevation of 8.0-ft was selected with a 5:1 interior slope. A minimum crest width of 50-ft was selected for the initial berm construction, so that any wave overtopping would have minimal erosion. The centerline of the berm was set 162.5 ft from the centerline of the interior breakwater so that the toe of the berm was offset a minimum 50 feet from the toe of the interior breakwater. This distance would allow for some minor landward migration of the earthen berm without risking the interior breakwater. See

The construction of a new barrier will require the excavation of material directly adjacent to the construction site equal to the volume of material needed to construct the barrier island. These "borrow sites" will then be filled in quickly with O&M material from the GIWW after construction has been completed. Future placement of O&M material from the GIWW will be performed using thin layer placement over the entire area of the widest portion between the barrier island and breakwater. In cases like zones 18 and 16, where existing barriers can be used, new earthen berms will not need to be constructed and adjacent borrow sites not excavated. See

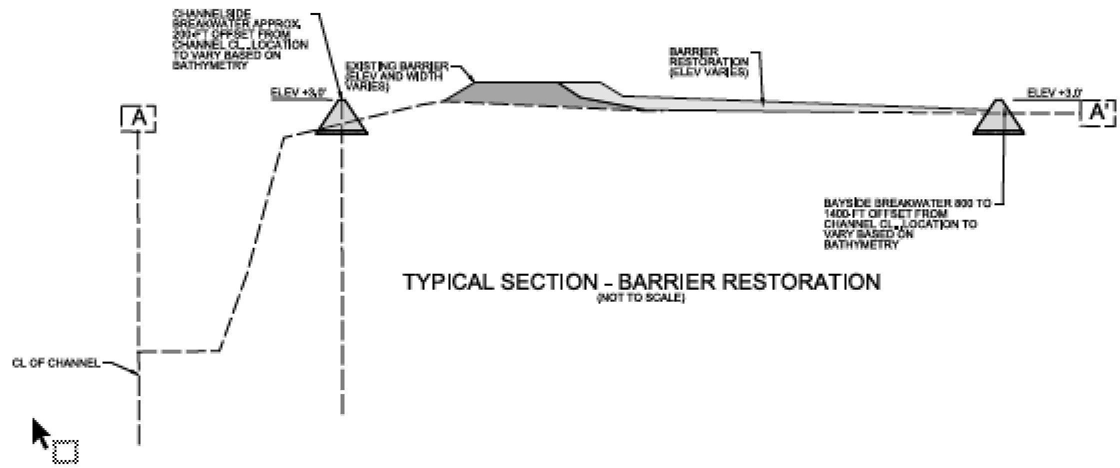

Figure 2-67 and Figure 2-68 for typical details without and with berm construction, respectively.

The earthen berm would have a varying slope on the front of the structure that more closely resembles a natural beach slope. This would provide the most optimal slope for marsh development and allows for vertical and horizontal marsh migration with sea levels rise.

The average earthen berm sq ft will be 600 sq. ft., so a borrow cut of 400 to 800 sq ft. is expected based on bulking and losses of the soils. It is intended to be no deeper -3 ft NAVD88.

The barrier elevation is designed to be emergent 99% of the time so that the feature does not attract nesting avian species only to set them up to have their nests inundated with seasonally and / or wind driven high tides and ship wake. Barrier features are not intended to be grassed, mowed, or maintained but rather planted and seeded with herbaceous and scrub shrub species.

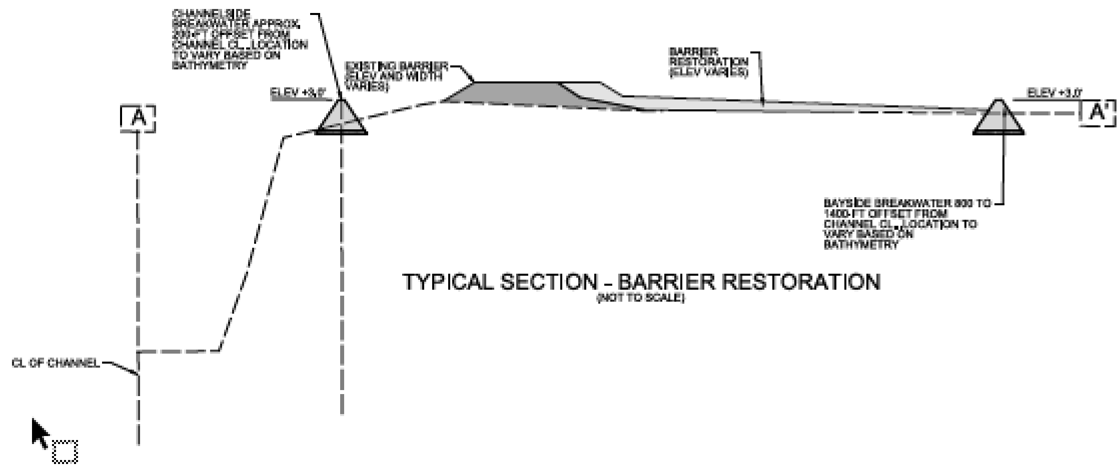

Figure 2-67: Typical Section for Beneficial Use Placement Area (Existing Barrier)

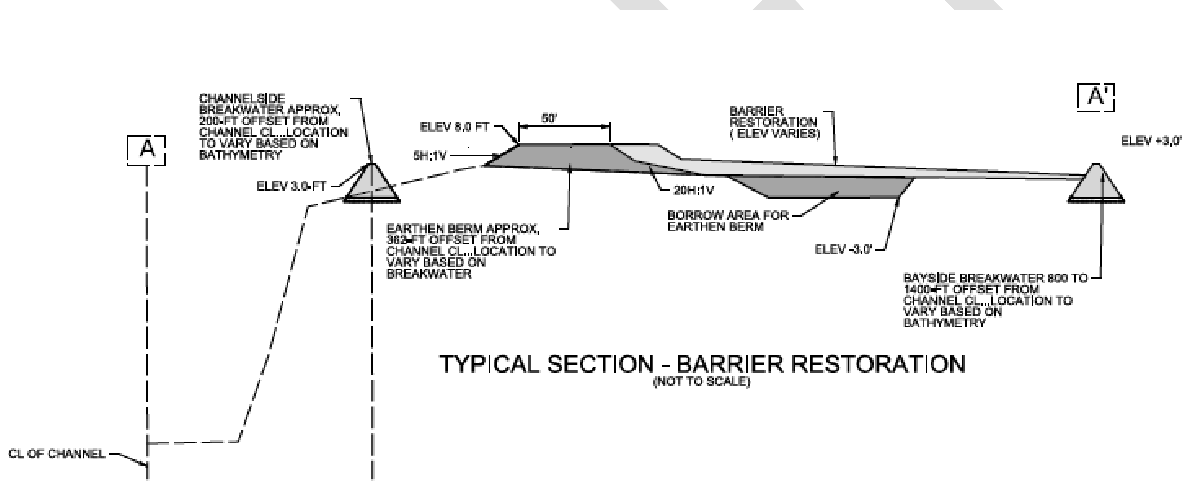

Figure 2-68: Typical Section for Beneficial Use Placement Area (New Barrier)

2.5.3.2. **Nourishment**

The intention for each of the beneficial use sites is that they serve as part of a long-term adaptive nourishment plan. These sites are intended to serve as combination barriers that includes an emergent earthen berm that transitions to marsh. These sites will be susceptible to erosion from coastal storms and sea level rise, so the placement of dredge material will be strategized to maintain and establish a healthy barrier system that addresses those impacts. To that end, the barrier system will be surveyed and the nourishment plan updated to prioritize and establish or re-establish a healthy barrier system as quickly as possible.

Regardless of the exact location, the construction of new barrier islands will require the excavation of material directly adjacent to the construction site equal to the volume of material needed to construct the barrier island. These “borrow sites” are not anticipated to be any deeper than -3 ft, which is common to East Matagorda Bay and not anticipated to cause water quality issues like low DO; however water quality optimization will be performed during PED to design hydrologic exchange measures.

After construction has been completed, these “borrow sites” will then be filled in over the course of the project life with O&M material from the GIWW as part of the dynamic sediment placement strategy. Future placement of O&M material from the GIWW will be performed using various BU strategies including marsh cells, thin layer placement, and training berms for sea grass. The breakwaters are intended to reduce barrier erosion; however erosion can and will occur, so the BU sites are intended for future adaptability, which may include earthen berm replenishment in addition to marsh creation. Because sea level change and barrier erosion will continue, the barriers and BU sites are not intended to have a completion date, but rather be adaptable for additional placement as needed. Some of the zone BU sites nearing design capacity by 2050; whereas others extending past 2080, but incrementally, marsh cells will be completed and planted with each dredge placement cycle until the site nears full capacity.

The earthen berm would have a varying slope on the front of the structure that more closely resembles a natural beach slope. This would provide the most optimal slope for marsh development and allows for vertical and horizontal marsh migration with sea levels rise. Nourishment elevations will be set between +1.5 and -0.5 MSL for optimal tidal elevation range for spartina growth.

The purpose of the marsh nourishment and plantings is to create marsh habitat that emulates the naturally occurring inertial marsh in these bay systems. This beneficial use (BU) of dredge material would provide additional O&M capacity while creating habitat and increasing the resilience of the berms to coastal stressors. Marsh in close proximity to berms has been shown to protect berms by reducing erosion and dampening energies. During the PED phase of project, the PDT will coordinate with resource agencies to identify nearby target sites which will be surveyed to determine the final substrate elevation and composition (open water, marsh, edge). Since the BU locations are expected to be intertidal estuarine marsh, the plan is broadcast locally sourced S. alterniflora seed across the edges of the BU locations once these are constructed. The resource agencies will be consulted to ensure proper species and sourcing are attained and to ensure any TPWD or TXGLO permissions are received prior to plantings.

Dredged material discharge points will be strategized so that dredge material enhances existing habitats (e.g. spartina alterniflora) and does not impact existing habitats (e.g. remnant emergent and submerged shell islands / deposits, and oyster reefs). Even though many of these features (shell islands / deposits)

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are the result of past dredging and dredged material disposal operations they are unique habitats that are in shortage. Same as with the wetland marsh restoration recommendations, existing adjacent marsh will be referenced to determine target marsh elevation(s).

An estuarine marsh complex (intertidal emergent marsh, regularly and irregularly flooded emergent salt flat marsh, regularly and irregular flooded sand flat and open water) will be the objective. It is intended to not fill marsh nourishment areas with dredged material all the way to the edge of the submerged or emergent breakwater, but rather gradually slope to the breakwater from emergent barrier. There should be a water interface between the marsh nourishment area and the breakwater. These interstitial spaces will create a unique habitat and encourage better tidal flushing through the hydrologic breaks.

All marsh nourishment areas will have a vegetation plan that includes planting or seeding or both.

2.5.3.3. Navigation and Hydrologic Breaks

The barrier system is not intended to be a wall. It is understood that there needs to be breaks in the barrier system to allow for navigation of small recreational vessels and for hydrologic connectivity to the watersheds. Wherever there is a watershed release (i.e. stream or river outlet) into the GIWW on the landward site, it is intended to provide a break in the barrier system to allow for connectivity to the Bay across the GIWW. These gaps and locations will be optimized during PED. These breaks will feature armoring on the sides to prevent erosion and widening of the breaks.

2.6. FUTURE WITH PROJECT INCREMENTAL ANALYSES

The intent of this section is to discuss how each alternative Future With Project (FWP) increment compares, particularly with respect to the project's resiliency objective.

2.6.1. Incremental Design and Analysis

Similar to the Future Without Project (FWOP) conditions, each of the alternatives were evaluated using the Sediment Budget Analysis and Coastal Modeling System.

2.6.1.1. Zone 12

At the onset of the study, the two primary issues at Zone 12 were the shoaling and the cross-currents. Engineering judgment suggests that the system dynamics may change under barrier restoration and that channel modification and groins could have strong potential as viable measures. The justification for the barrier restoration is that it redirects more flow into East Matagorda Bay near the inlet than through the GIWW. This also happens to be a pre-existing condition. The justification for the channel stabilization is that it could reduce channel dynamism, particularly erosion along the channel and address the currents at the GIWW. The reason for the jetties/groins is that it could reduce the source of sediment into the GIWW by blocking littoral drift of sediment from entering the cut and depositing in the GIWW. The reason for

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channel widening is that it could spread the shoaling volume across a greater area thus reducing its vertical impact as well as providing additional tolerance for navigational safety.

