TEXAS COASTWIDE EROSION RESPONSE PLAN

2020 Update

December 2020

Final Report to the Texas General Land Office

K. K. McKenna, P.G.

GLO Contract No. 20-110-000-C061

EXECUTIVE SUMMARY

In September 1999, the 76th Texas Legislature passed the Coastal Erosion Planning and Response Act (CEPRA) and provided the initial funds for addressing a hazard that threatens natural resources, property, and the Texas coastal economy. In the twenty years since the first CEPRA project was funded there have been over 300 projects implemented that enhanced shorelines, restored habitat, or protected critical infrastructure. The purpose of this Coastwide Erosion Response Plan is to provide an update that identifies critical erosion areas along the Texas coast and provides metrics that allow prioritization of erosion response studies and projects so that *benefits are balanced among areas throughout the coast, federal and local financial participation is maximized, studies and projects achieve efficiencies and economies of scale, and the severity of erosion effects in each area is taken into account* (TNC Sec.33.602).

This update evaluates the most recent shoreline change rates based upon research conducted by the University of Texas at Austin, Bureau of Economic Geology; identifies critical erosion areas along the Texas Gulf coast based on historical erosion rates and locations of critical infrastructure, critical natural resources (Sensitive Areas), and anthropogenic contributions (past CEPRA projects and beach nourishment); discusses plans and funding sources that complement the CEPRA program; evaluates existing data sets and data gaps; lists criteria for choosing priority sites for public funding; presents CEPRA Cycles 8 through 11 projects; summarizes the benefits/costs of selected CEPRA projects; and provides municipal/county government contributions for local erosion concerns and shoreline management practices.

Coastal erosion remains a continuing threat to Texas Gulf and bay shorelines. About 80% of the Gulf shoreline is eroding at greater than 2 ft/yr. Whether the erosion is caused by the lack of sediments to balance the long-term losses within the coastal compartments, or the episodic erosion brought on by storms or human activities, planning and implementation of erosion response and sediment management practices are essential to the sustainability of the shoreline and public beaches and natural resources.

In general, the highest rates of erosion occur on the shorelines of former deltaic headlands (Trinity and Brazos-Colorado). Gulf shorelines undergoing the rates of erosion of more than -8 ft/year [-2.5 m/yr] are found between Sabine Pass to Rollover Pass, on Galveston Island west of the seawall, Quintana Beach to Sargent Beach, eastern Matagorda Peninsula, northeast Matagorda Island (Aransas National Wildlife Refuge), isolated sections of North Padre Island, Padre Island near Port Mansfield Channel, southern Padre Island (Willacy County and Cameron County sections), and the southern portion of Brazos Island near the Rio Grande. The average movement rate of all Texas sites (-4.17 ft/yr [-1.27 m/yr]) was slightly higher than the average movement rate calculated from the previous update.

The CEPRA program is directed to focus Gulf and bay shoreline erosion when historical erosion is greater than two feet per year, bayshore erosion is documented, or if a shoreline is subject of an erosion response project, or if the shoreline has been impacted by a storm and requires remediation to preexisting conditions.

The 2019 study of CEPRA projects determined an economic benefit of $11 for every state dollar spent to protect Texas' coastal natural assets and infrastructure. Many projects had substantial cost savings due to outside grants and private partnerships.

In this plan update, several local management issues arose that are worthy of discussion. These included: the costs of large-scale projects that were out of reach for local governments; issues with project permitting, review, and approval process; inconsistencies with the Federal bidding process; limited leveraged funding for partner cost-share; management of vehicular beach access on eroding shorelines; local needs in planning and technical assistance, and adequate and economical sand sources to restore beaches.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This project was funded by the Texas General Land Office under Contract No. 20-110-000-C061. Special thanks are extended to Kelly Brooks (GLO, Project Manager), Kevin Frenzel (GLO), Thomas Durnin (GLO), Carver Wray (GLO), and Daniel Gao (GLO). The author is grateful for the time and responses of local government officials The Honorable Jeff Branick (Jefferson County Judge), The Honorable Nathan McDonald (Matagorda County Judge), Dustin Henry (City of Galveston), Sheryl Rozier, (Galveston Island Park Board of Trustees), Bryan Frazier (Brazoria County Parks Department), Darren Gurley (Nueces County Gulf Beaches, Natural Resources & Aquatics), Deidre D. Williams (Conrad Blucher Institute for Survey and Science, TAMU-CC), Colleen Simpson (City of Port Aransas Parks and Recreation), Rae Mooney (City of Port Aransas Nature Preserve), Kristina Boburka (City of South Padre Island), Joe E. Vega (Cameron County Parks), Augusto Sanchez (Cameron County Estuary, Environmental, & Special Projects), and Keith Barrett (Aransas County Navigation District). Also appreciated are the research and public access to data provided by Dr. Jeffrey Paine and Tiffany Caudle (The University of Texas at Austin Bureau of Economic Geology).

INTRODUCTION

Along the 367 Gulf miles and more than 3,300 bay miles of Texas shoreline, erosion has resulted in habitat loss, navigational challenges, and structures on the Gulf beach or teetering on the line of vegetation and threatening public access. Coastal erosion, defined in Section 33.601 of the Texas Natural Resources Code as *the loss of land, marshes, wetlands, beaches, or other coastal features within the coastal zone because of the actions of wind, waves, tides, storm surges, subsidence, or other forces,* is attributed to the lack of sediment in the littoral system to balance the impacts from storms, long-term sea level trends, and human influences.

Coastal erosion on both Gulf and bay shorelines was a key component of the Texas Coastal Management Program (CMP) (1996). With the passage of the *Coastal Erosion Planning and Response Act* (CEPRA) in 1999 and the erosion response program administered by the Texas General Land Office (GLO), the state of Texas acknowledged the impact of erosion on the state's coastal habitats and economy. For the first time, funding was available to support projects to reduce or eliminate shoreline and habitat losses.

The *Texas Coastwide Erosion Response Plan* was first published by the GLO in 1996 and was the motivation for the development of the CEPRA program. Section 33.602 of the Texas Natural Resources Code requires periodic updates to the plan to ensure erosion avoidance, remediation, and planning benefits occur coastwide, maximize federal and local funding participation, be economically efficient, and consider the severity of the erosion. Past coastwide erosion response plans and subsequent updates described the significance of coastal erosion and the impacts to local communities (GLO, 1996; McKenna, 2004; McKenna, 2009; McKenna, 2014). These plans also identified critical erosion areas and the efforts by the state to address some of the more vulnerable areas through the CEPRA program and partnerships with federal, local, and non-governmental agencies. These partnerships have provided a cost savings to the state while restoring and protecting the shoreline.

In a similar, but more expansive mission to restore and protect the state's coastal natural resources, the GLO led the development of the *Texas Coastal Resiliency Master Plan* (2017; 2019; CRMP) which provides a framework for strategies and actions that the state and communities can undertake to protect against coastal hazards (storm surge and long-term gradual impacts) and increase community, socio-economic, and ecologic resiliency. The CRMP's focus is to protect coastal infrastructure and natural resources through the implementation of high

priority (Tier 1) projects in four coastal regions. These projects were selected by federal, state, and local experts and represent the best methods to address coastal erosion. The Tier 1 projects are a priority for the CEPRA program and the CMP, both of which implement projects selected in the CRMP.

Managing shoreline erosion is difficult and expensive and although the CEPRA program was successful in its early years, legislative funding was not always consistent. This changed in 2019 when the Texas 86th Legislature provided the long-term financial commitment to fight against coastal erosion by allocating 2% of the revenue collected from the Hotel Occupancy Tax. These resources, combined with other federal and local sources, will help steer the future for prolonged coastal resiliency.

Purpose of Erosion Response Plan

Section 33.602 of the Texas Natural Resources Code requires the Land Commissioner to publish updates to the *Texas Coastwide Erosion Response Plan* coordinated with governmental agencies and the public to identify critical erosion areas and prioritize erosion response studies and projects so that

(1) benefits are balanced among areas throughout the coast designated by the commissioner as critical coastal erosion areas;
(2) federal and local financial participation is maximized;
(3) studies and projects are scheduled to achieve efficiencies and economies of scale; and
(4) the severity of erosion effects in each area is taken into account.

This update evaluates the most recent shoreline change rates based upon research conducted by the University of Texas at Austin, Bureau of Economic Geology; identifies critical erosion areas along the Texas Gulf coast based on historical erosion rates and locations of critical infrastructure, critical natural resources (Sensitive Areas), and anthropogenic contributions (past CEPRA projects and beach nourishment); discusses plans and funding sources that complement the CEPRA program; evaluates existing data sets and data gaps; lists criteria for choosing priority sites for public funding; presents CEPRA Cycles 8 through 11 projects; summarizes the benefits/costs of selected CEPRA projects; and provides municipal/county government contributions for local erosion concerns and shoreline management practices.

NOTE: In past Texas Coastwide Erosion Response Plan updates, five coastal regions established by the *Coastal Texas 2020* initiative in 2004 were used to determine trends. These regions included the boundary limits of the 18 coastal counties that comprise the Texas coastal zone. However, in this update, the former regions have been consolidated to match the four regions adopted in the Texas Coastal Resiliency Master Plan (Resiliency Plan) that are based on major bay systems and habitats. All maps presented herein are formatted to match the Resiliency Plan regions (Figure 1).

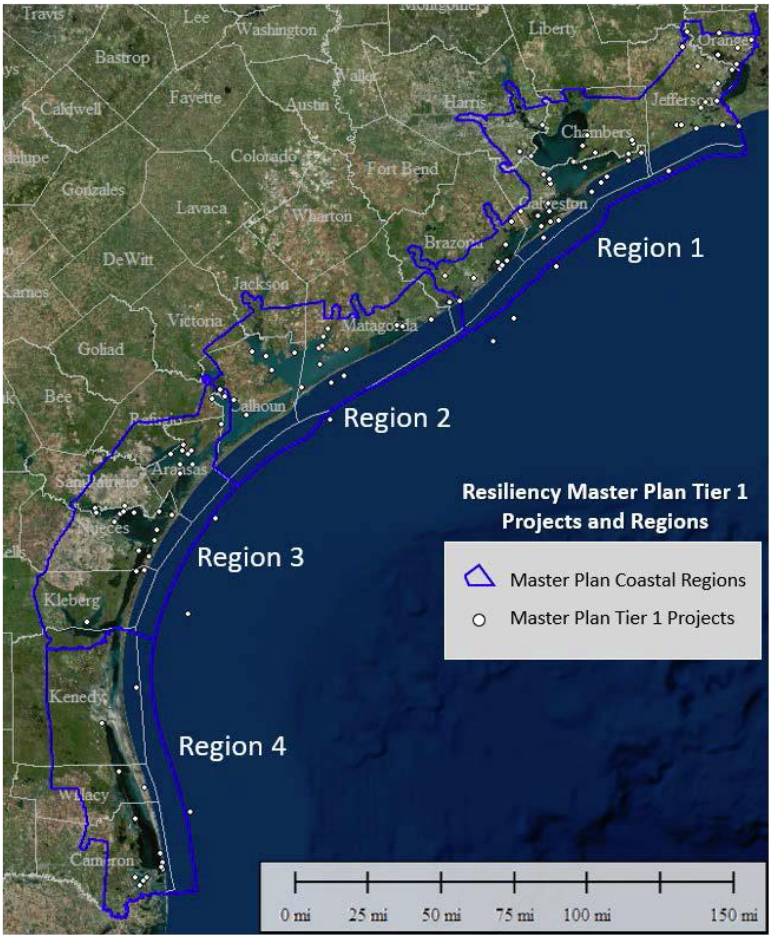

Figure 1. Map showing the Texas Coastal Resiliency Master Plan regions and counties and represent the Regions in this report (GLO, 2019).

COASTAL EROSION PLANNING AND RESPONSE ACT (CEPRA) & PROGRAM

During the development of the Texas Coastal Management Plan led by the Texas General Land Office (GLO) in the early 1990's, it was clear from stakeholders that coastal erosion was a primary issue of concern and its impacts to human and natural systems needed to be addressed in order to protect from future damages to the Texas economy and coastal ecosystems. The GLO established an Erosion Response Plan Advisory Committee to assist the agency in drafting the first Texas Coastwide Erosion Response Plan (1996) and establish the goals and priorities of a program to address erosion. The *Coastal Erosion Planning and Response Act* (CEPRA) was enacted by the 76th Texas Legislature in September 1999 and established a program and funding source to address those concerns. The GLO's Coastal Resources Division administers the CEPRA program with a goal to reduce impacts to valuable coastal resources caused by coastal erosion.

The purpose of the CEPRA program is to *implement coastal erosion response projects and preferred erosion response solutions, demonstration projects, and related studies to reduce the effects of and understand the processes associated with coastal erosion as it continues to threaten public beaches, coastal natural resource areas, coastal development, public infrastructure, and public and private property*.

CEPRA funds are appropriated by the Legislature on a two-year cycle that coincides with the Texas Legislative biennium. The funds are awarded through a competitive application process in which all applications are evaluated by the GLO's CEPRA team. Selected projects are approved by the Land Commissioner. Projects selected for funding must comply with administrative and budgetary requirements set forth in the CEPRA rules (GLO, 2019).

CEPRA PRIORITIES

To ensure that projects/studies meet the requirements of the Texas Natural Resources Code, when a project application is submitted to the CEPRA program for funding, each is ranked using the following priority criteria: erosion severity, emergency erosion situation, needs in other critical erosion areas, financial participation, economic efficiency, geographical location, and cost to the CEPRA Account. A minimum amount of match is required; however, the Land Commissioner can reduce or waive the match requirement and, the more funding a partner can leverage, the higher the project ranking.

TEXAS COASTAL RESILIENCY MASTER PLAN

With the mission to restore, enhance and protect the state's coastal natural resources, in 2017, the GLO began the planning process to identify the many hazards that threaten the Texas coast, its economy and societal needs, and diverse ecological habitats (GLO, 2017). This effort involved federal, state, local, and non-governmental resource experts to share experiences and research, and many serve on the project's Technical Advisory Committee (TAC).

Revisited in 2019, the GLO published the *Texas Coastal Resiliency Master Plan* (CRMP) (GLO, 2019) that provides adaptable "first line of defense" options to coastal communities to address hazards such as coastal erosion, sea level rise, coastal storm surge, habitat loss and degradation, and water quality degradation. Models used in the development of the 2017 CRMP show areas of economic, natural, and social vulnerabilities where there are risks of storm surge or land converted to open water. The vulnerable areas were also tested under future sea level conditions.

Under TAC guidance, the CRMP identified Issues of Concern (IOC): *natural and/or human-induced disturbances if left unaddressed that will have an adverse impact on infrastructure, natural resources, economic activities, or the health and safety of Texans.* The TAC provided the project priorities based on ecological resiliency strategies that address the following issues of concern:

- Beach and dune enhancement
- Wetland enhancement - Bay shoreline stabilization and estuarine wetland restoration (living shorelines)
- Uplands enhancement
- Oyster reef enhancement
- Rookery island enhancement
- Freshwater inflow and tidal exchange enhancement

The CRMP covers four planning regions based on watershed boundaries (Figure 1). Table 1 shows the regional boundaries with the extents covering coastal areas beyond the Gulf shoreline and including bays/lagoons, estuaries, and coastal rivers. In total, 18 counties are

covered in the planning effort. And, this includes areas not normally covered under the CEPRA program (i.e. non-public lands).

Table 1. Boundaries for the Texas Coastal Resiliency Master Plan planning regions (GLO, 2019)

Region No.	Region Name	Description	Counties
1*	Sabine Pass to Galveston Bay	Mouth of Sabine River at the Texas-Louisiana border to the mouth of the Brazos River near Cedar Lakes	Brazoria, Chambers, Galveston, Harris, Jefferson, and Orange
2	Matagorda Bay	Entire Matagorda Bay system from the Brazoria-Matagorda County line to eastern edge of San Antonio Bay	Calhoun, Jackson, Matagorda, and Victoria
3	Corpus Christi Bay	San Antonio Bay to Baffin Bay	Aransas, Kleberg, Nueces, Refugio, and San Patricio
4	Padre Island	Sothern edge of Baffin Bay to the Texas-Mexico border	Cameron, Kenedy, and Willacy

Figure 1 also shows the locations of proposed Tier 1 projects. These projects received the highest priority for funding from the TAC and GLO's planning team and were identified from data gathering and modeling. The most common projects embrace shoreline stabilization that also contribute to habitat restoration. Not all Tier 1 projects are eligible for CEPRA Program funding.

Implementation of the TCRMP Tier 1 projects is prioritized through the CEPRA Program. Tier 1 projects can utilize Gulf of Mexico Energy Security Act (GOMESA) funding to cover the project partner match during the construction phase, greatly reducing overall cost to the project partner. Project partners are still required to cost-share pre-construction tasks like preliminary design, engineering design, permitting, etc. before the construction phase. In addition, Tier 1 projects receive higher prioritization for CEPRA funding (https://www.glo.texas.gov/coast/grant-projects/funding/files/cepra-guidance.pdf). These priorities were established by the Technical Advisory Committee (TAC) and high-priority (Tier 1) projects were selected based on each Region's issues of concern, planning objectives, project feasibility, and benefits for coastal resiliency.

Erosion Response Plan Support

The intent of the Coastwide Erosion Response Plan is to call attention to the critical erosion areas (Gulf shoreline areas that are experiencing long-term erosion rates of >2 feet/year and threaten public infrastructure or natural resources) and set priorities for threatened public beaches, dunes, marshes, bay shores, and infrastructure. The common issues of concern between the Coastwide Erosion Response Plan (CEPRA program) and the CRMP are those that address Gulf beach erosion and dune degradation, public bay shoreline erosion and habitat loss, and coastal storm surge. Table 2 provides the list of Tier 1 projects that are eligible for CEPRA project funding (GLO personal communication).

The focus of the 2019 CRMP is to protect coastal infrastructure and natural resources through the implementation of recommended high priority (Tier 1) projects. Some of these can be implemented by the CEPRA program along with funding from several funding sources including GOMESA (GLO, 2019). However, CEPRA cannot fund some Tier 1 actions such as

watershed planning, but those projects could be eligible through the Coastal Management Program or other Federal programs.

Table 2. Texas Coastal Resiliency Master Plan Tier 1 projects eligible for CEPRA funding

TIER 1 PROJECT NAME	Region	2019 Resiliency Plan
Dune Management and Access Plan	0	R0-2
Subsidence Study and Monitoring	0	R0-11
Anahuac National Wildlife Refuge Living Shoreline	1	R1-1
Willow Lake Shoreline Stabilization	1	R1-2
Old River Cove Restoration	1	R1-3
Gordy Marsh Restoration and Shoreline Protection	1	R1-4
Sabine-Neches Waterway Dredge Placement Island Habitat Restoration	1	R1-5
Bessie Heights Wetland Restoration	1	R1-6
Brazoria National Wildlife Refuge GIWW Shoreline Protection	1	R1-10
Follet's Island Wetland Restoration	1	R1-11
Candy Abshier Wildlife Management Area Shoreline Protection and Marsh Restoration	1	R1-12
O'Quinn IH-45 Causeway Intertidal Marsh Restoration	1	R1-13
Galveston Island State Park Wetland Restoration & Shoreline Protection - Phase 3	1	R1-14
Green's Lake Shoreline Protection & Wetland Restoration - Phase 2	1	R1-15
Dollar Bay Wetland Creation, Restoration and Acquisition	1	R1-16
Oyster Lake - West Bay Breach Protection - Phase 3	1	R1-17
East Bay Living Shorelines and Wetland Restoration	1	R1-18
McFaddin National Wildlife Refuge Shoreline Restoration	1	R1-19
Bolivar Peninsula Beach and Dune Restoration	1	R1-20
Texas Point Beach Nourishment Project	1	R1-21
Galveston Island West of Seawall to 8 Mile Road Beach Nourishment	1	R1-22
Follet's Island Nourishment and Erosion Control	1	R1-23
Sabine-Neches Channel Shoreline Protection	1	R1-25
Galveston Bay Rookery Island Restoration	1	R1-33
Dickinson Bay Rookery Island Restoration - Phase 2	1	R1-34
Salt Bayou Siphons	1	R1-41
Replace Water Control Structure at Star Lake	1	R1-42
The Marshland Restoration Project at Anahuac National Wildlife Refuge	1	R1-43
Galveston Bay Oyster Reef Planning & Restoration	1	R1-45
Texas City Levee Erosion Control and Marsh and Oyster Reef Restoration	1	R1-46
Brazos River to Cedar Lake Creek GIWW Stabilization	2	R2-1
Boggy Cut GIWW Stabilization	2	R2-2
Welder Flats Wildlife Management Area	2	R2-3
Sargent Beach & Dune Restoration	2	R2-4
Redfish Lake Living Shoreline	2	R2-5
Mad Island Shoreline Protection and Ecosystem Restoration	2	R2-6
Ocean Drive Living Shoreline	2	R2-7
Port Lavaca Living Shoreline	2	R2-8
Palacios Shoreline Revitalization Project	2	R2-9
Chester Island Restoration	2	R2-10
San Antonio Bay Rookery Island Restoration	2	R2-11
Coon Island Restoration	2	R2-12
Half Moon Oyster Reef Restoration - Phase 3	2	R2-13
Oliver Point Oyster Reef Restoration	2	R2-14
Chinquapin Oyster Reef Restoration	2	R2-15
Lavaca Bay Oyster Reef Restoration	2	R2-16
Goose Island State Park Habitat Restoration and Protection	3	R3-1
Fulton Beach Road Protection	3	R3-2
Aransas National Wildlife Refuge Dagger Point Shoreline Preservation	3	R3-3
Portland Living Shoreline	3	R3-4
Lamar Beach Road Protection	3	R3-6
Flour Bluff Living Shoreline	3	R3-7
Newcomb's Point Shoreline Stabilization	3	R3-8
Indian Point Marsh Area Living Shoreline	3	R3-9
Long Reef and Deadman Island Shoreline Stabilization and Habitat Protection	3	R3-10
Shamrock Island Restoration - Phase 2	3	R3-11
Tern Island and Triangle Tree Island Rookery Habitat Protection	3	R3-12
Dagger Island Shoreline Protection	3	R3-13
Causeway Island Rookery Habitat Protection	3	R3-14
Nueces River Delta Shoreline Stabilization	3	R3-15
Guadalupe Delta Estuary Restoration	3	R3-17
Packery Channel Nature Park Habitat Restoration - Phase 2	3	R3-20
Restore Barrier Island Bayside Wetlands on Mustang Island	3	R3-22
Port Aransas Nature Preserve Stabilization and Restoration	3	R3-23
Corpus Christi & Nueces Bays Oyster Reef Restoration	3	R3-26
Copano Bay Oyster Reef Restoration	3	R3-27
Paso Corvinas Wetlands & Hydrologic Restorations	4	R4-2
City of South Padre Island Gulf Shoreline Restoration	4	R4-4
Bird and Heron Islands Restoration	4	R4-5
Restore Upper and Lower Laguna Madre Dredge Placement and Rookery Islands	4	R4-6
Mansfield Rookery Island Shoreline Protection	4	R4-7
Bahia Grande Living Shoreline	4	R4-8
Restore Barrier Island Backside Wetlands on South Padre Island	4	R4-9
City of South Padre Island Living Shoreline	4	R4-11
Laguna Madre Relative Sea Level Rise Monitoring and Adaptive Management	4	R4-13

COASTAL EROSION STATUS AND TRENDS

Coastal shoreline change is a complicated phenomenon that is influenced by a combination of factors: the region's depositional history, hydrodynamic forces, littoral drift, elevation, nearshore slope, relative sea level rise, tidal passes, and human activities. In Texas, changes in relative sea level and coastal storms have influenced long-term and episodic erosion of the Gulf and bay shorelines by modifying patterns of sediment transport and deposition.

The large geomorphic features that span the Texas Gulf coast include deltaic headlands, peninsulas, barrier islands, and spits, and their depositional origins provide clues on sediment erodibility. Present-day fluvial systems provide additional sediments to the bays and estuaries and open Gulf coast. The variations in the wave climate impacting those features influences the amounts of sediment that are supplied to the littoral drift (the amount of sediment carried along the shoreline) as well as the direction the sediment travels. On the open Gulf coast, elevations of the beaches and dunes found on those large geomorphic features can determine whether episodic high wave and tidal events allow overwash and landward barrier migration or merely erosion of the beachface that can be repaired by quieter waves.

Tidal passes that separate the barrier islands and peninsulas can act as sand "sinks" by capturing littoral sediments in either the ebb- (Gulf side) or flood- (lagoon side) tidal deltas. Inlets that have been jettied for navigation can stop the transport of sand and create accretion on the updrift side while erosion results downdrift due to the deficiency of sediments. Other human influences that could lead to sediment deficiencies or increased erosion are the damming of the rivers that empty at the coast, yearly maintenance of navigation channels, construction of revetments, seawalls, and groins which impede sediment transport, and waves from motorized watercraft (more likely to have a greater adverse effect on coastal wetlands).

Relative sea level is the combined effect of changes in global sea level and local changes in elevation of adjacent coastal land. In some areas of the Texas coast, land subsidence is exacerbated by the withdrawal of groundwater or hydrocarbons (Morton et al, 2004). This phenomenon is most significant to the shoreline stability and health of the low-lying marsh systems that line the bays and lagoons.

Researchers from the University of Texas at Austin Bureau of Economic Geology (BEG) have documented shoreline changes since the 1970s in an effort to understand long-term trends and the impacts from storms (Morton, 1974, 1975; Morton and Pieper, 1975, 1976, 1977a, 1977b; Morton et al., 1976; McGowen, et al., 1977; Morton and Paine, 1984, 1985; Paine and Morton, 1986). These studies produced the initial standards for shoreline monitoring and provided quantifiable rates of change. In 1993, the GLO's beach/dune rules (31 TAC§§15.1-15.10) and in 1999, the Texas Natural Resources Code (§33.607) required the BEG to publish historical erosion data for public use (Morton, 1993; Morton et al., 1994, 1995; Paine and Morton, 1993; Gibeaut et al., 2000; 2001; 2002; 2003).

Since the late 1990s, the BEG has utilized light detection and ranging (LiDAR) airborne surveys for measuring elevation changes along the Texas Gulf and bay shorelines (Smyth et al., 2003). The digital elevation models that are generated from the LiDAR surveys provide detailed topographic datasets that can be compared to other LiDAR datasets or to on-the-ground beach profiles. LiDAR datasets and accuracies have evolved to enable more precise elevations and

locations of shoreline position, line of vegetation, dune crest, landward dune boundary elevations, and calculation of volumetric changes along with shoreline movement. These datasets can be especially helpful when determining beach losses following storms and planning restoration efforts. Digital elevation models produced from LiDAR surveys were used to verify short-term shoreline recovery patterns and map washover deposits following Hurricanes Humberto (2007), Ike (2008), Dolly (2008), Harvey (2017) (Paine et al., 2013; HDR, 2014; Aylward et al., 2016; Paine et al., 2017).

Not only did the GLO's beach/dune rules require published data, it designated the BEG as the official source of coastal erosion data in Texas. Through the years the BEG has worked hard to make the data accessible for users to identify high risk areas, potential future shoreline positions, and for erosion response planning. The *Texas Shoreline Change Project* is the BEG's monitoring and change analyses program and source for public information (https://www.beg.utexas.edu/research/programs/coastal/the-texas-shoreline-change-project). Here, the public can learn about coastal erosion research and find published reports on Gulf and bay shorelines. The most recent published report for the Gulf provides historical changes measured between 1930s to 2019 (Paine and Caudle, 2020). The BEG report is supplemented by an interactive web viewer that provides the most recent published data for the Gulf of Mexico shoreline (https://coastal.beg.utexas.edu/shorelinechange2019/). Several screenshots of shoreline change maps created from this viewer are included in this document.

Summary of Gulf Shoreline Changes (1930s to 2019)

The most recent evaluation of shoreline changes along the Gulf shoreline were determined from a combination of historic NOAA T-sheets, aerial photographs (for early shoreline positions), and LiDAR (from the 1990s to present) to calculate long-term or historic (1930s to 2019) changes as well as intermediate (1950s to 2019) and short-term changes (2000 to 2019) (Paine, and Caudle, 2020). Figure 2 shows long-term eroding areas in hotter (orange to red tone) colors. "Eroding areas" are combined by increments of measure that begin at -2.0 to -4.9 ft/yr category and continue to the -14.8 ft/yr and more landward movement category. About 80 % of the Texas Gulf shoreline is eroding at greater than 2.0 ft/yr.

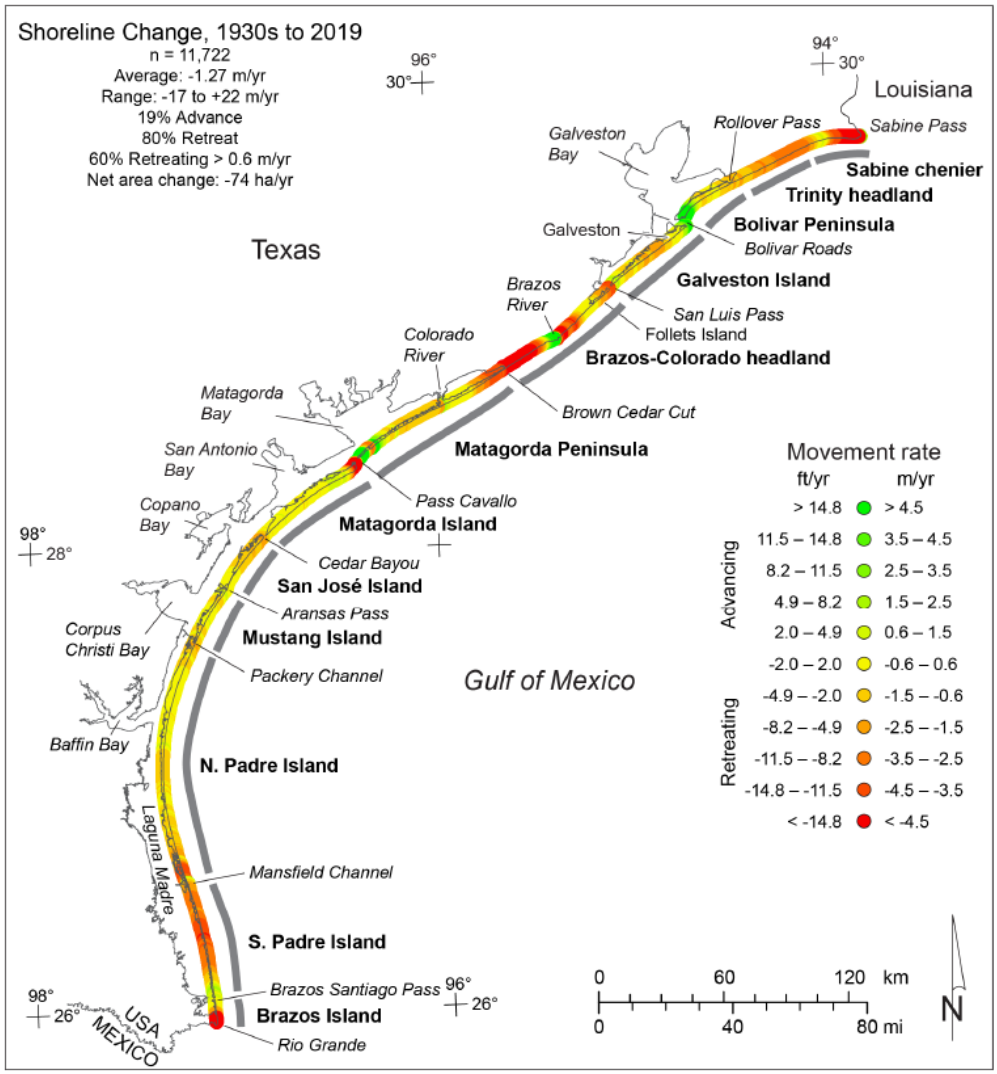

Figure 2. Long-term shoreline changes (1930s to 2019) of the Texas Gulf coast from research by the BEG (Paine and Caudle, 2020). Eroding areas are shown in orange to red tones (-2.0 to more than -14.8 ft/yr).

In general, the highest rates of erosion occur on the shorelines of former deltaic headlands (Trinity and Brazos-Colorado). Gulf shorelines undergoing rates of erosion of more than -8 ft/year [-2.5 m/yr] are found between Sabine Pass to Rollover Pass, on Galveston Island west of the seawall, Quintana Beach to Sargent Beach, eastern Matagorda Peninsula, northeast Matagorda Island (Aransas National Wildlife Refuge), isolated sections of North Padre Island, Padre Island near Port Mansfield Channel, southern Padre Island (Willacy County and Cameron County sections), and the southern portion of Brazos Island near the Rio Grande (Figure 2). Table 3 provides the shoreline change rates (in meters/year) of notable sections of the Gulf shoreline between 1930s and 2019. Sabine Pass to Rollover Pass had the highest net rate of change -10.0 ft/yr (-3.03 m/yr) and the greatest amount of acreage loss during that time period (4,482 acres [1,814 hectares]). The average movement rate of All Texas Sites (-4.17 ft/yr [-1.27 m/yr]) is slightly higher than the average movement rate calculated from the previous update (1930s to 2012) (Paine et al, 2014).

