TAYLOR ENGINEERING, INC.

Coastal Erosion Planning and Response Act (CEPRA) Economic and Natural Resource Benefits Study

Texas

May 2019

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Coastal Erosion Planning and Response Act (CEPRA)
Economic and Natural Resource Benefits Study

Final Report

Prepared for

Texas General Land Office

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by

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EXECUTIVE SUMMARY

The Texas Legislature requires the General Land Office (GLO) to report the economic and natural resource benefits derived from Coastal Erosion Planning and Response Act (CEPRA) construction projects every biennium. Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. This study finds the state of Texas receives $11.0 in economic and financial benefits for every dollar of state funding invested in these projects. This result is based on analysis of the following 13 CEPRA Cycle 7–9 projects, which is a representative sampling of the CEPRA program:

- #1529 Follet's Island Habitat Restoration (unofficially County Road 257 Dune Restoration)
- #1530 McFaddin National Wildlife Refuge Beach Ridge
- #1566 Galveston Seawall Beach Renourishment (between 12th and 61st streets)
- #1572 Dickinson Bayou Wetland Restoration
- #1574 South Padre Island Beach Nourishment with Beneficial Use of Dredge Material
- #1596 Virginia Point Wetland Protection & Restoration
- #1601 West Galveston Island Bayside Marsh Restoration
- #1604 Indianola Beach Renourishment
- #1610 Bolivar Beach Restoration Leveraging CIAP
- #1612 Mad Island Wildlife Management Area Shoreline Protection Phase 2
- #1614 Shamrock Island Protection & Habitat Enhancement Phase 2
- #1619 GIWW Rollover Bay Reach Beach Nourishment with BUDM
- #1627 Moses Lake Shoreline Protection Phase 3

The project benefits analyses classified and estimated economic and financial benefits associated with commercial and recreational fishing, tourism and ecotourism (wildlife viewing), improved water quality, carbon sequestration, beach recreation, out-of-state visitor spending, non-Texas project funding, and storm protection. The stream of economic benefits over time varied from project to project depending on a project's durability. The period of analysis for the various projects varied from 1 to 25 years.

This study adopts a Texas accounting perspective. Funding from outside Texas and spending by visitors from outside the state represent financial benefits to the state. A Texas accounting perspective views project contributions normally considered a cost when viewed from a national or world perspective as a financial benefit. Costs funded by non-Texas dollars represent a financial benefit because money flows into the Texas economy. As appropriate, the findings reported here show this adjustment to reflect the Texas accounting perspective for the estimates of benefits and costs. This report serves to estimate the cost-effectiveness of the 13 projects listed above via benefit-cost ratios and net benefits on an individual project basis, and as a group, or "portfolio."

Table E.1 presents a summary of the assessed projects. The direct and positive net benefits (benefit-to-cost ratios greater than one) from the 13 evaluated projects combined indicate that these coastal erosion control projects yield high returns on investment for the state of Texas. Preserving Texas' coastal assets proves a worthy public investment strategy for Texas taxpayers and citizens.

Table E.1 Summary of CEPRA Cycles 7 – 9 Projects, Costs, and Benefits

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).

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the Virginia Point Wetland Protection & Restoration reflects contributions from the National Fish and Wildlife Foundation (NFWF) and Coastal Impact Assistance Program (CIAP), which covered 98.4% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.26 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits, as described by the following examples. The Virginia Point Wetland Protection & Restoration experienced federal spending benefits ($4,863,030 discounted present worth) from NFWF and CIAP funding as mentioned above. Similarly, Follet's Island Habitat Restoration experienced federal spending benefits ($2,698,128 discounted present worth) from funding by U.S. Fish and Wildlife Service (USFWS) and CIAP. Funding provided by the Federal Emergency Management Agency (FEMA) led to significant federal spending benefits for the Galveston Seawall Beach Nourishment ($19,577,409 discounted present worth).

A discount rate of 3.93% was used in the benefit cost calculations to convert benefits and costs occurring at different points in time to comparable equivalent values ("discounted present worth") for comparison at the beginning of each project's period of analysis. In Table E.1, the discounted present worth of benefits and costs is also converted to equivalent values at a common point in time, 2018. This makes the benefits and costs of the different projects comparable and additive, allowing them to be viewed as a portfolio. The discount rate chosen for this study represents an average of 20-year AAA corporate bond rates existing at the time of study initiation.