Figure 2-69 shows increments 12.3.1, 12.3.2, and 12.3.3 which are the increments evaluated for Zone 12. Increment 12.3.1 proposes breakwaters to be constructed with crests at 5 feet above the North American Vertical Datum of 1988 (NAVD88) on the channel bayside of the GIWW. The breakwaters are designed to protect the vessels in the channel from waves and also protect the existing barrier islands from vessel wake which cause erosion. The breakwaters near the intersection at Caney Creek are also intended to reduce the effects of the strong cross currents reported by navigation vessels at this location. The alignment of the breakwaters at the intersection of Mitchell's Cut and GIWW is intended to trace the future shoreline as projected. At first glance, it may appear that it is cutting through the barrier, but that barrier spit is anticipated to completely erode by project construction. In addition, the hourglass shape of the shoreline protection will allow for greater dissipation of ebb and flood currents. Future analysis during PED will need to be performed to address potential scour at the ends. The CMS modeling suggest a reduction in shoaling but without further investigation this can't be quantified at this stage. Overall channel shoaling was reduced slightly as result of the channel stabilization and barriers.

Increment 12.3.2 proposes to add channel widening as an optimization measure to the breakwaters in 12.3.1. The channel widening is intended to provide vessels with more room to navigate in the portion of the channel which is identified as a shoaling hotspot. This location also poses a safety risk for vessels where 12 groundings were reported in the 2020 calendar year. Material dredged for the channel is planned to be placed in PA 99 and PA 100. The channel widening will have the same channel depth, but will be 125 ft wider on the south from stations 694+00 to 698+00 and 150 ft wider on the north from 695+00 to 697+00, each with 45 deg tapers. These dimensions will need further optimization during PED, but were selected to ensure as much additional channel volume as what is dredged to address shoaling as well capture the anticipated shift in vessel movement.

Increment 12.3.3 proposes to add a sediment trap as an optimization measure to the measures in 12.3.2. The sediment trap is intended to allow for more accumulation of sediment between scheduled dredging which would reduce or eliminate out-of-cycle dredging.

Between the three increments there is no difference in FWP shoaling; however the FWP shoaling is less than the FWOP shoaling. Due to limitations in modeling at this stage, all increments in Zone 12 computed similar changes to shoaling, although it is anticipated that is not the case. Further investigation is needed to assess the quantitative shoaling changes for these Zone 12 increments.

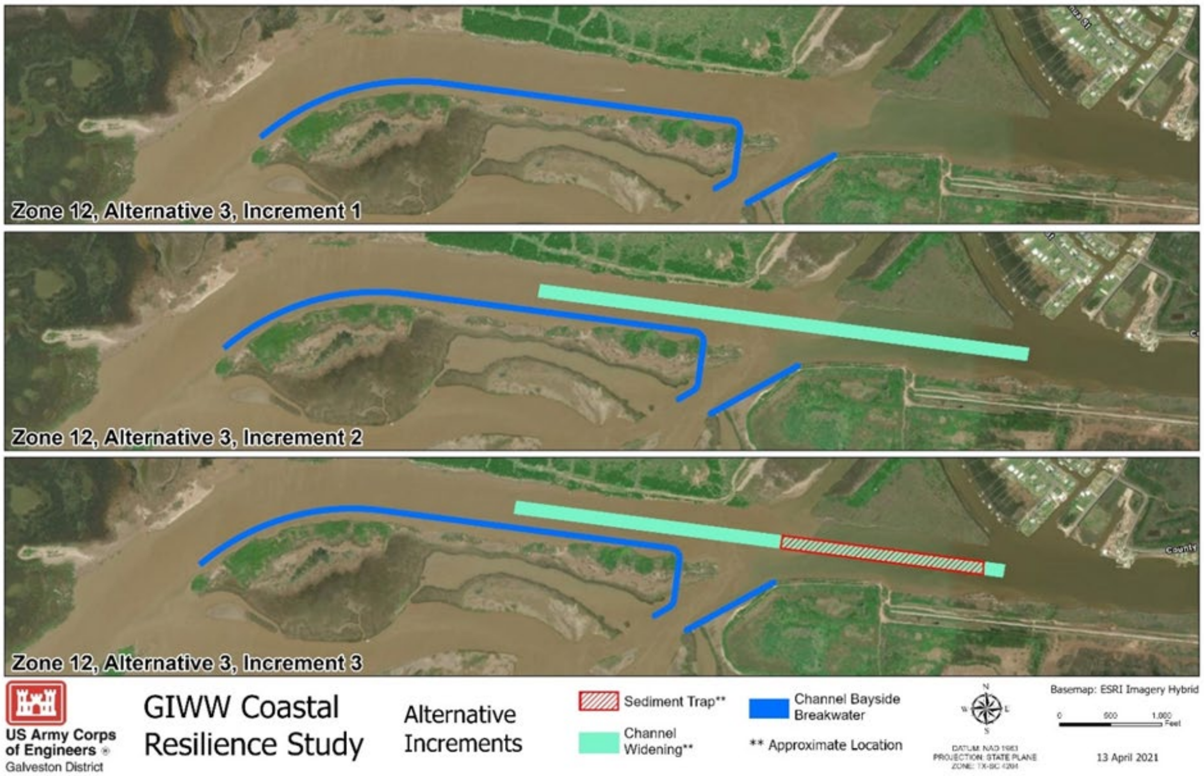

Figure 2-69: Zone 12 Increment Maps

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2.6.1.2. **Zone 13**

Figure 2-70 shows increments 13.3.1 and 13.6.1 which are the increments evaluated for Zone 13. Increment 13.3.1 proposes breakwaters to be constructed with crests at 5 feet NAVD88 on the channel bayside of the GIWW. The breakwaters are designed to protect the vessels in the channel from waves and also protect the existing barrier islands from vessel wake which cause erosion. The FWOP condition would lead to higher shoaling in the GIWW and greater landward shoreline erosion, which is guarded against by these breakwaters. Not illustrated in the figure are navigational and hydrologic breaks that will be optimized during PED. It is anticipated that at least one barrier opening will be implemented near the west end of this increment. These openings will have negligible reduction on overall project cost and BU capacity. The opening dimensions will be evaluated in PED to ensure hydrologic connectivity and navigation stability. The east end of this increment tapers to avoid critical habitat and transition into the zone 12 increment measures.

Increment 13.6.1 proposes a combination of sediment placement, an earthen berm, marsh plantings, and breakwaters. The sediment placement is intended to restore the barrier islands which would nearly be completely lost by the end of the period of analysis in year 2080. Borrow material will be sourced from the BU footprint. Marsh plantings are intended to prevent rapid erosion from wind and wave exposure by stabilizing the sediment with vegetation. The earthen berm is proposed to be constructed with a crest elevation of 8 feet NAVD88 and is designed to attenuate the crosswinds that vessels in the channel would be exposed to. Breakwaters are proposed to be constructed with crests at 3 feet NAVD88 on the channel bayside and bayside of the GIWW and are designed to contain the sediment in the placement area and prevent rapid erosion from wave exposure.

Between the two increments there is no difference in FWP shoaling; however the FWP shoaling is less than the FWOP shoaling.

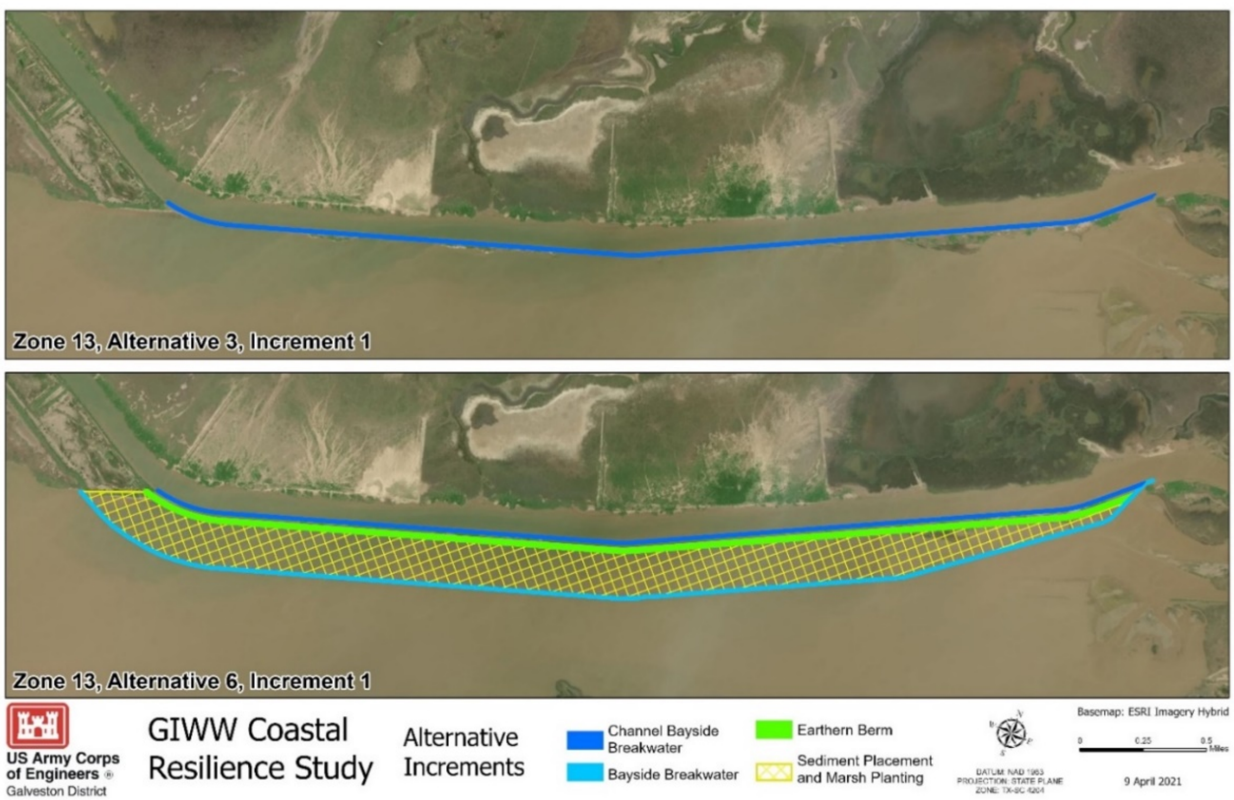

Figure 2-70: Zone 13 Increment Maps

2.6.1.3. Zone 14

Figure 2-71 shows increments 14.3.1 and 14.6.1 which are the increments evaluated for Zone 14. Increment 14.3.1 proposes breakwaters to be constructed on the channel bayside and bayside of the GIWW with crests at 3 feet and 5 feet NAVD88, respectively. The breakwaters are designed to protect the vessels in the channel from waves and also protect the existing barrier islands from waves from the bay and vessel wake which cause erosion. Under the FWOP condition, the barriers will be further breached and lost. This would lead to higher shoaling in the GIWW and greater landward shoreline erosion, which is guarded against by these breakwaters. The opening dimensions will be further evaluated in PED to ensure hydrologic connectivity. The proposed hourglass shape design was implemented per Fish and Wildlife request. The extent of marsh and BU implementation will be subject to shoreline conditions at time of construction. What is shown in the plan represents approximate projections for shoreline erosion, which is why the future BU appears to overlap existing barriers.

Increment 14.6.1 proposes a combination of sediment placement, earthen berms, marsh plantings, and breakwaters. The sediment placement is intended to restore the barrier islands, much of which would be lost by the end of the period of analysis in year 2080. Borrow material will be sourced from the BU footprint. Marsh plantings are intended to prevent rapid erosion from wind and wave exposure by stabilizing the sediment with vegetation. The earthen berm is proposed to be constructed with a crest elevation of 8 feet NAVD88 and is designed to attenuate the crosswinds that vessels in the channel would be exposed to. Breakwaters are proposed to be constructed with crests at 3 feet NAVD88 on the channel bayside and bayside of the GIWW and are designed to contain the sediment in the placement area and prevent rapid erosion from wave exposure.

Between the two increments there is no difference in FWP shoaling; however the FWP shoaling is less than the FWOP shoaling.