Table 3. Shoreline and land area changes measured between 1930s and 2019 (from Paine and Caudle, 2020)

Area	No.	Net rate (m/yr)	Std. dev. (m/yr)	Range (m/yr)	Area change rate (ha/yr)	Area change (ha)
All Texas sites	11,722	-1.27	2.77	-16.5 to +22.0	-74.5	-6,627
Geomorphic Areas						
Sabine Pass to Rollover Pass	1,345	-3.03	2.64	-11.6 to +10.6	-20.4	-1,814
Bolivar Peninsula	542	+0.28	2.60	-1.9 to +14.2	+0.75	+67
Galveston Island (all)	932	-0.21	1.76	-2.5 to +5.9	-0.98	-87
Galv. Is. (no seawall)	704	-0.22	1.99	-2.5 to +5.9	-0.78	-70
Galv. Is. (East Beach)	108	+3.66	1.38	+1.6 to +5.9	+2.0	+176
Galv. Is. (West Beach)	596	-0.93	1.06	-2.5 to +3.8	-2.8	-246
Brazos–Colorado headland	1,244	-2.16	4.79	-13.2 to +18.1	-13.4	-1,194
Matagorda Peninsula	1,589	-0.89	2.84	-12.2 to +22.0	-7.1	-631
Matagorda Island	1,116	-0.91	3.70	-16.5 to +14.4	-5.1	-452
San José Island	622	-0.84	0.67	-1.9 to +0.8	-2.6	-231
Mustang Island	574	-0.29	0.52	-1.4 to +1.7	-0.83	-74
N. Padre Island	2,403	-0.77	0.93	-4.4 to +1.0	-9.2	-820
S. Padre Island	1,120	-2.46	1.51	-4.7 to +2.8	-13.8	-1,227
Brazos Island	235	-1.57	2.60	-7.2 to +2.3	-1.8	-164

Summary of Bay Shoreline Changes

The CEPRA program is directed to address shoreline changes, however with over 3,300 miles of bay shoreline where erosion is threatening large swaths of habitat, public land, infrastructure, and access there is a need to learn about bay shoreline type and change rates to determine appropriate erosion responses. Bay shorelines often are privately owned and completing studies are often complicated by access issues and statutes prohibiting public funds being used for private property issues unless there is a threat or benefit to the public. Common ways to measure shoreline change are documented through photography, *Google Earth* imagery, or topographic/bathymetric shoreline surveys in the areas of concern.

Large-scale bay shoreline change studies were limited to special projects conducted by the Bureau of Economic Geology. Those former studies of Corpus Christi Bay, Galveston Bay, and Copano Bay systems determined changes in the bay shoreline positions from historic topographic surveys and aerial photography (Morton and Paine, 1984; Paine and Morton, 1986; Paine and Morton, 1993). With the use of LiDAR, more bay shorelines can be evaluated with greater elevation accuracy (Smyth et al., 2003; Gibeaut et al., 2003). However, these studies can be complicated by Federal Aviation Administration (FAA) rules or private property issues.

Funding for recent studies was awarded through the US Fish & Wildlife Service (Coastal Impact Assistance Program). Through the *Texas Shoreline Change Project*, the BEG completed studies of bay margin morphology, shoreline type and shoreline position changes between the 1930s and 2010 for the Copano Bay, San Antonio Bay and Matagorda Bay systems (Paine et al.,

2016). Rates of shoreline movement for these bay systems can be viewed at the BEG's online viewer (http://coastal.beg.utexas.edu/shorelinechange_bays/). LiDAR elevations were collected for the Laguna Madre in 2017, however funded is needed to complete data processing.

Shoreline Change Rates from Project Monitoring

The GLO established the *Beach Monitoring and Maintenance Plan* (BMMP) program for surveying changes at CEPRA-funded engineered beach projects. This monitoring program provides beach profile elevation datasets that can be compared over time to determine annual or post-storm morphologic or volumetric changes. The program also allows for those projects to qualify for FEMA reimbursement should the engineered beach suffer damages from a federally declared natural disaster.

Thirteen CEPRA-funded projects are surveyed annually using the BMMP protocol by the Conrad Blucher Institute for Surveying and Science (CBI) under contract to the GLO (Figure 3) (Williams, 2013; 2014; 2015; 2016; 2017; 2018). CBI collects beach profile elevations and notes changes in shoreline position (MHHW), beach width (relative to Action Width or design Target Width), and estimated volume change. These data and reports are used to determine relative beach stability or if future beach nourishment is needed and approximate timing for the next nourishment cycle. Most of the 13 sites have been surveyed since 2007. The recent report focuses on changes between 2007 and 2018 (Williams, 2019). Survey data are available for online review at the Coastal Habitat Restoration GIS (CHRGIS) mapping tool and beach profile tool (https://sandy.tamucc.edu/chrgis/maps/ and https://sandy.tamucc.edu/chrgis/profiles/). Figure 4 provides a sample of the data available via the CHRGIS tool and shows the locations of the survey transects at Sargent Beach and sampled points of elevation with a description of the substrate.

The combination of aerial photography and datum-based beach profiling is an effective tool for determining shoreline changes at small, easily accessible project areas. The survey process is time intensive, but the elevation datasets collected provide necessary information for quantifying changes and determining maintenance renourishment schedules. At the CEPRA BMMP projects, recommendations for future nourishment cycles are based upon the performance of an individual project: the amount of sand within the project limits (less than 50% of the recommended width or targeted sand volume) and whether there is "wide-spread," "accelerated," or "hot spot" erosion that threatens dunes or backshore infrastructure in the project area. The recommended actions can include additional sand placement, relocation of existing sand accumulations, or planting vegetation. Monitoring results are reported by CBI annually to the GLO. While these reports provide the essential information for managing the CEPRA engineered beaches, they do not provide insight for shoreline changes statewide or for other CEPRA funded beach nourishment projects. The GLO should ensure all beaches are monitored or are provided monitoring information to help coastal planning efforts.

Figure 3. Screen capture from CHRGIS interactive viewer showing all but the Sylvan Beach monitored locations.

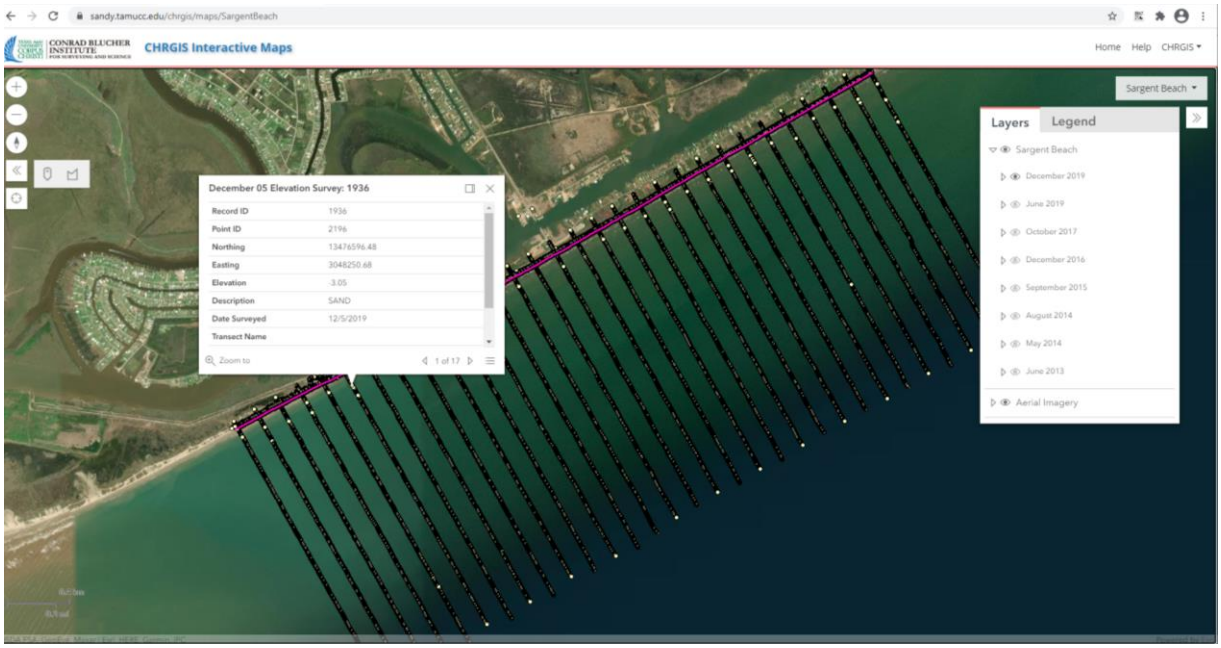

Figure 4. Screen capture from CHRGIS interactive map showing survey lines completed at Sargent Beach in December 2019. The interactive map provides elevations and sediment type at selected locations (https://sandy.tamucc.edu/chrgis/maps/SargentBeach).

The BEG commenced the Texas High School Coastal Monitoring Program in 1997 to train coastal teachers and students in survey methods to monitor shoreline changes. This includes measurements of topography, vegetation lines and shorelines using global positioning satellite (GPS) survey systems, and observations of weather and wave conditions. Student-collected data are used to monitor the effects of nourishment projects on South Padre Island,

foredune changes on Mustang Island, geotextile tubes on Galveston Island, and jetty construction on Matagorda Peninsula (Caudle and Paine, 2017). The student observations of wet-beach/dry-beach positions from those locations were used to compare with the BEG LiDAR dataset for the 2019 shoreline change update (Paine and Caudle, 2020).

In addition to the shoreline research programs mentioned above, federal permit conditions or partner funding sources can require project monitoring. For example, the CEPRA Cycle 7 McFaddin National Wildlife Refuge Beach Ridge Restoration Phase 1 (Pilot Project) placed 610,000 cy of sand on the beach. Beach and borrow area surveys were required immediately after construction, after equilibration, and yearly until pre-project conditions were established for the borrow area, or if the GLO requested to halt monitoring if another phase was imminent. Findings from the monitoring program indicated that the sediment loss from the pilot project was greater than originally expected for a single year, but not necessarily indicative of long-term trends and should not be applied to predict future shoreline positions. Also found, the borrow area filled to pre-project contours (HDR, 2020).

STORM IMPACTS ON THE TEXAS COAST 2017-2020

As widely known, Texas is susceptible to damages caused by hurricanes and tropical systems. Not only are the Gulf and bay shorelines vulnerable from wave attack, but the offshore seabed can substantially change as waves suspend bottom sediments causing erosion from centimeter (0.3 inches) to meter (3.2 feet) levels (Xu, et al., 2016). The changes in the shoreface profile offshore Bolivar Peninsula from Hurricane Ike produced large scarps following the storm that took over five years to reach equilibrium (Goff et al., 2015). Not only is erosion from storm surge a threat, but excessive rainfall can create phenomenal flooding in the coastal zone. Hurricanes Ike and Harvey were compared from sedimentation studies of the coastal marshes at McFaddin National Wildlife Refuge. While both storms left significant amounts of sediment on the marsh surface, Hurricane Harvey's flood sedimentation was the equivalent of seven years of "normal" sedimentation in the marsh and was a significant contribution to marsh accretion (Williams and Liu, 2019).

The notable storms that affected the Texas coast between 2017 and 2020 were:

- Hurricane Harvey, August 25-28, 2017 (Cat 4, first landfall San Jose Island and Rockport Beach and second landfall near Cameron, LA, maximum winds speed 130 mph, rainfall measured at over 60 inches near Beaumont, caused catastrophic flooding in upper Texas coast and storm surge on Galveston Island).
- Hurricane Hanna, July 25, 2020 (Cat 1, landfall Kenedy County, maximum wind speed 86 mph).
- Hurricane Laura, August 27, 2020 (Cat. 4, landfall Cameron Parish, LA, maximum winds 150 mph, storm surge).
- Tropical Storm Beta, September 21, 2020 (TS, landfall near Matagorda Peninsula, heavy surf and high waves and extreme high-water levels five to eight days ahead of the storm’s landfall).
- Hurricane Delta, October 9, 2020 (Cat. 2, landfall Cameron Parish, LA, winds up to 100 mph, storm surge, rain).

Post-storm shoreline impacts were measured by several engineers following Hurricane Harvey (2017). The rapid response Geotechnical Extreme Events Reconnaissance Association

(GEER) team, funded by the National Science Foundation, collected field observations of coastal erosion on the Texas barriers between Galveston to Corpus Christi. The GEER engineers documented dune toe erosion and overwash, scour at bridge piles, damage to coastal structures, significant sediment deposits from flooding, river bank and sheet pile wall failures, scour in front of a boulder wall, undermining of a beach access road, amongst others (Stark et al., 2017). The purpose of GEER is to learn from extreme events and advance research and improve engineering practices.

The BEG flew LiDAR after Harvey and the data were made available to coastal planners and engineers to illustrate storm effects on project locations

Hurricane Harvey's storm surge caused significant erosion at three Galveston Island engineered beach locations (Dellanera Beach, Babe's Beach, and Historic Galveston Beach). The City of Galveston funded a four-year topographic/bathymetric monitoring program at those beaches in 2014 to document sediment movement during normal and extreme weather events. Fortunately, this monitoring program was in place prior to the storm and the consultants were able to compare pre- and post-storm surveys to document sediment losses. Findings were that at both Dellanera and Babe's Beach each experienced more than 100,000 cy of beach sand loss due to Hurricane Harvey. At the Historic Galveston Beach there was a loss of more than 216,000 cy from the storm (Atkins, 2018).

Bay shorelines were not spared by the storm as several sections of the Texas central and upper coast were damaged by the high water levels and waves. Severe erosion occurred at the Port Aransas Nature Preserve, Dickinson Bayou, and Shamrock Island. Port Aransas received 406 Hazard Mitigation FEMA funds. The others were funded with CEPRA funding.

Shoreline impacts from Hurricane Harvey were measured in the annual beach profile surveys of several CEPRA BMMP beaches. Williams (2018) found damages from the storm at Sargent Beach, Surfside Beach, Bryan Beach (Quintana), North Beach, Rockport Beach, Sylvan Beach, and Indianola Beach and recommended Tier 1 Action to implement nourishment in portions of those projects within 1-2 years. (A Tier 1 Action is a recommendation based on the profile data collected by CBI.) By 2019, planning was underway for using FEMA disaster funding to repair the beaches at Surfside Beach, Rockport Beach, and Sylvan Beach (Williams, 2019). Several other CEPRA sites qualified for FEMA reimbursement under Section 406 Hazard Mitigation, reimbursing up to 90% of total project repairs. In addition to the three beach repairs mentioned above six other shoreline projects qualified for the funding and were included in the CEPRA Cycle 10 projects (GLO, 2019).

In the *Local Government Erosion Response Planning & Coastal Management* section, each interviewed participant provided insight on how their shorelines fared during Hurricane Harvey and the 2020 hurricane season.

CRITICAL COASTAL EROSION AREAS

The Texas Administrative Code (31 TAC Subchapter A Ch. 15 [§§15.1-15.10 GLO beach/dune rules]) and the Texas Natural Resources Code (TNC Subchapter H. Coastal Erosion, Sec. 33.601) provide the definition, authority, and rules for identifying "eroding areas" and "critical coastal erosion areas." "Eroding areas" are defined as "*A portion of the shoreline which*

is experiencing an historical erosion rate of greater than two feet per year based on published data of the University of Texas at Austin, Bureau of Economic Geology." These areas are generally defined along the Gulf of Mexico shoreline and form the scientific basis for the policies of the GLO beach/dune rules. "Critical coastal erosion areas" are determined by the Land Commissioner as eroding coastal areas that "*finds to be a threat to: public health, safety, or welfare; public beach use or access; general recreation; traffic safety; public property or infrastructure; private commercial or residential property; fish or wildlife habitat; or an area of regional or national importance."*

The Texas Natural Resources Code (Sec. 33.602) provides a list of metrics that may be used to designate critical coastal erosion areas and guide the allocation of resources. This section of the code allows the Land Commissioner to "*conduct a coast-wide analysis of the costs and benefits of coastal erosion avoidance, remediation, and planning. An analysis conducted under this subsection may consider:*

(1) historical erosion rates in an area;
(2) the elevation of an area adjacent to the shoreline;
(3) the presence of critical infrastructure in an area adjacent to the shoreline;
(4) the population density of an area adjacent to the shoreline;
(5) the presence of economic activity conducted in an area adjacent to the shoreline;
(6) the presence of critical natural resources in an area adjacent to the shoreline;
(7) anthropogenic contributions to erosion; and
(8) any other factor identified as relevant by the commissioner."

To help determine the areas that should be designated as critical erosion, this Erosion Plan update provides maps that show historical erosion rates, critical infrastructure, critical natural resources, and anthropogenic contributions.

METRICS USED TO DETERMINE CRITICAL AREAS

Several metrics must be considered when establishing priorities. One must consider the common issues of concern listed in the Coastwide Erosion Response Plan (with oversight by the GLO's CEPRA Program) and the CRMP (with oversight by the GLO's Planning Program) as both plans identify critical areas and projects that address Gulf beach erosion and dune degradation, public bay shoreline erosion and habitat loss, and coastal storm surge vulnerability. Priorities should also consider any limitations for the use of GOMESA funding as that source is often used as match with CEPRA allocations for projects.

The datasets to support the shared goals of the CEPRA program, CRMP, and GOMESA funding criteria are available via web-based viewers or in geographic information system formats. The mapped information that would help accomplish the goals for erosion response planning and allocation of funds include:

- Shoreline Change Rates
- Public Access Points
- Coastal Infrastructure
- Coastal Natural Resource Areas-*Sensitive Areas*
- CEPRA Beach Nourishment Projects
- Texas Coastal Resiliency Master Plan Tier 1 Projects
- Critical Erosion Areas

BEG Shoreline Change Rates (Gulf)

The most important dataset required for establishing project and funding priorities under the CEPRA program is the BEG Gulf shoreline change rate. This offers the locations of *eroding areas* (those Gulf shorelines that experience erosion greater than 2 ft/yr measured between 1950s and 2019). The rates are calculated from a compilation of maps, aerial photographs, ground surveys and airborne LiDAR surveys (Paine et al., 2020). The 1950s to 2019 "intermediate term" comparison timeframe was chosen to reflect the conditions after many of the USACE projects were constructed and the shoreline was able to maintain equilibrium with respect to the presence of the structure. The rates were calculated using end-point analyses (the net amount of change from the 1950s shoreline to the 2019 shoreline location). Shoreline change data are accessible at the Bureau of Economic Geology's (BEG) Shoreline Change Map-2019 web viewer https://coastal.beg.utexas.edu/shorelinechange2019/. Here, a user can review the erosion severity within their jurisdiction and make maps that can accompany applications for funding.

Public Beach & Shoreline Access Points

Public beach access data are available from the GLO but a user must have working knowledge or access to a geographic information system (GIS) in order to view the locations (https://www.glo.texas.gov/land/land-management/gis/). In its website *Programs, Tools, and Resources*, the GLO offers links to several map viewers, guides, and plans (https://glo.texas.gov/coast/coastal-management/tools/index.html). Here, a user can access the Texas Coasts web viewer (http://txcoasts.com/) that provides locations of designated public access to the shorelines, wildlife refuges, and management areas along the Texas coast. In addition, the site includes descriptions about each access location and provides listings of amenities and recreational opportunities. Figure 5 is an example from McGee Beach in Nueces County.

Figure 5. Public access information provided by the Texas Coasts web application.

Coastal Infrastructure

Coastal infrastructure includes public government and public non-government structures, and sites of artificial reefs, beach nourishment and shoreline protection (Figure 6). This data layer also includes the Gulf Intracoastal Waterway (GIWW). Coastal infrastructure becomes critical infrastructure in areas where coastal erosion is greater than 2 ft/yr. Coastal infrastructure data were downloaded from the GLO's coastal leases (points and polygons) vector website (https://www.glo.texas.gov/land/land-management/gis/). These data are also available on the Coastal Resources Mapping Viewer if GIS capabilities are not available (https://cgis.glo.texas.gov/rmc/index.html)

Figure 6. Coastal infrastructure data layers available from the GLO.

Coastal Natural Resource Areas

Coastal natural resource areas (CNRAs) are defined in §33.203 of the Texas Natural Resources Code and include sixteen historic, hazard, and ecological features of the Texas coastal zone that are afforded special management actions for natural resource stewardship. The Texas Resource Management Codes (RMC) provide guidelines for projects located near or within CNRAs on state tracts within Texas bays and estuaries and Gulf waters. In addition, RMCs provide recommendations to promote best management practices for development or other activities to avoid or minimize impacts to Sensitive Areas which can include coastal marshes and critical dunes among others. For example, dredging or pipeline placement, may be limited in

some tracts and the RMCs may indicate that any potential work should be located at a specific distance or water depth from a Sensitive Area.

Sensitive Areas were identified during the 2014 RMC update by the Texas Data Standards Committee (DSC), a team composed of state and federal agency, practitioner, and academic subject matter experts, to standardize language for the regulatory environment (Gibeaut et al, 2015, 2018). Sensitive Areas not only include critical areas (coastal wetlands, oyster reefs, hard substrate reefs, submerged aquatic vegetation, tidal sand or mud flat) defined in the Texas Natural Resources Code, but include other coastal natural resources or habitats that were determined to require special attention in the permitting process. The GLO's Coastal Resources Mapping Viewer shows the locations of Sensitive Areas (https://cgis.glo.texas.gov/rmc/index.html). Figure 7 provides the list of Sensitive Areas selected for presentation in the following maps. These areas are more likely to be affected by coastal erosion or erosion response projects and help identify shorelines subjected to critical erosion.

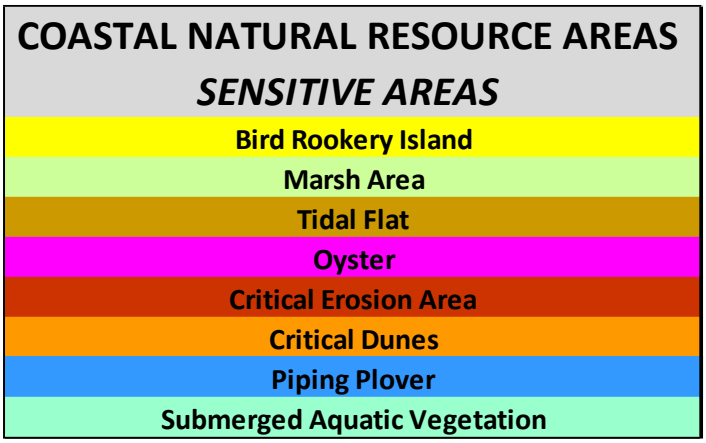

Figure 7. Selected Sensitive Areas presented to identify critical erosion areas.

Anthropogenic Contributions

Anthropogenic contributions can include CEPRA-funded projects and CEPRA-eligible Resiliency Plan Tier 1 projects and should be included in viewable maps in the effort for establishing critical erosion areas and priorities. These projects are considered critical coastal infrastructure since they have been vetted and paid for using public funds. The mapped locations can show gaps in coastal areas in need of projects. These data could be included in a web viewer with shoreline change rates to show vulnerabilities. This recommendation is aimed at coastal planners and the GLO as an aid for selecting priority projects.

Gulf Shoreline Local Government Reference Lines

Other anthropogenic contributions can include local government references lines. The rules set forth in §15.17 Title 31 Texas Administrative Code for the development of local erosion response plans require Gulf shoreline governments to create building setback lines based upon the BEG's historical shoreline change rates measured from a reference line of the local government's choosing (line of vegetation, mean low tide, mean high tide, or coastal boundary survey). The local plans supply maps that show the location of the dune protection line (approved from earlier beach access and dune protection plans) and an evaluation of public beach access areas to determine if improvements are necessary to protect from erosion or storm surge. The datasets used in the local erosion response plans could be useful in post-storm

assessments and are also important for the implementation of the CEPRA program as some of the information may be used in applying for grant funding or could be used to determine priority status. In addition, if a potential project is located within the jurisdictions of the Open Beaches Act and Dune Protection Act, then the local government must have submitted an Erosion Response Plan prior to receiving CEPRA funding.

Some of the information is readily accessible via web viewers, but others such as the location of mean low tide and mean high tide require licensed state land surveys to certify elevations. Other information developed by the local governments (building setback lines and dune protection lines) will require a GIS-based effort to consolidate all information into one central location.

Coastal Elevations, Population Density, Economic Activity

Though considered important metrics that could be used to designate critical coastal erosion areas (TNC Sec. 33.602) gaining access to coastal elevations, population densities, and economic activities are not as easy as other metrics mentioned above. LiDAR elevations are available along the Gulf shoreline (2010, 2011) and (2013) for some areas of the San Antonio Bay shoreline and portions of the lower Texas Gulf coast. The Texas Demographic Center provides interactive maps that show population by race and ethnicity (https://idser.maps.arcgis.com/apps/MapSeries/index.html?appid=3ca585f84ec34b4d936beb54a9c57416). Economic activities appear to be held in reports rather than in interactive web applications.

Critical Erosion Areas, Critical Natural Resources, and Critical Infrastructure

Critical erosion areas are identified where erosion threatens public safety and access, general recreation, traffic safety, public property or infrastructure, private commercial or residential property, fish or wildlife habitat, or an area of regional or national importance. When combined with the data layers above, there is a better understanding of the spatial relationships of the erosion threat.

Critical natural resource areas and critical infrastructure are not specifically defined in the Texas Natural Resources Code but can be identified from maps that show eroding areas and Sensitive Areas or coastal infrastructure (Figures 8 through 15). The greater the erosion rate, the more vulnerable the natural resource or infrastructure is to damages or overall loss, and higher priority should be placed for conservation, restoration, or enhancement projects in those areas.

The maps presented in Figures 8 through 15 show the BEG's intermediate timeframe 1950s to 2019 shoreline change rates (in feet) where the erosion rate is greater than 2 ft/yr. This time was chosen to coincide with the GLO's CEPRA application process (https://www.glo.texas.gov/coast/grant-projects/funding/files/cr-funding-app.pdf). The shoreline change rates are further separated into two categories (-2 to -11.5 feet/year) and (-11.5 to -65.0 feet/year) to show the regions of the shoreline that are the most vulnerable. Not only are these areas eroding at greater than two feet per year, but the erosion threatens some or all the criteria listed in TNC Subchapter H. Sec. 33.601 (also listed herein on page 15). Based on the updated shoreline change data provided by the BEG, net retreat occurred along 80% of the Gulf shoreline (Paine and Caudle, 2020). Consequently, most of the Texas Gulf shoreline qualifies as critical coastal erosion areas. Note the high erosion rates from Sabine Pass to Rollover Pass and

portions of Bolivar Peninsula. The erosion threatens evacuation routes, wildlife habitat, and critical natural resource areas at McFaddin Beach (Region 1). In Region 2, erosion threatens the Gulf Intracoastal Waterway and Aransas National Wildlife Refuge. Public structures, beach access, and beach nourishment are threatened in Regions 3 and 4.

The mapped eroding areas combined with coastal natural resource areas (Sensitive Areas) and anthropogenic projects (CEPRA-funded beach nourishment) are shown in Figures 8 through 11. Figures 12 through 15 show the same eroding areas mapped against public access and coastal infrastructure including Federal, state, county parks and preserves. These maps help identify the sections of the shoreline that should be considered as critical erosion areas and that should be a focus of project funding.

Along bay shorelines, measured changes through historical imagery, photographs or surveys can be used to illustrate need in areas where shoreline change data are not available or updated. These methodologies can also be used along the Gulf shoreline following storms where the BEG has not updated the shoreline change rates.

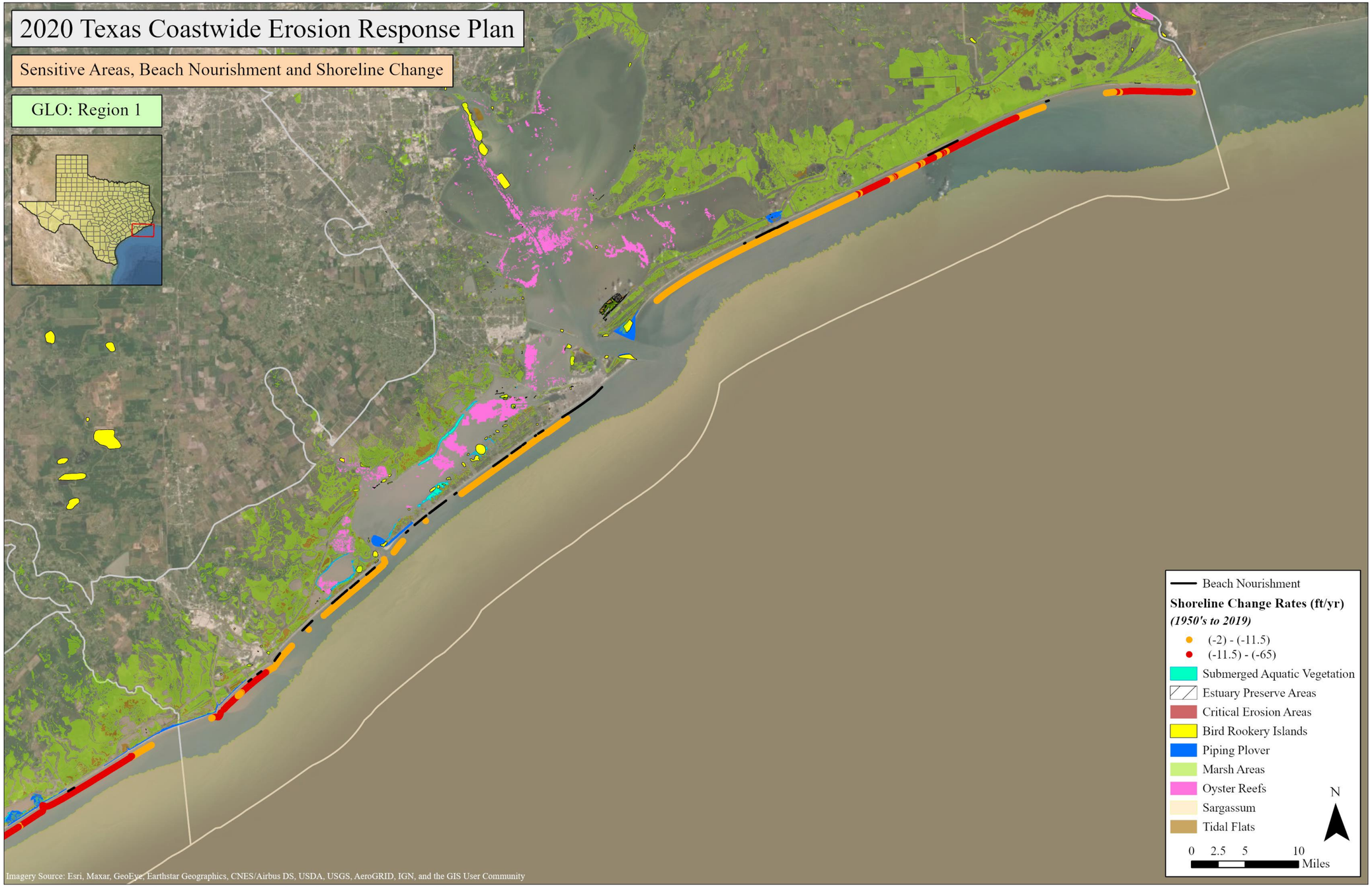

Figure 8. Region 1 critical erosion areas with selected Sensitive Areas and beach nourishment projects.