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1.0 INTRODUCTION

1.1 Purpose

Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. To address the significant erosive threat to Texas coastal areas, the 76th Texas Legislature passed the Texas Coastal Erosion Planning and Response Act (CEPRA) in 1999. The CEPRA program, in concert with local and other project partners, invests significant state resources to control coastal erosion. Funded biennially in accordance with the state's budget cycles, the CEPRA program has allocated approximately $112 million combined for Cycle 1–9 projects, covering state fiscal years 2000–2017. The Texas General Land Office (GLO) has created project partnerships between federal, state, and local entities, which have matched the Cycle 1–9 CEPRA funds with an additional $52 million from other state and local resources and $165 million in federal funds, resulting in a total investment of approximately $329 million. The GLO applies CEPRA funds for beach nourishment projects, dune restoration projects, shoreline protection projects, habitat restoration/protection, coastal research and studies, and estuary programs.

The Texas Legislature requires the GLO to report the economic and natural resource benefits derived from CEPRA construction projects every biennium. The GLO contracted Taylor Engineering, Inc.—under GLO Contract No. 18-127-059 and Work Order No. B523—to perform the benefit-cost analyses for selected Cycles 7–9 construction projects. This study analyzed the following five CEPRA projects:

- #1529 Follet's Island Habitat Restoration (unofficially County Road 257 Dune Restoration)
- #1530 McFaddin National Wildlife Refuge Beach Ridge
- #1566 Galveston Seawall Beach Renourishment (between 12th and 61st streets)
- #1572 Dickinson Bayou Wetland Restoration
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These projects represented $11.5 million out of a collective $43.6 million ($15.3 million for Cycle 7, $14.0 million for Cycle 8, and $14.3 million for Cycle 9) allocated for funding coastal erosion projects and studies during Cycles 7–9. Figure 1.1.1 presents a map of the projects' locations along the Texas coast. These projects include seven beach restoration projects, one revetment repair project, six associated with shoreline protection and natural resource protection and/or creation, and one project solely for natural resource protection/creation. This report serves to estimate the cost-effectiveness of the 13 projects listed above via benefit-to-cost ratios.

1.2 Report Scope

This report discusses the methodology and results of the natural resource and economic benefit analyses for select projects constructed during Cycles 7–9. Following this introduction, Chapter 2 describes the economic and natural resource benefit methodologies applied in the study. Chapter 3 discusses economic benefits and costs associated with beach restoration and coastal storm risk management. Chapter 4 discusses benefits and costs associated with natural resource protection and/or creation. Chapter 5 summarizes and concludes the report.