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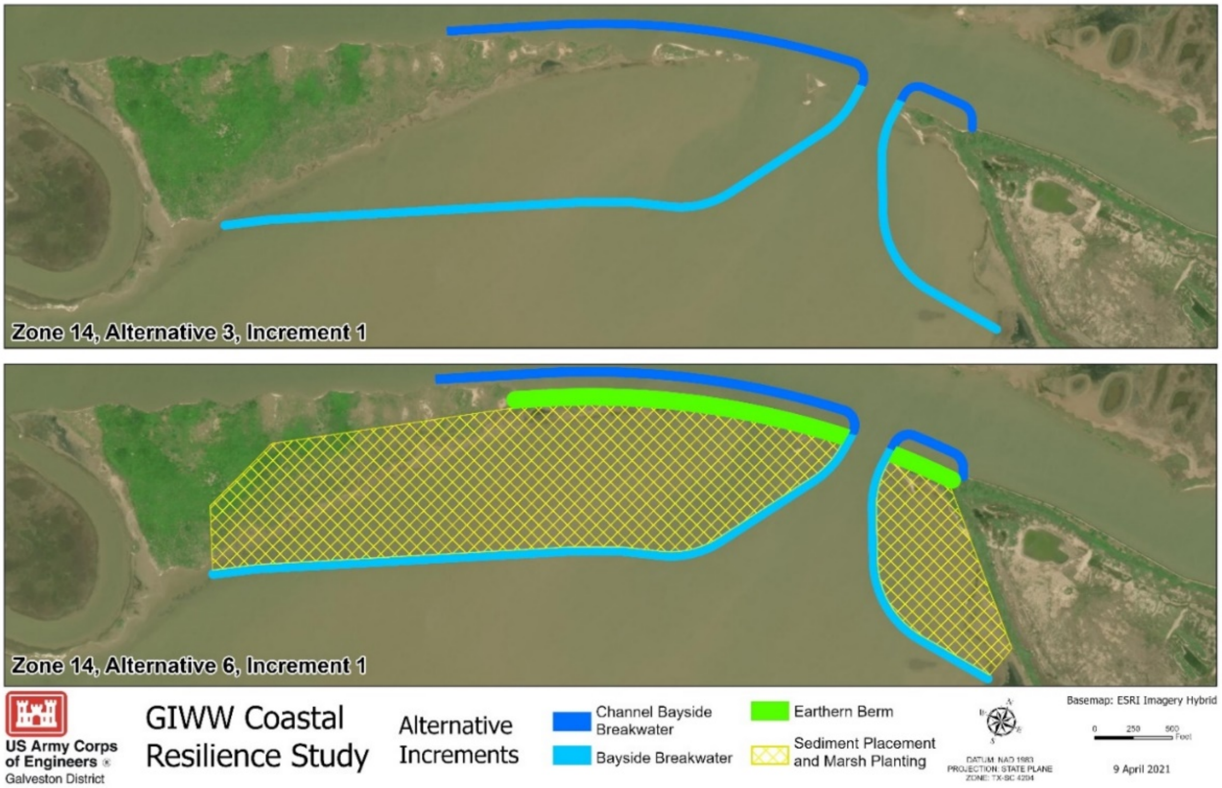

Figure 2-71: Zone 14 Increment Maps

2.6.1.4. **Zone 16**

Figure 2-72 shows increments 16.3.1 and 16.6.1 which are the increments evaluated for Zone 16. Increment 16.3.1 proposes breakwaters to be constructed on the bayside of the GIWW with crests at 5 feet NAVD88. The breakwaters are designed to protect the barrier islands from waves from the bay which cause erosion. The barrier islands protect the vessels in the channel from winds and waves. Under the FWOP condition, a majority of this barrier is projected to be breached and lost. This would lead to higher shoaling in the GIWW and greater landward shoreline erosion, which is guarded against by these breakwaters.

Increment 16.6.1 proposes a combination of sediment placement, earthen berms, marsh plantings, and breakwaters. The sediment placement is intended to restore the barrier islands, much of which would be lost by the end of the period of analysis in year 2080. Borrow material will be sourced from the BU footprint. Marsh plantings are intended to prevent rapid erosion from wind and wave exposure by stabilizing the sediment with vegetation. The earthen berm is proposed to be constructed with a crest elevation of 8 feet NAVD88 and is designed to attenuate the crosswinds that vessels in the channel would be exposed to. Breakwaters are proposed to be constructed with crests at 3 feet NAVD88 on the channel bayside and bayside of the GIWW and are designed to contain the sediment in the placement area and prevent rapid erosion from wave exposure.

Between the three increments there is no difference in FWP shoaling; however the FWP shoaling is less than the FWOP shoaling.

Breakwaters on channel side were not investigated for this zone due to screening. This is due to overall project cost and the prioritization of channel side breakwaters only along new barriers. An exception to this is Zone 18 due to current high shoaling rates.

Figure 2-72: Zone 16 Increment Maps

2.6.1.5. Zone 18

Figure 2-73 shows increments 18.3.1, 18.3.2, and 18.3.3 which are the alternative 3 increments evaluated for Zone 18. Increment 18.3.1 proposes breakwaters to be constructed with crests at 5 feet NAVD88 on the bayside of the GIWW and are designed to protect the barrier islands from waves from the bay which cause erosion. The barrier islands protect the vessels in the channel from winds and waves. Under the FWOP condition, the barriers are projected to be lost along several miles of the GIWW. This would lead to higher shoaling in the GIWW and greater landward shoreline erosion, which is guarded against by these alternatives. Increment 18.3.1 only guards against wind-driven waves from the Bay side.

Increment 18.3.2 proposes to add breakwaters on the channel bayside of the GIWW in addition to the breakwaters in 18.3.1. The breakwater crests on the channel bayside are proposed to be constructed to 3 feet NAVD88 and are designed to protect the barrier islands from vessel wake which cause erosion. The barrier islands protect the vessels in the channel from winds and waves.

Increment 18.3.3 proposes to add breakwaters and reef balls on the channel landside of the GIWW in addition to the breakwaters in 18.3.2. The breakwater crests on the channel landside are proposed to be constructed to 3 feet NAVD88 and are designed to protect the coastal lands from vessel wake which cause erosion. The reef balls are designed to attenuate waves while also allowing fish passage at the openings to Oyster Lake.

Figure 2-74 shows increments 18.6.1 and 18.6.2 which are the alternative 6 increments evaluated for Zone 18. Increment 18.6.1 proposes a combination of sediment placement, marsh plantings, and breakwaters. The sediment placement is intended to restore the barrier islands, most of which would be lost but not breached by the end of the period of analysis in year 2080. Because it is not projected to be beached new earthen berms are not anticipated. Marsh plantings are intended to prevent rapid erosion from wind and wave exposure by stabilizing the sediment with vegetation. Breakwaters are proposed to be constructed with crests at 3 feet NAVD88 on the channel bayside and bayside of the GIWW and are designed to contain the sediment in the placement area and prevent rapid erosion from wave and vessel wake exposure.

Increment 18.6.2 proposes to add breakwaters and reef balls on the channel landside of the GIWW in addition to the sediment placement, marsh plantings, and breakwaters in 18.6.1. The breakwaters on the channel landside are designed to protect the coastal lands from vessel wake which cause erosion. The reef balls are designed to attenuate waves while also allowing fish passage at the openings to Oyster Lake.

The transition between Zones 18 and 19 has high shoaling. This shoaling is a result of high erosion along all the shorelines, contribution of sediment yield from Oyster Lake, and reanimation of material from OWPA circulated back into the GIWW. The incremental analysis only evaluated the influence of adjacent shoreline erosion so the FWP shoaling rates while lower than the FWOP condition are highly conservative.