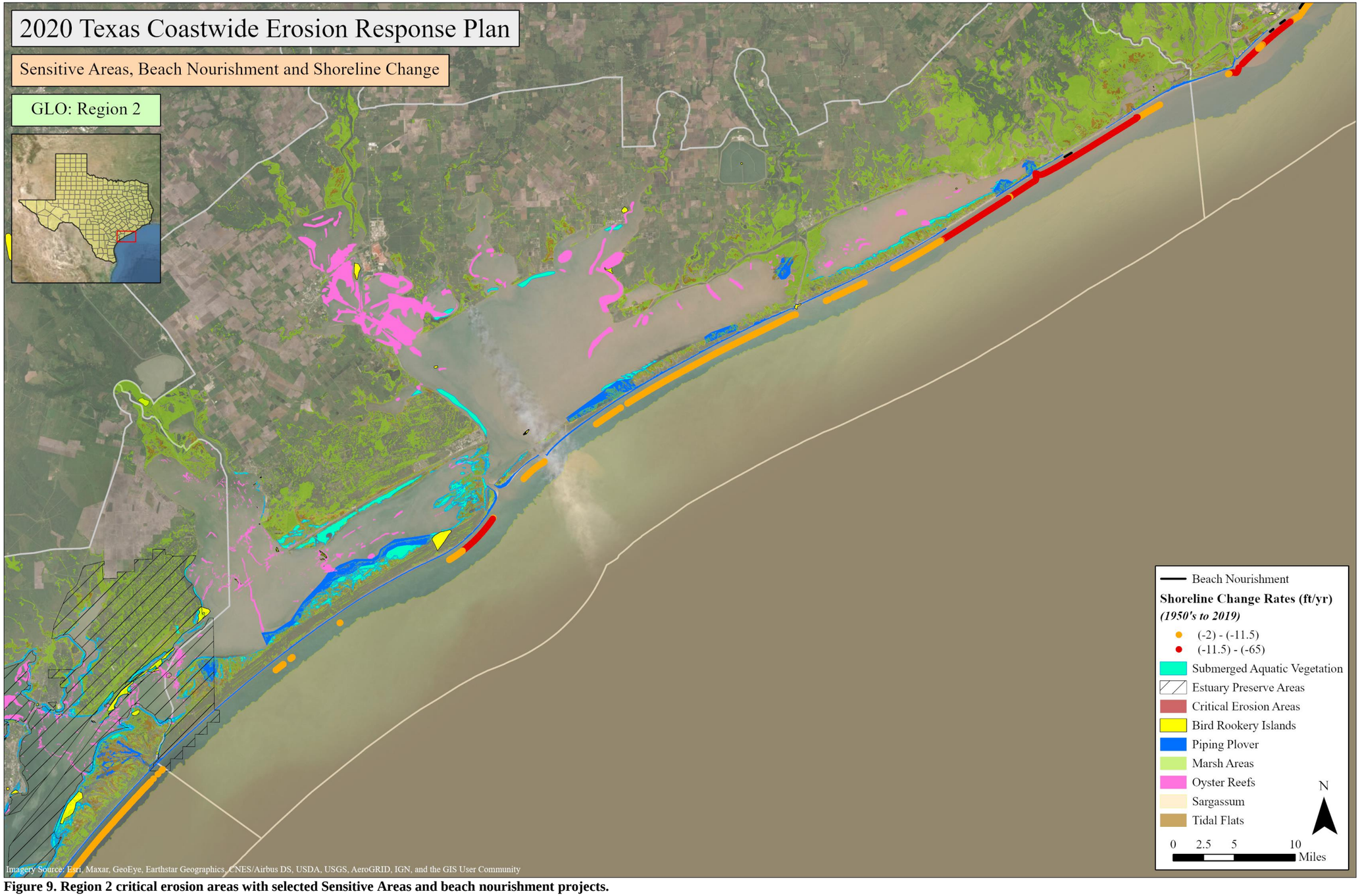

Figure 9. Region 2 critical erosion areas with selected Sensitive Areas and beach nourishment projects.

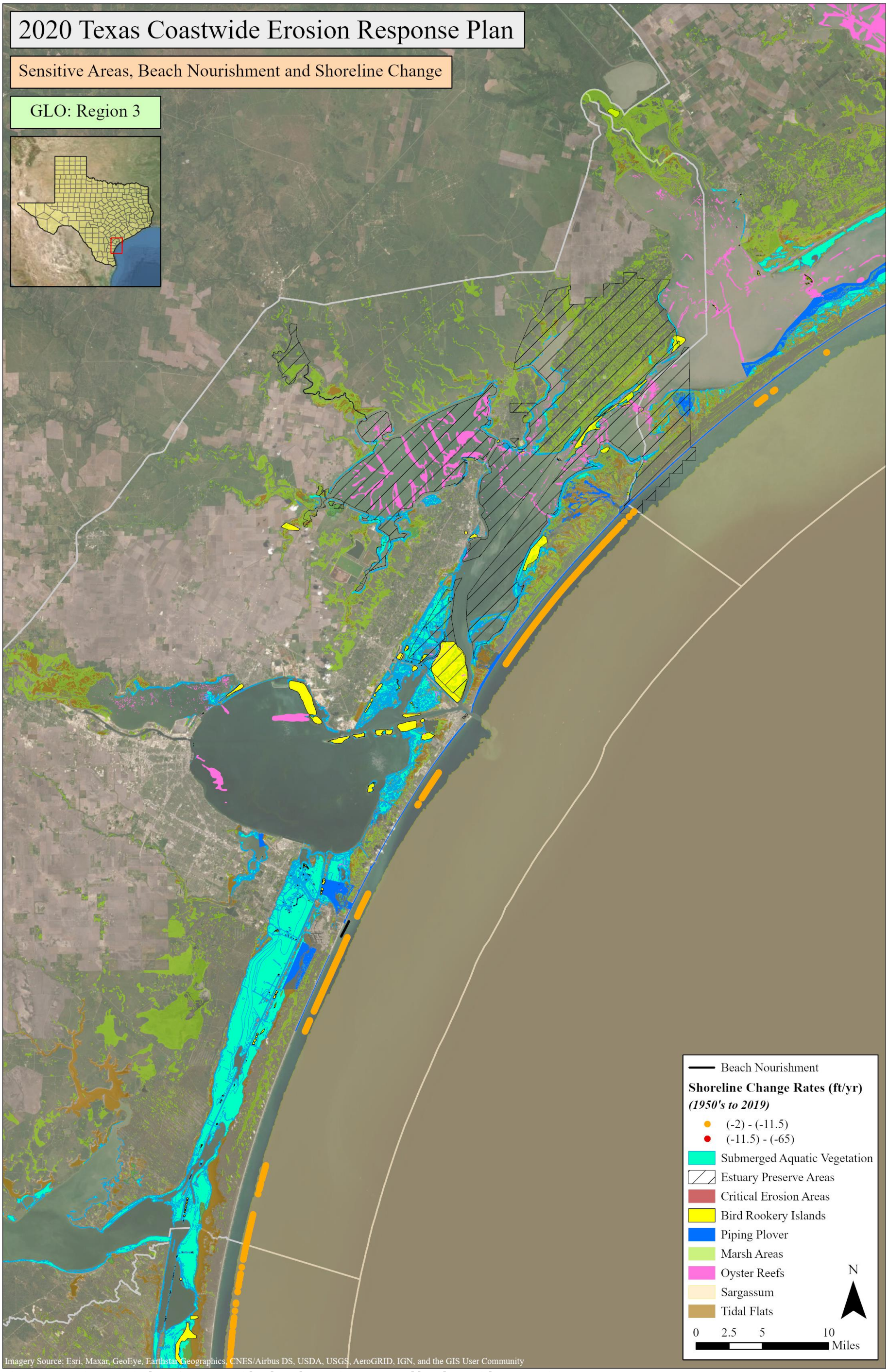

Figure 10. Region 3 critical erosion areas with selected Sensitive Areas and beach nourishment projects.

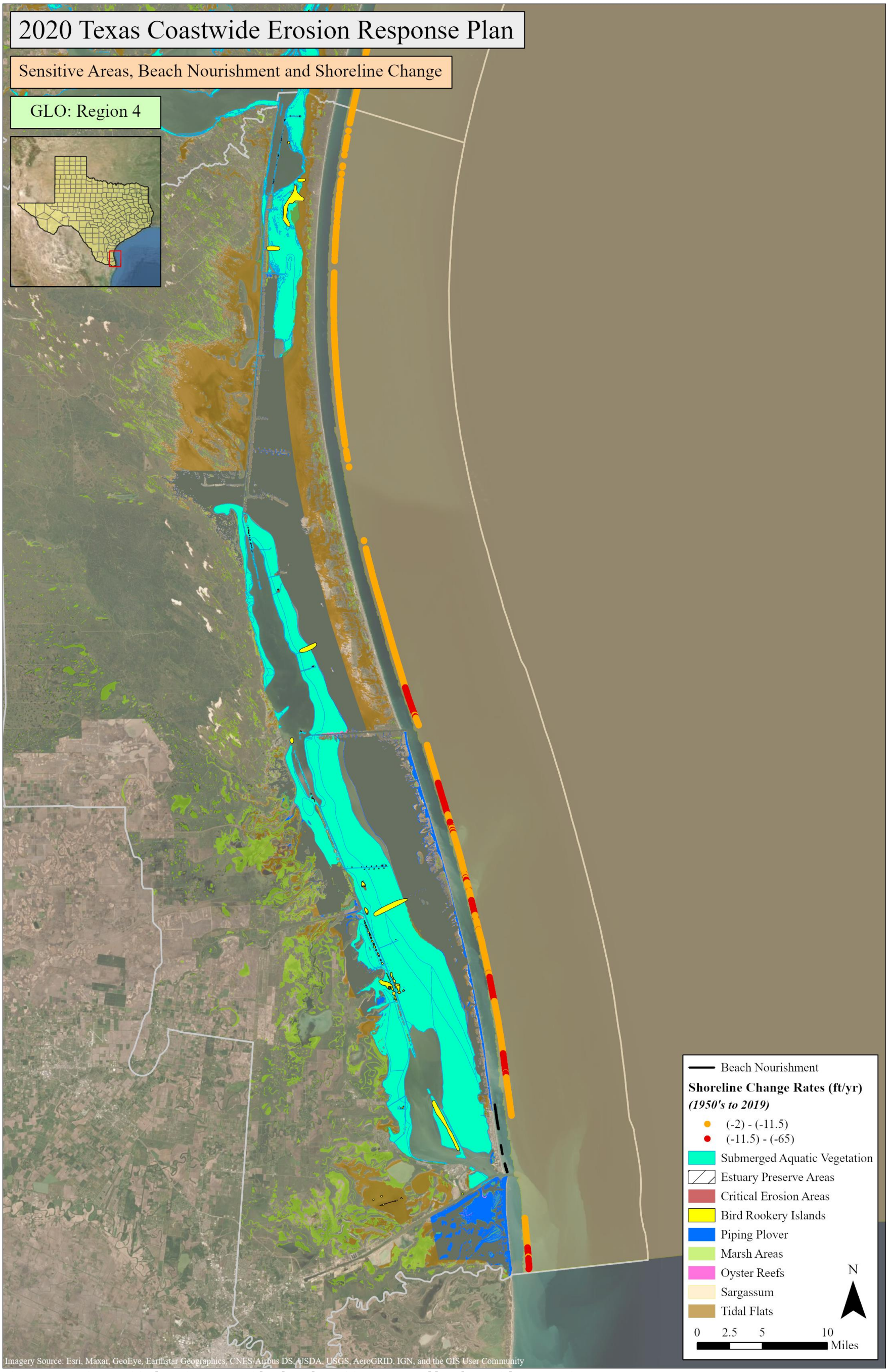

Figure 11. Region 4 critical erosion areas with selected Sensitive Areas and beach nourishment projects.

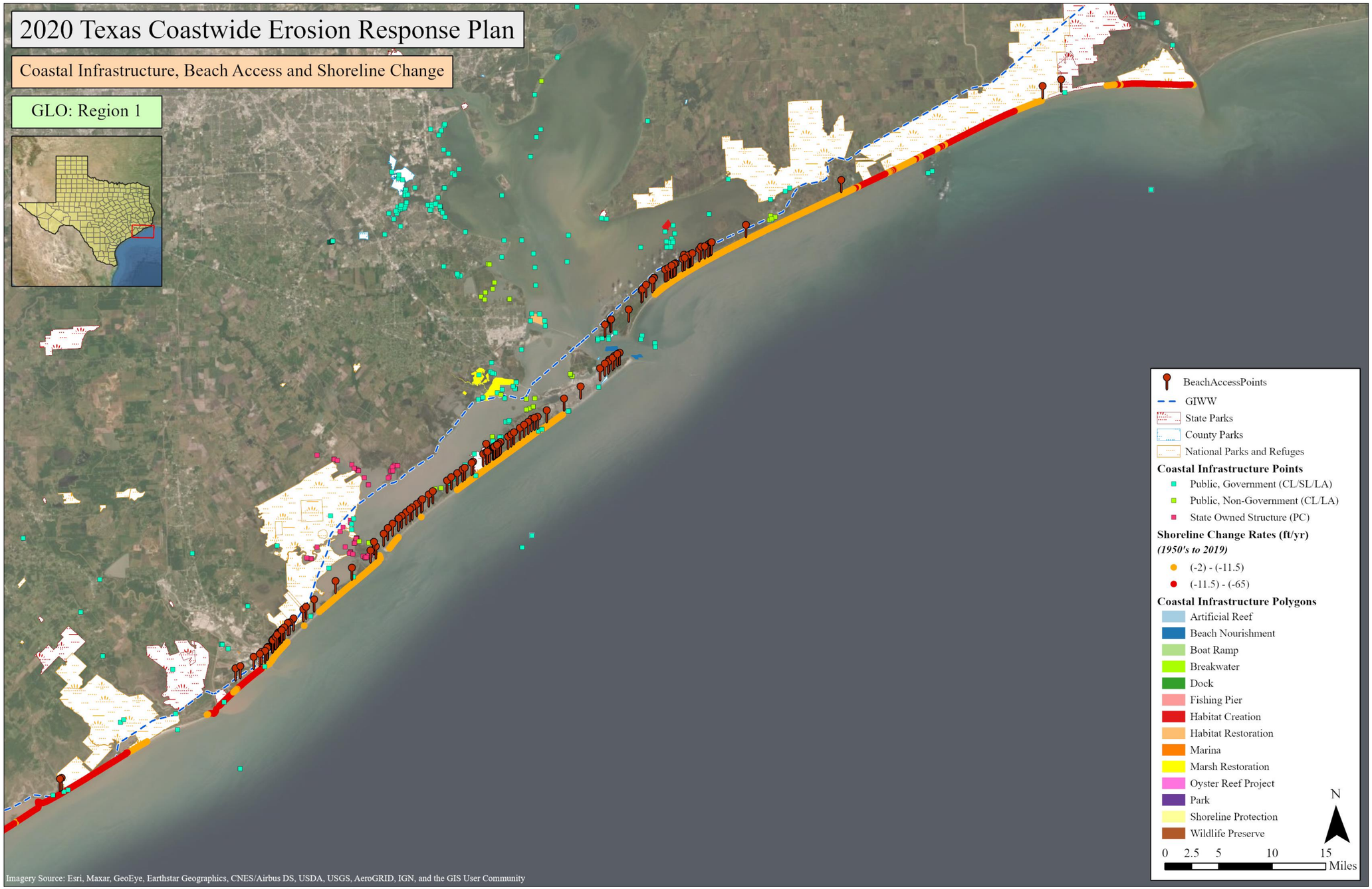

Figure 12. Region 1 critical erosion areas showing coastal infrastructure and beach access.

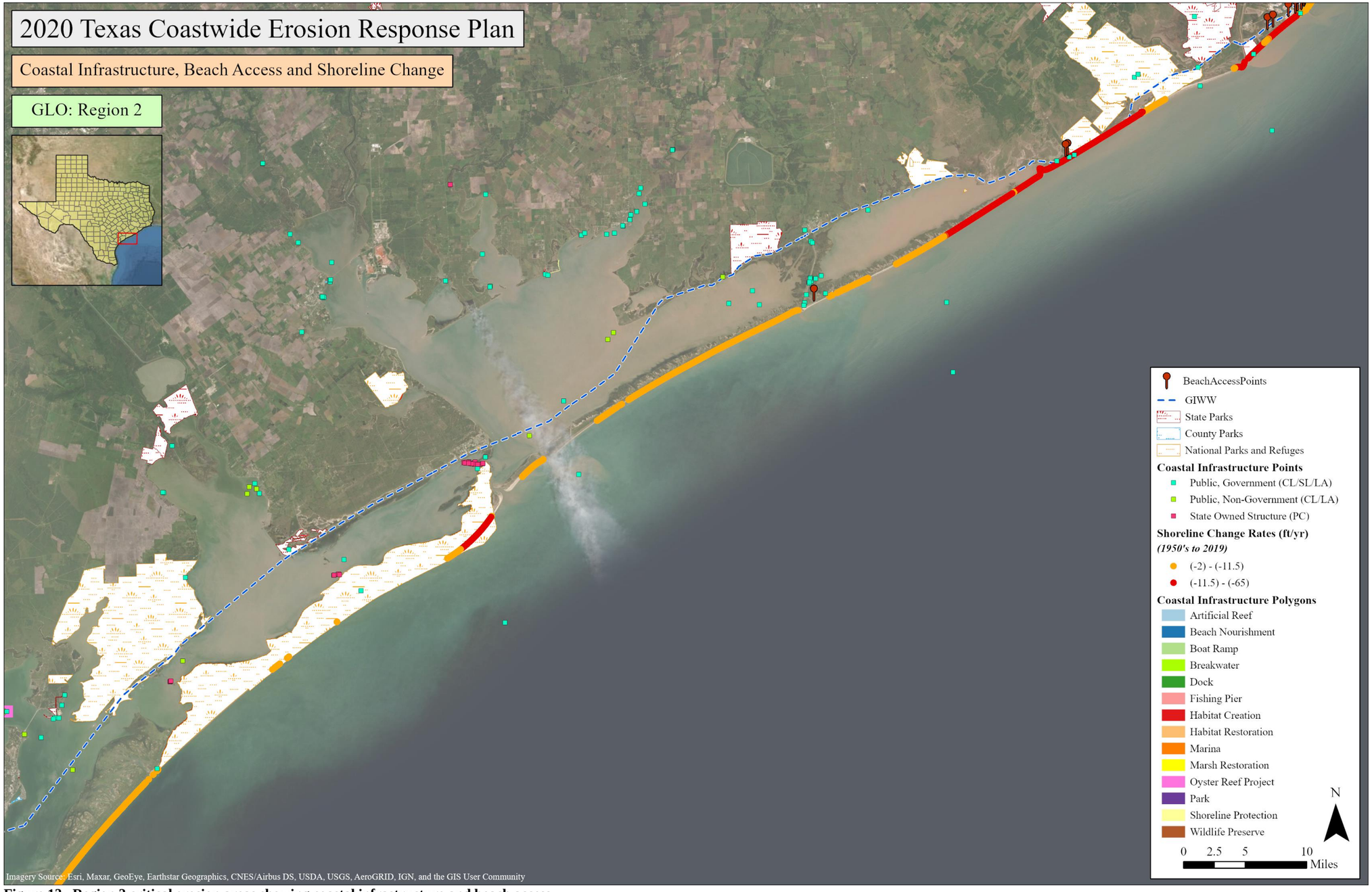

Figure 13. Region 2 critical erosion areas showing coastal infrastructure and beach access.

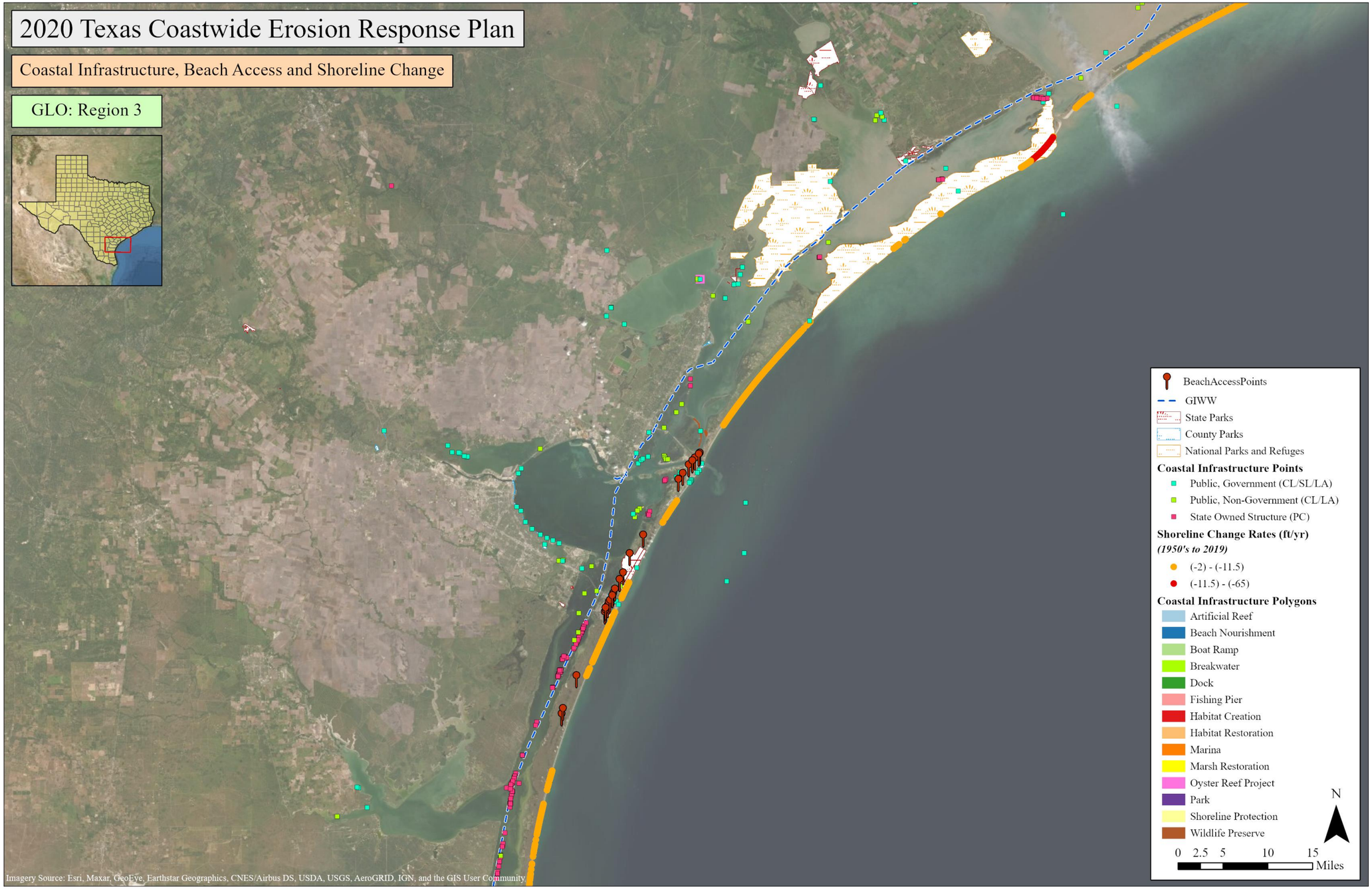

Figure 14. Region 3 critical erosion areas showing coastal infrastructure and beach access.

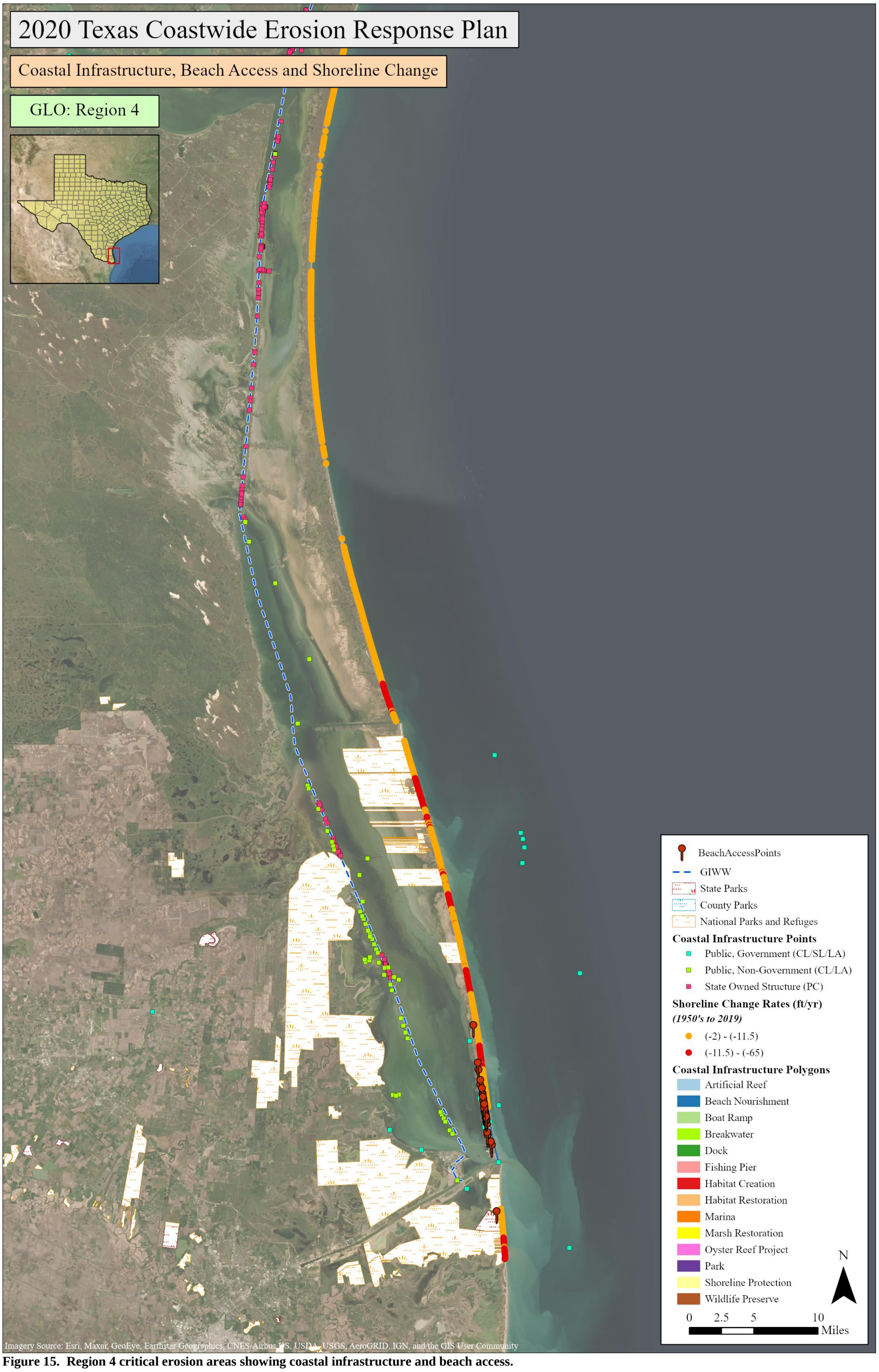

Figure 15. Region 4 critical erosion areas showing coastal infrastructure and beach access.

FUNDING PROGRAMS AND PARTNERSHIPS

For shoreline erosion response, some key programs and partners share CEPRA's goals to reduce flood and storm damages, restore coastal habitats, and reduce risks to human populations. These programs provided significant funds to match those appropriated to the CEPRA program.

Federal entities such as the Federal Emergency Management Agency (FEMA) and the US Department of Housing and Urban Development (HUD) provided cost-shared public assistance funding for hurricane response and economic recovery within declared Hurricane Harvey disaster areas. The US Army Corps of Engineers Galveston District (USACE-SWG), National Oceanic and Atmospheric Administration (NOAA), US Fish and Wildlife Service (USFWS) and Bureau of Ocean Energy Management (BOEM) also provided cost-shared funds for state-supported coastal erosion response projects and studies. Funding created through civil and criminal penalties stemming from the Deepwater Horizon Spill include NFWF Gulf Environmental Benefit Fund (GEBF), NRDA's DWH Restoration Plan funds, and Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies (RESTORE) funds. These funds have provided various opportunities for partnership. Since coastal restoration involves significant engineering, design, permitting, and high construction costs, the following programs often provide the match funding for project completion.

Texas Coastal Management Program

A program of the GLO with source funding from NOAA, the Texas Coastal Management Program (CMP) awards grants that address coastal development, water quality, public access, habitat protection, energy facility siting, ocean planning, coastal hazards, and climate change. Protection of the state's natural resources are based on goals set forth via the *National Coastal Zone Management Program Strategic Plan 2018-2023.* CMP projects generally involve planning and outreach for coastal resiliency but the program overlaps with CEPRA by supporting sediment management planning, coastal monitoring, dune restoration, and construction of living shorelines. Since CEPRA funds cannot be utilized to fund public access or recreational projects, the CMP Program is a great complement to many CEPRA projects that can enhance overall project success and access for the public once a CEPRA project has been constructed.

Gulf of Mexico Energy Security Act (GOMESA)

The Gulf of Mexico Security Act of 2006 apportions outer continental shelf leasing revenue from the oil and gas industry to participating Gulf producing states to protect, conserve, or restore coastal areas. The funding can be allotted to the GLO's CEPRA Program, CMP, or Restoration Management Program. These funds may only be used for the following authorized activities:

- *projects and activities for coastal protection, including conservation, coastal restoration, hurricane protection, and infrastructure directly affected by coastal wetland losses;*
- *mitigation of damage to fish, wildlife, or natural resources;*
- *implementation of a federally approved marine, coastal, or comprehensive conservation management plan;*
- *mitigation of the impact of Offshore Continental Shelf OCS activities through the funding of onshore infrastructure projects; and*

- *planning assistance and administrative costs not-to-exceed 3 percent of the amounts received.*

There is a cap of $500 million/year to be shared between four Gulf oil & gas producing states, (Texas, Louisiana, Mississippi, Alabama) however the cap amount is not guaranteed. The CEPRA program uses GOMESA funds as partner match for restoration project construction. In addition, GOMESA funds are provided directly to the Gulf coastal counties of Texas which helps counties fund coastal restoration projects. Priority for use of these funds is given to projects located in critically eroding areas. Tier 1 Resiliency Plan projects are also eligible for the combined funding. The CEPRA Program and CMP facilitate the funds via prioritization of the Tier 1 projects or through the establishment of Projects of Special Merit.

Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE)

In 2012, Congress passed the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act that established a trust fund from criminal and civil penalties resulting from the Deepwater Horizon Oil Spill. Money from the trust fund can be used to restore or protect natural resources, ecosystems, beaches, coastal wetlands, and Gulf coast economies. RESTORE match funds will beth used for beach nourishment at McFaddin Beach and Babe's Beach, and Shamrock Island habitat restoration.

National Fish and Wildlife Foundation (NFWF)

In 1984, Congress established the National Fish and Wildlife Foundation as a Federally chartered non-profit organization to administer funding in connection with US Fish and Wildlife Service programs and conservation activities. NFWF receives annual Congressional appropriations as well as private funds to support its mission for sustaining, restoring, or enhancing fish, wildlife, plants, and habitat. The establishment of the GEBF provided $203 million for natural resource projects in Texas of which the GLO and the CEPRA Program received funding for various Cycle 10 and 11 projects. NFWF provided funding for shoreline protection and marsh restoration at Virginia Point, Galveston Island State Park (Phases I, II, and III), and Carancahua Bay (Phases I and II). NFWF also provided 32% of the total budget for the upcoming McFaddin project which will restore the dune ridge and provide beach nourishment for 17 miles of severely degraded shoreline in Region 1. The McFaddin project is the GLO's largest and longest beach nourishment project ever implemented (GLO, personal communication).

Coastal Impact Assistance Program (CIAP)

The US Outer Continental Shelf Lands Act established the Coastal Impact Assistance Program to mitigate the impacts of the oil and gas industry. The grant-funding program is administered through U.S Fish and Wildlife Service. In 2007, over $109 million in CIAP funds were dedicated to the State of Texas to conserve, restore, enhance, and protect renewable natural resources. Non-federal matching funds are not required for approved grant projects. In Cycle 10, the CEPRA program applied CIAP funding to restore the dune system on Bolivar Peninsula and for wetland protection and restoration at Virginia Point.

Federal Emergency Management Agency (FEMA)

FEMA administers the Section 406 Hazard Mitigation Public Assistance Program that allows funding to repair disaster-damaged facilities. CEPRA BMMP monitored shoreline projects qualify for assistance under this program and are eligible for reimbursement to repair damages following a federal disaster declaration. The program reimburses total project costs up to 90% with a qualified partner to cost share the remaining 10% non-federal amount. Nine Cycle 10 Hurricane Harvey beach repair projects qualified under this program to restore the engineered beaches to above the 50% fill threshold. Texas SB 500 provides the funds to cover the remaining 10%, so those Cycle 10 projects are now fully funded outside of CEPRA or partner match.

Natural Resources Damage Assessment (NRDA; DWH and Various Oil Spills)

Penalty funds from various oil spills and most notably the Deepwater Horizon oil spill were allocated to the Texas Natural Resources Damage Assessment Trustees for cooperative projects with CEPRA. NRDA contributed over $17 million in Cycle 10 for restoration projects. A portion was used to restore dunes at McFaddin Beach National Wildlife Refuge and construction of shoreline structures at Indian Point and engineered design of breakwaters at Bird Island Cove. NRDA funds were also used to conduct an Alternatives Analysis of the Swan Lake Marsh Restoration Plan.

US Army Corps of Engineers (USACE)

One of the most important partners in addressing shoreline erosion in Texas is the US Army Corps of Engineers, Galveston District (USACE-SWG). The Civil Works and Environmental missions and programs of the Galveston District complement state and local erosion response activities. USACE-SWG is responsible for maintenance of the federal navigation channels and provides technical support for coastal erosion and storm damage risk reduction projects. Through its beneficial use of dredged material program (BUDM), the USACE placed sand dredged from Federal navigation channels onto adjacent beaches at South Padre Island and at Caplen Beach. These placements helped to reduce the effects of erosion and added valuable sand to the littoral system.