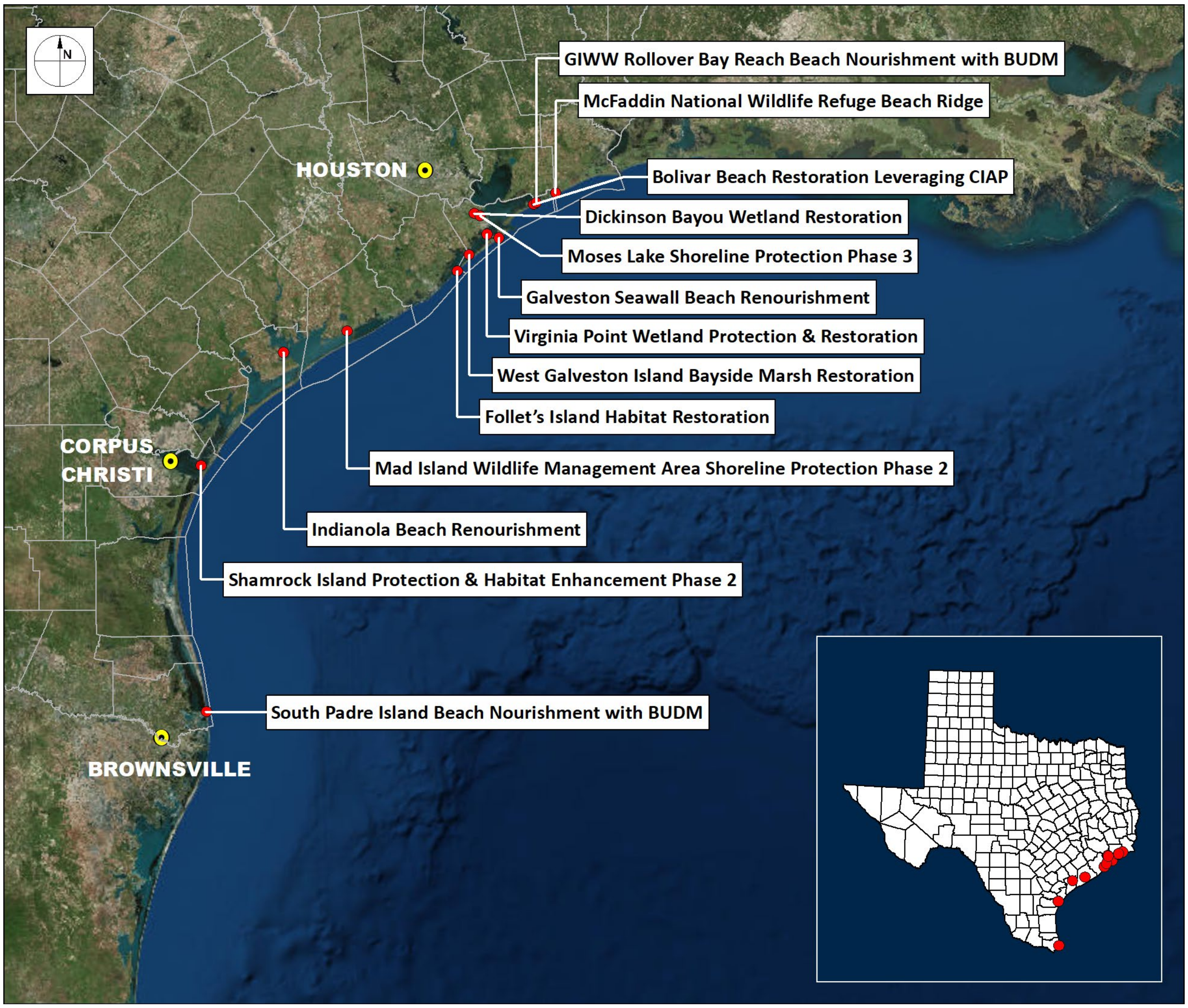

Figure 1.1.1 Location Map of Cycles 7–9 Subject Projects

2.0 ECONOMIC AND NATURAL RESOURCE BENEFITS METHODOLOGY

2.1 General Concepts

Beach restoration and shoreline protection projects result in economic benefits when the projects mitigate for erosion and degradation of beaches and dunes and protect upland property and infrastructure. Natural resource projects result in economic benefits when the projects protect, restore, or create wetlands and other habitats. Beach/dune and natural resource projects' economic benefit methodologies differ in many respects as detailed in Sections 2.2 and 2.3. While each project type requires different methodological steps and procedures, some over-arching concepts apply to all of these projects. This study adopts methodologies similar to those applied in the previous economic benefit studies (Stites et al., 2008; Krecic et al., 2009; Krecic et al., 2011; Trudnak et al., 2013, and Trudnak et al., 2015).

Overall, benefits and costs represent the estimated difference, over the period of analysis, between conditions with the project and conditions without the project. Adjusting each year's benefits and costs reflects then-current price levels with an assumed annual inflation rate derived from the consumer price index (CPI) (https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-and-inflation-rates-1913) for historical years and long-term forecasts by the Federal Open Market Committee of the U.S. Federal Reserve and the Congressional Budget Office for years beyond 2014. Table 2.1.1 summarizes these rates. An annual discount rate of 3.93% (reflecting an average of 20-year AAA corporate bond rates at the time of this study) converts values occurring at different points in time to comparable equivalent values, adjusting for the time preference function. The reference point in time for this discounting, or present worth adjustment calculation, is the beginning of the first year of the project life for each project. This point varies among projects (beginning of 2016, 2017, and 2018). After all benefit cost calculations are complete for the different projects included in this study, further present worth adjustments are made to express benefit cost analysis results at the beginning of 2018 (i.e., as of the same point in time). This enables the group of projects in this report to be additive and comparable, enabling them to be viewed as a portfolio.