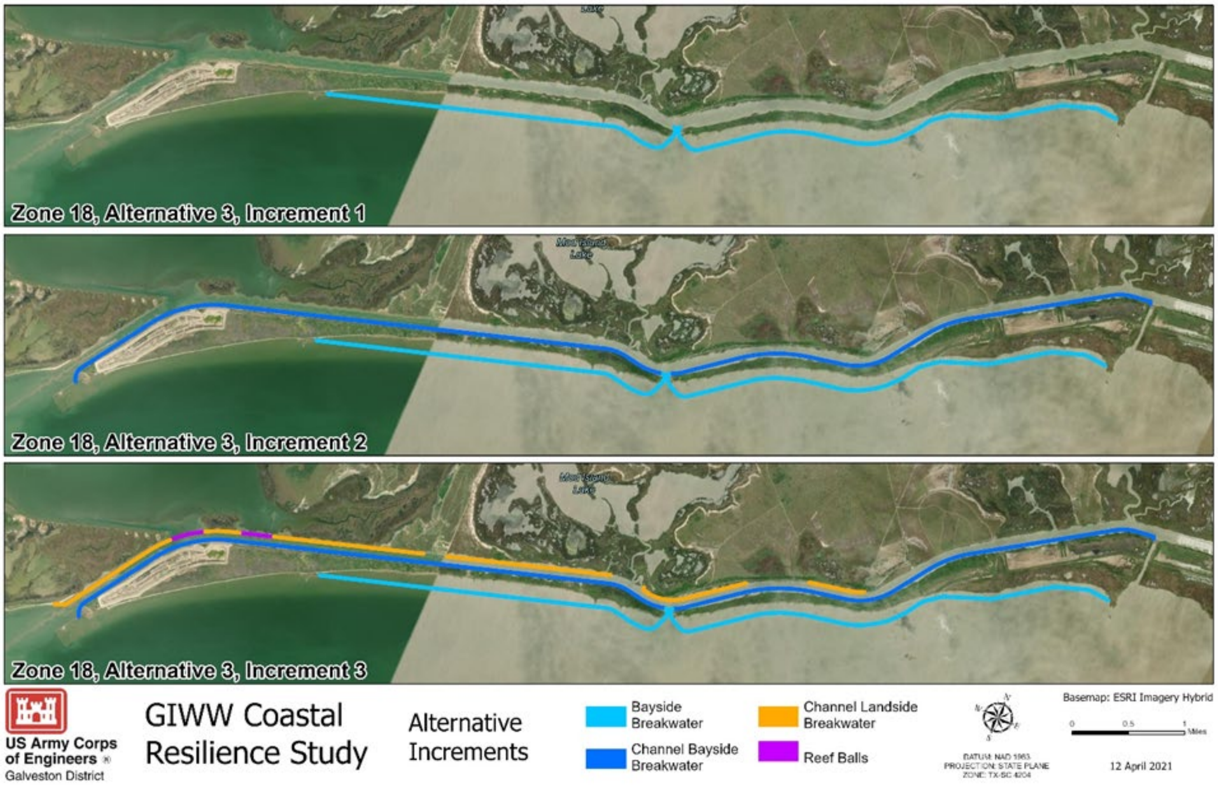

Figure 2-73: Zone 18 Alternative 3 Increment Maps

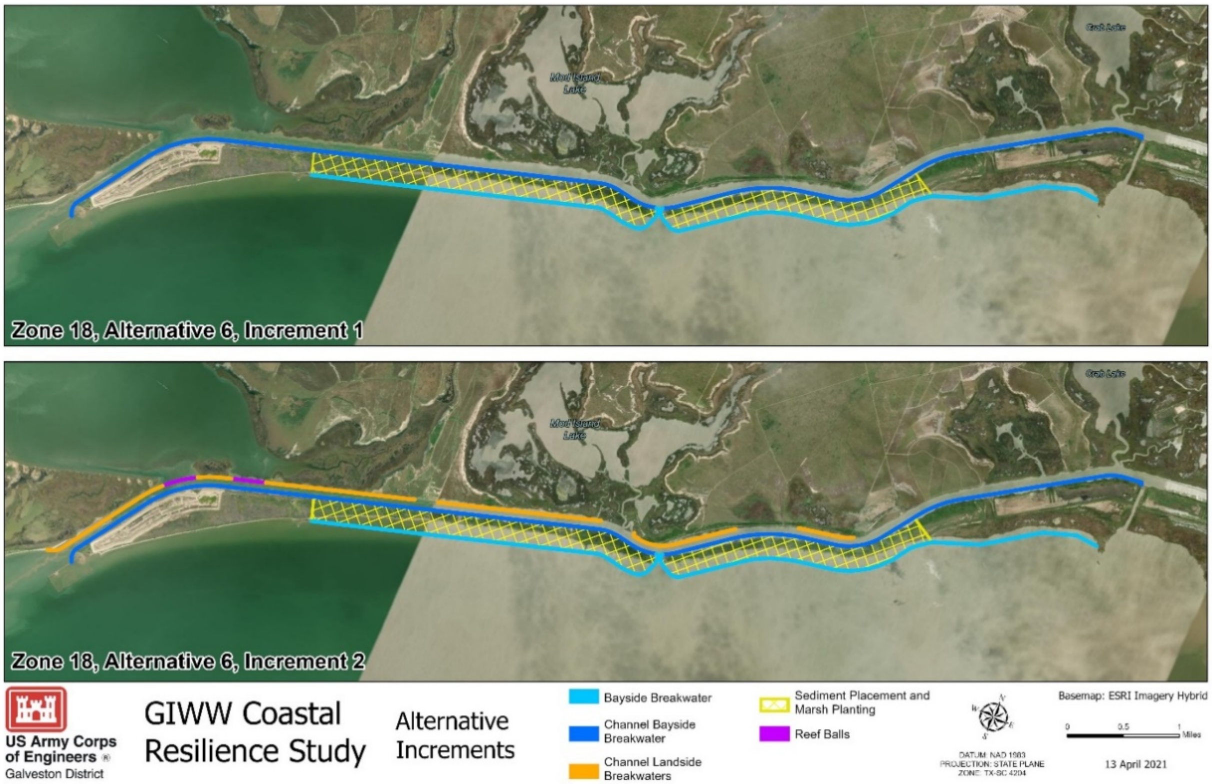

Figure 2-74: Zone 18 Alternative 6 Increment Maps

2.6.2. **TSP Environmental Impacts**

For each of the alternatives, tidal and salinity variations may be affected but are not likely to be adversely affected. Each alternative represents a binary variation in barrier condition (i.e. barrier or no barrier), similar to historical conditions. Historically, barriers lined the GIWW and have since eroded at various rates. The system has been productive for a long period of time whether a barrier existed or not, so changes to the barrier system, while it may affect tides and salinity, are not anticipated to introduce a non-pre-existing condition. Projected FWP changes to salinity, currents, and tidal range can be found in the Annex 3: CMS Report. Observation points were collected at the entrance to Mitchell's cut, at the intersection of the GIWW and Mitchell's Cut, inside East Matagorda Bay, and along the GIWW.

2.7. INVESTIGATIONS AND ANALYSIS REQUIRED DURING PRECONSTRUCTION ENGINEERING AND DESIGN (PED)

The features in this feasibility study, including alternatives analysis and feasibility design, were completed using available data. There will be additional data and analysis requirements during PED which include:

- Survey data will need to be collected in several areas. The existing elevations in the locations of project features were assumed based on discussions with the non-federal sponsor and local resource agencies.

- Marsh cell boundaries will need to be refined based on the results of site-specific surveys and based on anticipated availability of O&M material for those features where BUDM is assumed.

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3. GEOTECHNICAL

3.1. SCOPE OF WORK

Breakwaters will be constructed along the Gulf Intracoastal Waterway (GIWW) to reduce erosion, provide channel resiliency, and create Beneficial Use Sites (BUs) to increase dredge material placement capacity. Several existing placement areas are reaching capacity and will soon require long pump distances to reach placement areas with available capacity. Creating BUs adjacent to the GIWW should allow for short pump distances to locations with large capacities. Earthen embankments will be constructed on the channel side of the BUs to allow for additional placement capacity while preventing dredge material from flowing back into the channel.

3.2. BORROW SOURCES

Fill material for the embankment in Alternative 6 increments will come from within the proposed BUs footprint, therefore increasing the capacity. Embankment fill material is assumed to be of sufficient quality to create earthen berms with a 1:5 slope. Additional soils data will need to be collected during PED to verify this assumption.

3.3. GEOLOGY

The project area is in a region known as the Gulf Coast Prairies and Marshes Ecoregion (Gould, 1975). This region is a narrow band about 60 miles wide along the Texas coast bordering the Gulf of Mexico and stretching from the Sabine River to the Rio Grande. The region is generally flat and gradually slopes coastward from an elevation of approximately 245 feet (Diamond and Smeins, 1984). It is comprised of shallow bays, estuaries, salt marshes, dunes, and tidal flats, as well as tallgrass coastal prairie, riparian forests, mottes, coastal woodlots, and dense brush habitats. The Beaumont rock formation of the Quaternary and Pleistocene underlie the study area with Holocene alluvial deposits located along the rivers and streams (Eifler et al., 1994). The unit is a sheet like body of Seguin sediment that varies in texture but is typically sandy within the study area (Gustavson and Holliday, 1985). The floodplain deposits, including low terrace deposits 3-8 feet above floodplain, are subject to flooding. Soil composition consists mainly of clay, silt, sand, gravel, and organic matter.

3.4. **ZONE 12**

3.4.1. **Existing Conditions**

3.4.2. **The current dredged material placement plan requires approximately one-third of the O&M dredge material to be placed into existing upland confined placement areas (PAs) DA 99, DA 100, and PA 102-C. If the O&M dredge material is suitable for beach placement the dredge material will be pumped to PA 98 and PA 98-A to restore the eroding shoreline of Sargent Beach. Generally two-thirds of dredge material is suitable to be placed into Sargent Beach placement areas. Zone 12 experiences high rates of shoaling and requires frequent emergency dredging to remove areas of high shoaling O&M dredge material from the channel. Future without Project**

Future O&M shoaling rates remain relatively constant until 2030 when Texas Coastal Project has construction planned in this zone. Due to the construction of the Texas Coastal Project the annual shoaling quantities decrease immediately from approximately 110,600 CY per year to 104,400 CY per year in 2030. The shoaling rates are expected to increase gradually from approximately 104,400 CY per year in 2030 to 105,600 CY per year in 2080. The Texas Coastal Project will require 247,778 CY of dredge material to be mined from the San Bernard to Colorado River reach and 1,195,299 CY to be mined from PA 102-C in 2030. Approximately one-third of the O&M dredge material will be placed into existing upland confined placement areas (PAs) DA 99, DA 100, and PA 102-C. PAs will be raised as necessary to contain the O&M dredge material. One raise is required in DA 99 and one raise in DA 100 to provide sufficient dredge material capacity until 2080. Approximately two-thirds of the O&M dredge material is suitable to be placed in the surf zone in PA 98 and PA 98-A to restore the eroding shoreline. The frequency of emergency dredging is expected to stay the same through 2080.

3.4.3. **Future With Project**

Increment 12.3.1Future O&M shoaling rates remain relatively constant until 2030. Due to the construction of the Texas Coastal Project and the implementation of breakwaters from this project the annual shoaling quantities decrease immediately from approximately 110,600 CY per year to 96,200 CY per year in 2030. The shoaling rates are expected to decrease gradually from approximately 96,200 CY per year in 2030 to 93,400 CY per year in 2080. The Texas Coastal Project will require 247,778 CY of dredge material to be mined from the San Bernard to Colorado River reach and 1,195,299 CY to be mined from PA 102-C in 2030. Approximately one-third of the O&M dredge material will be placed into existing upland confined placement areas (PAs) DA 99, DA 100, and PA 102-C. PAs will be raised as necessary to contain the O&M dredge material. One raise is required in DA 99 and one raise in DA 100 to provide sufficient dredge material

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capacity until 2080. Approximately two-thirds of the O&M dredge material is suitable to be placed in the surf zone in PA 98 and PA 98-A to restore the eroding shoreline. The frequency of emergency dredging is expected to stay the same through 2080 if channel widening is not performed.

Increment 12.3.2

In Zone 12 with channel widening it was possible to change the dredging cycle for the entire zone to every 2 years, eliminating the need for out of cycle dredging as vessels should be able to navigate channel better even in high shoaling conditions. The new work widening dredge material will be placed into PA 102- unless in PED the new work material is considered sufficient to construct the earthen dike of newly constructed BU site. Although not quantifiable with current data O&M dredged volumes and cost are expected to decrease after channel widening which should increase the BCR further encouraging the implementation of this recommendation.

3.5. ZONE 13

3.5.1. **Existing Conditions**

The current placement plan requires O&M dredge material to be placed into existing upland confined placement areas PA 104-A and PA 104-B. Capacity in PA 104-B is shared between Zone 13 and Zone 14. Recent real estate constraints may prohibit the placement of dredged material in PA 104-A and PA 104-B. Galveston District is currently pursuing an exemption to continue utilizing these placement areas.

3.5.2. **Future Without Project**

Future O&M shoaling rates decrease from 66,600 CY per year to 55,700 CY per year until 2030 when Texas Coastal Project has construction planned in this zone. Due to the construction of the Texas Coastal Project, the annual shoaling quantities decrease immediately from approximately 55,700 CY per year to 30,000 CY per year in 2030. The shoaling rates are expected to decrease gradually from approximately 30,000 CY per year in 2030 to 29,000 CY per year in 2080. PAs will be raised as necessary to contain the O&M dredge material. Three raises are required in PA 104-A and three raises in PA 104-B to provide sufficient dredge material capacity until 2080. PA 104-A and PA 104-B will be required to be raised 1’ above maximum recommended elevation stated in EIS in order to contain O&M dredge material through 2080.

3.5.3. **Future With Project**

Increment 13.3.1Future O&M shoaling rates decrease from 66,600 CY per year to 55,700 CY per year until 2030. Due to the construction of the Texas Coastal Project and the implementation breakwaters from this project the annual shoaling quantities decrease immediately from approximately 55,700 CY per year to 25,500 CY per year in 2030. The shoaling rates are expected to remain stable at approximately 25,500 CY per year until 2080. PAs will be raised as necessary to contain the O&M dredge material. Three raises are required in PA 104-A and three raises in PA 104-B to provide sufficient dredge material capacity until 2080.

Increment 13.6.1Future O&M shoaling rates decrease from 66,600 CY per year to 55,700 CY per year until 2030. Due to the construction of the Texas Coastal Project and the implementation of this project the annual shoaling quantities decrease immediately from approximately 55,700 CY per year to 25,500 CY per year in 2030. The shoaling rates are expected to remain stable at approximately 25,500 CY per year until 2080.

BU 102-B utilizes the existing authorized footprints from PA 102-A and PA 102-B which are currently abandoned unconfined placement areas that have been left eroded and unusable over time. BU 102-B will be utilized to contain dredge material from Zone 13 and from 2030 to 2080. Existing upland placement areas PA 104-A and PA 104-B will be abandoned after construction of BU 102-B as they will be redundant. Utilizing BU 102-B should minimize the pump distances for dredging and provide sufficient placement of dredged material through 2080. As BU 102-B is large it expected that training dikes or geotubes will be used to confine areas within the BU and fill in the confined areas with dredged material to construct upland marsh placement. Marsh planting can start as the elevation of the material within the BUs reach +1.0 MLLW. The footprint is not finalized and may be reduced upon further analysis in PED.

3.6. ZONE 14

3.6.1. **Existing Conditions**

The current placement plan requires O&M dredge material to be placed into existing upland confined placement areas PA 104-B and PA 105-A. Capacity in PA 104-B is shared between Zone 13 and Zone 14. Recent real estate constraints may prohibit the placement of dredged material in PA 104-B. Galveston District is currently pursuing an exemption to continue utilizing this placement area.

3.6.2. **Future Without Project**

Future O&M shoaling rates remain relatively constant until 2030 when Texas Coastal Project has construction planned in this zone. Due to the construction of the Texas Coastal Project, the annual shoaling quantities decrease immediately from approximately 47,700 CY per year to 35,700 CY per year in 2030. The shoaling rates are expected to increase gradually from approximately 35,700 CY per year in 2030 to 38,900 CY per year in 2080. PAs will be raised as necessary to contain the O&M dredge material. Three raises are required in PA 104-B and four raises in PA 105-A to contain O&M dredge material until 2080. PA 104-B and PA 105-A will be required to be raised 1’ above maximum recommended elevation stated in EIS in order to provide sufficient dredge material capacity until 2080.

3.6.3. **Future With Project**

Increment 14.3.1Future O&M shoaling rates remain relatively constant until 2030. Due to the construction of the Texas Coastal Project and the implementation of breakwaters from this project the annual shoaling quantities decrease immediately from approximately 47,300 CY per year to 34,600 CY per year in 2030. The shoaling rates are expected to remain stable at approximately 34,600 CY per year until 2080. PAs will be raised as necessary to contain the O&M dredge material. Three raises are required in PA 104-B and four raises in PA 105-A to provide sufficient dredge material capacity until 2080.