In addition to these activities, the USACE-Galveston District partnered with the GLO to develop a plan that recommends large-scale coastal storm risk management and ecosystem restoration actions aimed at providing Texas coastal communities with multiple lines of defense to reduce impacts from coastal hazards (USACE and GLO, 2020). The *Coastal Texas Study* evaluated resiliency projects under future sea level conditions and their effectiveness for providing protection. The Coastal Texas Study recommends beach and dune restoration, shoreline protection, hydrologic restoration, island creation, and habitat enhancements throughout the Texas coastal zone. Among the recommendations are storm surge barriers at Bolivar Roads and a ‘Galveston Ring Barrier System’ that surrounds the City with tie in to the Galveston Seawall; storm surge barrier north of the Gulf Intracoastal Waterway (GIWW) with tie in to the Texas City Dike; and surge barrier gate across the middle of Galveston Bay. The tentatively selected plan provides a coastwide ecosystem restoration plan, a multiple line of defense for the upper coast (Region 1), and beach restoration for the lower coast (Region 4). The Final Feasibility Report is expected for review in March 2021. If approved and funded there will

be a need for a significant amount of sediment for the construction of dunes, beach nourishment, marsh restoration, and ring levee projects.

CEPRA PROJECTS

For over 20 years the CEPRA Program has implemented strategies for coastal erosion avoidance, remediation, and planning to protect the common law rights of the public from erosion shorelines. CEPRA sponsored beach nourishment, shoreline protection, habitat restoration projects among other projects to reduce the threat to public access, public infrastructure, and wildlife habitat. The CEPRA program reports submitted to the Texas Legislature (GLO, 2015; 2017; 2019) describe projects, partnerships, and cost-share amounts for CEPRA Cycle 8 (2014-2015), Cycle 9 (2016-2017) and Cycle 10 (2018-2019). In the past, the program endured limited appropriation levels as well as mandatory budget reductions due to state budget deficits. Funding amounts have varied through each biennial cycle; however, requests for CEPRA funding from potential project partners always exceed the amounts allocated. These requests are expected to climb with the implementation of the Tier 1 Texas Coastal Resiliency Master Plan projects.

Fortunately, federal and non-federal partner matches helped to fund the 50 projects in Cycles 9 and 10 where the CEPRA appropriations totaled over $29 million. Match funding totaled over $11 million for Cycle 9 and over $133 million for Cycle 10 (Table 4) (GLO, 2019). The jump in match funding in Cycle 10 was attributed to sources that targeted restoration projects.

Table 4. Legislative appropriations and CEPRA matching funds for Cycles 6 through 10 (GLO, 2020 personal communication)

Funding Cycle	Projects Funded	Appropriated CEPRA Funds	CEPRA Match Funding	Total Budget for Cycle
6 (FY10-11)	28	$15,907,639	$68,914,538	$84,822,177
7 (FY12-13)	26	$17,394,456	$41,972,295	$59,366,751
8 (FY14-15)	21	$17,038,734	$27,349,977	$44,388,711
9 (FY16-17)	18	$14,920,538	$11,462,267	$26,382,805
10 (FY18-19)	32	$14,271,940	$133,115,582	$147,387,522

Probably the most significant action to affect the CEPRA program since the last *Coastwide Erosion Response Plan* update was the passage of the Hotel Occupancy Tax Bill by the 86th Texas Legislature in 2019 that dedicates 2% of coastal counties state occupancy tax revenue directly to the CEPRA Program. This act provides a permanent source of funding to the program to meet the needs of coastal communities and opens opportunities for matching funds from other sources.

Table 5 and Figures 16 through 19 provide the list and locations of the 114 projects funded through CEPRA Cycles 8 - 11. These include GOMESA funded projects as well as Resiliency Plan Tier 1 projects. Project descriptions can be found at the GLO *Grant Projects* website and searched by funding group (e.g. CEPRA) (https://www.glo.texas.gov/coastal-grants/#search/). The table and accompanying figures show the distribution and types of projects that have been funded throughout the four planning regions. Due to the nature of the types of projects that are funded, it can take longer than one biennial funding cycle to plan, permit, and

construct a project, especially if background data (e.g. sand resource studies) must be obtained prior to permitting. Shoreline protection (44), beach nourishment (30), erosion -related studies or monitoring (27), and habitat restoration (23) were the most common project categories funded during Cycles 8 – 11, with many projects representing more than one category. Note only one project for structure relocation and none for debris removal. Forty-eight percent of the projects were concentrated in the upper Texas coast (Region 1) where the population concentration is greatest and where long stretches of the coast have high erosion rates (Figure 16). Region 2 had 17% of the projects with most focused on shore protection and habitat restoration (Figure 17). Region 3, at 13% of the total projects, included shore protection and many BMMP beach nourishment projects (Figure 18). Region 3 also includes a large portion of private property with the private barrier island. Region 4 had the lowest number of projects at 10.5 % and concentrated on utilizing dredged material for beach nourishment and shore protection (Figure 19). This section of the Gulf coast includes Padre Island National Seashore where management goals do not require CEPRA funding assistance. In addition, population densities are lower in this section of the Texas coast.

Table 5. List of CEPRA Cycle 8 through Cycle 11 projects

CEPRA PROJECTS - Cycle 8 through Cycle 11													
Project No.	Project Name	CEPRA Funding Cycle	County	Project Type	Study / Monitoring (SM)	Beach Nourishment (BN)	Dune Restoration (DR)	Shoreline Protection (SP)	Habitat Restoration / Protection (HR)	Structure Relocation (SR)	Debris Removal (DM)	Maintenance / Emergency (MP)	Beneficial Use of Dredged Material (BUDM)
1463	Port Aransas Nature Preserve	6, 7, 8	Nueces	SP				1					
1495	Rollover Pass Closure	6, 7, 8	Galveston	BN, SP		1				1			
1523	USACE Feasibility Study Re-scoping Project	7, 8	Brazoria, Chambers, Galveston, Harris, Jefferson, Orange	SM	1								
1525	Isla Blanca BUDM Cameron County	7, 8	Cameron	BN BUDM		1							1
1528	Nueces River Delta Stabilization and Habitat Protection	7, 8	Nueces, San Patricio	SP				1					
1563	BEG shoreline change update	7, 8	Coastwide	SM	1								
1564	Critical Erosion Area Update	8	Coastwide	SM	1								
1566	Galveston Seawall Beach Nourishment	7, 8	Galveston	BN		1							
1569	BMMP - Corpus Christi	7, 8	Nueces	BN		1						1	
1571	BMMP - Bryan	7, 8	Brazoria	BN		1						1	
1572	Dickinson Bayou Wetland Restoration	8	Galveston	HR					1				
1574	South Padre Island Beach Nourishment with Beneficial Use of Dredged Material	8	Cameron	BN, BUDM, MP		1						1	1
1576	Arturo Galvan Coastal Park Living Shoreline	8	Cameron	SP, HR				1	1				
1577	Keith Lake Fish Pass Baffle Marsh Restoration	8	Jefferson	HR					1				
1581	Innovative Technology Seaweed Prototype Dunes Demonstration Project	8	Galveston	SM	1								
1583	Feeder Beach at Follett's Island Phase 1	8	Brazoria	BN		1							
1584	Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material	8	Galveston	BN BUDM		1							1
1585	North Jetty Sand Search Investigation	8	Galveston	SM	1								
1588	Oyster Lake Habitat Protection Marsh Restoration & Shoreline Protection Phase 2	8	Brazoria	SP, HR				1	1				
1590	Nueces River Delta Shoreline Stabilization-Phase 2	8	Galveston	SP, HR				1	1				
1591	Magnolia Inlet Marsh Restoration	8	Calhoun	SP, HR				1	1				
1592	Moses Lake Shoreline Protection Phase 3 and Dollar Bay Marsh Restoration	8	Galveston	SM, SP, HR	1			1	1				
1593	Mustang and North Padre Island Beach Maintenance Impacts and Recommendations for Best Management Practices	8	Nueces	SM	1								
1596	Virginia Point Wetland Protection and Restoration	8, 9	Galveston	SP, HR				1	1				
1601	West Galveston Island Bayside Marsh Restoration	8	Galveston	HR, BUDM					1				1
1602	Beach Monitoring and Maintenance Plan Monitoring (Cycle 8, Cycle 10)	8, 10	Coastwide	SM	1								
1603	Rockport Beach Nourishment	8	Aransas	BN		1							
1604	Indianola Beach Nourishment	8	Calhoun	BN		1							
1605	McGee Beach - Beach Nourishment	8	Nueces	BN		1							
1607	Economic-Natural Resource Benefits of CEPRA Cycle 6-7-	8	Coastwide	SM	1								
1608	GIWW-Rollover Bay Reach Beneficial Use of Dredged Material FY2015 & FY2016 events	8	Galveston	BN, BUDM		1							1
1609	Galveston Seawall Renourishment with Beneficial Use of Dredge Material	8	Galveston	BN		1							
1610	Bolivar Beach Restoration Leveraging	9	Galveston	BN, DR		1	1						
1612	Mad Island Wildlife Management Area Shoreline Protection Phase 2	9	Matagorda	SP, HR				1	1				
1614	Shamrock Island Protection and Habitat Enhancement Phase 2	9	Nueces	SP, HR				1	1				
1615	Dellanera Park Beach Nourishment	9	Galveston	BN, SP		1		1					
1616	Park Board U.S. Army Corps of Engineers Permit Amendments	9	Chambers, Galveston	SM, BN BUDM	1	1							1
1617	Greens Lake Shoreline and Marsh Protection - Phase 2	9	Galveston	SP, HR				1	1				
1618	Innovative Technology: Sustaining Dune Growth With Seabales	9	Galveston	SM, DR	1		1						
1619	GIWW-Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material State FY2017-18	9	Galveston	BN		1							
1620	Isla Del Sol Shoreline and Marsh Protection Erosion Response Project	9	Galveston	SP, HR				1	1				
1621	Galveston Local Dredging Feasibility Study	9	Galveston	SM, BN BUDM	1	1							1
1623	Causeway Rookery Island Habitat Protection, Nueces Bay	9	Nueces	SP				1					
1624	Port Alto North Beach Shoreline Restoration Project	9	Calhoun	BN BUDM, DR, HR		1	1		1				1
1625	Sundown Island Shoreline Protection & Habitat Restoration	9	Matagorda	SP, HR				1	1				
1626	Treasure Island MUD Shoreline Protecton	9	Brazoria	SP, DR			1	1					
1627	Moses Lake Shoreline Protection Phase 3 & Dollar Bay Marsh Restoration	9	Galveston	SP, HR				1	1				

Project No.	Project Name	CEPRA Funding Cycle	County	Project Type	Study / Monitoring (SM)	Beach Nourishment (BN)	Dune Restoration (DR)	Shoreline Protection (SP)	Habitat Restoration / Protection (HR)	Structure Relocation (SR)	Debris Removal (DM)	Maintenance / Emergency (MP)	Beneficial Use of Dredged Material (BUDM)
1628	Upland Sand Source Assessment Feasibility Study	9	Galveston	SM	1								
1631	BEG Erosion Rate Update	9	Coastwide	SM	1								
1632	Economic-Natural Resource Benefits of CEPRA Cycle 8-9	9	Coastwide	SM	1								
1635	Coastal Texas Study	9	Coastwide	SM	1								
1636	Swan Lake Marsh Restoration Planning	9	Galveston	SM, HR	1				1				
1637	Galveston Is State Park Shoreline Protection Ph 3	10	Galveston	SP				1					
1638	Sargent Beach Segmented Breakwater Study	10	Matagorda	SM	1								
1639	Mad Is Marsh Preserve Shoreline Protection	10	Matagorda	SP				1					
1640	Aransas NWR Dagger Point Shoreline Protection	10	Aransas	SP				1					
1641	Shamrock Island Protection and Habitat Enhancement Phase 3	10	Nueces	SP				1					
1642	Treasure Island MUD BN/BUDM	10	Brazoria	BN, BUDM		1							1
1643	Babe's Beach BN with BUDM	10	Galveston	BN, BUDM		1							1
1644	Surfside Beach-BMMP	10	Brazoria	BN		1							
1645	Carancahua Bay Shoreline Protection Ph 1	10	Matagorda	SP, HR				1	1				
1646	Galveston Park Board Back-Passing Nourishment Practices Study	10	Galveston	SM	1								
1648	Triangle Tree Rookery Island Shoreline Protection	10	Kleberg	SP				1					
1649	Caplen GIWW Rollover Bay BUDM-BMMP	10	Galveston	BN, BUDM		1							1
1650	Adolph Thomae Park Shoreline Protection	10	Cameron	SP				1					
1651	Indian Point Causeway Shoreline Protection	10	Nueces	SP				1					
1653	South Padre Island Beach Nourishment BUDM-BMMP	10	Cameron	BN, BUDM		1							1
1657	214 Jettyview Rd Surfside Structure Relocation	10	Brazoria	SR						1			
1658	McFaddin Dune Restoration & Beach Nourishment Phase 2	10	Jefferson	BN, DR		1	1						
1659	Texas Coastwide Erosion Plan Update	10	Coastwide	SM	1								
1660	Indian Point Shoreline Protection Phase 2	10	Nueces	SP				1					
1661	Port Aransas Nature Preserve H. Harvey Repair	10	Nueces	MP								1	
1662	Bureau of Economic Geology Shoreline Change Update Study	10	Coastwide	SM	1								
1663	Economic & Natural Resource Benefits of CEPRA Prog Cyles 7-10	10	Coastwide	SM	1								
1664	Bird Island Cove Shoreline Protection	10	Galveston	SP				1					
1665	Corpus Christi North Beach H. Harvey Repair-BMMP	10	Nueces	MP								1	
1666	Sylvan Beach H. Harvey Repair-BMMP	10	Harris	MP								1	
1667	Rockport Beach H. Harvey Repair-BMMP	10	Aransas	MP								1	
1668	Indianola Beach H. Harvey Repair-BMMP	10	Calhoun	MP								1	
1669	Quintana/Bryan Beach H. Harvey Repair-BMMP	10	Brazoria	MP								1	
1670	Historic Seawall Harvey Repairs FEMA GPB-BMMP	11	Galveston	MP								1	
1671	Surfside Pedestrian H. Harvey Repair-BMMP	10	Brazoria	MP								1	
1672	Sargent Beach East H. Harvey Repair-BMMP	10	Matagorda	MP								1	
1674	WGIPOA Marsh Restoration with BUDM	11	Galveston	HR, BUDM					1				1
1675	Oyster Lake Shoreline Protection GBF	11	Brazoria	SP				1					
1676	Gordy Marsh SP & MR	11	Chambers	SP, HR				1	1				
1677	North Cameron County BN Phase I Cameron Co	11	Cameron	BN		1							
1678	Adolph Thomae SP Phase IV	11	Cameron	SP				1					
1679	Magnolia Beach SP Calhoun Co	11	Calhoun	SP				1					
1680	Boggy Nature Park SP Calhoun Co	11	Calhoun	SP				1					
1681	Anahuac NWR Shoreline Protection DU	11	Galveston	SP				1					
1682	Oliver Point Shoreline Protection	11	Matagorda	SP				1					
1683	SPI Brazos Santiago Pass BN with BUDM CofSPI	11	Cameron	BN, BUDM		1							1
1684	Children's Beach SP SPI	11	Cameron	SP				1					
1685	Causeway Rookery Island SP Phase II CBBEP	11	Nueces	SP				1					
1686	Triangle Tree Rookery SP Phase II CBBEP	11	Kleberg	SP				1					
1687	Matagorda Island Marsh Restoration CBBEP	11	Aransas	HR					1				
1688	Jamaica Beach BN CofJB	11	Galveston	BN		1							
1689	GIWW Rollover Bay Reach BUDM GalCo	11	Galveston	BUDM									1
1690	Bolivar Peninsula Beach & Dune Restoration Gal Co	11	Galveston	BN, DR		1	1						
1691	Sediment Bedload Collector GPB	11	Galveston	SM	1								
1692	West of Galveston Seawall to 8-mile Road GPB	11	Galveston	SM	1								
1693	Babe's Beach BN with BUDM	11	Galveston	BN, BUDM		1							1
1694	Jones Bay Oystercatcher Island Creation	11	Galveston	HR					1				
1695	Port A Nature Preserve SP FEMA	11	Nueces	SP				1					
1696	Dickinson Bayou SP TPWD	11	Galveston	SP				1					
1697	City of Port Isabel SP CofPI	11	Cameron	SP				1					
1698	Nueces Bay Rookery Islands SP CBBEP	11	Nueces	SP				1					
1699	Willow Lake SP and Star Lake MR DU	11	Jefferson	SP, HR				1	1				
1700	SH 316 SP TxDOT	11	Calhoun	SP				1					
1701	Miramar Pointe Keller Bay SP MBF	11	Calhoun	SP				1					
1703	Longshore Transport Modeling	11	Coastwide	SM	1								
1705	TCRMP Region I Offshore Sand Source Survey Ph 1	11		SM	1								
1706	Trinity River Valley Paleochannel Investigation	11		SM	1								
	Totals				27	30	6	44	23	2	0	12	16

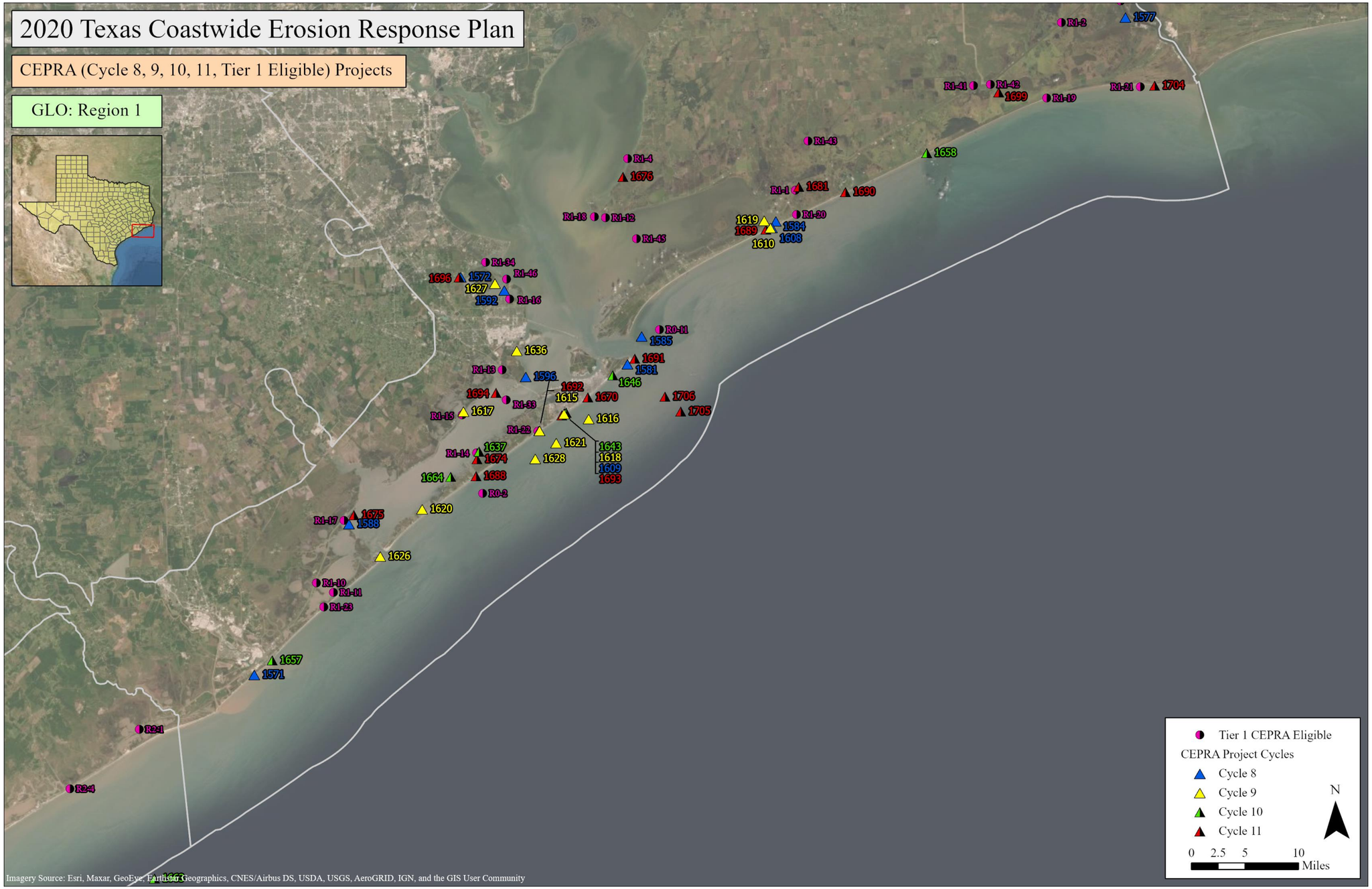

Figure 16. Locations of CEPRA Cycles 8-11 projects and Tier 1 Resiliency Plan projects in Region 1.

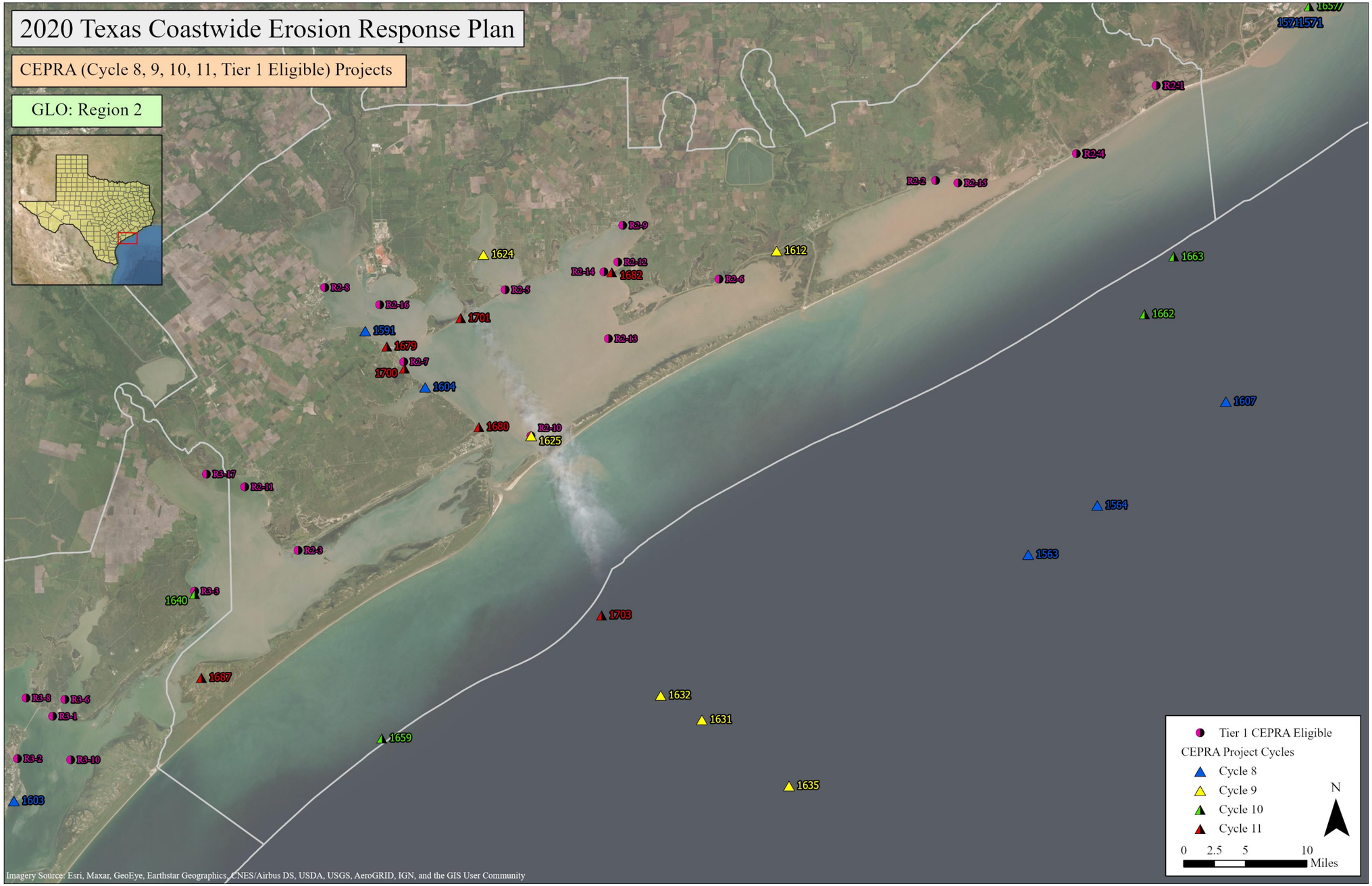

Figure 17. Locations of CEPRA Cycles 8-11 projects and Tier 1 Resiliency Plan projects in Region 2.

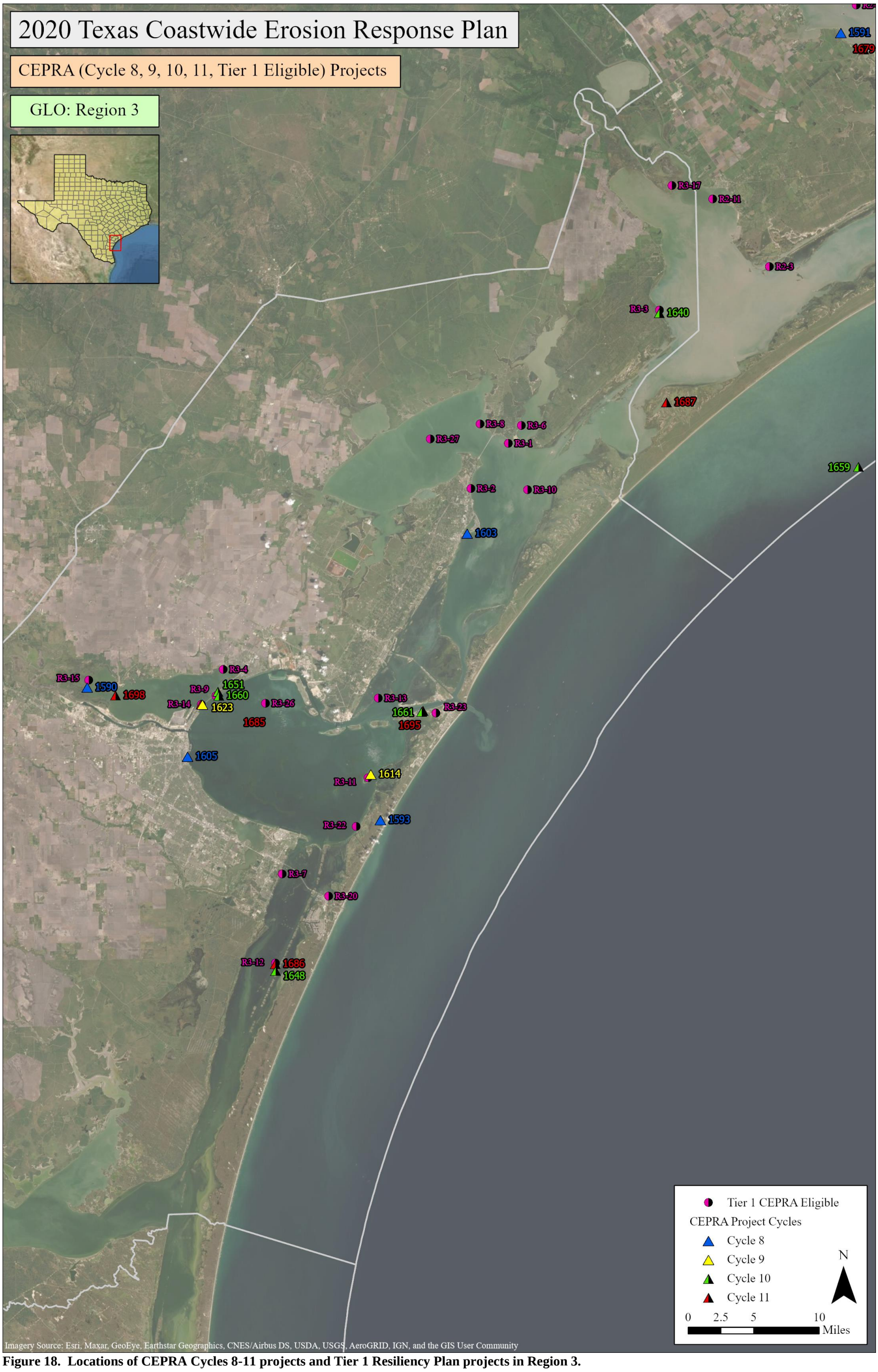

Figure 18. Locations of CEPRA Cycles 8-11 projects and Tier 1 Resiliency Plan projects in Region 3.

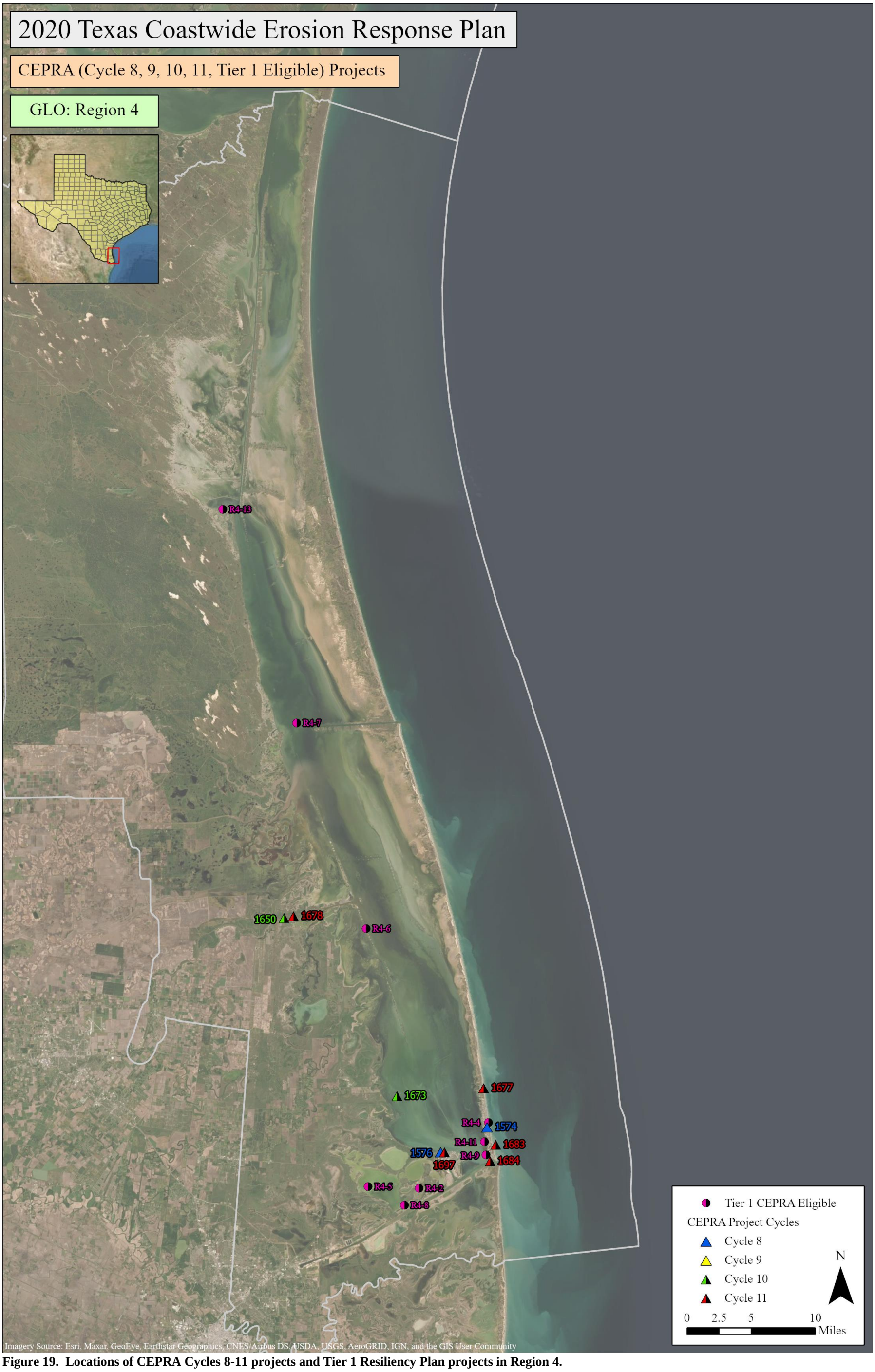

Figure 19. Locations of CEPRA Cycles 8-11 projects and Tier 1 Resiliency Plan projects in Region 4.