Present value factors, based on the 3.93% discount rate, convert values at different points in time to comparable values at the same point in time. In these evaluations, the beginning of the period of analysis represents the point in time used for these discounting calculations. The key to this discounting process, or present value conversion, is equivalence. For example, a benefit accruing in year five is equivalent to its discounted value at the beginning of year one. Discounting reflects the concept that values received or spent in the future are worth less than those received or spent now because of interest. Interest reflects a combination of two effects: (1) changes in prices (inflation), and (2) the time preference function (i.e., even without any inflation an interest rate still exists because a dollar now is preferable to a dollar later). These analyses include inflation in the estimates of benefits accruing and costs occurring over time.

This study assumes most benefits accrue throughout the year. To approximate this effect, the present value calculations apply mid-year discounting (instead of the conventional end-of-period convention) for all benefit calculations.

Table 2.1.1 Price Level Adjustment Information

Year	Annual Average Consumer Price Index	Annual Inflation from Previous Year (%)
2004	188.9	2.7
2005	195.3	3.4
2006	201.6	3.2
2007	207.3	2.8
2008	215.3	3.9

Year	Annual Average Consumer Price Index	Annual Inflation from Previous Year (%)
2009	214.5	-0.4
2010	218.1	1.7
2011	224.9	3.1
2012	229.6	2.1
2013	233.0	1.5
2014	236.7	1.6
2015	237.0	0.1
2016	240.0	1.3
2017	245.1	2.1
2018	250.5	2.2
2019	-	2.2
2020 & Beyond	-	2.0

Regardless of initially estimated price levels, benefits are adjusted (based on historical and forecast inflation estimates previously discussed) to represent price levels existing in the year benefits accrue. For some projects, construction took place early in the year, and even though benefits did not begin to accrue until later in that year, this study treats benefits as though they accrue throughout the same year. For these projects, the authors recognize that this method reflects, if not what really happens, then something very close. The small effect of this calculation method (i.e., the difference between the method and what really happens) on the outcome is insignificant.

This study treats costs as single point-in-time values at the beginning of the period of analysis. The analyses usually exclude a time value adjustment to reflect the actual pattern of project implementation spending that occurred over time because of the relatively short project implementation period (less than a year). The effect of that adjustment would prove insignificant. But for projects with costs spread over a longer period of time, or occurring later in the period of evaluation, appropriate discounting of costs is done.

The stream of economic benefits over time varies from project to project depending on the durability of the project. The period of analysis for the various projects varies from 1 to 25 years.

This study adopted a Texas accounting perspective. Texas taxpayers and citizens likely have the most interest in Texas costs and benefits. Funding from outside Texas and spending by visitors from outside the state represent financial benefits to the state. From a national or world perspective, funding sourced from outside Texas is a cost. A "Texas" accounting perspective, however, views project contributions that originate from outside Texas as a financial benefit to Texas. Costs funded by non-Texas dollars represent a financial benefit because money flows into the Texas economy, including the multiplier effect described below. Along with this effect, this study also properly subtracts this non-Texas part of the project cost from the total implementation cost because it does not represent a state-incurred expense. The estimates of costs and benefits in this study reflect this Texas accounting adjustment.

With respect to spending by out-of-state visitors, this study applies multipliers to estimate the secondary effects of spending by non-Texans visiting project sites within the state. These multiplier factors, when multiplied by out-of-state visitor spending, capture the effects of changes in sales, income, and employment brought about by the initial spending amounts. Two types of such effects exist. One type of multiplier effect takes place within backward-linked industries located within the state. These industries include businesses that supply goods and services to the business operations (e.g., food, gas, and lodging) where visitors/tourists spend their money. The other type of multiplier effect results from the spending by employees of the businesses where visitors spend their money and by employees of the backward-linked businesses and industries involved. The part of this spending that takes place within Texas creates additional sales and economic activity.