Increment 14.6.1Future O&M shoaling rates remain relatively constant until 2030. Due to the construction of the Texas Coastal Project and the implementation of breakwaters for this project the annual shoaling quantities decrease immediately from approximately 47,300 CY per year to 34,600 CY per year in 2030. The shoaling rates are expected to remain stable at approximately 34,600 CY per year until 2080. BU 102-C and BU 103 will be utilized to contain dredge material from Zone 14 from 2030 to 2080.

BU 102-C and BU 103 expand on the existing authorized footprint from PA 102-C and PA 103. PA 102-C is a current placement area currently being utilized. PA 103 is currently an abandoned unconfined placement area that has been left eroded and unusable over time. BU 102-C and BU 103 will be utilized to contain dredge material from Zone 14 and from 2030 to 2080. Existing upland placement areas PA 104-B and PA 105-A will be abandoned after construction of BU 102-C and BU 103 as they will be redundant. Utilizing BU 102-C and BU 103 should minimize the pump distances for dredging and provide sufficient placement of dredged material through 2080. BU 102-C and BU 103 are expected to be constructed utilizing thin layers of dredged material. Marsh planting can start as the elevation of the material within the BUs reach +1.0 MLLW approximately 20 years following construction. The footprints are not finalized and may be reduced upon further analysis in PED. An access route is currently planned to remain unobstructed between BU 102-C and BU 103 to allow for passage of recreational vehicles.

3.7. ZONE 16

3.7.1. **Existing Conditions**

The current placement plan requires O&M dredge material to be placed into existing upland confined placement area PA 106. Capacity in PA 106 is shared between Zone 15, Zone 16, and Zone 17.

3.7.2. **Future Without Project**

Future O&M shoaling rates remain relatively constant until 2033. After 2033 the annual shoaling quantities increase from approximately 51,600 CY per year to 64,000 CY per year in 2080. PA 106 will be raised as necessary to contain the O&M dredge material. Two raises are required in PA 106 to provide sufficient dredge material capacity until 2080.

3.7.3. **Future With Project**

3.7.3.1. **Increment 16.3.1**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of this project after 2030 the annual shoaling quantities immediately decrease from approximately 51,600 CY per year to 50,600 CY per year. The shoaling rates are expected to remain stable at approximately 50,600 CY per year through 2080. PA 106 will be raised as necessary to contain the O&M dredge material. Two raises are required in PA 106 to provide sufficient dredge material capacity until 2080.

3.7.3.2. **Increment 16.6.1**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of breakwaters from this project after 2030 the annual shoaling quantities immediately decrease from approximately 51,600 CY per year to 50,600 CY per year. The shoaling rates are expected to remain stable at approximately 50,600 CY per year through 2080. BU 105 will be utilized to contain dredge material from Zone 15 and Zone 16 from 2030 to 2080. Depending on the increment BU 105 will also be utilized to contain dredge material from Zone 14.

BU 105 utilizes the existing authorized footprints from PA 105 which is currently an abandoned unconfined placement area that has been left eroded and unusable over time. BU 105 will be utilized to contain dredge material from Zone 16 and from 2030 to 2080. Existing upland placement area PA 106 will be abandoned after construction of BU 105 as it will be redundant.

Utilizing BU 105 should minimize the pump distances for dredging and provide sufficient placement of dredged material through 2080. As BU 105 is large it expected that training dikes or geotubes will be used to confine areas within the BU and fill in the confined areas with dredged material to construct upland marsh placement. Marsh planting can start as the elevation of the material within the BUs reach +1.0 MLLW. The footprint is not finalized and may be reduced upon further analysis in PED.

3.8. ZONE 18

3.8.1. **Existing Conditions**

The current placement plan requires O&M dredge material from Sta. 825+000 to Sta. 848+000 is placed into existing upland confined placement areas PA 109, PA 110 and PA 112-B. O&M dredge material from Sta. 848+000 to Sta. 883+000 is placed into existing open water placement areas PA 113 and PA 114.

3.8.2. **Future Without Project**

Future O&M shoaling rates remain relatively constant until 2030. The annual shoaling quantities increase gradually from approximately 254,300 CY per year to 352,000 CY per year in 2080. O&M dredge material from Sta. 848+000 to Sta. 883+000 will be placed into existing open water placement areas PA 113 and PA 114 due to insufficient capacity of existing upland confined placement areas to contain O&M dredge material until 2080. PAs will be raised as necessary to contain the O&M dredge material. O&M dredge material from Sta. 825+000 to Sta. 848+000 is placed into existing upland confined placement areas PA 109, PA 110 and PA 112-B. One raise is required in PA 109, two raises in PA 110, and two raises in PA 112-B to contain O&M dredge material until 2080. PA 110 and PA 112-B will be required to be raised 1' above maximum recommended elevation stated in EIS in order to provide sufficient dredge material capacity until 2080.

3.8.3. **Future With Project**

3.8.3.1. **Increment 18.3.1**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of breakwaters from this project after 2030 the annual shoaling quantities immediately decrease from approximately 254,300 CY per year to 241,000 CY per year. The shoaling rates are expected to decrease gradually from approximately 241,000 CY per year in 2030 to 235,800 CY per year in 2080. O&M dredge material from Sta. 855+000 to Sta. 883+000 is placed into existing open water placement areas PA 113 and PA 114 due to insufficient capacity of existing upland confined placement areas to contain O&M dredge material until 2080. PAs will be raised as necessary to contain the O&M dredge material. O&M dredge material from Sta. 825+000 to Sta. 855+000 is placed into existing upland confined placement areas PA 109, PA 110 and PA 112-B. Two raises are required in PA 109, two raises in PA 110, and two raises in PA 112-B to contain O&M dredge material until 2080. PA 109, PA 110 and PA 112-B will be required to be raised 1’ above maximum recommended elevation stated in EIS in order to provide sufficient dredge material capacity until 2080.

3.8.3.2. **Increment 18.3.2**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of breakwaters from this project after 2030 the annual shoaling quantities immediately decrease from approximately 254,300 CY per year to 214,100 CY per year. The shoaling rates are expected to remain stable at approximately 214,100 CY per year until 2080. O&M dredge material from Sta. 857+000 to Sta. 883+000 is placed into existing open water placement areas PA 113 and PA 114 due to insufficient capacity of existing upland confined placement areas to contain O&M dredge material until 2080. PAs will be raised as necessary to contain the O&M dredge material. O&M dredge material from Sta. 825+000 to Sta. 857+000 is placed into existing upland confined placement areas PA 109, PA 110 and PA 112-B. Two raises are required in PA 109, two raises in PA 110, and two raises in PA 112-B to contain O&M dredge material until 2080. PA 109, PA 110 and PA 112-B will be required to be raised 1’ above maximum recommended elevation stated in EIS in order to provide sufficient dredge material capacity until 2080.

3.8.3.3. **Increment 18.6.1**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of breakwaters from this project after 2030 the annual shoaling quantities immediately decrease from approximately 254,300 CY per year to 214,100 CY per year. The shoaling rates are expected to remain stable at approximately 214,100 CY per year until 2080. BU 111 and BU 112-A will be utilized to contain dredge material from Zone 18 from 2030 to 2080.

BU 111 and BU 112-A utilizes the existing authorized footprints from PA 111 and PA 112-A which are currently an abandoned unconfined placement area that has been left eroded and unusable over time. PA 111 and PA 112-A are currently abandoned placement areas that have been left eroded and unusable over time. BU 111 and BU 112-A will be utilized to contain dredge material from Zone 18 and from 2030 to 2080. Existing upland placement areas PA 110 and PA 112-B will be abandoned after construction of BU 111 and BU 112-B as they will be redundant. Utilizing BU 102-C and BU 103 should minimize the pump distances for dredging

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and provide sufficient placement of dredged material through 2080. BU 111 and BU 112-A are expected to be constructed utilizing thin layers of dredged material. Marsh planting can start as the elevation of the material within the BUs reach +1.0 MLLW. The footprints are not finalized and may be reduced upon further analysis in PED.

3.8.3.4. **Increment 18.6.2**

Future O&M shoaling rates remain relatively constant until 2030. Due to the implementation of breakwater from this project after 2030 the annual shoaling quantities immediately decrease from approximately 254,300 CY per year to 188,600 CY per year. The shoaling rates are expected to remain stable at approximately 188,600 CY per year until 2080. BU 111 and BU 112-A will be utilized to contain dredge material from Zone 18 from 2030 to 2080.

BU 111 and BU 112-A utilizes the existing authorized footprints from PA 111 and PA 112-A which are currently an abandoned unconfined placement area that has been left eroded and unusable over time. PA 111 and PA 112-A are currently abandoned placement areas that have been left eroded and unusable over time. BU 111 and BU 112-A will be utilized to contain dredge material from Zone 18 and from 2030 to 2080. Existing upland placement areas PA 110 and PA 112-B will be abandoned after construction of BU 111 and BU 112-B as they will be redundant. Utilizing BU 102-C and BU 103 should minimize the pump distances for dredging and provide sufficient placement of dredged material through 2080. BU 111 and BU 112-A are expected to be constructed utilizing thin layers of dredged material. Marsh planting can start as the elevation of the material within the BUs reach +1.0 MLLW. The footprints are not finalized and may be reduced upon further analysis in PED.

3.9. FWOP, RESILIENCY, AND NED PLACEMENT PLAN QUANITITIES

3.9.1. **FWOP placement Plan**

The FWOP Alternative dredge material placement plan is described in Sections 3.4 to 3.8. The chart below illustrates the estimated quantities of dredge material to be placed into the designated placement areas thru 2080.

Zone	From Station	To Station	PA Names	Dredge Material to PAs & BUs (MCY)
12	691+500	704+000	PA 98	2,202,000
			PA 98-A	2,202,000
			DA 99	272,000
			DA 100	643,000
			PA 102-C	1,286,000
13	704+000	723+000	PA 104-A	2,013,000
			PA 104-B	217,000
14	723+000	739+500	PA 104-B	1,171,000
			PA 105-A	1,250,000
15	739+500	757+500	PA 106	1,886,000
16	757+500	797+000	PA 106	3,571,000
17	797+000	825+000	PA 106	3,142,000
			PA 108	1,336,000
			PA 108-A	234,000
18	825+000	883+000	PA 109	2,195,000
			PA 110	2,818,000
			PA 112-B	1,370,000
			OWPAs	12,431,000

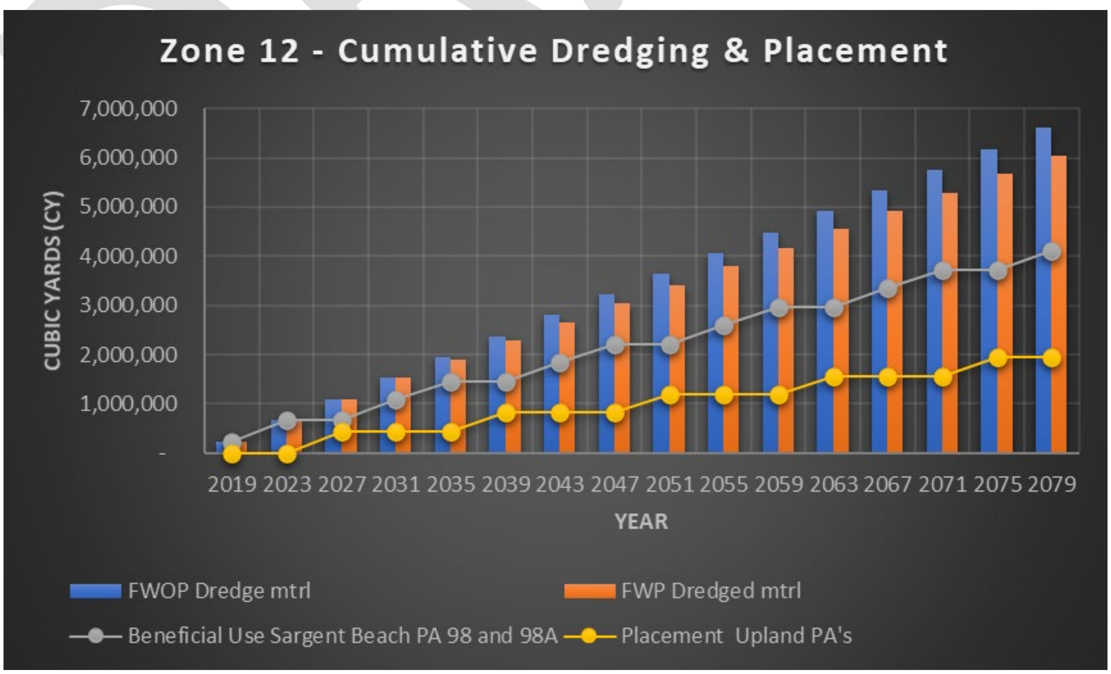
Fig. 33. FWOP Alternative Placement Plan (Zones 12 to 18) thru 2080