Application and guidance documents for the CEPRA program are provided at https://www.glo.texas.gov/coast/grant-projects/funding/files/cepra-guidance.pdf. A CEPRA application requires the following: project description, type (beach nourishment, shoreline protection, dune restoration, other), location, permission to access the project area/ownership, length, erosion rate, use of dredged material or whether a sand source has been identified, whether the local jurisdiction has an approved erosion response plan or hazard mitigation plan, monitoring and maintenance plans, and project benefits. If funded, a signed funding commitment of a minimum partner match of 25% or 40% depending on the type of project is required. In many cases, this can be the limiting factor for project commencement. To ease the burden of the project partner match, the CEPRA Program is prioritizing Tier 1 Texas Coastal Resiliency Master Plan projects and utilizing GOMESA funds in place of the partner match requirements during the construction phase. This methodology greatly reduces partner costs to the 25% and 40% requirement for only pre-construction phases like data collection and engineering and design. The implementation of this during CEPRA Cycle 11 illustrated more partner participation and more funding availability to underutilized communities (GLO, personal communication).

Guidance for the evaluation process of CEPRA applications and subsequent funding for erosion response projects is outlined in 31 TAC §15.41(a). This allows the GLO to consider funding projects at Gulf and bay shorelines within the coastal zone boundary where erosion is documented, if a former erosion response project exists or needs maintenance, or if the shoreline has been impacted by a storm and requires remediation to preexisting conditions.

Coastal studies, demonstration projects, and monitoring of existing projects (e.g. BMMP program) are other examples of the use of CEPRA funding. These projects provide further understanding of project performance or of the natural processes that create change. Examples of the studies funded between Cycles 8 – 11 include determining shoreline change rates and identifying critical erosion areas, investigating innovative technologies to determine ways to increase dune stability or vegetation growth, and recommending best management practices for sediment management at nourished beaches. Since many construction projects involve the placement of sand, CEPRA has supported sand search investigations of upland sources as well as regional offshore and paleochannel surveys to develop sediment inventories and estimates of volumes available. Some projects include data collection and designs of erosion control structures to protect vulnerable infrastructure. CEPRA funding is also used as nonfederal partner cost share to address dredging and US Army Corps of Engineers involvement in coastal erosion projects (Coastal Texas Study) (USACE and GLO, 2020). All projects contribute to CEPRA's goal for efficiently managing the effects of coastal erosion and protecting public health and safety.

Beach Nourishment

Table 6 provides the list of CEPRA-funded Gulf beach nourishment projects since 2000. A total of 11,115,288 cy of sand were used to restore beaches or dunes throughout the coastal regions. The largest project occurred at the Galveston Seawall in 2017 with the placement of 1.2 million cy of sand (61.8 cy/ln ft of shoreline). At some locations, multiple beach fills or nearshore placement took advantage of beneficial use of dredged material (BUDM) programs facilitated by a partnership with the USACE (e.g. South Padre Island Dredged Material Placement Site #1). These placements are intended to keep sediment within the barrier's littoral system rather than disposing them offshore in deeper

waters. The projects funded by the CEPRA program are making positive impacts on Gulf erosion however, the impacts are limited to the community level and have little regional impact.

Table 6. CEPRA-funded Gulf Beach Nourishment Projects

CEPRA #	CEPRA Project	Linear Feet	Fill	Date Completed
Jefferson and Chambers Counties				
1003	McFaddin Dune Restoration	1,775	14,000	2002
1530	McFaddin Beach Nourishment Phase I	15,300	640,000	2016
1658	McFaddin Beach Nourishment Phase II	89,760	TBD	TBD
1704	Texas Point	31,680	TBD	TBD
Galveston County-Bolivar Peninsula				
Gilchrist-East side of Rollover				
1037	Gilchrist BN	5,280	300,000	2000
1087	Caplen Gilchrist Beach BN	18,200	110,140	2004
1112B	Rollover Pass BUDM 2003	1,400	104,000	2003
Caplen-West side of Rollover				
1039A	GIWW Rollover Bay Reach BN FY00	3,000	138,400	2000
1039B	GIWW Rollover Bay Reach BN FY01	3,000	126,000	2001
1086	Caplen Beach Dune Restoration	750	5,000	2004
1112A	Rollover Pass BUDM 2002	3,000	119,000	2002
1276	Rollover Pass BUDM	3,000	185,646	2006
1400	Rollover Pass BUDM	3,000	134,716	2008
1494	Rollover Pass BUDM	3,000	176,755	2010
1519	GIWW Rollover Bay Reach BN	1,200	105,000	2012
1584	GIWW Rollover Bay Reach BN	3,000	173,000	2014
1608	GIWW Rollover Bay Reach BN	3,000	194,000	2016
1610	Bolivar Beach	9,415	TBD	TBD
1619	GIWW Rollover Bay Reach BN	3,000	70,000	2019
1649	GIWW Rollover Bay Reach BN	3,000	TBD	TBD
	GIWW Rollover Bay Reach BN	3,000	143,217	2018
	GIWW Rollover Bay Reach BN	3,000	171,000	2015
Galveston Island				
1016	Bermuda Beach	3,100	12,140	2001
1016	San Luis Pointe	1,311	11,077	2001
1016	Sea Isle I	2,650	6,378	2001
1016	Sea Isle II	750	3,095	2001
1016	Sea Isle III	1,675	3,519	2001
1016	Spanish Grant	1,775	5,509	2001
1016	Terramar	2,800	11,652	2001
1088	Pirates Beach	7,815	57,012	2004
1095	5500	4,400	30,984	2004
1095	Kahala Street	1,150	8,551	2004
1095	Sea Isle I, II, & III	8,570	23,793	2004
1095	Terramar	2,800	8,880	2004
1100	Bermuda Beach	3,100	35,767	2004
1100	Hershey Beach	920	5,131	2004
1100	Sands of Kahala	1,375	9,791	2004
1100	Spanish Grant	1,745	29,884	2004
1100	Sunny Beach	660	10,618	2004
1100	West Grand Riviera I&II	460	17,531	2004
1313	Hershey Beach	862	5,171	2008
1313	Sands of Kahala	1,878	13,875	2008
1313	Spanish Grant	1,581	21,000	2008
1313	Sunny Beach	727	4,500	2008
1447	Seawall	17,183	470,000	2009
1521	Dellanerra	2,100	113,500	2015
1566	Seawall	19,400	1,200,000	2017
1643	Babes Beach	5,350	423,027	2020
Brazoria County				
1015	Surfside BN	4,780	44,000	2001
1109	Surfside BN	4,780	37,181	2003
1154	Quintana Dune Restoration	750	?	2003
1154	Quintana Dune Restoration	750	?	2003
1175	Quintana BN	2,000	101,700	2005
1175	Quintana BN	1,846	168,500	2005
1229	Surfside BN	4,780	950	2006
1471	Surfside Shoreline Stabilization	4,780	27,000	2009
1511	Surfside Emergency BN	4,500	210,000	2011
1529	CR257 Dune Restoration	16,000	13,950	2017
1570	Surfside BMMP BN	1,964	98,270	2015
1571	Bryan Beach BMMP BN	1,700	36,000	2016
Matagorda County				
1532	Sargent Beach Nourishment	3,600	82,000	2013
1638	Sargent Beach Pilot Project/Groins and BN	TBD	TBD	TBD
Nueces County				
1113	Packery Channel/North Padre Is.	7,000	688,000	2005
Cameron County				
1010	South Padre Island BN	3,200	370,000	2000
1053	South Padre Island BN-Park Road 100	2,800	13,665	2002
1107	South Padre Island BN-Park Road 100	2,000	120,000	2003
1115	South Padre Island BN	3,400	331,031	2002
1233	South Padre Island BN	8,000	71,045	2007
1355	South Padre Island BN-Park Road 100	2,500	100,216	2008
1356	South Padre Island BN	4,700	406,825	2009
1453	South Padre Island BN	2,800	92,000	2010
1456	South Padre Island BN	3,000	130,000	2010
1574	Dredged Material Placement #2		380,460	2018
1165A	South Padre Island BN	2,100	49,037	2005
1165B	South Padre Island BN	3,100	228,960	2005
1209A	South Padre Island BN	1,400	65,400	2006
1209B	South Padre Island BN	3,750	261,600	2006
1524?	South Padre Island BN	2,500	210,000	2012
1525?	Isla Blanca Park BN	1,500	140,000	2012
USACE	Dredged Material Placement		329,000	2002
USACE	Dredged Material Placement		356,000	2003
USACE	Dredged Material Placement		340,000	2006
USACE	Dredged Material Placement		443,000	2007
USACE	Dredged Material Placement		500,000	2008
USACE	Dredged Material Placement	1,500	199,000	2011
USACE	Dredged Material Placement	2,700	368,000	2011
USACE	Dredged Material Placement		305,000	2014
USACE	Dredged Material Placement	1,800	324,344	2015
USACE	Dredged Material Placement	2,400	361,027	2016

Economic and Natural Resource Benefits of Coastal Erosion Projects

Each biennium, the GLO is required to submit a report to the Texas Legislature that outlines the economic and natural resource benefits of CEPRA-funded projects. The most recent economic study was completed in 2019 (Taylor Engineering Inc., 2019). The 2019 study evaluated beach nourishment, shoreline protection, and marsh restoration projects from CEPRA Cycles 7, 8, and 9 and found that the CEPRA program offers a financial benefit to the state. The economic and natural resource benefits of the 13 projects amounted to the state receiving eleven dollars in economic benefit for every state dollar spent to protect Texas' coastal natural assets and infrastructure (Figure 15). This value was determined from evaluating projects that restored, enhanced, or protected dunes, beaches, and wetlands, and calculated the financial benefits/costs to commercial/recreational fishing, tourism and ecotourism, improved water quality, carbon sequestration, beach visitation, out-of-state visitor spending, non-Texas project funding, and storm damage reduction.

Many projects had substantial cost savings due to federal (US Army Corps of Engineers, US Fish and Wildlife Service) and private (National Fish and Wildlife Foundation) partnerships. For example, NFWF and CIAP funding provided around 98% of total project costs for CEPRA project #1596 that restored and protected wetlands. The project with the highest benefit was #1566, beach nourishment at the Galveston Seawall. Here, the Federal Emergency Management Agency (FEMA) contributed 81% of the total project costs with CEPRA and the Galveston Park Board of Trustees contributing the remaining funds.

Table 7. Economic benefits/costs for selected Cycles 8-9 projects (from Taylor Engineering, 2019).

CEPRA Project Number / Name	County	Project Year[1]	Beginning of Project Year		Beginning of 2018[3]		Benefit-to-Cost (B/C) Ratio
			Discounted Cost[2] ($)	Discounted Benefits ($)	Discounted Cost ($)	Discounted Benefits ($)	
#1529 Follet's Island Habitat Restoration (unofficially County Road 257 Dune Restoration)	Brazoria	2017	1,907,520	4,179,129	1,982,486	4,343,369	2.2
#1530 McFaddin National Wildlife Refuge Beach Ridge	Jefferson	2017	2,590,695	12,828,494	2,692,509	13,332,654	5.0
#1566 Galveston Seawall Beach Renourishment (between 12th and 61st streets)	Galveston	2017	5,102,452	160,622,754	5,302,978	166,935,228	31.5
#1572 Dickinson Bayou Wetland Restoration	Galveston	2016	767,156	1,112,967	828,639	1,202,165	1.5
#1574 South Padre Island Beach Nourishment with Beneficial Use of Dredge Material	Cameron	2016	1,379,964	13,553,631	1,490,561	14,639,880	9.8
#1596 Virginia Point Wetland Protection & Restoration	Galveston	2016	450,579	5,626,754	486,690	6,077,707	12.5
#1601 West Galveston Island Bayside Marsh Restoration	Galveston	2016	785,570	12,156,643	848,529	13,130,931	15.5
#1604 Indianola Beach Renourishment	Calhoun	2017	207,038	81,242	215,175	84,435	0.4
#1610 Bolivar Beach Restoration Leveraging CIAP	Galveston	2017	2,375,200	4,865,396	2,468,545	5,056,606	2.0
#1612 Mad Island Wildlife Management Area Shoreline Protection Phase 2	Matagorda	2017	880,100	95,331	914,688	99,078	0.1
#1614 Shamrock Island Protection & Habitat Enhancement Phase 2	Nueces	2016	1,140,357	1,103,821	1,231,750	1,192,286	1.0
#1619 GIWW Rollover Bay Reach Beach Nourishment with BUDM	Galveston	2017	171,659	59,987	178,405	62,344	0.3
#1627 Moses Lake Shoreline Protection Phase 3	Galveston	2018	1,983,400	65,595	1,983,400	65,595	0.03
Total[4]					$20,624,356	$226,222,278	11.0

Notes: [1]Project Year represents the year benefits begin to accrue and may not represent the actual construction year.
[2]Texas portion only; dollar values reflect present worth equivalents at the beginning of Project Year.
[3]Dollar values reflect present worth equivalents at the beginning of 2018 with a 3.93% discount rate.
[4]Total B/C Ratio represents the Total Discounted Benefits divided by the Total Discounted Cost of all 13 projects combined (i.e., 226,222,278 / 20,624,356 = 11).

Projects with greater than 1.0 B/C ratio indicate a cost savings to Texas and are dispersed throughout the coastal regions. Of the 13 projects listed in Table 7, Follets Island, McFaddin Beach,

South Padre Island, and Bolivar Beach all include Gulf shoreline critical erosion areas. All these projects have greater than 1.0 B/C ratio. The costs of dune and beach restoration vary by location due to geography and the availability of beach-quality sand. Costs can be lower and B/C ratio higher if material is available through partnering opportunities with the USACE for the beneficial use of dredged material (BUDM) resulting from federal maintenance dredging operations (Table 7).

USE OF LIVING SHORELINES FOR EROSION RESPONSE

As in many states in the US coastal zone, the practice of using natural and nature-based features to stabilize eroding shorelines has been in use for several decades. Texas documented its first *living shoreline* projects in the late 1980s (GLO, 2020). *Living shorelines* are an ecological approach to shoreline stabilization by integrating approved structural components, sediment, and/or vegetation to maintain shoreline position as well as ecosystem function. The GLO promotes these ecologic coastal practices to reduce erosion, decrease wave energy, and improve water quality. Many projects have been implemented along the bay shorelines where wave energy is lower and shoreline stabilization success is higher. For the most part beach nourishment alone is not considered a living shoreline though such projects may contribute to shoreline stabilization.

The GLO published *A Guide to Living Shorelines in Texas* that presents suggestions for installation, permitting, and planting techniques based on shoreline type, slope, wave energy, fetch distance, erosion rate, salinity, and water depth. The *Living Shoreline Site Suitability Model* and web tool was developed by Harte Research Institute https://gomaportal.tamucc.edu/GLO/LivingShorelines/. This web tool can be used at the property-level scale and shows locations where soft, hybrid, retrofit soft stabilization, or retrofit hybrid stabilization techniques are recommended. The web tool also shows areas not suitable for living shoreline restoration and areas noted as "retrofit" where existing shoreline structures are in place. The GLO's guide places emphasis on the use of oyster reef and marsh plantings instead of seawalls to buffer wave activity. It is important in the planning process that living shoreline projects include adaptive management procedures that allow for project modifications if success criteria are not met. Many living shoreline projects require years of monitoring and maintenance to determine success. Living shoreline development and permit assistance is available through the GLO's Permit Service Centers (http://www.glo.texas.gov/psc)

The US Army Corps of Engineers provides regulatory oversight of living shoreline projects in navigable waters via a Nationwide Permit 54 (effective March 2017) under the authority of Section 10 of the Rivers and Harbors Act of 1899 and section 404 of the Clean Water Act (Sections 10 and 404). A proposed living shoreline project must comply with federal water quality and coastal zone management consistency rules and regulations to be issued a federal permit. The USACE describes a living shoreline to be composed of mostly native material and can incorporate vegetation or other living, natural "soft" elements alone or in combination with some type of harder shoreline structure (e.g., oyster or mussel reefs or rock sills) for added protection and stability. General conditions relating to navigation, erosion and sediment controls as well as endangered species among others are presented in Nationwide Permit 54
https://www.nao.usace.army.mil/Portals/31/docs/regulatory/nationwidepermits/Nationwide%20Permit%2054.pdf

Only two CEPRA Cycles 8 through 11 projects fall into this category: Arturo Galvan Coastal Park (Cameron County) and Dickinson Bayou Wetlands Restoration (Galveston County) (Table 1). The Arturo Galvan project combined shoreline protection measures with native marsh vegetation while the Dickinson Bayou restoration utilized dredged material from a shoaled channel to restore and protect an intertidal marsh. Both projects show initial success in mitigating shoreline erosion.

Since 2019 Texas Coastal Management Program (CMP) funds have been used to construct living shoreline projects. A new CMP study will determine the value of living shorelines for restoring shoreline habitat and stability and include long-term project maintenance in the assessment. Other CMP funded projects include the Fulton Beach Road Living Shoreline and the Harte Research Institute's *Living Shoreline Site Suitability Model* and web tool. The CEPRA program cannot fund these types of projects but understands the erosion affecting bay shorelines.

SEARCHING FOR QUALITY SEDIMENT

The impact of storms and long-term erosion has left many Texas coastal communities vulnerable to flooding and future storm damages. The CEPRA program has consistently funded emergency beach repairs and shoreline restoration with many projects taking advantage of the beneficial use of dredged materials. However, some projects require large quantities of quality sediment to meet project designs. A sand source investigation was necessary for construction of the beach ridge and beach nourishment for the McFaddin National Wildlife Refuge which utilized offshore sands for restoration (Cycle 8). Upland sources were investigated on Galveston Island (Cycle 9) for replenishing local beaches. Cycle 11 funded the development of a sand transport model for the Texas Gulf shoreline to determine sediment pathways and volumes within the littoral system. CEPRA Cycle 11 also funded the Region 1 Offshore Sediment Inventory Survey and Outer Continental Shelf (OCS) Survey was funded through GOMESA and BOEM.

The Texas Coastal Management Program also assisted in sediment planning by funding the Regional Sediment Management Study, a desktop inventory of existing coastal sediment and dredged material data that could help identify potential sediment sources for coastal protection or restoration. The analyses collected information and datasets from geological, geomorphological, watershed sedimentation, navigation channel dredging, and sediment impoundment investigations to estimate sediment availability, quantity, and quality (Moya et al, 2016). The project recommended actions such as undertaking offshore geological and geotechnical studies, implementation of an Innovative Technologies program to facilitate long-distance sediment dredging and delivery, investigation of former dredged material placement areas, establishment of committees for sediment science and regional use of dredged material, and expanding the TxSed Program to include 3D mapping of sediment sources. A Tier 1 project identified in the Texas Coastal Resiliency Master Plan acts on the recommendations and will conduct sediment mapping surveys in the Gulf of Mexico. The CMP along with CEPRA Program are cooperating to create a Texas Sediment Management Plan to assess sediment needs, create an inventory, update policies, and prioritize sediment to projects in need.

AVAILABLE DATA AND INTERACTIVE TOOLS

With an internet connection, local governments and CEPRA applicants can access abundant information that supports erosion response project development. The GLO provides a wealth of interactive web viewers to help the public identify land- and energy-related data, water quality at Texas

beaches, recreational and historical resources, oil spill mapping, and coastal resources among others (https://www.glo.texas.gov/land/land-management/gis/). The GLO also hosts a catalog of historical aerial imagery and LiDAR elevation datasets as well as geographic information system compatible (.shp) and *Google Earth* compatible (.kmz) files. A potential CEPRA applicant can find most information necessary for submitting an application (https://www.glo.texas.gov/coast/grant-projects/funding/files/cr-funding-app.pdf). For erosion on bay shorelines, an applicant may show erosion through the use of historical imagery available via *Google Earth*. BEG bay shoreline erosion rates are only available for Copano, San Antonio, and Matagorda Bay systems (http://coastal.beg.utexas.edu/shorelinechange_bays/). As CEPRA expands to cover more bay shoreline Tier 1 projects it will be necessary for the public to access erosion rate information in other areas of the Texas coast.

If the project concerns beach nourishment, the CEPRA application requires the identification of a sand source. The Texas Coastal Sediments Geodatabase (TxSed) mapping viewer shows locations of cores and grab samples (in the Gulf as well as within the bays and upland areas), dredged material placement sites, and waterways (https://cgis.glo.texas.gov/txsed/index.html) (Figure 20). For some locations, sediment grain size is available by percent gravel, sand, and silt/mud for only grab samples. This information can be helpful, but does not provide details of geologic character necessary for locating potential borrow sites for future beach nourishment projects. The GLO is undertaking an update to TxSed and is interpreting the available cores to create a more robust and interactive planning tool (GLO, personal communication).

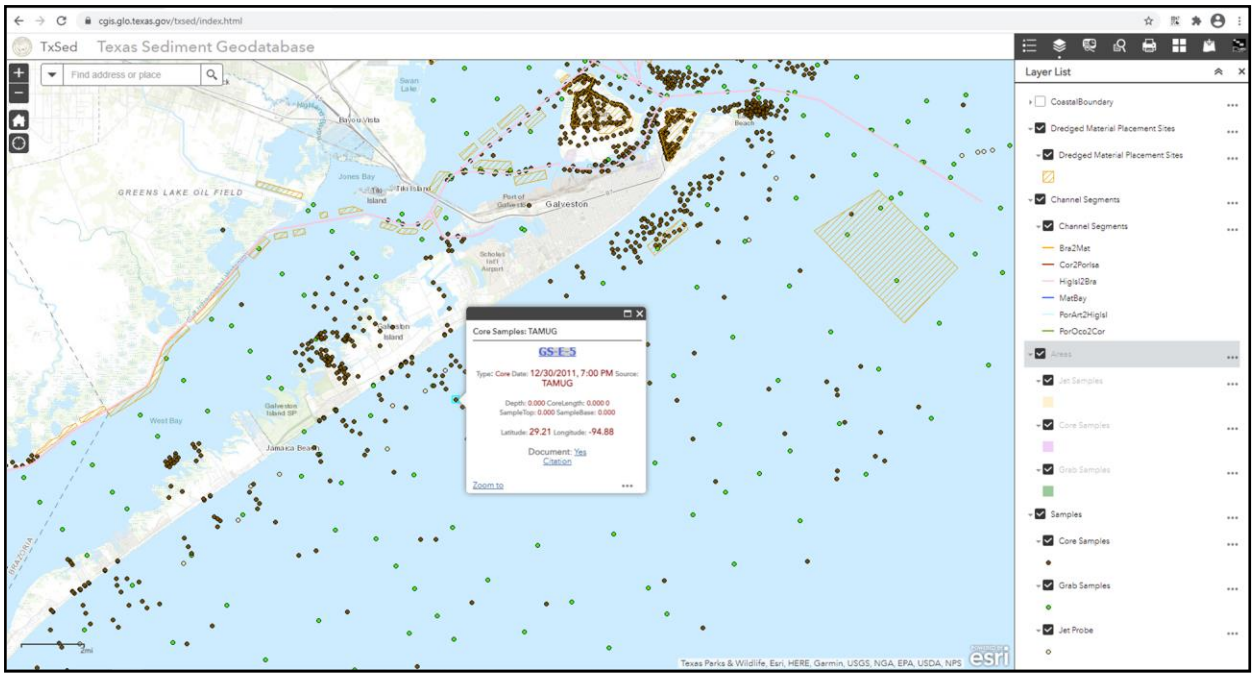

Figure 20. Screenshot from TxSed mapping viewer that shows locations of cores and dredged material placement sites near Galveston Island.

TxSed is a desk-top planning tool that can help project design teams determine the type of material that could be available for erosion response as well as guide research for sand for large beach

nourishment projects. TxSed and the Coastal Resources Mapping Viewer tool are expected to be updated to make planning more efficient.

As described earlier, the BEG provides a Gulf shoreline change web viewer to inform coastal managers, landowners, and the public the locations of eroding areas within their community (where erosion is greater than 2 ft/yr). Rates of change are presented at 50 m (approximately 160 feet) increments (https://coastal.beg.utexas.edu/shorelinechange2019/). Maps generated from the viewer can show community or property vulnerabilities or areas where critical erosion is of concern. Several screenshots from the BEG web viewer are included in this document (Paine and Caudle, 2020).

The CBI Coastal Habitat Restoration GIS (CHRGIS) program hosts a data archive and map viewer that shows the locations of the CEPRA-funded projects monitored by CBI. The viewer provides a description of the project area, historic aerial photographs, before- and after-project photographs, and beach profile survey data that could be used for post-storm applications to FEMA (https://cbi.tamucc.edu/CHRGIS/). The website also provides shoreline change rates and annual reports of project performance for the monitored locations.

Data Gaps

One of the requirements in applying for CEPRA funding is to supply the erosion rate at the proposed project location. While Gulf shoreline change rates are readily available via the BEG website, available bay shoreline change rates (with the exception of Copano Bay and nearby systems) are not as well documented and in the absence, a potential applicant must provide to the GLO photos or historical imagery from *Google Earth* to determine change rates. Other datasets that would be beneficial to local governments for erosion planning include digital compilations of county and municipal building dune protection lines and building setback lines (from the local dune protection and beach access and erosion response plans).

The GLO-hosted Coastal Resources Mapping Viewer provides information for permitting on state-owned lands. Data from the revised TxSed map viewer could be added to the Coastal Resources Mapping Viewer as the main planning tool for use in the CEPRA program and to determine critical erosion areas and priority erosion response projects.

LOCAL GOVERNMENT EROSION RESPONSE PLANNING AND COASTAL MANAGEMENT PRACTICES

Coastal county and municipal governments are responsible for the day-to-day management of the Gulf beaches and dunes including erosion response planning. Since August 2010, Gulf-fronting governments are required to adopt an Erosion Response Plan and ordinances that accommodate strategies for managing shoreline erosion and reducing public expenditures (§15.17 of Title 31 Texas Administrative Code). Elements of the local plans include applying historical erosion rates in setting building setback lines, providing reference lines such as the line of vegetation, mean low tide and the location of the local dune protection line, providing construction requirements in eroding areas, criteria for exempt structures and for buyouts, and the community's procedures for protecting public beach access and critical sand dunes. Most Gulf shoreline communities and counties have approved Erosion Response Plans to help guide their priorities for addressing coastal erosion.

Managers from ten Gulf and bay shoreline communities were contacted to discuss the impacts of the CEPRA program on local critical erosion areas and response initiatives, funded projects, municipal or county erosion response plans, as well as the impacts of storms. The geographical and geomorphological features of the communities provide the foundation for the different management techniques. This section offers an opportunity for local governments to discuss their priority erosion areas, highlight successful CEPRA projects, and insights on management issues for their section of the Texas coast.

For this update, local managers were contacted via video call or email. Video/phone discussions were held on September 30, October 2, and October 9, 2020. Other community managers provided responses to the questions posed. Those responses are included in Appendix A and are summarized in the following paragraphs.

- Does your community have critical erosion area(s)?
- What area is your greatest concern and why?
- Do you have a current erosion response plan?
- How is coastal erosion addressed in your community? (ex. beach fill, sand management, other). Is this effective and do you suggest other measures to combat erosion or increase your community's resiliency to storms and erosion?
- Have you applied or received CEPRA funding? Is there anything you recommend that would help your community to better understand the program and how to apply for funding?
- How are erosion response projects prioritized? (ex. initiated by the community, local government, other). Has this method worked for your area?
- What are the obstacles in moving projects to completion?
- What were the impacts to your shoreline from Hurricane Harvey (2017) and 2020 storms (H. Hanna-central to lower coast [July 25, 2020], H. Laura-upper coast [August 27, 2020], TS Beta-central to lower coast [September 21, 2020], and H. Delta-upper coast [October 9, 2020])?
- Does your community experience bay shoreline erosion? If so, how are these areas managed?
- Is there a specific project that is of grave concern for implementation in your area? Are there any projects recently completed that you would like to highlight? Any lessons learned for your community that the plan should highlight? Do you have a specific CEPRA-funded project or a specific erosion area of concern? If possible, can you include a photo or plan that will be included in the 2020 update?

The GLO works with all coastal managers and while several communities provided feedback, other partners who could benefit from the CEPRA program missed the opportunity to share their experiences with coastal erosion. The author reached out to some but did not receive return communication. This included the Gulf communities: Galveston County, Jamaica Beach, Surfside Beach, and Quintana Beach. In addition, many bay shoreline communities could benefit from the CEPRA program. It is recommended that the GLO continue outreach to those communities to share updates on the program.

Gulf Shoreline Communities

JEFFERSON COUNTY

Information courtesy: The Honorable Jeff Branick, Jefferson County Judge

Most of the 33 miles of Gulf shoreline in Jefferson County are considered critically eroding except for about six miles at Sea Rim State Park. Erosion threatens habitat at Texas Point, dunes at McFaddin National Wildlife Refuge, and public infrastructure. The extreme movement of the shoreline is displayed via the BEG's shoreline envelope that shows the limits of the shorelines during the study period. For example, the shoreline envelope at Texas Point National Wildlife Refuge between the 1950s and 2019 exceeds 2,700 feet (Figure 21).

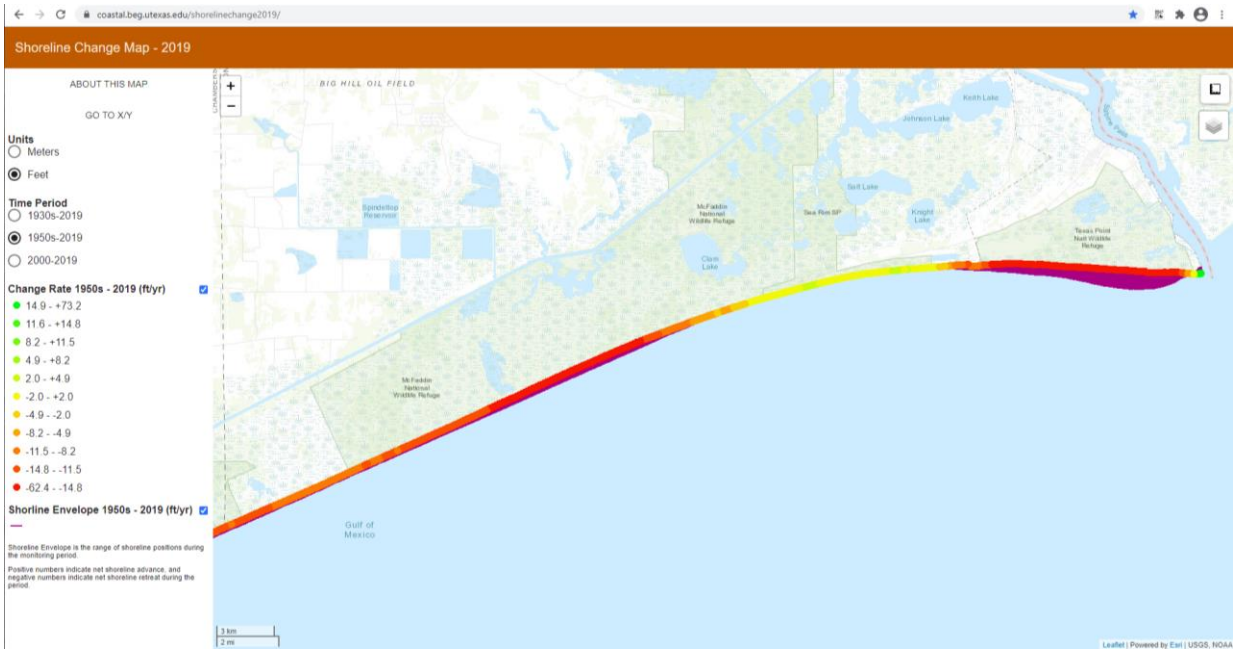

Figure 21. Screenshot showing shoreline changes along the Gulf coast in Jefferson County 1950s to 2019 (https://coastal.beg.utexas.edu/shorelinechange2019/).

The County's greatest concern is protecting its marshes as they provide important habitat and ecosystem functions as well as lessening the impacts from storm surge. The County's goal is to re-establish the dunes and beaches, minimize saltwater intrusion, and redirect freshwater runoff into the marshes. Beach nourishment is the most common method for addressing erosion, however the County is concerned about the high cost of this method and need for maintenance over time. The following bullet points outline the County's erosion response program:

- The County has not adopted a formal Erosion Response Plan though it has an approved Dune Protection and Beach Access Plan (1994). Erosion is addressed when it becomes problematic or when funding becomes available.
- The County has applied and received CEPRA funding (i.e. Cycle 8 – Keith Lake habitat restoration; Cycle 10 – McFaddin Dune). They use consulting services for application preparation.
- Erosion response projects are selected by the County and are based on input from all the stakeholder agencies. This method has worked out well.
- A major obstacle in moving projects to completion is the review/approval process for developing a project and moving it to construction as it is long and complicated.
- Jefferson County does not have open bay shorelines, though wetland lakes have suffered habitat losses from erosion.

- Impacts from H. Harvey and the 2020 hurricane season:
  - The Jefferson County Gulf shoreline was not significantly impacted by Hurricane Harvey (2017) as that storm was considered a rain event.
  - Drone imagery from Lamar University shows that Hurricane Laura (August 27, 2020) reversed some of the restoration project at McFaddin Beach, damaging vegetation and moving sand along the beach to the west.
  - Coastal boundary surveys recorded in 2019 and 2020 along McFaddin beach illustrate the effects of the 2020 storm season on the shoreline. Pilot project shoreline areas maintained some form of beach width post-storm season and non-nourished sections along the remaining 17 miles suffered upwards of 65 ft of erosion landward.