Detailed analysis could yield this multiplier effect by applying the results of input-output tables (representing the complex web of economic relationships in the economic system) that exist for states and regions and a myriad of economic sectors of the economy. Conducting such an analysis exceeds the scope of this study. Instead, this study applied a more general approach to determine the multiplier effect for out-of-state visitor spending associated with the various CEPRA projects. For purposes of this evaluation, an overall average multiplier of 1.75 serves as a general average effect representative of conditions in the Texas economy (multipliers often range from 1.5 to 2.0.)

The multiplier value of 1.75 is reasonable in light of the following observations. In the Cycle 3 CEPRA report, Oden and Butler (2006) acknowledge that this multiplier effect is "typically in the range of two times the direct effects." This multiplier effect is generally larger for large regions, such as the state of Texas, and smaller for small areas, such as cities and counties. This tendency relates to the higher population, greater number of industries, and overall higher level of economic integration for a large, diverse, and vigorous economy, such as exists in Texas, than for small intra-state areas. Some (e.g., Horwath Tourism & Leisure Consulting, 1981) have estimated tourism multipliers to range from 1.56 to 2.17 for select counties and regions in Pennsylvania, Wisconsin, Wyoming, and Colorado. In addition, Wiersma et al. (2004) have estimated tourism output multipliers to range from 1.33 to 1.45 for various regions in New Hampshire and 1.51 for the state of New Hampshire. Horváth and Frechtling (1999) report multiplier values of 2.40 for the United States, 2.08 for Puerto Rico, 1.76 for Miami, Florida, 1.63 for Washington, DC, 1.21 for Oregon, and 1.44 for Maryland.

Reducing this multiplier effect reflects that only the retail margins and, in some cases, the wholesale and transportation margins of goods and services purchased by visitors remain in the Texas economy. These margins vary across the economy. For lodging, the margins are very large. Most lodging and related service spending likely remains within Texas. For most items made outside of Texas, the margins likely approach about 50%. The average combined effect of this margining can be expressed as a "capture rate," representing on average the portion of visitor spending that the Texas economy captures. This study adopts a capture rate of 80% (0.8). Combining the capture rate of 0.8 with an overall average multiplier effect of 1.75 results in a net multiplier effect of 1.4 (i.e., 0.8 * 1.75 = 1.4). For example, if non-Texans visiting Texas project sites represent 10% of total visitors who spend, on average, $100/day, then the estimated overall financial economic beneficial impact for Texas of this spending equals total visitation days times 0.1 times $100/visit-day times 1.4.

Estimation of a similar effect can also account for any federal spending that may occur as part of initial project construction or recurring annual operations (e.g., maintenance and inspection), because a major portion of federal spending taking place within Texas represents a net increase inflow of spending for the state economy. However, we must reduce the amount of initial federal spending to account for contributions to federal tax revenues from individuals and businesses in Texas. Applying the ratio of the state of Texas population to the U.S. population total as a proxy for this effect (approaching 10%), an estimated net multiplier effect to apply to any such spending would equal federal spending times 0.9

times 1.4, or federal spending times 1.26. This federal spending and its multiplier effect would represent the estimated net economic financial benefit to the Texas economy.

Many could argue that "outside money subsidies," as described in the preceding paragraph, do not really constitute part of a project's intrinsic economic performance. However, this study's purpose is to show the net economic and financial benefit-cost accounting for Texas' citizens, taxpayers, and their representatives. Meeting this objective requires making these net adjustments. Although not "project benefits" in a traditional sense, this outside funding is an important part of the net economic and financial benefit-cost story for Texas.

Comparing the estimated benefits to the project costs reveals the net benefits of the projects evaluated in this report. Dividing the discounted present worth of estimated benefits by the discounted present worth of costs produces the benefit-to-cost (B/C) ratio for each project. B/C ratios greater than one indicate cost-effectiveness for a particular project. Comparing the sum of the benefits of all the projects examined in this study to the sum of the costs of all these projects indicates the economic performance of the suite of projects looked at as a portfolio of CEPRA endeavors.

As a final note, hand calculations may yield different results from those tabulated in this report because of number rounding versus spreadsheet calculations.