3.9.2. **Resiliency Placement Plan**

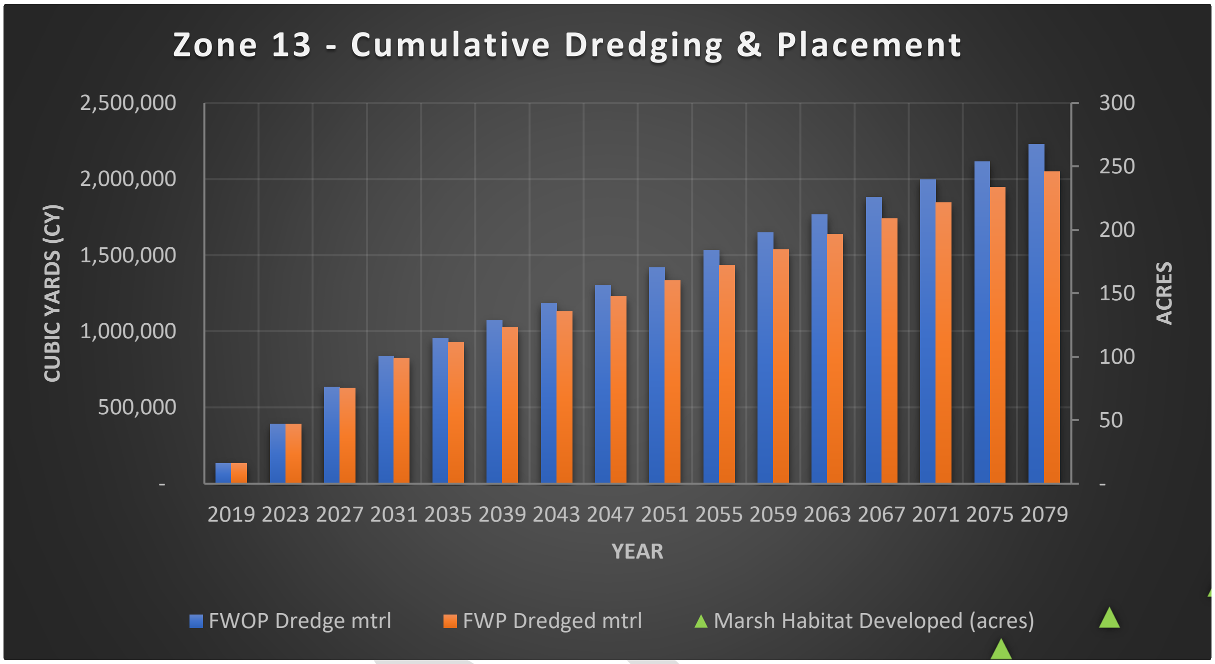
The Resiliency Alternative dredge material placement plan is described in Sections 3.4 to 3.8. Zone 12 will implement channel side breakwater construction along with channel widening as described in "Alternative 3" in Section 3.4. Zones 13, 14, 16, and 18 will implement channel side breakwaters, bayside breakwaters, and earthen dikes forming beneficial use sites BU 102-B, BU 102-C, BU 103, BU 105, BU 111, and BU 112-A as described in "Alternative 6" in Sections 3.5 to 3.8. The chart below illustrates the quantities of dredge material to be placed into the designated placement areas thru 2080.

Zone	From Station	To Station	PA Names	Dredge Material to PAs & BUs (MCY)
12	691+500	704+000	PA 98	2,017,000
			PA 98-A	2,017,000
			DA 99	215,000
			DA 100	267,000
			PA 102-C	1,814,000
13	704+000	723+000	PA 104-A	686,000
			BU 102-B	1,362,000
14	723+000	739+500	PA 104-B	455,000
			PA 105-A	68,000
			BU 102-C	377,000
			BU 103	1,412,000
15	739+500	757+500	PA 106	508,000
			BU 105	1,359,000
16	757+500	797+000	PA 106	568,000
			BU 105	2,581,000
17	797+000	825+000	PA 106	2,625,000
			PA 108	366,000
			PA 108-A	286,000
			PA 109	1,435,000
18	825+000	883+000	PA 110	2,013,000
			PA 112-B	784,000
			BU 111	3,895,000
			BU 112-A	5,857,000

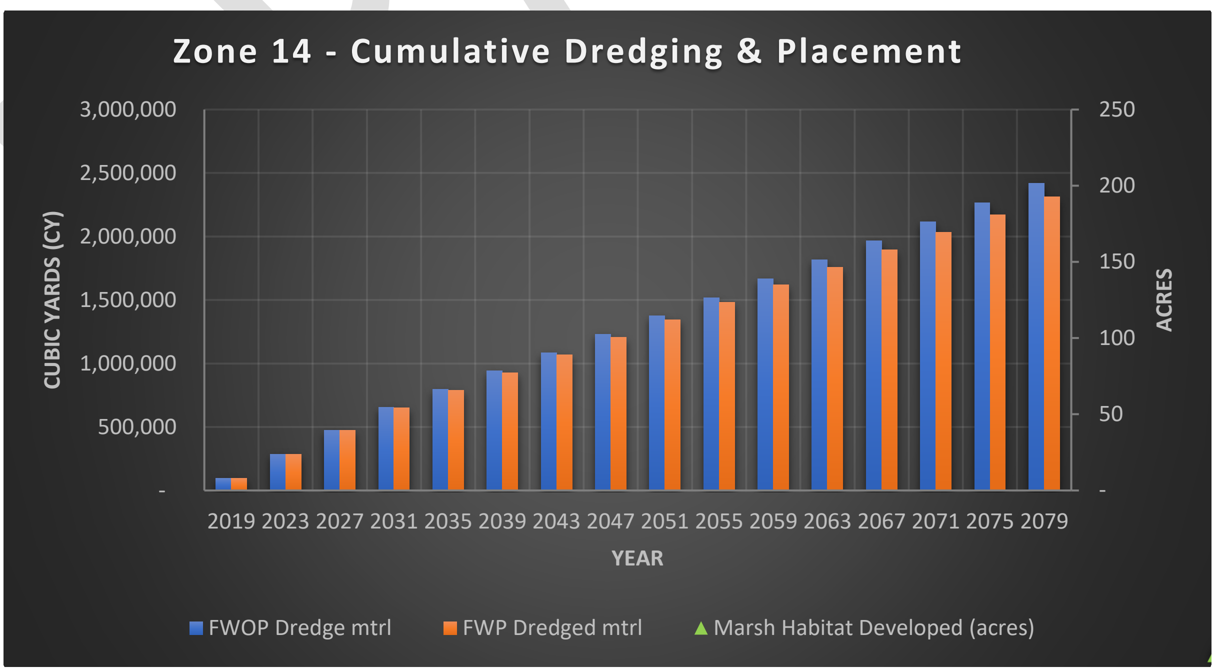
Fig. 34. Resiliency Alternative Placement Plan (Zones 12 to 18) thru 2080



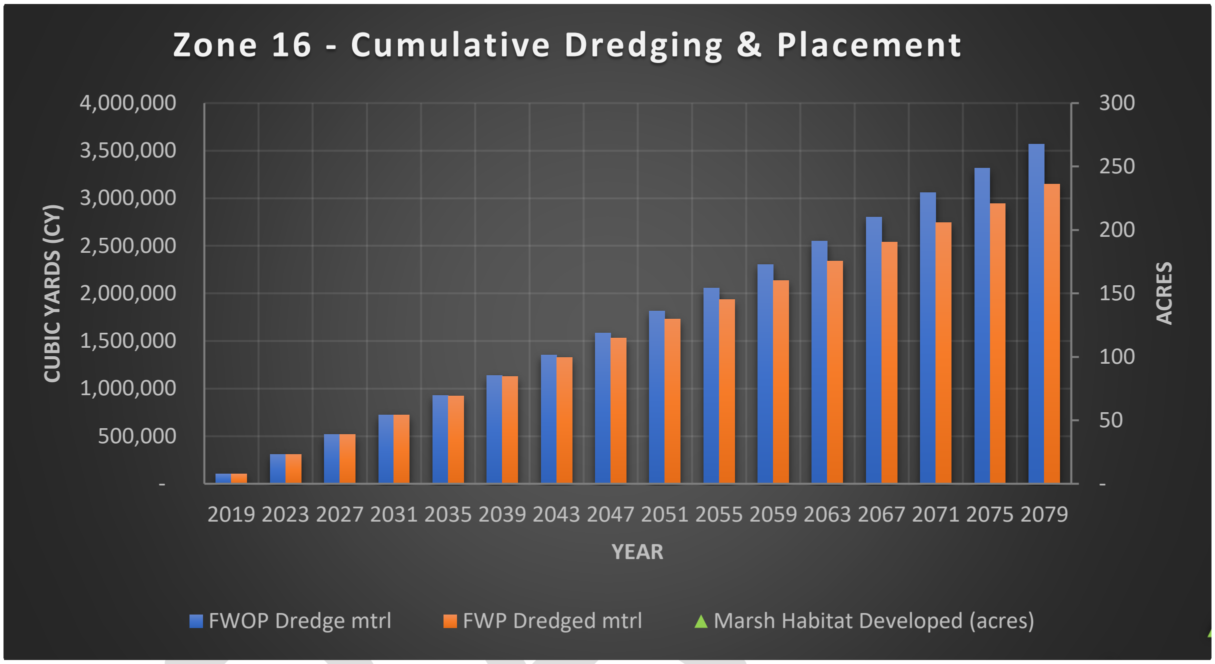
Zone 12 – No marsh creation



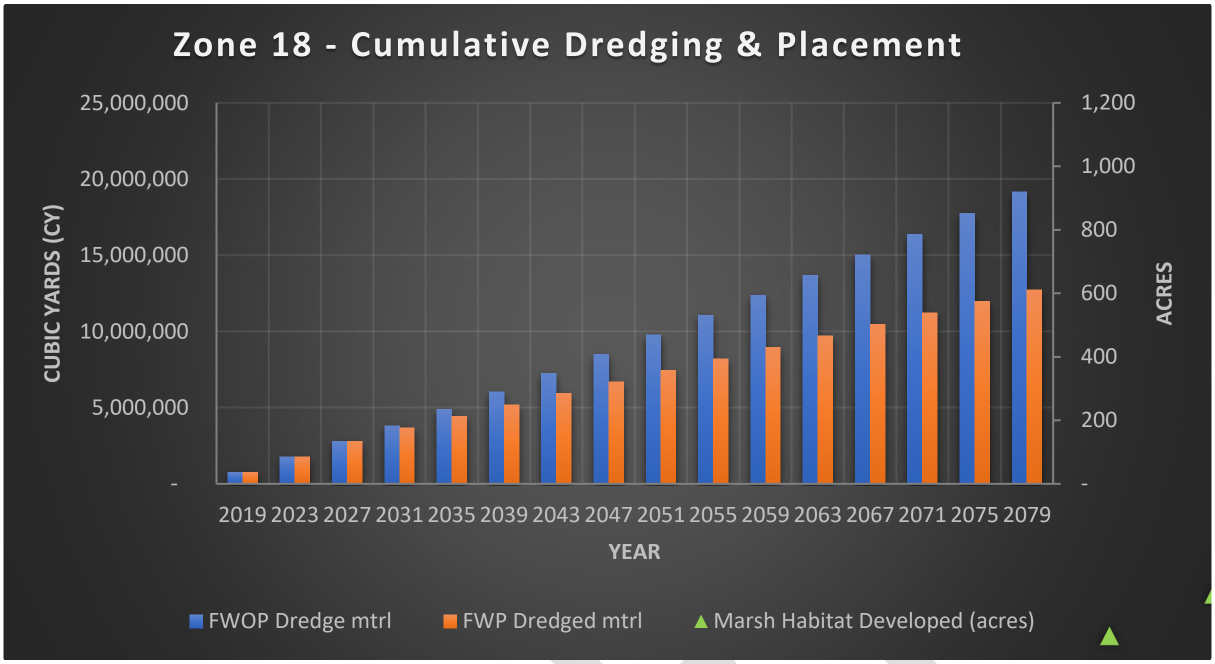
Zone 13 – According to current predictions the full 376-acre maximum marsh planting capacity will be reached by approximately 2150. If implemented the BU will likely be resized or cells will be created within BU 102-B to create areas for marsh planting at a faster rate. The size of these cells will need to be determined in PED.