Highlighted Project: The County is spending significant resources for its McFaddin Dune Restoration & Beach Nourishment Phase 2 (Cycle 10 CEPRA Project #1658). This project involves sand borrow site investigation, permitting, design and engineering, and beach nourishment and dune restoration along 17 miles of shoreline at the McFaddin National Wildlife Refuge. Other projects that are under consideration are the freshwater siphons that will increase hydroconnectivity of the marsh between the GIWW and the Texas Point NWR Project which will restore dune and beach habitat along 6 miles of shoreline.

CITY OF GALVESTON

Information courtesy: Dustin Henry, Coastal Resources and Flood Plain Manager, City of Galveston

Galveston Island is located along the upper Texas coast and within a 45-minute drive for over four million people. The island is considered the only urban Gulf coast beach in Texas and except for the City of Jamaica Beach and Galveston Island State Park, the entire island lies within the City of Galveston's jurisdiction. The City identified four erosional areas that they consider are in a critical state: the western terminus of the Galveston Seawall which currently has the highest erosion rates on the island, exceeding -8 ft/yr of landward movement of the shoreline; the beaches fronting the Galveston Seawall; the beaches adjacent to smaller subdivisions on the western portion of the island with stormwater drainage issues; and five miles of beaches with vehicular access. In each of these areas public beach use or access, public infrastructure, or general recreation are threatened by ongoing erosion. The following bullet points refer to the City's erosion response program:

- The eroding areas of greatest concern are those where free and unrestricted vehicular access to the City's beaches are threatened. The landward migration of the beach threatens homes and infrastructure. High tide flooding events are increasing in frequency and intensity, which results in more days in which the public beach is inaccessible due to unsafe conditions. The high flood events are expected to become more frequent, increasing 2 to 3-fold by 2030, without flood management efforts (Sweet et al, 2020).
- The City of Galveston's Erosion Response Plan (ERP) was adopted April 2012 and predominantly reflects the effects of Hurricane Ike (2008) on the island and region. The Plan needs updating to address issues associated with storm water runoff, unrestricted and minimally managed vehicular access to the beach, and high tide flooding.
- Galveston routinely collaborates with the GLO and USACE for scheduled beach nourishment activities along the Seawall. These are effective projects for this portion of the island, however

stormwater drainage and vehicular beach access on eroding beaches have long been neglected and need planning or technical assistance to help derive solutions.

- The Galveston Park Board applies for CEPRA funding on the City's behalf.
- Beach nourishment fronting the Galveston Seawall is high priority and is tied to how funding can be spent for public benefit.
- Obstacles include the limitations for using public funds to address eroding beaches and dunes on private property and the challenges demonstrating the public benefits from those projects.
- Bay shoreline erosion response projects have occurred between private landowners and nongovernmental organizations.
- Of grave concern is drainage infrastructure adjacent to the public beach as it can exacerbate erosion, impede public access, and depreciate water quality (Figure 22).
- Impacts from H. Harvey and the 2020 hurricane season:
    - Hurricane Harvey (2017): high rates of storm water runoff exceeded capacity of stormwater infrastructure and swales in dune areas, resulting in several breaches in the dunes.
    - Laura/Beta/Delta (2020): separately these storms were not catastrophic to the Galveston community, but the frequency and persistence of storm surge associated with them resulted in considerable beach and dune erosion along the entire extent of Galveston Island. As these storms were not direct hits to Galveston County, a federal disaster declaration was not made which would have triggered public assistance funding. Hurricane Laura was later declared a disaster for Galveston County around four months after the Governor asked the President to reconsider.
    - Additionally, the 2020 storm season adversely affected the tourism industry in Galveston, which was already significantly challenged associated with the careful management of crowd-gathering events and activities associated with the COVID-19 pandemic.

Highlighted Project: The Galveston Island West of Seawall to 8 Mile Road Beach Nourishment Project (Project ID R1-22 in the Texas Coastal Resiliency Master Plan). The City encourages future nourishment projects to be planned further down the coast and would like to see the implementation timeline for these sorts of projects moved up after funding has been committed.

Figure 22. Drone view of the beach and access following Tropical Storm Beta (September 2020) and legacy drainage infrastructure that is collocated and affecting public beach access. (Photo courtesy: D. Henry)

GALVESTON ISLAND PARK BOARD OF TRUSTEES

Information courtesy: Sheryl Rozier, Project Manager, Galveston Island Park Board of Trustees

The Galveston Island Park Board of Trustees (Park Board) is responsible for managing the tourism, beach maintenance, and convention center including the beach pocket parks on Galveston Island. The Park Board has often been the City's applicant for CEPRA projects that involve beach nourishment, dune restoration, and public access.

As noted earlier by the City of Galveston, the Park Board's greatest concern is for adequate public access at the end of the Galveston Seawall (at 103rd Street) near Dellanera RV Park. Figure 23 shows the shoreline changes at the end of the seawall where the shoreline erosion rate exceeds 7.0 ft/yr between 1950s and 2019. The following bullet points outline the City's erosion response program:

- The City manages coastal erosion under two plans: City of Galveston Erosion Response Plan and the Park Board of Trustees Sand Management Plan
- The Park Board addresses shoreline erosion through regularly programmed nourishment programs, maintenance of vegetation and protection of natural barriers, as well as beach maintenance best practices.
- The Park Board has applied and received funding from CEPRA for beach nourishment and dune restoration (i.e. Cycle 11 West of Galveston Seawall to 8-mile Road) for protection of FM 3005, an essential emergency evacuation route.

- Erosion response projects are placed in priority through the Park Board's Sand Management Plan. Available funding also plays a role in completing projects.
- Obstacles in seeing projects to completion are Federal funding local matches, when it comes to projects funded by FEMA due to storm damage. Local and State funds alone are not sufficient for the level of investment needed for the Galveston coastline.

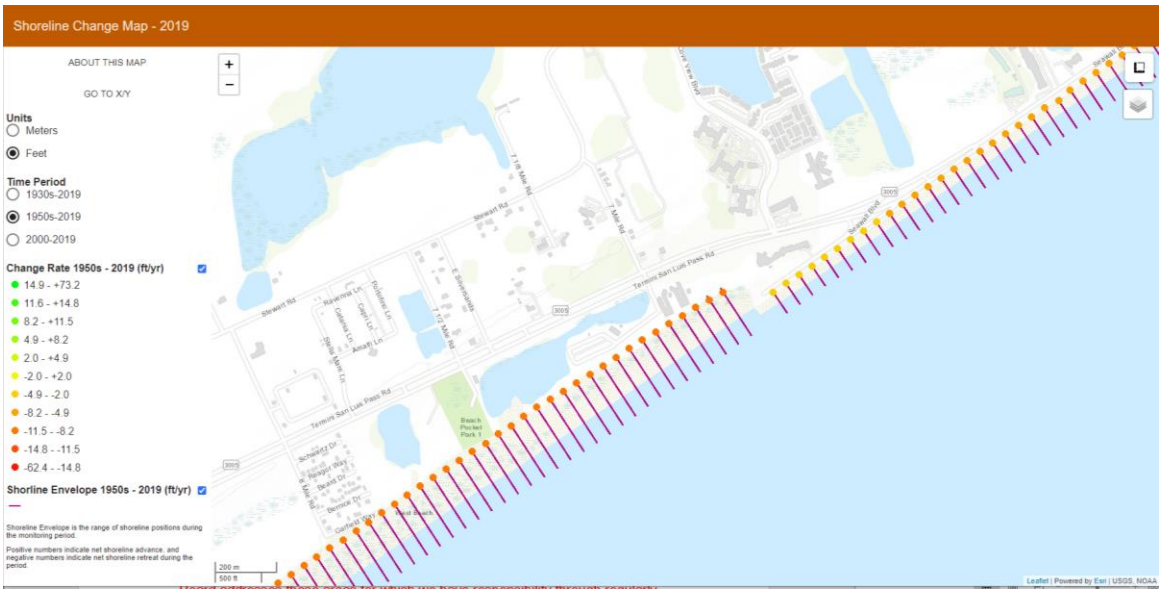

Figure 23. Shoreline change rates along the Galveston Seawall an at the end of the seawall near Dellanera Park (https://coastal.beg.utexas.edu/shorelinechange2019/).

- Impacts from H. Harvey and the 2020 hurricane season:
  - The Park Board manages the two FEMA-funded projects that were the result of H. Harvey (Babe's Beach & Dellanera Beach/Dune).
  - The community is evaluating damage from H. Laura (August 27, 2020), through post storm surveys along the Galveston coastline. The damage from TS Beta (September 21, 2020) just added insult to injury from the damage of H Laura (Figure 24).
- The Park Board does not manage bay shorelines.

Highlighted Project: CEPRA 1615 (Cycle 9) will begin to repair Harvey damages at Dellanera RV Park and include additional funding from FEMA funding following H. Laura.

Figure 24. The beach at Dellanera following Tropical Storm Beta (photo taken 2020-09-23 courtesy S. Rozier)

BRAZORIA COUNTY

Information courtesy: Bryan Frazier, Director, Brazoria County Parks Department

The approximately 21 miles of Brazoria County Gulf shoreline ranges from relatively stable to highly erosional (Paine and Caudle, 2020). The highest erosion rates are found at the Brazos deltaic headland and at east Follet's Island. Past CEPRA-funded projects focused on bay shoreline erosion and restoring marsh habitat, but beach nourishment at Surfside Beach, Quintana Beach, and Bryan Beach, and structure relocation have been funded in the County. The following are important take-aways from the discussion:

- The Parks Department has jurisdiction for Gulf shoreline projects and is generally the local sponsor for beach erosion and dune enhancement projects funded by the CEPRA program.
- Beaches and coastal parks have the most visitors.
- Storm surge is a major concern. Beaches are inundated to the dunes and flooding of County Road 257 is common.
- Debris on beach has become significant.
- The County's beach/dune plan includes beach maintenance.
- Projects are prioritized by beach erosion, public safety, and restricted access.
- Projects are initiated from the public then to the Parks Department or County Commissioners. Projects can also be scheduled under existing Park budget for short-term, urgent needs.
- County Master Plan provides long-term planning. Beach maintenance is included, but beach/dune is not mentioned in detail. Erosion response could be included in future master plan.
- Impacts from H. Harvey and the 2020 hurricane season:
    - H. Harvey – some erosion but more of a rain event, clean-up from river flooding was the focus of recovery.
    - H. Laura – significant dune loss, 3-4 ft storm surge topped dunes, at Surfside Jetty Park, 50-ft of both sides of pedestrian area was damage.
    - TS Beta – the actual storm had little effect, but the pronounced high tides associated with the storm were about 4 ft and remained high for five days. The high tide event did more

damage to shoreline than all others and exposed old septic systems and pilings. As a result, stretches of beach are impassable and there is no drivable beach access from Beach Access 5 east to Treasure Island.

Highlighted Project: There is an urgency in keeping beach access open. Beach Access Road 5 will be lost if nothing is done and sand is needed for dune and beach restoration (Figure 25). Other areas of concern are eastern end of Follets Island and western end of Quintana.

Figure 25. High water from TS Beta hinders public beach access at Beach Access Road 5 on Follets Island (photo courtesy B. Frazier).

MATAGORDA COUNTY

Information courtesy: The Honorable Nathan McDonald, Matagorda County Judge

The deltaic headland shoreline between the San Bernard River and Brown Cedar Cut in Matagorda County has among the highest erosion rates of the Texas Gulf coast (-16 ft/year to -42 ft/year between Cedar Lakes Pass and Mitchell's Cut) (Paine and Caudle, 2020). In some sections, only 300 ft of land separates the Gulf of Mexico from the Gulf Intracoastal Waterway (GIWW), an important artery for commerce along the Texas coast. In 1998, the US Army Corps of Engineers completed an eight-mile long revetment (elevation 3 to 6 ft NAVD88) to reduce the risk of storm surge damages to the GIWW. In 2013, CEPRA Cycle 7 funded a beach nourishment project that extended 3,600 ft at approximately 120 ft wide with no dune. In total, 87,271 cubic yards of truck-hauled sand were placed (Williams, Volume 1, 2016). The following are important take-aways from the discussion:

- Sargent Beach is the most critical erosion concern in the County.

- The County is concerned that beach nourishment will not be enough to protect the GIWW and is requesting a pilot project of five segmented breakwaters, beach nourishment, and terminal groin at Mitchell's Cut to reduce storm surge. The project cost is estimated at $30-$33 million and the County will need partners.
- The Sargent Beach and Dune Restoration Project (R2-4) is considered a Tier 1 project (high priority—top 25% in Region) in the Texas Coastal Resiliency Master Plan (2019).
- The project may qualify for GOMESA funding as well as for funds under CEPRA Cycle 12.
- Impacts from H. Harvey and the 2020 hurricane season:
    - After H. Hanna (July 25, 2020), debris stacked up on FM 457
    - H. Laura moved the debris and scoured the landward side of the revetment
    - Then, TS Beta created 6-8 ft of scour and in some sections, rocks were moved into roadway and dune sand was moved to areas directly adjacent to the GIWW.
- Other bay shoreline erosion areas of concern have been identified by the Matagorda Bay Foundation: Mad Island Marsh, mouth of Carancahua Bay, others.

Highlighted Project: Sargent Beach Breakwater and Beach Nourishment pilot project (CEPRA Cycle 10 Project # 1638) (Figure 26). The County has requested the assistance of the USACE-Galveston District in obtaining permits for the project.

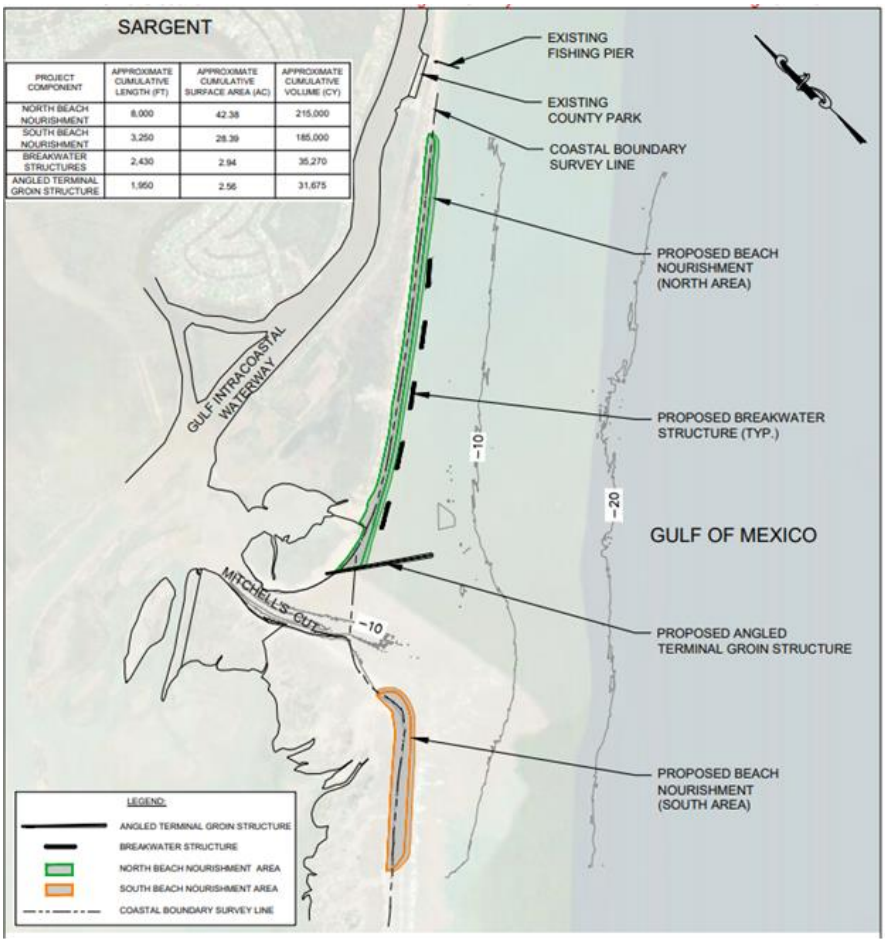

Figure 26. Proposed breakwater project at Sargent Beach for protection of the GIWW (courtesy GLO).

CITY OF PORT ARANSAS

Information courtesy: Colleen Simpson, Parks and Recreation Director and Rae Mooney, Nature Preserve Manager, City of Port Aransas

The City of Port Aransas manages approximately 7.5 miles of Gulf beaches on northeast Mustang Island in Texas planning Region 3 and is fortunate to have stable beaches and high dunes. However, the City also manages sections of the shoreline along the Corpus Christi Ship Channel within its jurisdiction limits where shoreline erosion induced by wakes from passing vessels and storm surge threatens natural resources and the City's Nature Preserve at Charlie's Pasture. This area is deemed critical erosion and its future concerns City managers. Hurricane Harvey damaged the revetment that protects marshes and mangroves near Piper Channel. The following refer to the City's erosion response program:

- In addition to the shoreline at the Nature Preserve, other areas along the back side of Mustang Island in the marshes and mangroves appear to be eroding.
- The City attributes the erosion along the ship channel to the large tankers that pass daily and requests that the Port of Corpus Christi take some responsibility for the damages to the Nature Preserve shoreline.
- The City of Port Aransas Erosion Response Plan was adopted in 2012 and incorporated via amendment into the City's Coastal Management Plan which can be found at (https://www.glo.texas.gov/coast/coastal-management/forms/files/portaransas.pdf).
- The City's Public Works Department manages the sand on the Gulf beaches to maintain public access.
- To address resiliency, the City is repairing and elevating the bulkhead along the ship channel and working with the GLO on the appropriate rock sizes.
- CEPRA Cycle 10 funding is slated for repairs caused by Hurricane Harvey to the revetment and jetties at Piper Channel. Similar repairs were made following Hurricane Ike in 2008.
- Erosion response projects are prioritized by the City based on the severity of damages, threats to public safety and infrastructure, and funding availability. The most recent hurricane damages are being address through local coordination, FEMA, and State assistance.
- Obstacles in moving projects to completion include lengthy timelines for FEMA 404 Hazard Mitigation funding and complex Federal regulatory permitting procedures as well as burdensome timelines.
- Impacts from H. Harvey and the 2020 hurricane season:
    - Hurricanes Harvey and Hanna scoured the Gulf beaches.
    - High tides associated with the 2020 storms caused beach erosion and increased erosion of the cuts from H. Harvey in the Nature Preserve. The City applied for emergency FEMA funding to harden the shoreline to prevent the loss of the Nature Preserve Pavilion at the end of Port Street.
- Most bay shoreline erosion on the back side of the island have been hardening projects with bulkhead or rock revetment.

Highlighted Project: Closure of large breaches in the shoreline at the Nature Preserve. Figure 27 shows the location bulkhead and they are documenting the closing of one of the large breaches through the shoreline of the Nature Preserve with a time-lapse camera. A crane on barges will be used to place sheet pile across the opening. Later a more permanent bulkhead and 100ft of material will be added behind the

bulkhead. The temporary bulkhead is under construction. After the permanent structure is complete, habitat restoration of the mud flat area will commence.

Figure 27. Map showing location of bulkhead at the Nature Preserve at Charlie's Pasture, City of Port Aransas (courtesy C. Simpson).

CITY OF CORPUS CHRISTI

Information courtesy: Darren Gurley, Gulf Beaches, Natural Resources & Aquatics Superintendent and Deidre D. Williams. Conrad Blucher Institute for Survey and Science, TAMU-CC (CBI)

The City of Corpus Christi is unique because it is responsible for managing the Gulf-fronting beaches in the vicinity of the seawall on North Padre Island (NPI), the beaches adjacent to Packery Channel as well as the bayshore within its limits along Corpus Christi Bay (Figure 28). Researchers at CBI complete annual assessments of beach elevation and mean high water line position (beach profile surveys) at several city locations and the data may be viewed online through the Coastal Habitat Restoration GIS (CHRGIS) portal in both map view and profile view apps (https://sandy.tamucc.edu/chrgis/maps/ and https://sandy.tamucc.edu/chrgis/profiles/). These studies are a smaller-scale review of beach, dune, and shoreline changes to determine the impact of beach nourishment or impoundment projects and are an additional resource for Corpus Christi and the GLO (see section *Coastal Erosion Status and Trends*). From these surveys, managers can calculate volumetric changes which help in planning restoration projects. See Appendix A for detailed explanations of shoreline changes and erosion response projects at the City's Bayshore beaches as well as at Packery Channel and the NPI Seawall.

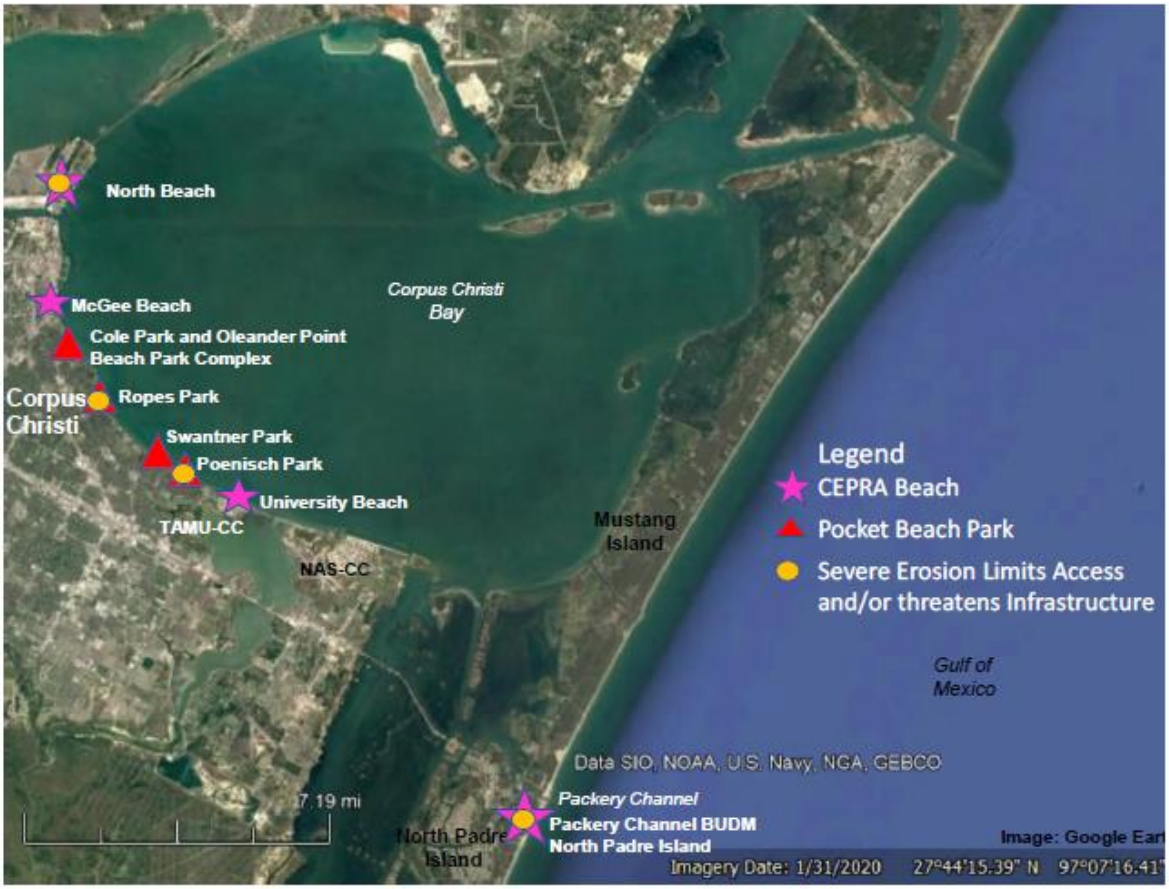

Figure 28. Map showing locations of beaches managed by the City of Corpus Christi and monitored annually by CBI.

The following summarizes the City's erosion response program:

- The Gulf beaches within the City of Corpus Christi's jurisdiction are considered critical erosion areas with some areas exceeding the -2 ft/yr criteria. However, Gulf coast beaches that were labeled critical erosion areas prior to 2005 have benefitted directly or indirectly from beach nourishment or the sheltering effects of jetties.
- The primary area of concern is the Gulf shoreline located along the NPI Seawall and southward to Access Rd 4 (Viento del Mar) (Figure 29).
- Despite a dedicated source of material for nourishment efforts, the beach at the southern half of the NPI Seawall remains problematic (erosion hot spot). This has resulted in the closure of beach vehicular access on this segment since 2015.
- Pedestrian safety is a concern along the NPI Seawall as the useable beach widths vary depending on coastal conditions. This presents a challenge to the City in maintaining safe access from the beach to public facilities.
- The location of bollards placed at the north and south limits of the pedestrian safe area at the NPI Seawall is reviewed annually based on the beach width determined through a shoreline position survey.
- The City manages and monitors seven bay beaches that line Corpus Christi Bay. Currently, no long-term plans are in place, though the City initiated the development of a City of Corpus Christi 10-year park management plan in 2020.

- Bayshore and Gulf shoreline erosion are addressed predominately through planned beach nourishment, though structural responses may be justified but have not been used since 2001. CEPRA funded beach nourishment at McGee Beach (Cycle 8 #1650).
- On the Gulf beaches, the beach fills appear to be effective for achieving short-term beach template designs, but greater amounts of sand will be needed to be effective in managing long-term or episodic erosion. Alongshore redistribution of Gulf beach sand (sand backpassing) is proposed for managing beach widths at the NPI Seawall to address severe event-driven erosion.
- The City has applied for CEPRA funding for supplemental nourishment at the southern end of the NPI Seawall and project discussions have spanned five years. For better understanding of the CEPRA program and funding cycles, the City recommends annual meetings with City officials and stakeholders that showcase project implementation examples with hurdles and challenges.
- The City prioritizes projects based on need and opportunity to maximize project success through opportunities for collaboration. An emphasis is placed on public access.
- The City recommends inclusion in CEPRA's *Beach Monitoring and Maintenance Plan* (BMMP) program for all its bayshore pocket beaches (Cole Park, Ropes Park, Swantner Park, Palmetto Park, Poenisch Park). This will provide a nourishment planning process and beach monitoring program to determine annual and post-storm changes. Currently, North Beach, McGee Beach, and University Beach are included in the BMMP program.
- Obstacles in moving projects to completion are permit delays, channel shoaling dynamics, need for interim alternate sand sources, administrative delays, lack of mechanism to define funding allocations, lack of supplemental sand resources, and funding for more frequent nourishment.
- Impacts from H. Harvey and the 2020 hurricane season:
    - H. Harvey damaged Packery Channel infrastructure and persistent high water for months afterward created additional erosion.
    - The level of damages to North Padre Island and Mustang Island during the 2020 hurricane season approached the level of damage documented after H. Ike (2008).
    - H. Hanna was more damaging to the area bay and Gulf beaches (than H. Harvey) due to prolonged onshore forcing that accompanied the storm. It initiated erosion of the Gulf beaches that continued through the 2020 storm season.
    - The CBI TAMU-CC documented the cumulative changes over the 2020 hurricane season. Coastal infrastructure were damaged and significant erosion of the berm and dunes as well as focused accretion of sand and debris that required substantial effort by beach operation crews to restore safe beach access.

Highlighted Project: The most critical need is for coordinated planning to address two primary concerns:

- The deficit in beach nourishment material to maintain the beach fronting the NPI Seawall and south to Access Rd 4 at design width or at a minimum between 150 and 200 ft.
- Plan for managing erosion of bayshore pocket parks that provide beach access points.

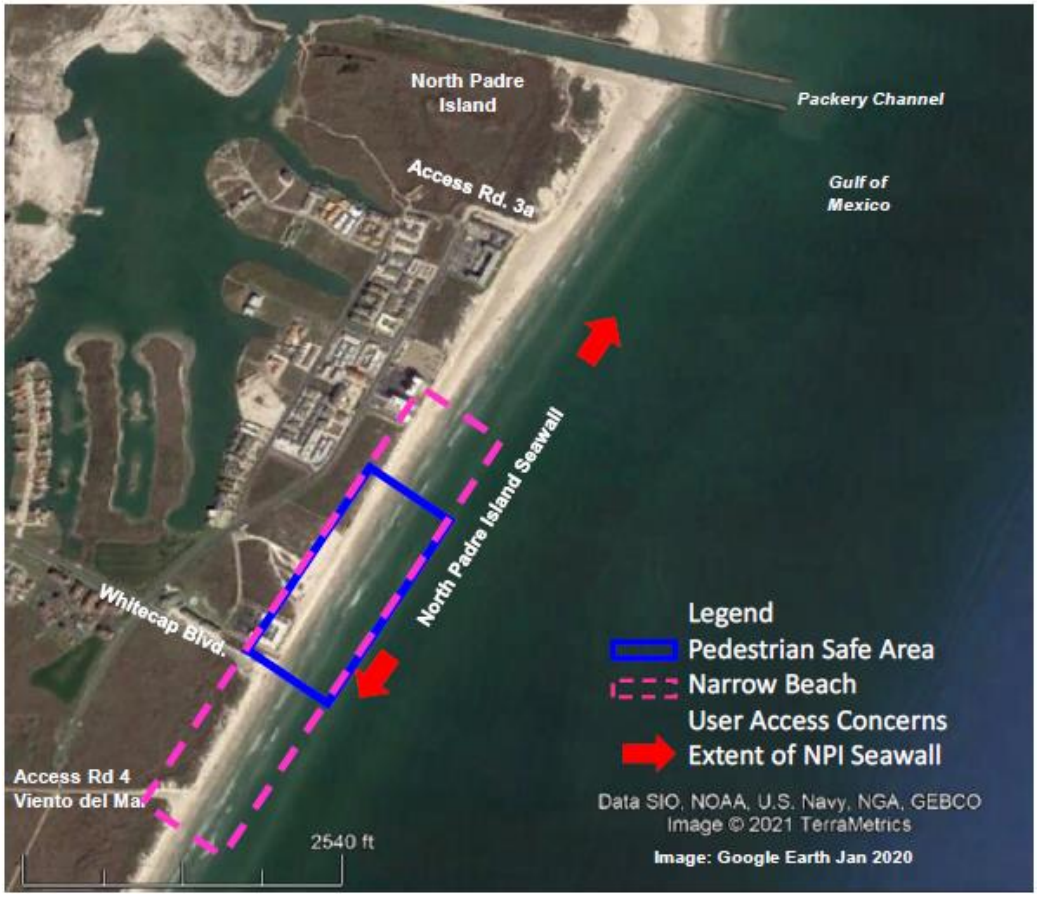

Figure 29. Aerial view of the North Padre Island Seawall and Packery Channel. Erosion at the south end of the Seawall has created difficulties in managing public access.

CITY OF SOUTH PADRE ISLAND

Information courtesy: Kristina Boburka, Shoreline Director, City of South Padre Island

The Gulf shoreline at the City of South Padre Island was one of the example critical erosion areas that was highlighted in the first Texas Coastwide Erosion Plan (1996). The highest rates of Gulf shoreline erosion occur in the northernmost section (Paine and Caudle, 2020). Long-term and short-term shoreline change trends are comparable, but the 2000-2019 timeframe shows generally higher erosion rates within the city (Figure 30). The City received CEPRA funding for dune restoration and beach nourishment projects through coordinated efforts with the US Army Corps of Engineers regional sediment management (RSM) and beneficial use of dredged material programs (BUDM). Sands dredged from the Brazos-Santiago Pass and Brownsville Ship Channel were placed on the beaches within the corporate limits of the City as well as Isla Blanca County Park. Over 6.4 million cubic yards have been placed on the beaches or in the nearshore since 2000. The impact of this sediment management practice is shown by the slightly accretional short-term shoreline change rates in the southern section of South Padre Island between 2000 and 2019 (Figure 30). The following are important take-aways from the discussion:

- HDR has monitored the beach since 2000; the last beach profile survey was completed in May 2020.
- CEPRA does not require post-storm surveys; USACE requires them for permits.

- The last CEPRA project was in 2016.
- Highest priority areas (based on erosion) are central to northern SPI. The City uses the survey data to determine critical areas.
- SPI has a current beach/dune plan and erosion response plan is included. The plan was last amended in 2012. Since then, the beach has changed.
- CMP will fund a shoreline change study.
- In the erosion plan, the primary focus is on Gulf beaches, but the City is also looking to use living shorelines for bay side eroding areas with rights-of-way.
- The City experiences some back-barrier flooding mostly due to blocked drainage systems, though higher tides can cause nuisance flooding on the back barrier.
- Back barrier areas may also be considered eroding areas.
- BEG completed lower Laguna Madre LiDAR survey in 2017. No data/reports yet.
- Bids for next maintenance dredging of Brazos-Santiago Pass will be out soon and the City is hopeful that sand will be placed on the beach this November.
- Unfortunately, the bid process is inconsistent; bids are low for dredging, but high for beach placement. This creates an issue with USACE contracting and forces them to move all sand offshore due to the high costs.
- Bayside erosion may be brought into the current Master Plan.
- Key to success of bayside projects is working through private property ownership.
- Street ends on Laguna Madre side are public.
- Impacts from H. Harvey and the 2020 hurricane season:
    - Impacts from 2020 hurricane season were increasingly worse with each storm; TS Beta appeared to be the most damaging due to several days of high water.