2.2 Beach Restoration and Shoreline Protection Projects

The recently constructed beach restoration and shoreline protection projects intend to provide immediate protection to the upland property owners against high frequency storms. Beach restoration generally adds large quantities of sand to the beach; most sand placement occurs on the dry portion of the beach. This process results in a seaward movement of beach elevation contours, typically from the beach berm to the shallow nearshore. Beach nourishment represents a means to turn back time. Because the erosion mechanisms still exist, erosion will return the beach to its original state and continue to erode further. Beach restoration design includes specifications of berm elevations to mimic those of the natural beach, berm extensions to obtain desired beach widths, and beach foreshore slopes, typically steeper than the natural beach, to transition the beach fill to the existing beach. Wave action subsequently reshapes the beach profile to a more natural profile.

"Hard" shoreline protection projects, such as the Shamrock Island Restoration Project breakwaters, typically limit the landward extent of erosion. These rock or concrete structures, typically sloped, induce wave breaking and loss of wave energy during the wave runup process and, therefore, limit reflection of wave energy from shore. Rock revetments typically consist of two or more layers of rock with the upper, larger rock providing stability against wave attack. A properly designed revetment must ensure that the lower, smaller rock does not wash out through the upper layers. Should this occur, the revetment may lose elevation, and therefore its protective capabilities, through settlement.

Another purpose of beach restoration projects includes restoring and maintaining public recreational beaches. Beach erosion detrimentally affects public recreational use of the sandy beaches by narrowing the dry beach width along the shoreline. Absent sand placement, the recreational beach would continue to narrow and become less suitable for many types of public recreation. As such, this study identified storm damage reduction and visitation benefits as pertinent to the project areas. The paragraphs below discuss these two types of benefits and the associated methodologies used for their calculation.

2.2.1 Storm Damage Reduction Benefits

Beach restoration and shoreline protection projects protect land, infrastructure, and structures on the landward side against both the ongoing background shoreline erosion and episodic, storm-related erosion. The prevention of land loss and damage to infrastructure and structures form the basis of storm protection benefits to upland properties. Storm damage reduction benefits require estimates of background erosion; storm-related erosion; location of properties, infrastructure, and structures with respect to the shoreline; and value of land, infrastructure, and structures near the shoreline. Similar to the above-mentioned prior economic benefit studies, this study adopted a rigorous engineering approach to develop storm damage reduction benefits. Note that not all the components of the approach discussed below applied to the project evaluations conducted for this study. For example, storm protection benefits to habitable structures may not have occurred for any of the projects. However, for informational purposes, this report discusses all components of the approach, as they have been pertinent to previous studies and will likely apply to future studies.

Background erosion estimates obtained from the University of Texas at Austin, Bureau of Economic Geology (UTBEG) (www.beg.utexas.edu), unless otherwise noted, provide the data for predicting the long-term erosion expected to occur at a beach.

Computing storm-induced beach erosion requires applying a numerical model such as Storm-Induced Beach Change (SBEACH) (Larson and Kraus, 1989). This storm erosion model, developed to simulate beach profile change due to cross-shore transport of sediment under changing water levels and breaking waves, provides short-term erosion and recovery predictions on straight beaches. The model assumes that a beach profile evolves to a new equilibrium profile in response to the elevated water levels associated with the storm surge and increased breaking wave heights associated with the storm wave height. Model application requires information on beach profiles, beach sand size, and wave height and period and water level time series (hydrographs) for the duration of the storm.

The GLO, Texas A&M University, and/or UTBEG provided site-specific beach profile survey data along the project shorelines. The survey data include both pre- and post-construction information. Engineering reports supplied representative sand size information in the project areas.

The U.S. Army Corps of Engineers (USACE) Wave Information Study (WIS) hindcast provides offshore wave conditions (wave height, period, and direction) for the SBEACH model. Other numerical models (e.g., WISWAVE, WAM) driven by climatological wind fields overlaid on grids of the estimated bathymetry generate the WIS hindcast data. The WIS numerical hindcasts supply long-term wave climate information at nearshore locations (stations) of U.S. coastal waters. In some instances, measurements from National Data Buoy Center (NDBC) offshore buoys provided wave information.

Water level (storm surge) information originates from sources such as site-specific Federal Emergency Management Agency (FEMA) flood insurance studies. These studies report peak water level elevations for various return period storms. These reported elevations include astronomical tide in addition to storm effects. In some instances, measured water levels originate from the Texas Coastal Ocean Observation Network (TCOON) stations.