Zone 14 – According to current predictions the full 86.5-acre maximum marsh planting capacity will be reached by approximately 2040. Thin layer placement will likely be utilized to construct BU 102-C and BU 103. After achieving target elevation and marsh is established the thin layer placement will continue and theoretically continue to raise the beneficial use sites with over time.



Zone 16 – According to current predictions the full 401-acre maximum marsh planting capacity will be reached by approximately 2120. If implemented the BU will likely be resized or cells will be created within BU 102-B to create areas for marsh planting at a faster rate. The size of these cells will need to be determined in PED.



Zone 18 – According to current predictions the full 708-acre maximum marsh planting capacity will be reached by approximately 2055. Thin layer placement will likely be utilized to construct BU 111 and BU 112-A. After achieving target elevation and marsh is established the thin layer placement will continue and theoretically continue to raise the beneficial use sites with over time.

3.9.3. **Alternative 6 - Placement Plan**

The Alternative 6 dredge material placement plan is described in Sections 3.4 to 3.8. Zone 12 will implement channel side breakwater construction along with channel widening as described in "Alternative 3" in Section 3.4. Zones 14, 16, and 18 will implement channel side breakwaters, bayside breakwaters, and earthen dikes forming beneficial use sites BU 102-C, BU 103, BU 105, BU 111, and BU 112-A as described in "Alternative 6" in Sections 3.6 to 3.8. The chart below illustrates the quantities of dredge material to be placed into the designated placement areas thru 2080.

Zone	From Station	To Station	PA Names	Dredge Material to PAs & BUs (MCY)
12	691+500	704+000	PA 98	2,017,000
			PA 98-A	2,017,000
			DA 99	215,000
			DA 100	267,000
			PA 102-C	1,534,000
13	704+000	723+000	PA 104-A	1,369,000
			PA 104-B	858,000
14	723+000	739+500	PA 104-B	449,000
			PA 105-A	74,000
			BU 102-C	377,000
			BU 103	1,413,000
15	739+500	757+500	PA 106	508,000
			BU 105	1,359,000
16	757+500	797+000	PA 106	568,000
			BU 105	2,581,000
17	797+000	825+000	PA 106	2,625,000
			PA 108	366,000
			PA 108-A	286,000
			PA 109	1,435,000
18	825+000	883+000	PA 110	2,013,000
			PA 112-B	784,000
			BU 111	3,895,000
			BU 112-A	5,857,000

Fig. 35. Placement Plan (Zones 12 to 18) thru 2080

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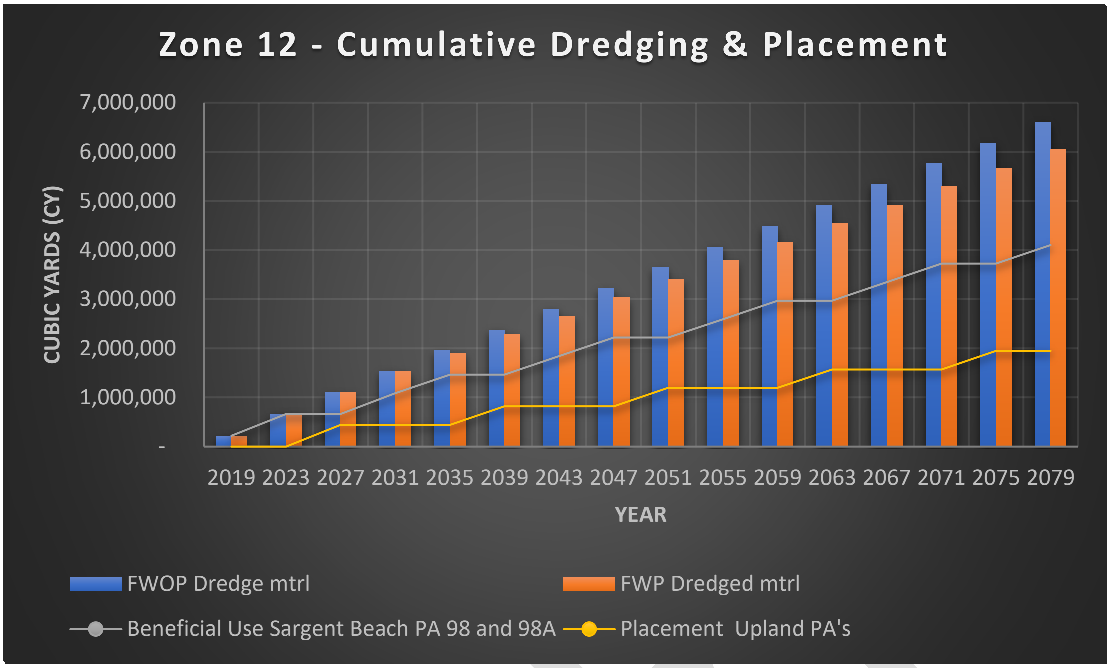
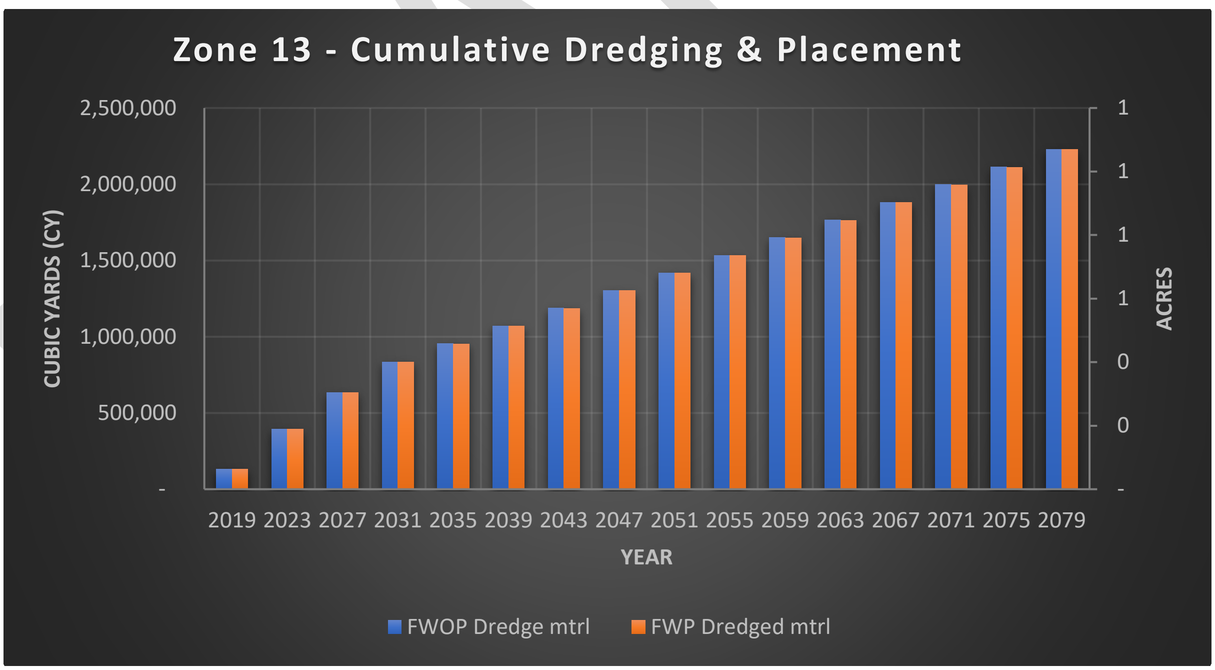
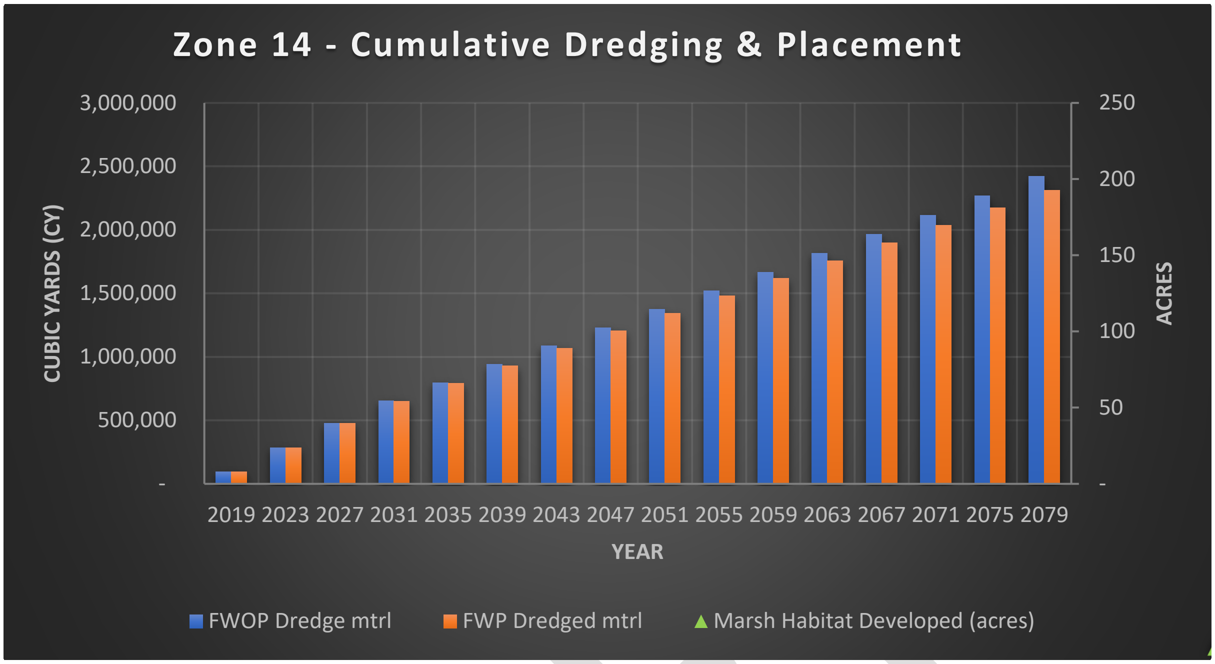