Highlighted Project: The BUDM project with USACE – placing dredged sand on the Gulf beaches instead of relying on offshore disposal. This keeps the sand in the littoral system. There are difficulties in timely placement due to bid process and procurement rules.

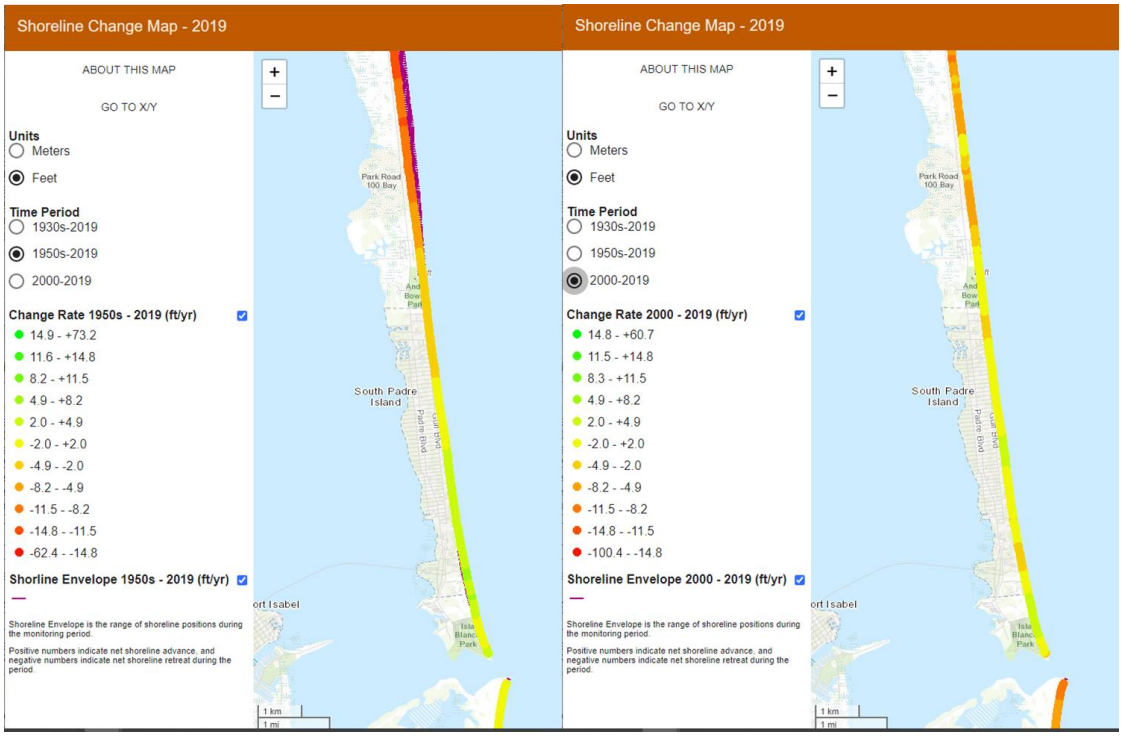

Figure 30. Comparison of shoreline change rates at South Padre Island (left 1950s-2019 and right 2000-2019) (from BEG web viewer https://coastal.beg.utexas.edu/shorelinechange2019/).

CAMERON COUNTY

Information courtesy: Joe E. Vega (Parks Director) and Augusto Sanchez (Director of Estuary, Environmental, & Special Projects)

In Cameron County, erosion extends beyond the Gulf beaches. The County Parks Department has received CEPRA funding for beach nourishment of the Gulf beaches and for the creation of living shorelines projects along the Laguna Madre (Arturo Galvan Coastal Park) and Arroyo Colorado (Adolph Thomae Jr. County Park) (Figure 31). The County has an approved beach/dune plan and erosion response plan. The following are important take-aways from the discussion:

- Without CEPRA, the County would not be able to restore shorelines (re: Phases of habitat, beach, and revetment work at Adolph Thomae Jr. County Park on Arroyo Colorado).
- Critical erosion area North Beach (Gulf coast) was replenished using dredged material.
- Requesting beach nourishment at County Gulf beaches: the last three storms (H. Laura, H. Hanna, and TS Beta) caused a lot of erosion.
- County beach/dune team has focused on increasing public access.
- Children's Beach adjacent to ship channel is eroding and project includes riprap, dock repair, data collection.
- Proposed projects are discussed at Commissioners' Court.
- CEPRA, CMP, and CIAP funds have been used for shoreline restoration projects.
- There is interest to increase the amount of living shoreline projects to provide habitat and shore protection. CEPRA funded living shoreline at Port Isabel.

- Critical erosion areas and potential CEPRA requests: Laguna Madre County Park repair sea wall and establish bird watch area; and McFarland Park living shoreline alternative analysis for addressing erosion and restoring shoreline.
- TS Beta produced very high tides and did the most damage to the beaches. Water covered from beach across Park Road 100. Caused erosion of dunes (7-8 ft scarps).

Highlighted Project: Atwood Park- $20 million in beach access improvements, moving Gulf pavilions landward and building dunes seaward of the pavilions with an access boardwalk in between. Project shows that dunes protect infrastructure.

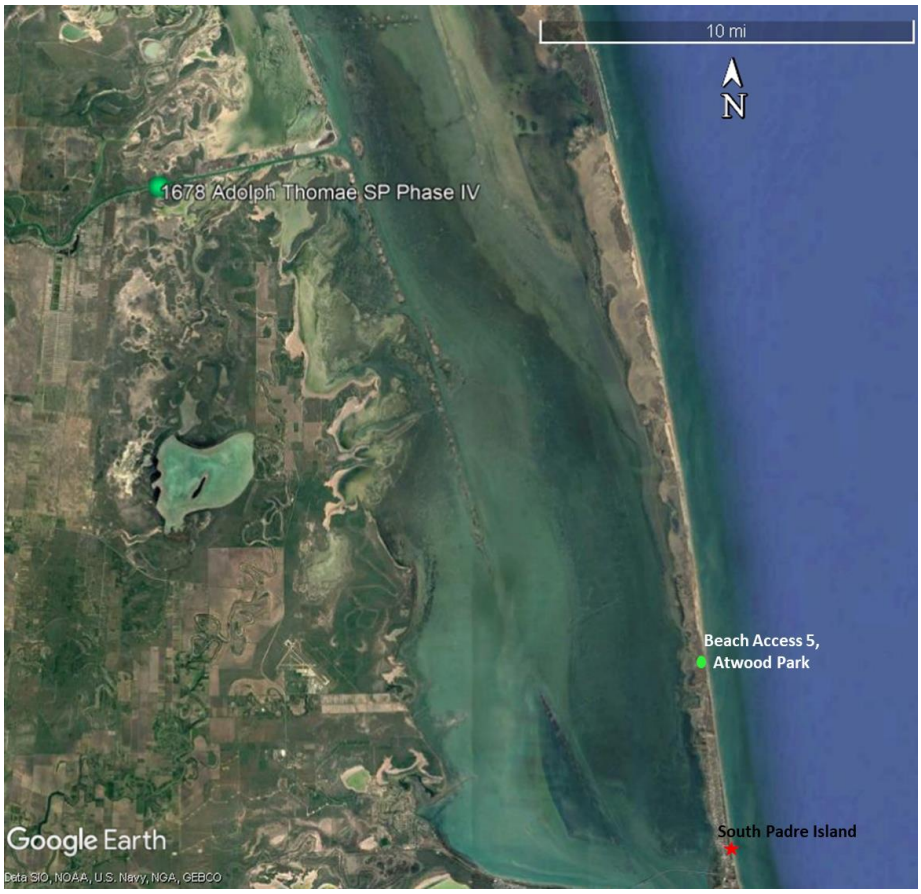

Figure 31. Locations of two CEPRA-funded projects in Cameron County.

Bay Shoreline Communities

Though the CEPRA Program does not mandate bay shoreline communities to define critical erosion areas, many have been proactive in seeking solutions to halt shoreline erosion which has decimated coastal habitats and threatened homes and infrastructure. The following contact describes how a county governmental organization is addressing bay shoreline erosion.

ARANSAS COUNTY

Information courtesy: Keith Barrett, Harbor Master, Aransas County Navigation District

In the past, navigation districts have not played a significant role in managing coastal erosion. But in the Coastal Bend, these Texas political subdivisions are increasing their involvement, due in part because the shoreline they manage is public property and much of it is eroding. The Aransas County Navigation District's mission is to preserve and develop natural resources on lands they manage. The BEG Shoreline Change viewer shows long-term erosion for most of the bay shorelines in Aransas County http://coastal.beg.utexas.edu/shorelinechange_bays/ (Figure 32). The following are important take-aways from the discussion:

- Aransas County is not required to administer a beach/dune plan and has no erosion response plan.
- The Navigation District mostly works directly with property owners on most projects, not as much with towns, county, state, or federal (though grants from those agencies are the lifeblood of projects).
- Projects with patent-private ownership are intermingled with Navigation District lands (Rockport Beach, Fulton Beach, Copano Bay structures).
- Navigation board members select projects based on local input, but efforts are geared toward conservation and protecting land.
- Rockport Beach - Navigation District and County have completed several beach fills (monitored by Conrad Blucher Institute for Surveying and Science)
- Many projects are funded through grants (CEPRA, FEMA – Rockport Beach Fill; NRDA, CMP, - Little Bay).
- Post-Harvey repair to Rockport Beach was funded by FEMA. May have been impacted by H. Hanna and H. Laura.
- Funding source and timing drive priorities – sometimes lower priority projects may be elevated above those with higher need.
- GLO requires a coastal boundary survey for projects adjacent to state-owned lands.
- Key to successful projects is public outreach and education – garnering support from adjacent landowners via workshops and public information sessions. Engage local citizens early in the project planning process.
- GLO must be more proactive in dealing with private ownership issues. Many landowners are dismissive of government involvement and oftentimes there are issues with multi-family ownership.
- Monitoring is important to show impact to shoreline, ecosystem, and to communities.

Highlighted Project: Little Bay living shoreline project (oyster shell on top of crushed concrete, all at same elevation - top at normal tide level so as to not disrupt view to private landowners, appears to have provided an ecological uplift-locals note more birds and fish in area); cutting edge project design. Since construction of this living shoreline, the change in the ecosystem cannot be underestimated.

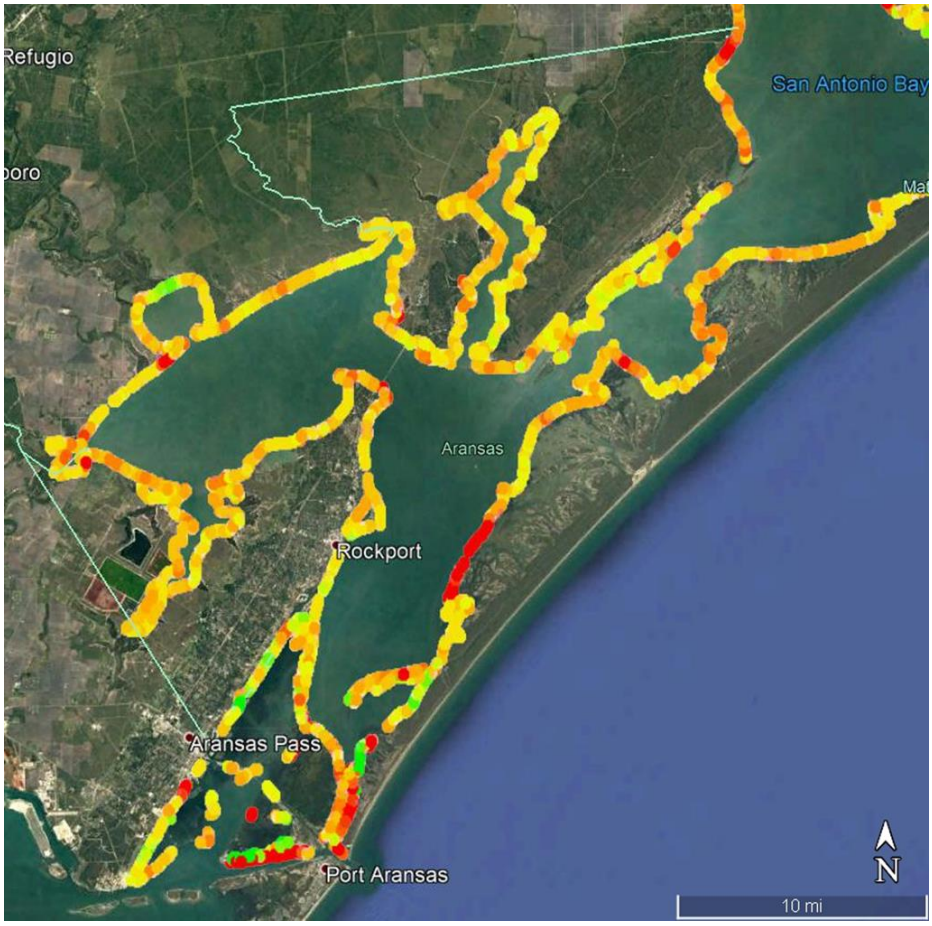

Figure 32. Aransas County Copano Bay system long-term, 1930s to 2010s, shoreline change rates (red = -6.5 ft/yr to green = +6.5 ft/yr) (Paine et al., 2016)

Common Issues of Concern

In this plan update, several management issues arose from the coastal managers' perspectives that are worthy of future state and local discussions. Among those who took part in the meetings and surveys, the most common shoreline management challenges were:

- Project Price Tag – the costs of some of the large-scale beach nourishment that is necessary to stabilize long sections of the shoreline is beyond the capability of local governments. And having the funds for repetitive expenditures (for long-term maintenance or following storms).
- Permitting, Review, Approval Process – developing a project and moving it to construction is long, complicated, and oftentimes burdensome.
- Federal Contracting – the bid process is inconsistent between dredging and placement activities. This creates an issue with USACE contracting and forces dredged sand offshore instead of on the beach or, does not allow bids for specific project line items.
- Erosion Response – while beach nourishment is the preferred erosion response, it may not be enough to reduce the threat to public infrastructure.
- Cost-Shared Funding – for Federal funds, there can be lengthy timelines and complex permitting procedures to seeing a project through to completion. Expand efforts with navigation districts to assist local communities with addressing erosion that could be linked to marine transport.
- Management of Vehicular Beach Access – complications arise when infrastructure is threatened.

- Local governments need planning and technical assistance to address some of the difficult problems associated with public beach access and use at critical erosion areas.
- Adequate Sand – adequate and economical sources of sand for maintaining Gulf beaches for public access are not available.
- Erosion Response on Private Lands - successful living shoreline projects were funded by the CEPRA program at public parks and should be expanded to areas of private ownership. However, the GLO is prohibited from spending state dollars on private property unless there is a public benefit (i.e. protect evacuation routes).

SUMMARY

Long-term and episodic erosion continue to threaten the Texas coast with 80% of the Gulf shoreline eroding at greater than 2.0 ft/yr. In the twenty years since the passage of CEPRA, the state is making great strides in protecting its vulnerable coastal natural resources and coastal infrastructure. Because planning, designing, and implementing successful erosion response projects are expensive, the program benefited from cost-shared funding sources (FEMA, GOMESA, CIAP, NFWF, NRDA, and RESTORE) which defrayed costs from the state's budget. Many projects require long-term maintenance and funding commitments that would not have been possible without the assistance of the non-CEPRA sources.

Sediment management is key to reducing erosional trends and it appears that the large CEPRA-funded beach nourishment projects are making positive impacts on Gulf erosion, however; volume and length of shoreline covered may only positively benefit at the community level and have little regional impact. Figure 33 shows the long-term (1930s to 2019) and short-term (2000 to 2019) comparisons of shoreline position at the Historical Galveston Seawall where the largest beach fill took place in 2017 (1.2 million cy over 19,000 ft of shoreline). The short-term erosion rates were reduced due to the beach fill.

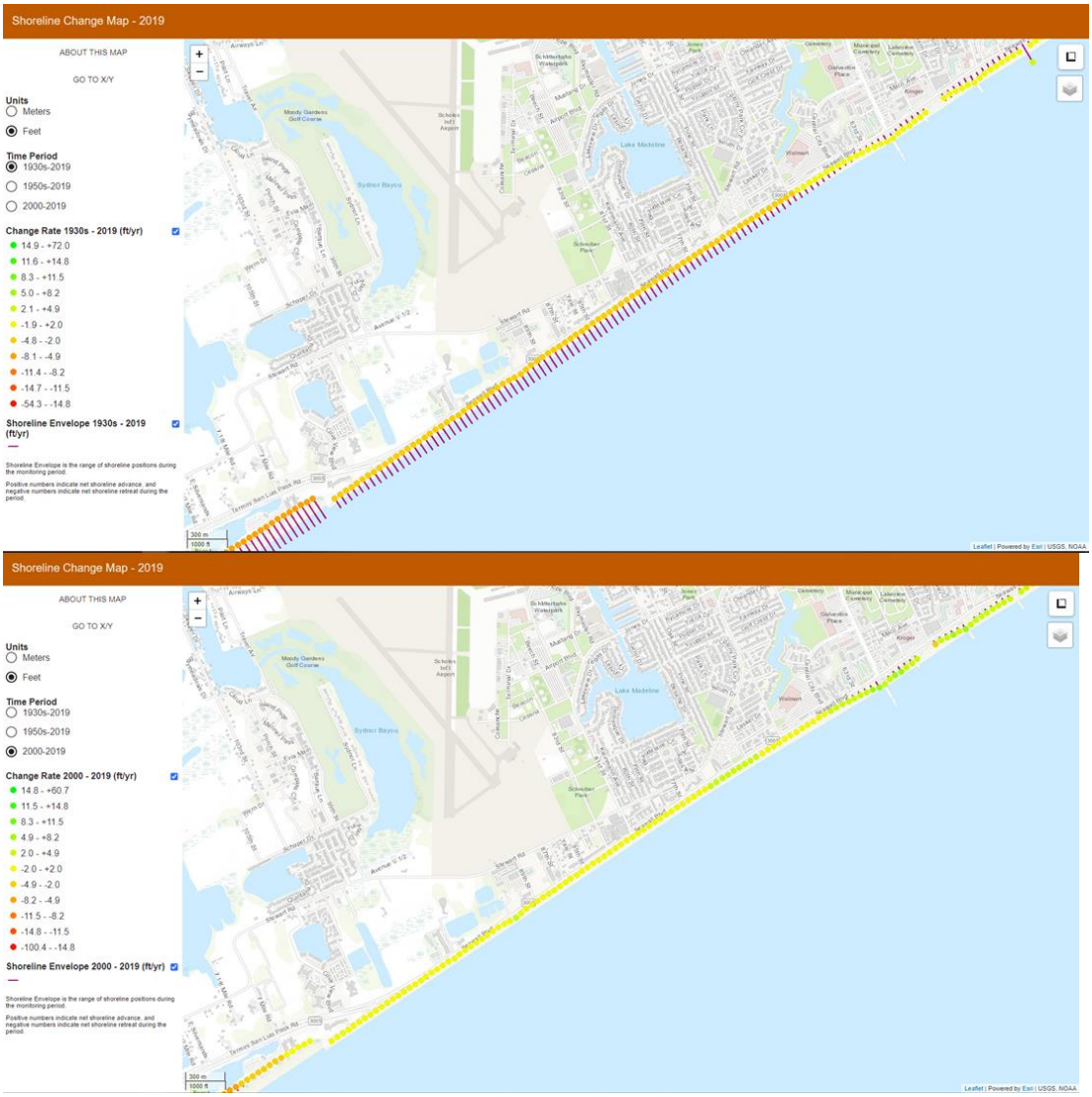

Figure 33. Long-term (top) and short-term (bottom) shoreline changes at the Historic Galveston Seawall where 1.2 million cy of sand were placed in 2017.

Many small-scale beach fills (below 10 cy/linear foot of shoreline) occurred on west Galveston Island while the larger fills included sands dredged from navigation channels (South Padre Island, 180 cy/linear foot of shoreline) (Table 6). The nourishment projects at the BMMP monitored beaches provided local benefits for public use, however; due to their size, did not contribute great amounts to the regional sediment budget. Some of the BMMP sites suffered severe erosion from Hurricane Harvey (e.g. Rockport Beach).

Between 2000 and 2018, there were ten tropical storms and six hurricanes that made landfall on the Texas coast, including seven on the upper coast, four on the middle coast, and five on the lower coast. This coincides with historical tropical cyclone history however, relative sea level rise over the same time period was closer to the high end of historically observed rates (12 mm/yr or 0.47 in/yr) (Paine and Caudle, 2020). This may explain why some erosion rates calculated from the short-term category are higher than the long-term rates in some areas of the Gulf shoreline.

Figures 16 through 19 show that most CEPRA and Resiliency Plan Tier 1 projects (48%) are in Region 1, the most populous. However, critical erosion is addressed in the other planning regions to address critical natural resources or critical infrastructure. The projects supported by the CEPRA program have reduced the effects of coastal erosion at over 100 locations in Cycles 8 through 11. Continued monitoring programs provide valuable information for project design and performance as well as a better understanding of shoreline changes due to local forcing conditions. These programs also allow the state to qualify for federal disaster funding should projects be damaged from storms.

Studies and projects supported by the CEPRA program have identified and addressed eroding areas, found viable sediment sources, and have contributed to overall erosion response planning. These efforts will continue with the dedicated source of funding that was provided by the Texas Legislature in 2019.

RECOMMENDATIONS

The following are recommendations arising from this review of the CEPRA program projects and discussions with local governmental officials:

- Allocation of funding resources should continue to seek sediment sources for larger-scale beach nourishment as these projects appear to show benefits in short-term shoreline trends and produce substantial economic gains to the local community by promoting public beach access and use and protecting critical dunes.
- Continue maximizing federal participation in erosion response planning and projects. Include USACE programs (BUDM, shore protection/flood risk, and regional sediment management), BOEM outer continental shelf sand studies, USFWS-administered programs, FEMA hazard mitigation, and NOAA Coastal Management Program funding.
- Continue maximizing outside grant participation in erosion response planning and continue to seek funds through NFWF, NRDA, and RESTORE or other restoration and planning programs and funding sources.
- Continue and promote CEPRA funding for structure and debris relocation/removal projects that ensure public beach access and allow the facilitation of potential beach nourishment projects.
- Continue allocating CEPRA funding for erosion response studies including sand resources, shoreline change, and BMMP project studies. It is important to use these data for identifying vulnerabilities and project design and performance.
- Expand the BEG's Texas Shoreline Change Project to include Texas bay and estuarine shorelines.
- Require BMMP protocols for monitoring all beach nourishment projects, and commitment from local sponsor to pay for a period determined by all parties involved.
- Consider and determine benefits/costs of all erosion response alternatives including relocation of public infrastructure.
- Work with federal contracting to keep sediment in the system and expand the use of dredged sediment for erosion response projects.
- Expand outreach to counties, navigation districts, and bay shoreline communities to discuss roles in managing erosion and possible CEPRA program collaborations.
- Update and expand the GLO's interactive web tools (TxSed and Coastal Resources Mapping Viewer) to include geologic descriptions useful for identifying sand sources for beach nourishment, and coastal infrastructure, CEPRA-funded projects, CEPRA-eligible Tier 1

projects, bay shoreline change rates, public access to bayshores and Gulf beaches, local dune protection and building setback lines, population density, and economic activity.

REFERENCES

Aylward, D., J. M. Swartz, T. A. Goudge, and D. C. Mohrig, 2016, Alongshore distribution of washover deposits; Hurricane Ike and the Texas coast, 2008: American Geophysical Union 2016 fall meeting, Abstract EP11A-0964.

Atkins, 2018, Post-storm Data Collection Surveys Hurricane and Tropical Storm Harvey Galveston Island, Texas, contract report to the City of Galveston, Houston, p. 32.

Caudle, T. L., and J. G. Paine, 2017, Applications of Coastal Data Collected in the Texas High School Coastal Monitoring Program (THSCMP): Journal of Coastal Research, v. 33, p. 738–746.

Gibeaut, J. C., White, W. A., Hepner, T., Gutierrez, R., Tremblay, T. A., Smyth, r., and Andrews, J. L., 2000, Texas Shoreline Change Project: Gulf of Mexico Shoreline Change from the Brazos River to Pass Cavallo, Report to the Texas coastal Coordination Council pursuant to national Oceanic and Atmospheric Administration, Austin, TX, University of Texas at Austin, Bureau of Economic Geology, p. 34.

Gibeaut, J. C., Hepner, T., Waldinger, R. L., Andrews, J. R., Gutierrez, R., Tremblay, T. A., and Smyth, R., 2001, Changes in Gulf Shoreline Position, Mustang and North Padre Islands, Texas, Final Report Prepared for the Texas Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration, Austin, TX, University of Texas at Austin, Bureau of Economic Geology, p. 28.

Gibeaut, J. C., Gutierrez, R., and Hepner, T., 2002, Threshold conditions for episodic beach erosion along the southeast Texas coast: Transactions Gulf Coast Association of Geological Societies, v. 52, p. 323-335.

Gibeaut, J. C., Waldinger, R. L., Hepner, T., Tremblay, T. A., and White, W. A., 2003, Changes in bay shoreline position, West Bay system, Texas, Report to the Texas Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration, Austin, TX, University of Texas at Austin, Bureau of Economic Geology, p. 27.

Gibeaut, J. C., D. Del Angel, B. Lupher, and W. Nichols, 2015, Resource Management Codes: Data Standards Committee Procedures and Update Process, Corpus Christi, Harte Research Institute, Texas A&M University Corpus Christi, p. 47.

Gibeaut, J. C., B. Lupher, M. Dotson, D. Del Angel, and W. Nichols, 2018, Texas Resource Management Codes, Status and Update Process, Corpus Christi, Harte Research Institute, Texas A&M University-Corpus Christi, p. 56.

Goff, J. A., M. A. Allison, S. P. S. Gulick, R. Reece, M. Davis, D. Duncan, and S. Saustrup, 2015, Shoreface ravinement evolution tracked by repeat geophysical surveys following Hurricane Ike, Bolivar Peninsula, Texas, 2008–2013: Geophysics, v. 80, p. WB1-WB10.

HDR, 2020, Monitoring Survey – 2-Year Post Construction REV 1: McFaddin NWR Beach Ridge Restoration Pilot Project Monitoring, p. 57.

McGowen, J. H., L. E. Garner, and B. H. Wilkinson, 1977, The Gulf Shoreline of Texas: Processes, Characteristics, and Factors in Use, Austin, TX, The University of Texas at Austin, Bureau of Economic Geology, p. 27.

McKenna, K. K., 2004, Texas Coastwide Erosion Response Plan: 2004 Update, Final report to the Texas General Land Office, Contract No. 04-077C, Newark, DE, p. 61.

McKenna, K. K., 2009, Texas Coastwide Erosion Response Plan: 2009 Update, Final Report to the Texas General Land Office, Contract No. 06-076-000, Newark, DE, p. 196.

McKenna, K. K., 2014, Texas Coastwide Erosion Response Plan: 2009 Update, Final Report to the Texas General Land Office, Contract No. 14-148-000, Newark, DE, p. 66.

Morton, R. A., 1974, Shoreline Changes on Galveston Island (Bolivar Roads to San Luis Pass), An analysis of Historical changes of the Texas Gulf Shoreline, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 34.

Morton, R. A., 1975, Shoreline Changes between Sabine Pass and Bolivar Roads, An Analysis of Historical changes of the Texas Gulf Shoreline, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 43.

Morton, R. A., 1993, Shoreline Movement Along Developed Beaches of the Texas Gulf Coast; A Users' Guide to Analyzing and Predicting Shoreline Changes, Open-File Report 93-1, Bureau of Economic Geology, University of Texas at Austin, p. 79.

Morton, R. A., and Gibeaut, J. C., 1993, Physical and environmental assessment of sand resources-Texas continental shelf, The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of the Interior, Minerals Management Service, Office of International Activities and Marine Minerals, under cooperative agreement no. 14-35-0001-30635, p. 66.

Morton, R. A., and Gibeaut, J. C., 1995, Physical and environmental assessment of sand resources, Sabine and Heald Banks: second phase 1994-1995, The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of the Interior, Minerals Management Service, Office of International Activities and Marine Minerals, under cooperative agreement no. 14-35-0001-30635, p. variously paginated. [246 p].

Morton, R. A., Gibeaut, J. C., and Paine, J. G., 1995, Mesoscale Transfer of Sand During and after Storms - Implications for Prediction of Shoreline Movement: Marine Geology, v. 126, p. 161-179.

Morton, R. A., Miller, T. L., and Moore, L. J., 2004, National Assessment of Shoreline Change: Part 1 Historical Shoreline Changes and Associated Coastal Land Loss Along the U.S. Gulf of Mexico, St. Petersburg, FL, p. 45.

Morton, R. A., and Paine, J. G., 1984, Historical Shoreline Changes in Corpus Christi, Oso, and Nueces Bays, Texas Gulf Coast, Geological Circular 8406, Bureau of Economic Geology, University of Texas at Austin, p. 66.

Morton, R. A., and Paine, J. G., 1985, Beach and Vegetation-Line Changes at Galveston Island, Texas, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 39.

Morton, R. A., Paine, J. G., and Gibeaut, J. C., 1994, Stages and Durations of Post-Storm Beach Recovery, Southeastern Texas Coast, USA: Journal of Coastal Research, v. 10, p. 884-908.

Morton, R. A., and Pieper, M. J., 1975, Shoreline Changes in the Vicinity of the Brazos River Delta (San Luis Pass to Brown Cedar Cut) An Analysis of Historical changes of the Texas Gulf Shoreline, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 47.

Morton, R. A., and Pieper, M. J., 1976, Shoreline Changes on Matagorda Island and San Jose Island (Pass Cavallo to Aransas Pass), An Analysis of Historical Changes of the Texas Gulf Shoreline, Geological Circular, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 42.

Morton, R. A., and Pieper, M. J., 1977a, Shoreline Changes on Mustang Island and North Padre Island (Aransas Pass to Yarborough Pass)—An Analysis of Historical Changes of the Texas Gulf Shoreline, Geological Circular, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 45.

Morton, R. A., and Pieper, M. J., 1977b, Shoreline Changes on Central Padre Island (Yarborough Pass to Mansfield Channel)—An Analysis of Historical Changes of the Texas Gulf Shoreline, Geological Circular, Austin, TX, Bureau of Economic Geology, University of Texas at Austin, p. 35.

Moya, J., A. Riskl, K. Calvez, H. Gerkus, C. Weber, K. Buckley, and B. Nickerson, 2016, Texas Sediment Sources-General Evaluation Study, Austin, Freese and Nichols, Inc, p. 247.

Paine, J. G., Caudle, T., and Andrews, J., 2013, Shoreline, Beach, and Dune Morphodynamics, Texas Gulf Coast, Final Report to the Texas General Land Office, Contract No. 09-242-000-3789, Bureau of Economic Geology, University of Texas at Austin, p. 74.

Paine, J. G., Caudle, T. L., and Andrews, J. L., 2014, Shoreline Movement Along the Texas Gulf Coast, 1930's to 2012, Final Report to the Texas General Land Office, Contract No., Bureau of Economic Geology, University of Texas at Austin, p. 59.

Paine, J. G., T. Caudle, and J. Andrews, 2016, Shoreline movement in the Copano, San Antonio, and Matagorda Bay systems, central Texas coast, 1930s to 2010s, Austin, TX, The University of Texas at Austin, Bureau of Economic Geology, p. 82.

Paine, J. G., T. L. Caudle, and J. R. Andrews, 2017, Shoreline and Sand Storage Dynamics from Annual Airborne LIDAR Surveys, Texas Gulf Coast: Journal of Coastal Research, v. 33, p. 487–506.

Paine, J. G., and T. Caudle, 2020, Shoreline Movement along the Texas Gulf Coast, 1930s to 2019, final report prepared for the General Land Office Contract No. 16-201-000, Austin, The University of Texas at Austin, Bureau of Economic Geology, p. 64.

Paine, J. G., and Morton, R. A., 1986, Historical Shoreline Changes in Trinity, Galveston, West, and East Bays, Texas Gulf Coast, Geological Circular 8603, Bureau of Economic Geology, University of Texas at Austin, p. 58.

Paine, J. G., and Morton, R. A., 1993, Historical Shoreline Changes in Copano, Aransas, and Redfish Bays, Texas Gulf Coast, Geological Circular 9301, Bureau of Economic Geology, University of Texas at Austin, p. 66.

Smyth, R. C., Gibeaut, J. C., Andrews, J. L., Hepner, T. L., and Gutierrez, R., 2003, The Texas Shoreline Change Project: Coastal Mapping of West and East Bays in the Galveston Bay System Using Airborne Lidar, Final Report to the Texas General Land Office, GLO Contract No. 02-520-C, Bureau of Economic Geology, University of Texas at Austin, p. 44.