Computation of storm-induced erosion requires selection of representative beach profiles along the various project areas. Delineation of the project shoreline into reaches minimizes the amount of these computations. SBEACH application with the above information and with select model tuning parameters provided beach recession-frequency curves for each examined beach profile in this study.

Analyses necessitated computing damages due to background erosion and storms for each project year. For years 2016 and 2018, no tropical storms significantly affected the project areas. In 2017, Hurricane Harvey made landfall along San Jose Island in Aransas County, causing flooding from storm surge and rainfall; the storm's coastal erosion impact on projects varied across the study area. For 2019 and beyond, this study modeled the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for each future year's shoreline position.

Damage calculations considered the values of land, infrastructure, and structures on the affected properties. For undeveloped properties, this analysis considered the location of the seaward edge of the property from the shoreline, the land area lost due to the corresponding storm-related recession, and the estimated unit land market value for the particular property as obtained from the appropriate property appraisal district. For developed properties, this analysis considered the location of the seaward edge of the property from the shoreline, the distance of the seaward and landward sides of infrastructure and structures from the shoreline, the values of structures for the particular property as obtained from the appropriate property appraisal district, the land area lost due to corresponding storm-related recession, and the unit land value for the particular property as obtained from the appropriate appraisal district.

Following similar USACE methods, this analysis distinguishes between slab-on-grade and pile-supported structures. It assumes damage to slab-on-grade structures occurs when the shoreline recedes landward of the seaward edge of the structure and that total damage occurs when the shoreline recedes halfway through the structure. Note that many post-storm observations (e.g., GEC, 2005) revealed that mid- and high-rise residential buildings with robust structural systems and on deep foundations tend to sustain inundation and wave damage only to the lowest floors, with upper floors remaining intact and undamaged by flood. Accordingly, this study assumes damage occurs to pile-supported structures (with two or more stories that likely have deep foundations) when the shoreline recedes landward of the seaward edge of the structure and that total damage (damage to the lowest two stories only) occurs when the shoreline recedes to the landward edge of the structure. Figure 2.2.1 presents a typical damage function curve for these two structure types. For example, given erosion extends 35% into a slab-on-grade structure's footprint and the structure appraises at $200,000, this structure sustains 70% damage or $140,000 worth of damage with the above assumptions applied.

Property appraisers usually do not disaggregate structure values by story. Therefore, the present analysis assumes the values divide equally across the number of stories. For example, a five-story, pile-supported structure appraised at $500,000 has a $100,000 per-story value. Therefore, the lowest two stories' total value equals $200,000, the value eligible for damage.