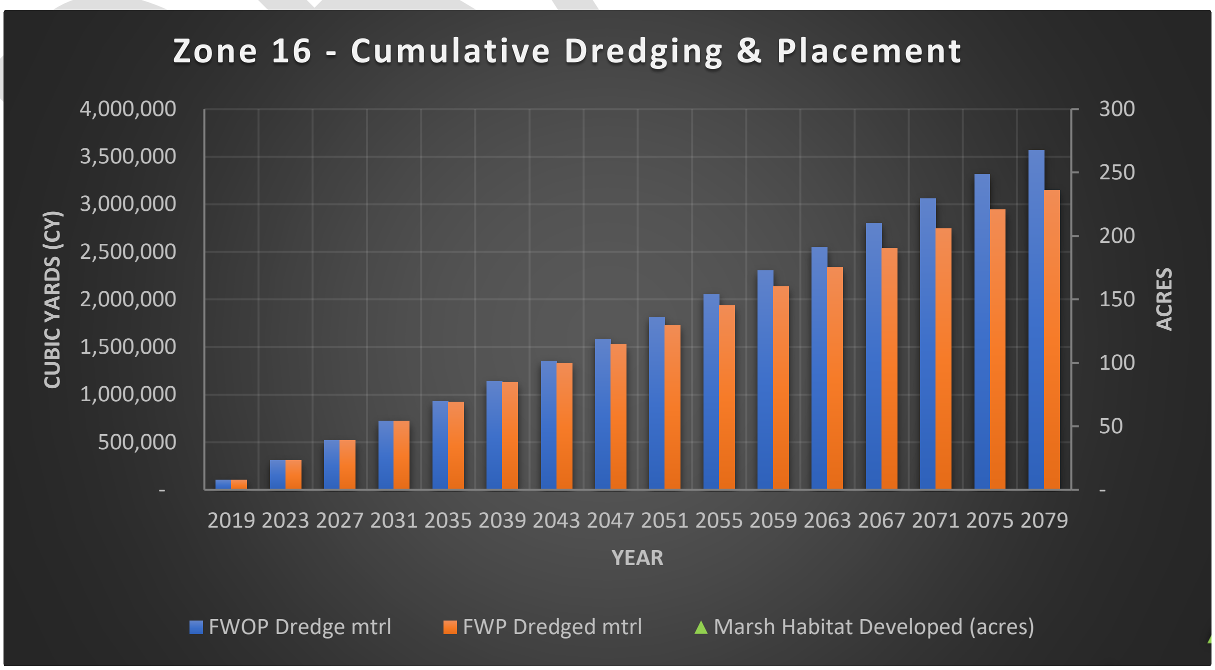
Zone 12 – No marsh creation



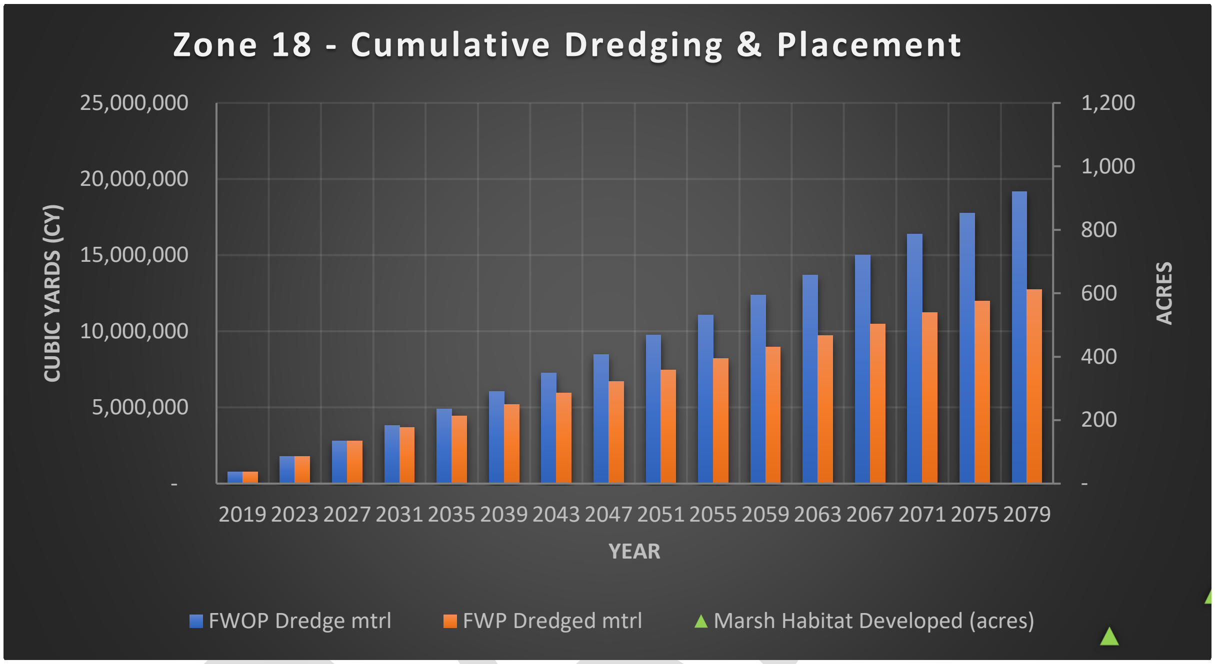
Zone 13 – According to current predictions, the 376-acre maximum marsh planting capacity will be reached by approximately 2150. If implemented the BU will likely be resized or cells will be created within BU 102-B to create areas for marsh planting at a faster rate. The size of these cells will need to be determined in PED.



Zone 14 – According to current predictions the 86.5-acre maximum marsh planting capacity will be reached by approximately 2040. Thin layer placement will likely be utilized to construct BU 102-C and BU 103. After achieving target elevation and marsh is established the thin layer placement will continue and theoretically continue to raise the beneficial use sites with over time.



Zone 16 – According to current predictions the 401-acre maximum marsh planting capacity will be reached by approximately 2120. If implemented the BU will likely be resized or cells will be created within BU 102-B to create areas for marsh planting at a faster rate. The size of these cells will need to be determined in PED.



Zone 18 – According to current predictions the full 708-acre maximum marsh planting capacity will be reached by approximately 2055. Thin layer placement will likely be utilized to construct BU 111 and BU 112-A. After achieving target elevation and marsh is established the thin layer placement will continue and theoretically continue to raise the beneficial use sites with over time.

3.10. ENGINEERING CONSIDERATIONS AND ASSUMPTIONS

3.10.1. **Alternatives/Increments Assumptions**

Shrinkage and swelling are generally not able to be accurately calculated in a planning study with dredging due to the insufficient soils data for O&M material. The assumption was made that the shrinkage and swelling factor for dredged material is 1.0 for all increments. The Texas Coastal Project will require 247,778 CY of dredge material to be mined from the San Bernard to Colorado River reach and 1,195,299 CY to be mined from PA 102-C in 2030. The shoaling data was generated from the CSAT analysis performed by the Hydraulics and Hydrology Branch and quantities were calculated assuming a uniform channel width of 125 feet. The stationing for emergency dredging was identified by observing high shoaling areas from CSAT shoaling data and quantities were generated for appropriate stationing assuming a uniform channel width of 125 feet. Single zone increments and FWOP increments were evaluated based on a 3-year cycle as this is the current dredging cycle except for Zone 12 with channel widening. When increments were combined, they were evaluated based on a 4-year cycle as the combination of features of work done in multiple zones compounded shoaling savings and reduced the need for emergency dredging. Dike raises will be performed when the placement area dike reaches capacity and approximately 3 ft of freeboard is reached. Current placement areas are all assumed to have a crest width of approximately 10 feet. The crest width will be changed to 15 ft after the first lift. Increasing the crest width allows for minor erosion to occur while crest remains to be easily navigable by vehicles for inspection and construction purposes.

3.10.2. **Future Without Project (FWOP) Assumptions**

FWOP dredging operations will likely utilize existing placement areas as a 50-year dredge capacity is expected to be viable with placement area improvements, although due to limitations of the maximum capacities in placement areas in Zone 18, the FWOP analysis between Sta. 848+000 and Sta. 883+000 the Operations and Maintenance (O&M) dredge material will be dredged to Open Water Placement Areas. An increase in overall shoaling is expected in most zones over time due to increased erosion. All outlet structures will need to be replaced once within the 50-year timeframe to maintain proper drainage of placement areas. O&M shoreline restoration quantities were calculated by taking averages of historical shoreline restoration O&M projects quantities and frequencies from 2007 to 2020 from Sta. 691+500 to Sta. 883+000.

3.10.3. **Alternative 3 Increments Assumptions**

Alternative 3 increments utilize breakwaters to create shoreline protection to decrease the amount of shoreline erosion which correlates to decreasing the shoal material in the channel. Dredging operations will likely utilize existing placement areas as a 50-year dredge capacity is expected to be viable with placement area improvements, although due to limitations of the maximum capacities of placement areas in Zone 18, between Sta. 858+000 and Sta. 883+000 the O&M dredge material will be dredged to Open Water Placement Areas. Dike raises at PAs are necessary during the analysis period and will be performed as required to provide capacity for O&M dredge material. All outlet structures will need to be replaced once within the 50-year timeframe to maintain proper drainage of placement areas. O&M quantities regarding shoreline erosion were calculated from placing approximate erosion rate factors on each feature of work. Lower O&M

quantities is due to the expectation that there is significantly less exposed shoreline in zones where work is performed, and only minor repairs should be needed.

Bathymetric survey data was not available along the alignment of the proposed breakwater. Bathymetric survey data will be obtained in PED and the alignment of breakwater may change if bathymetry is significantly different than anticipated. Likewise, soil boring data was not available so settlement for the constructed breakwater is assumed to be approximately 1 foot from engineering judgement until boring data is collected in PED and settlement revised. In PED additional modeling will be performed to further determine any breaks, gaps, or additional structures needed to provide adequate water circulation and ecological accessibility.

3.10.4. **Alternative 6 Increments Assumptions**

Alternative 6 increments utilize breakwaters to create BUs to increase dredge capacity of zones and promote shoreline protection to decrease the amount of shoreline erosion which correlates to decreasing the shoal material in the channel. No O&M material is needed to be dredged to Open Water PAs due to the decrease in shoaling and increase in placement capacity due to newly constructed BUs. No placement area raises will be needed in zones where BUs are constructed as the newly constructed BUs will accept the additional dredge material that would otherwise be allocated to raised placement areas. O&M quantities regarding shoreline erosion were calculated from placing approximate erosion rate factors on each feature of work. Lower O&M quantities is due to the expectation that there is significantly less exposed shoreline in zones where work is performed, and only minor repairs should be needed.

Bathymetric survey data was not available along the alignment of the proposed breakwater. Bathymetric survey data will be obtained in PED and the alignment of breakwater may change if bathymetry is significantly different than anticipated. Likewise, soil boring data was not available so settlement for the constructed breakwater is assumed to be approximately 1 foot from engineering judgement until boring data is collected in PED and settlement revised. In PED additional modeling will be performed to further determine any breaks, gaps, or additional structures needed to provide adequate water circulation and ecological accessibility.

4. OPERATION, MAINTENANCE, REPAIR, REPLACEMENT AND REHABILITATION (OMRR&R)

The GIWW-CR Alternative 3 increments consist primarily of breakwaters that are designed for 50 years assuming the USACE intermediate sea level rise condition. Unless there are needs for emergency repairs (e.g., collision with barge, scour hole), these features are designed to last and perform for the intended 50-year project period. With this assumption, OMRR&R costs are excluded in all ER features.

The GIWW-CR Alternative 6 increments include out-year nourishment as part of O&M as well as breakwaters designed for 50 years assuming the USACE intermediate sea level rise condition. The breakwaters would also only require emergency repairs as described for the alternative 3 increments above.

4.1. GIWW-CR OUT-YEAR NOURISHMENT

See 2.5.3.2 Nourishment for technical details.

4.2. COASTAL TEXAS OUT-YEAR NOURISHMENT

Following the ADM in the Coastal Texas Study, out-year marsh nourishment and future construction activities were removed. Coastal Texas Measures G-28, B-12, M-8, and CA-5 included nourishment in areas that will become progressively more susceptible to marsh loss and conversion to open water given RSLC projections. These future activities were excluded based on USACE policy.

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5. CONSTRUCTION SCHEDULE

At the completion of the Feasibility Study, and upon approval by the Chief of Engineers of the United States Army, the Recommended Plan would be provided to Congress for authorization and funding. If authorized and funded by Congress, subsequent phases of the project would include PED, construction, and operations and maintenance. This project lifecycle, showing anticipated durations of each phase, is illustrated in Figure 5-1.

2023 Chief's Report
2025-2027 PED
2028-2030 Construction

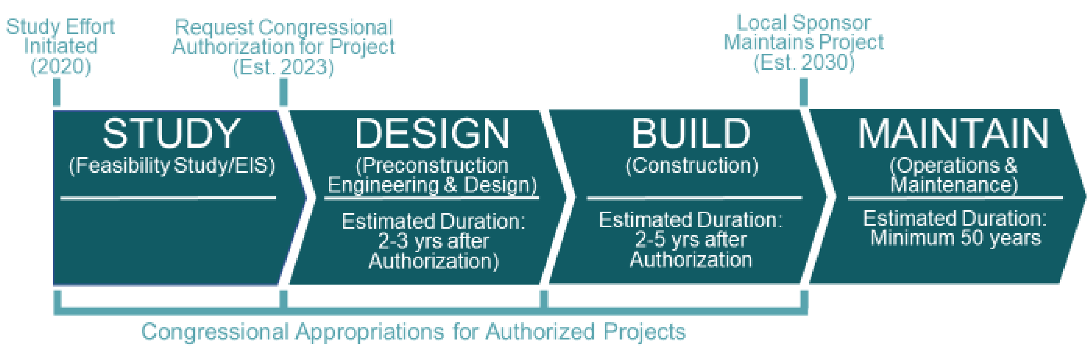

Figure 5-1: GIWW-CR Phases

Completion of PED and construction of the Recommended Plan, specifically the pace of construction, is highly dependent on Congressional approval and funding. Assuming an ample funding stream, the Recommended Plan described could be designed and then constructed over a period of 3 to 5 years. Furthermore, construction sequencing will also be dependent on completion of supplemental engineering and environmental studies.

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Annex 1

Engineering Plates

Annex 2

CSAT Report

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Annex 3

CMS Report

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