Stark, N., N. Jafari, N. Ravichandran, I. Shafii, S. M. Smallegan, P. Bassal, and J. Figlus, 2017, The Geotechnical Aspects of Coastal Impacts during Hurricane Harvey, Geotechnical Extreme Events Reconnaissance, National Science Foundation, p. 73.

Sweet, W., G. Dusek, G. Carbin, J. Marra, D. Marcy, and S. Simon, 2020, 2019 State of U.S. High Tide Flooding with a 2020 Outlook, Silver Spring, MD, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, p. 24.

Taylor Engineering Inc., 2019, Coastal Erosion Planning and Response Act (CEPRA) Economic and Natural Resource Benefits Study, Jacksonville, p. 163.

Texas General Land Office, 1996, Texas Coastwide Erosion Response Plan: A report to the 75th Texas Legislature, National Oceanic and Atmospheric Administration Cooperative Agreement No. NA570Z0268, Austin, TX, p. 91.

Texas General Land Office, 2015, Coastal Erosion Planning and Response Act, Report to the 84th Legislature, FY13-15 Biennial Report, Austin, Texas General Land Office, George P. Bush, Commissioner, p. 29.

Texas General Land Office, 2017, Coastal Erosion Planning and Response Act, Report to the 85th Legislature, FY15-17 Biennial Report, Austin, Texas General Land Office, George P. Bush, Commissioner, p. 34.

Texas General Land Office, 2019, Coastal Erosion Planning and Response Act, Report to the 86th Legislature, FY18-19 Biennial Report, Austin, Texas General Land Office, George P. Bush, Commissioner, p. 45.

Texas General Land Office, 2017, Texas Coastal Resiliency Master Plan, Austin, Texas General Land Office, p. 208.

Texas General Land Office, 2019, Texas Coastal Resiliency Master Plan, Austin, Texas General Land Office, p. 234.

Texas General Land Office, 2019, Texas Coastal Resiliency Master Plan Technical Report, Austin, Texas General Land Office, p. 928.

Texas General Land Office, 2020, A Guide to Living Shorelines in Texas, Austin Texas, p. 63. living-shorelines-in-texas.pdf

US Army Corps of Engineers and Texas General Land Office, 2020, Coastal Texas Protection and Restoration Feasibility Study, p. 175.

Williams, D. D., 2013, CEPRA Beach Monitoring Phase 4 Surveys and Analysis: 2012/2013 Survey Year, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 119.

Williams, D. D., 2015, CEPRA Beach Monitoring Phase 5 Surveys and Analysis: 2014 Survey Year Volume 1, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 90.

Williams, D. D., 2015, CEPRA Beach Monitoring Phase 5 Surveys and Analysis: 2014 Survey Year Volume 2, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 66.

Williams, D. D., 2016, CEPRA Beach Monitoring Phase 6 Surveys and Analysis: 2015 Survey Year Volume 1, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 105.

Williams, D. D., 2016, CEPRA Beach Monitoring Phase 6 Surveys and Analysis: 2015 Survey Year Volume 2, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 96.

Williams, D. D., 2017, CEPRA Beach Monitoring Phase 7 Surveys and Analysis: 2016 Monitoring Year Volume1, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 130.

Williams, D. D., 2017, CEPRA Beach Monitoring Phase 7 Surveys and Analysis: 2016 Monitoring Year Volume 2, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 117.

Williams, D. D., 2018, CEPRA Beach Monitoring Phase 8 Surveys and Analysis: 2017 Monitoring Year Volume1, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 95.

Williams, D. D., 2018, CEPRA Beach Monitoring Phase 8 Surveys and Analysis: 2017 Monitoring Year Volume 2, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 142.

Williams, D. D., 2019, CEPRA Beach Monitoring Phase 9 Surveys and Analysis: 2018 Monitoring Year Volume 1, Corpus Christi, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, p. 130.

Williams, H., and K. Liu, 2019, Contrasting Hurricane Ike washover sedimentation and Hurricane Harvey flood sedimentation in a southeastern Texas coastal marsh: Marine Geology, v. 417.

Xu, K., R. C. Mickey, Q. Chen, C. K. Harris, and R. D. Hetland, 2016, Shelf sediment transport during hurricanes Katrina and Rita: Computers & Geosciences, v. 90, p. 24-39.

APPENDIX
Local Government Response to Questionnaire

Additional management information from Nueces County:

Response to TGLO/CEPRA Questionnaire
Information compiled through the collaboration of Darren Gurley (Gulf Beaches, Natural Resources & Aquatics Superintendent) and Deidre D. Williams (Conrad Blucher Institute for Survey and Science, TAMU-CC). Information included is in part based on assessment conducted as part of the Packery Channel Monitoring Program (PCMP) and CEPRA Beach Monitoring Program both conducted by CBI for the City of Corpus Christi and Texas General Land Office, respectively. The data may be viewed online through the Coastal Habitat Restoration GIS (C HRGIS) portal in both map view and profile view apps (https://sandy.tamucc.edu/chrgis/maps/ and https://sandy.tamucc.edu/chrgis/profiles/).

Contact: CharlesGu@cctexas.com and Deidre.williams@tamucc.edu

A site map is provided in Figure 1 showing the location of beaches discussed in the responses below. Key features related to discussion of erosion in the vicinity of the North Padre Island (NPI) Seawall are shown in Figure 3.

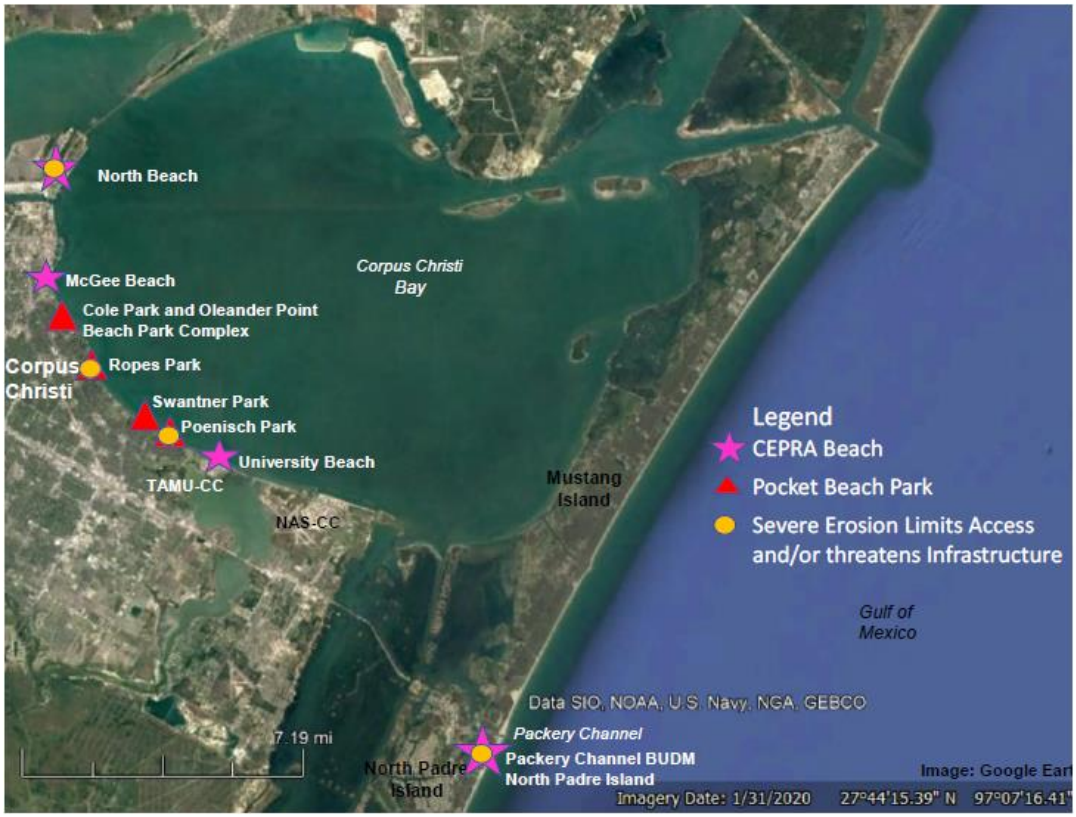

Figure 1. Location of Gulf and Bayshore beach locations within the City of Corpus Christi Jurisdiction which includes Mustang Island and North Padre Island.

1. Does your community have critical erosion area(s)?

A. The majority of the Gulf facing beaches both under City of Corpus Christi jurisdiction and along adjacent segments within the shared littoral system (Nueces County and Port Aransas jurisdiction)

meet the criteria as a critically eroding area with a rate of historic shoreline recession at or in excess of -2 ft/yr as defined by the BEG shoreline Map Project 2019 (Fig 2). Note: the rate of recession documented in the BEG Shoreline Map Project may not fully capture the degree of erosion relative to locations influenced by nourishment and impoundment within the Packery Channel project footprint (South end of Newport Pass to Access Rd 4 (Viento del Mar).

B. The rate of shoreline recession along the NPI Seawall was in excess of 6 ft between the last BUDM nourishment (2012/2013) and Nov 2020.

C. Extreme event-based erosion has been documented following the 2020 Hurricane Season with the majority of the coast sustaining significant beach erosion including loss of 10 to 50 ft of dunes on both Mustang and North Padre Island within the City of Corpus Christi jurisdiction. Not only is the erosion documented by measured shoreline recession but also through beach profile surveys which represent the full extent of erosion including dune loss.

D. The 2020 post-storm shoreline position was measured at all CEPRA locations including the beaches in the City jurisdiction along Mustang and North Padre Island. Although Bayshore beaches are not included in the BEG Shoreline Change Map, the rate of shoreline recession along the southern segment of North Beach is at or in excess of -2 ft/yr calculated for periods between nourishment applications.

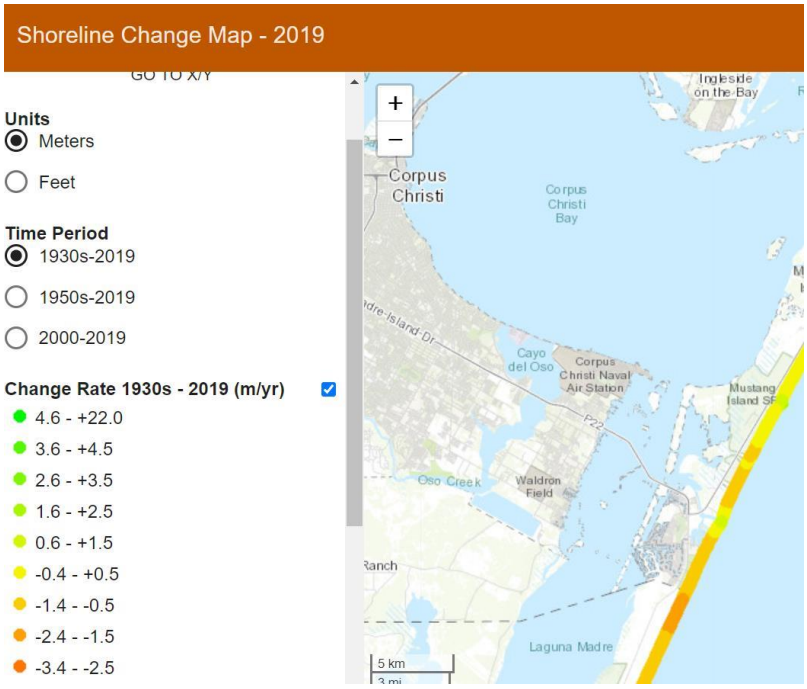

Figure 2. Segments of critical erosion within the jurisdiction of Corpus Christi and adjacent segments on Mustang and North Padre Islands as per BEG Shoreline Change Project (https://coastal.beg.utexas.edu/shorelinechange2019/)

With regard to the 2019 BEG Shoreline Change Project criteria, two limited areas of exception along *formerly* (prior to 2005) critically eroding segments are located immediately adjacent to Packery Channel, 1) the fillets on the north and south side of the inlet and 2) along the northern end of the North Padre Island Seawall (NPI Seawall). The beach at the north end of the seawall has benefited from 1) one direct BUDM nourishment application (2005/2006) and 2) indirect benefit from the nourishment of the adjacent beach to the south (2012/2013). The beach fronting the northern third of the NPI Seawall has also benefited from the sheltering influence of the jetties since construction was completed in 2006. The pivotal point between stability to the north and instability to the south lies just north of the Windward Parking.

Note Related to pedestrian safety along the NPI Seawall: The beach segment fronting the seawall from the Windward Parking Lot to the Holiday Inn is highly transitional, with significant variability in shoreline position and usable beach width which is relative based on water level and onshore forcing on any given day. The highly variable degree of runup along this narrow beach backed by a seawall represents a challenging situation for City officials attempting to provide for safe pedestrian access across the beach from backshore public facilities (restrooms, showers, and parking).

Despite two BUDM nourishment applications, erosion along the beach fronting the southern segment of NPI Seawall has continued. The persistent erosion of the beach along the southern end of the seawall has contributed, in part, to accretion in the form of a fillet adjacent to the south jetty. The width of the beach along the southern half of the NPI Seawall (south of the Holiday Inn) has remained not only less than the design width of 200 ft but also less than the trigger for beach closure at 150 ft since monitoring began in 2003, with the except of immediately post-nourishment during 2005/2006 and 2012/2013. During these two BUDM nourishment events the beach was restored to 200 ft, albeit briefly. After each placement, rapid erosion focused along the southern half of the NPI Seawall reduced the beach south of the Holiday Inn to less than 150 ft. Persistent erosion has resulted in the closure of a beach segment ranging from 1,000 to 1,700 ft long to vehicular traffic since 2015. This pedestrian beach segment remains closed to vehicular traffic until the beach is restored to a minimum width of 150 ft as per City Ordinance (Ord. No. 028494, § 3, 2-23-2010) and in agreement with TGLO. The location of bollards placed at the north and south limits of the pedestrian safe area is reviewed annually based on the beach width determined through a shoreline position survey. It is anticipated that the northern extent of the pedestrian safe area will increase expanding the length to in excess of 2,000 ft due to the cumulative erosion sustained during the 2020 hurricane season. Severe erosion was experienced within the Packery Channel project footprint during the 2020 hurricane season, including the beach fronting the NPI Seawall and along the wider fillets adjacent to the inlet.

Despite a dedicated BUDM source from the dredging of Packery Channel, the beach along the southern half of the NPI Seawall erodes at a faster rate than the rate of channel shoaling resulting in a sand deficit. Persistent erosion along the seawall was exacerbated during the 2020 hurricane season. The City of Corpus Christi is actively pursuing alternative sand sources for placement along the NPI Seawall between cyclic Packery BUDM nourishment applications. Other planned interim measures include alongshore redistribution of sand within the Packery Channel project area and possibly securing BUDM from the maintenance dredge of the Corpus Christi Ship Channel in the vicinity of Port Aransas to ensure grain size compatibility.

What area is your greatest concern and why?
Development of a feasible forward-looking long-term plan that includes partnerships for management of background erosion as well as storm event damage at Gulf and Bayshore beaches. This would target concerns now and anticipated future erosion issues. The primary area of immediate concern is located along the NPI Seawall and to the south up to Access Rd 4 (Viento del Mar). A site map for reference to the following discussion is shown in Figure 3.

A. Identification of partners to provide supplemental BUDM for cyclic placement along Gulf facing beaches in response to demonstrated need. Identification of partners to commit to dedicated offsite sand resources. To date the only BUDM source has been from Packery Channel which is insufficient to meet the nourishment schedule required to maintain the beach between 150 ft and 200 ft based on monitoring since 2005.

B. Identification of partners in the development of a plan to manage erosion along bayside beach parks that are not currently part of the CEPRA program and to potential supplement cyclic nourishment along the southern segment of North Beach.

A primary concern is to reduce the energy that is causing erosion along the beach and along the backshore of pocket beach parks due to the backshore limit composition consisting of an eroding unconsolidated mixture of clay, concrete rubble, and fill material. Possible options include vertically stratified living shoreline features that are integrated into pedestrian friendly backshore/bluff stabilization. Such a design has been demonstrated at a private residence along Corpus Christi Bay. This comprehensive approach would stabilize the backshore and bluff and reinforce beach stability while supporting pedestrian access. The greater stability of the beach and bluff would protect park infrastructure that is located atop the eroding bluff. At North Beach an option is to increase the frequency of nourishment along the southern segment of the beach to incrementally increase and maintain the beach width in an effort to provide uninterrupted access in a high use area and protect the backshore public infrastructure.

2. Do you have a current erosion response plan?

Yes, a joint plan with Nueces County. The plan is due for an update pending our 2020 storm season assessment and was last updated (2012). https://www.nuecesco.com/home/showdocument?id=3416.

Figure 3. Key features in the vicinity of the NPI Seawall and Packery Channel 3.

3. How is coastal erosion addressed in your community? (ex. beach fill, sand management, other). Is this effective and do you suggest other measures to combat erosion or increase your community's resiliency to storms and erosion?

Due to the diversity of the bayshore and Gulf shore under jurisdiction of the City of Corpus there have been two primary types of response 1) planned nourishment and/or 2) structural reinforcement (revetment, seawall, riprap, groins, and breakwaters). Nourishment projects at the CEPRA beaches are based on recommendations from the research/assessment conducted through the CEPRA Beach Monitoring Program while many coastal structures were inherited from projects constructed in excess of 30 years ago, with the exception of University Beach (2001).
Presently there are no long-term plans in place to address the erosion along the Bayshore pocket beaches and larger Cole Park complex, but the development of a City of Corpus Christi 10-year park management plan was initiated during 2020 which may include this recommendation. Approach applied for Gulf and Bayshore projects are described below.

Gulf

a. **BUDM** (Implemented 2005/2006 and 2012/2013)

Location: NPI Seawall

Source: Packery Channel

Schedule: 6-8 yr cycle (based on channel performance to date)
Effectiveness: Short-term. Volume required to restore and maintain beach design width is greater than the channel shoaling rate and recoverable sand volume as BUDM. Erosion continues south of the NPI Seawall and this segment would benefit from additional sand resources and sponsorship.
Options: Interim alongshore sand redistribution and securing offsite supplemental sand sources

b. **Alongshore Redistribution** (proposed: pending COE permit amendment)
Target Location: Beach fronting NPI Seawall and south to Access Rd 4
Interim/Supplemental: Event and need**-based.**
Source: Wide accretionary fillets north/south of Packery Channel and focused areas post-storm deposition.
Schedule: Post-storm and seasonally driven accumulation events
Effectiveness: TBD (in planning stages) purpose is to function as an interim solution to alleviate erosion along seawall and restore design beach width to maintain public access.
Note: This type of sand management is in response to address severe event driven erosion or persistent erosion (such as along the seawall) which is frequently accompanied by large, focused areas of deposition in areas where additional sand overwhelms access management and long-term channel maintenance (blows in channel resulting in peak shoal development) such as at access roads and fillets adjacent to inlet.

Bayshore
a. **CEPRA Beach Nourishment**
Note that beach approaching a "Target Width" defined for each CEPRA location triggers nourishment planning.
Locations: North Beach, McGee Beach and University Beach (restoration included coastal structures)
Schedule: Based on annual PCMP and TGLO assessment
Effectiveness:
-North Beach: Focused event driven erosion requires nourishment (based on Action Width = Target Width/2) more frequently and on a schedule to maintain Target Width and beach access along the southern segment of the beach that fronts infrastructure.
-McGee Beach: Annual assessment-based nourishment has been effective due to low rate of erosion and limited storm impact since 2003.
-University Beach: Annual assessment-based maintenance is recommended due to low rate of erosion and no nourishment since construction (> 19 years).
Exception is that the beach will require cyclic redistribution of sand from nearshore behind breakwaters in order to maintain design depth within the beach cell and to ensure compatibility of reclaimed sediment. Tombolo formation has limited depth and diversity of recreational use. Sand reclaimed from within the cell may be applied to re-nourish the subaerial beach (pending core samples to determine quality of sand due to 19 years of sedimentation) or determine a plan that would permit application of material available.

Recommendations
1. Assistance in identifying and securing a mechanism to secure cyclic BUDM from the periodic dredging of the Corpus Christi Ship Channel in the vicinity of Port Aransas for application along

the NPI Seawall as well as other locations along Mustang Island and North Padre Island that are identified during monitoring. The goal would be to return sediment back into the littoral system to benefit long term coastal resiliency. Frequent cyclic placement of this presently available BUDM would increase the stability of the beach and dune system and could be applied to restore other beach segments damaged during hurricanes and other onshore forcing events.

2. Funding assistance for baseline monitoring and development of bayshore beach alternatives for pocket beach parks along Corpus Christi Bay. The purpose would be to stabilize eroding beaches and the unconsolidated backshore bluff. The benefits would be twofold, 1) protect the backshore park infrastructure and 2) stabilize and improve safe and functional beach access.

4. Have you applied or received CEPRA funding? Is there anything you recommend that would help your community to better understand the program and how to apply for funding?

Yes, the City of Corpus Christi has applied for and received CEPRA funding in the past. The City of Corpus Christi has two on-going CEPRA nourishment projects (North Beach and McGee Beach). The City also has one beach restoration project (University Beach) consisting of a cellular design including groins and breakwaters. University Beach has not required additional nourishment since construction in 2001. In addition, CEPRA contributed to the BUDM nourishment of the beach fronting the NPI Seawall during the initial construction of Packery Channel. Finally, the City applied for CEPRA funding for supplemental nourishment of the beach south of the NPI Seawall in the past although that request has not been funded to date the ongoing discussion has spanned over 5 years. This beach segment remains narrow due to erosion that exacerbated by the proximity of the beach access Rd (Whitecap Blvd.) and the south end of the NPI Seawall (Fig 3). Hydrodynamic forcing resulting from the interaction of waves and flow with the end of the seawall and the funneling effect of water rushing into the access road results in dynamic erosion and subsequent deposition of debris during high water events with onshore forcing.

Recommendation: Meetings that showcase project implementation examples with hurdles and challenges.

How are erosion response projects prioritized? (ex. initiated by the community, local government, other). Has this method worked for your area?

The projects have been prioritized based on need and opportunity to maximize project success through opportunities for collaboration. Long-term solutions for management of areas with historic erosion concerns that have the potential to limit public access have been identified and implemented in partnership with the TGLO. This includes CEPRA beach nourishment at McGee Beach (Bayshore), North Beach (Bayshore) and along North Padre Island along the NPI Seawall. CEPRA funds were contributed to original Packery construction dredge and nourishment in 2005/2006. In addition, the City, TAMU-CC and the TGLO collaborated through a CEPRA grant for a successful beach restoration (2001) fronting the TAMU-CC campus on Ward Island (Bayshore). University beach has not required nourishment since construction in 2001 (over 19 years!). This beach is recommended for redistribution of sand from within the beach cell (reclaiming sand from nearshore and placing on dry beach) saving a significant cost in contrast to importing sand from offsite sources. This process functions similar to the process of backpassing.

Recommendation: TGLO CEPRA initiation of an annual meeting with City officials and stakeholders (if applicable) in order to ensure open communication due to historic high turnover in City staff. This is applicable at all CEPRA beach locations due to communication issues stemming from high staff turnover and lack of cooperate knowledge of projects and collaboration with TGLO.

CEPRA Bayshore Beaches:
The renourishment of the active CEPRA sponsored beaches (3) in Corpus Christi is prioritized based on assessment conducted annually and post-storm as needed by the CEPRA Beach Monitoring Program (CBMP). The CBMP is conducted by the Conrad Blucher Institute at TAMU-CC under the sponsorship of the TGLO. In the past the nourishment planning process has been initiated by TGLO at the CEPRA beaches. No assessment process has been developed for the small pocket beach parks along Corpus Christi Bay. Such a program is needed to quantify erosion and design a plan to stabilize these valuable bayside parks where access has increased as well as diversity of use since COVID-19.

Effectiveness (Bayshore examples)
North Beach: Delays in implementation of recommended nourishment in focused areas of significant erosion along the southwest end allows for exacerbation of erosion due to the proximity of backshore infrastructure (parking, concrete). Due to the lack of facility set back and rapid erosion during inundation events, the beach frequently meets the criteria for nourishment. A defined nourishment cycle of 2 to 3 years that can be revised if event damage occurs or over stable periods would increase the success of maintaining the beach width along the highly erosive southern segment of North Beach. Managing erosion at North Beach is a high priority because persistent erosion threatens both private and public infrastructure and limits user access along a high use beach segment near the Lexington.

An annual assessment approach is better suited for University Beach and McGee Beach where erosion has been documented as more gradual and where planning/administrative delays are less imperative to the success of beach management. In addition, these beaches have limited backshore infrastructure.

Gulf Facing Beaches:
The beach along North Padre Island and Mustang Island within the Packery Channel project area are assessed annually but nourishment has been conducted only along the nourishment template boundary that extends along the NPI Seawall to Viento del Mar (Access Rd 4). The beach is nourished in conjunction with the cyclic dredging of the

channel which serves as a dedicated source of BUDM material. Channel dredging is triggered by taking into consideration both shoal development that has the potential to limit navigation and the availability of a volume of potentially recoverable sand that is adequate to successfully restore the beach to design width.

Effectiveness (Gulf examples)

According to annual monitoring and assessment (PCMP), the rate of erosion along the North Padre Island Seawall south of the Holiday Inn has exceeded the rate of channel shoaling since construction was completed in 2006. Therefore, additional interim nourishment options are needed to plan for long-term proactive management of the beach in the project area and options are being investigated by City Staff. These interim or supplemental nourishment options include identification of offsite sand resources (and partnerships to this end) and alongshore redistribution of sand from the seaward expanding fillets located immediately adjacent to the inlet. Integrating alongshore sand redistribution as a management tool into beach management will also serve to address and provide a mechanism to accommodate event deposition that occurs along the wider beach segments located adjacent to Packery Channel. These storm-induced, large-scale depositional events are specific to the wider beach segments and at access roads and are difficult for the beach operations crews to manage as they insure safe access both for visitors and emergency vehicles.

5. What are the obstacles in moving projects to completion?

a. Permit delays (Example: 3 years to acquire the COE maintenance dredge and nourishment permit).
b. Channel shoaling at slower rate than originally predicted to meet needs along the NPI Seawall.
c. Need for interim alternate sand sources such as BUDM from the Corpus Christi Ship Channel (Port Aransas vicinity for compatibility).
d. Administrative delays inherent to the process (North Beach).
e. Lack of mechanism to define funding allocation for nourishment on a cyclic basis at North Beach.
f. Lack of supplemental sand resources and funding for more frequent nourishment of the beach fronting the NPI Seawall or other locations after storm damage.

6. What were the impacts to your shoreline from Hurricane Harvey (2017) and 2020 storms (H. Hanna-central to lower coast [July 25, 2020], H. Laura-upper coast [August 27, 2020], TS Beta-central to lower coast [September 21, 2020], and H. Delta-upper coast [October 9, 2020])?

The damage to the bay and Gulf beaches was greater during Hanna than documented after Hurricane Harvey due to the prolonged onshore forcing that accompanied Hanna and the storms that followed over the 2020 Hurricane season. The damage during Harvey was focused on Packery Channel infrastructure with additional erosion occurring along the beach over the months of persistent high water and onshore forcing that followed Harvey.

The erosion and damage along North Padre Island and Mustang Island during the 2020 hurricane season approached the level of damage documented after Hurricane Ike. Both bayshore and Gulf facing beaches along with coastal infrastructure were damaged during Hanna. Beach erosion that occurred during Hanna was exacerbated during subsequent high water and onshore forcing and was reinforced by

persistent seasonal high-water levels. Damage along the gulf facing beaches was cumulative over the course of the 2020 hurricane season. The greatest damage to the beach and specifically the dune system occurred during Hurricane Hanna which disturbed the system and was reinforced and exacerbated by storms over the remaining hurricane season.

The PCMP conducted a beach profile and shoreline position survey during October and November 2020 (CBI TAMU-CC) to document the cumulative change over the 2020 Hurricane Season. Damage included both significant erosion of the berm and dunes as well as significant focused accretion of sand and debris that required substantial effort by beaches operations crews in order to restore safe beach access. Analysis is underway to quantify the cumulative change to the beach and dunes. Preliminary findings indicate that significant erosion of the duneline and backshore was widespread along the study area (South of Bob Hall Pier to north of Fish Pass). Isolated segments of dune stability were identified and are being further investigated.

Highlights Storm Season 2020:

Gulf Facing Beaches

a. Severe dune erosion is estimated up to 50 ft of foredune erosion south of NPI Seawall.
(Initiated during Hanna and exacerbated during onshore forcing events that followed)

b. Displacement of sand from highly eroded areas such as along the NPI Seawall to episodic depositional areas positioned at the mouth of access roads and along wider beach segments such as near the inlet. These deposits included significant volume of debris.
(Initiated during Hanna and cumulative over 2020 storm season)

c. Shoreline recession dominated along the NPI Seawall with 60 % of the beach at < 150 ft wide. Stimulated a request for expanding the pedestrian beach northward.
(Initiated during Hanna and cumulative over 2020 storm season)

d. Erosion dominated along 100 % of beach in study area.
(Initiated during Hanna and cumulative over 2020 storm season)

e. Narrowing beach encroached on high use area fronting Windward Parking Lot facilities and handicapped access which complicates management of pedestrian/vehicle safety concerns.
(Initiated during Hanna and cumulative over 2020 storm season)

f. Successive storm damage put high stress on beach operations with staff battling storm and COVID-19 related response tasks.

Bayshore Beaches (2020 Hurricane Season)

a. Preliminary observations and analysis indicate that erosion was focused across the berm with deposition along the backshore of the bayside CEPRA beaches. This resulted in loss of sand from the system in some cases and the need for redistribution of sand across the berm to reclaim sand resources, to restore beach width, and user access.

b. Backshore bluffs along non-CEPRA beaches eroded an estimated 2 to 8 ft along the base along taller bluffs and up to the top of the bluff at lower elevation parks such as Poenisch Park. Bluff erosion resulted in loss of safe access to beaches and threaten park infrastructure and usable footprint. The most damaging event was Hurricane Hanna which forced high water in excess of 6 ft along and onshore shore due to the easterly forcing direction. Erosion related to this surge extended 6 to 8 ft up the backshore bluffs. Although erosion was the primary concern, there was also a significant volume of debris deposited at Ropes and Cole Park pocket beaches that required removal by City crews.

7. Does your community experience bay shoreline erosion? If so, how are these areas managed?

Yes (See #6). Persistent erosion along two landmark urban beaches (North Beach and McGee Beach) led to them being included in the CEPRA program in order to plan and implement cyclic need-based nourishment. The University Beach project restored a beach segment along a once more expansive native beach that had completely eroded along Ward Island and TAMU-CC in the 1930s and 1940s. But erosion is not limited to these CEPRA beach locations. Coastal erosion focused along the beaches and backshore bluffs extends along segments of unarmored shoreline along Corpus Christi Bay from TAMU-CC to Cole Park. This includes erosion of not only the narrow native pocket beaches but also cumulative erosion along the backshore bluff (extreme during Hanna) at these parks which is resulting in loss of the park acreage, threatening park infrastructure and amenities such as hike/bike trails, lighting, as well as limiting safe access to the beaches due to the rugged interface from the elevated parks across the bluff. The end result is the loss of usable outdoor space that provides beach access at neighborhood parks along Corpus Christi Bay.

Management:

a. **Annual Assessment:** CEPRA Beaches are monitored annually and nourished based on annual assessment through collaboration between TGLO and CBI. TGLO coordinates with City of Corpus Christi Staff.

(North Beach, McGee Beach and University Beach)

b. **TBD:** Pocket beaches have no monitoring, nourishment, or restoration plan in place to date:
Cole Park: small native migratory beach (no bluff)
-Oleander Point: pebble veneer created beach and additional small beaches (along tall eroding bluff and seaward park limit)
-Note: additional presently inaccessible intermittent pocket beaches along a 3,000 ft long elevated park area.
Ropes Park: small native migratory beach backed by tall (20 ft) eroding unconsolidated bluff that defines the receding seaward park limit)
Swantner Park: small native transient beach (along seawall)
Palmetto Park: no measurable transient beach (seawall)
Poenisch Park: small native migratory beach (eroding bluff and seaward park limit)

8. Is there a specific project that is of grave concern for implementation in your area? Are there any projects recently completed that you would like to highlight? Any lessons learned for your

community that the plan should highlight? Do you have a specific CEPRA-funded project or a specific erosion area of concern? If possible, can you Include a photo or plan that will be included in the 2020 update?

As described in previous responses the most critical need is for coordinated planning to address two primary concerns:

1. Deficit in beach nourishment material to maintain the beach fronting the NPI Seawall and south to Access Rd 4 at design width or at a minimum between 150 and 200 ft.
2. Plan for managing erosion of bayshore pocket parks that provide beach access points. Implement plant to control erosion the bluff that threatens to reduce the active footprint of the elevated park and encroaches on park infrastructure through failing seaward limit of the bluff.