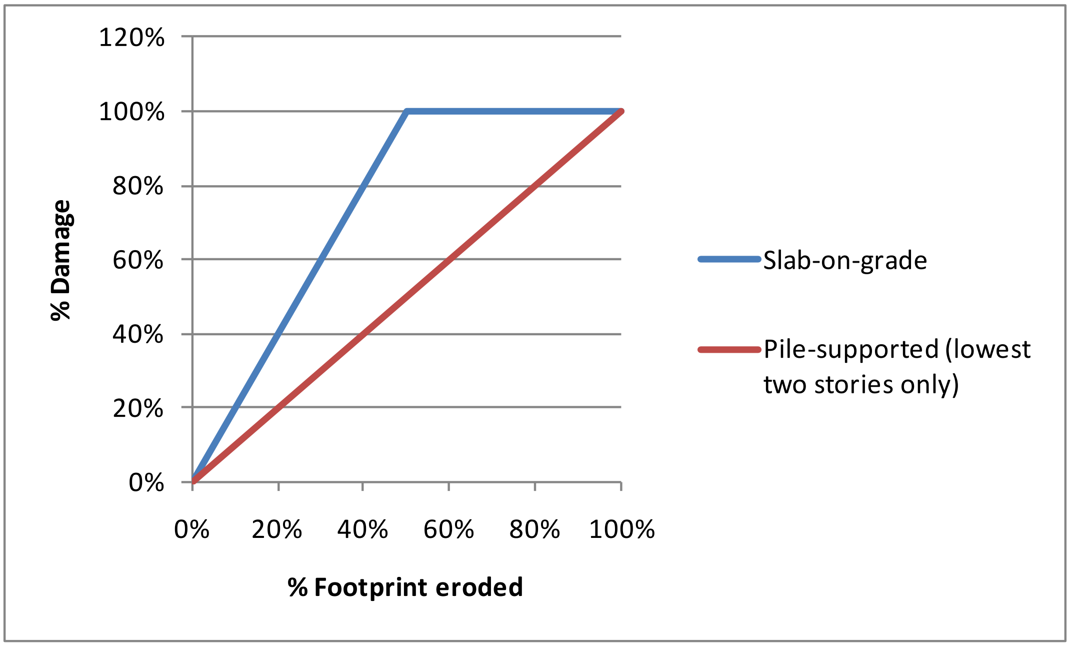

Figure 2.2.1 Structure Damage Functions

The functional relationship between return period and cumulative probability relates damage to cumulative probability. That is, return period relates to the cumulative probability distribution by

$$T_r = \frac{1}{1 - P(X)} \tag{2.1}$$

where Tr is the return period and P(X) is the cumulative probability of X, a storm event. As noted above, this study modeled the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms. Substituting 1 for Tr in Eq. 2.1 and solving for P(X) yields 0 or 0%. Therefore, storms will exceed the 1-year storm, on average, 100% of the time. Similarly, substituting 20 for Tr in Eq. 2.1 and solving for P(X) yields 0.95 or 95%. Therefore, storms will exceed the 20-year storm, on average, 5% of the time.

After modeling the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for a particular year's shoreline position, one may develop a damage-cumulative probability curve similar to Figure 2.2.2. The area under the damage-cumulative probability curve then establishes the expected annual damage for the year. Calculating the area under the curve requires averaging the total damage between adjacent damage points and multiplying by the probability interval between cumulative probabilities corresponding to the damage points (i.e., the trapezoidal integration method). By way of an example, Figure 2.2.2 shows two labeled points on the damage-cumulative probability curve. The area (valued at $792,000) under the portion of the curve bound by the two points equals the average of $4,900,000 and $380,000 ($2,640,000) times the difference of 0.8 minus 0.5 (0.3). Following this procedure and summing the individual results produces the total area under the curve (i.e., expected annual damage for that year).

Note the expected annual damage will not necessarily occur in a particular year. Rather, over a long time period, the average damage will approach this expected value. The damage-cumulative probability relationship changes every year because background erosion moves the shoreline landward every year. Accounting for this erosive beach behavior requires calculating damage-cumulative probability curves for each project year throughout the period of analysis. Furthermore, this analysis, consistent with USACE practice, assumes the repair of the preceding year's structural damage before each subsequent year. For example, say a total expected annual damage equals $2,000,000 including $1,250,000 in structural damage and $750,000 in land loss in 2015. Before 2016, this analysis assumes repair of the $1,250,000 structural damage such that the damage could occur again in 2016. Only the land loss ($750,000) becomes ineligible for future years' damage (or benefit). The total project benefit for a given year represents the difference in the expected value of storm damage between without- and with-project conditions.

Table 2.2.1 presents an example damage-cumulative probability distribution for a given year's without-project conditions. Calculating the expected average interval damage requires three steps. First, average two adjacent total damage estimates of different return period storms. For example, the total damage for 10- and 20-year return period storms equals $108,009 and $132,125 based on model simulations. The average of these two values equals $120,067. Next, determine the interval probability (0.05) by subtracting the cumulative probability value for the 10-year (0.90) from the 20-year (0.95) return period storm. Third, multiply the average interval damage ($120,067) by the interval probability (0.05) to yield the expected value interval damage ($6,003). Repeating these calculations for each expected value interval damage calculation and summing produces the expected average annual damage for a given year and project condition. Performing this procedure for each year in the period of evaluation for conditions with and without the project results in expected value annual damages for each year with and without the project. Table 2.2.2 presents an example storm damage reduction benefit calculation, which shows the cumulative present worth of the storm damage reduction benefit for all years in the period of analysis. For the example results shown in Table 2.2.2, no major storms actually impacted the project area during 2016, hence the project did not provide storm damage reduction benefits for that year.

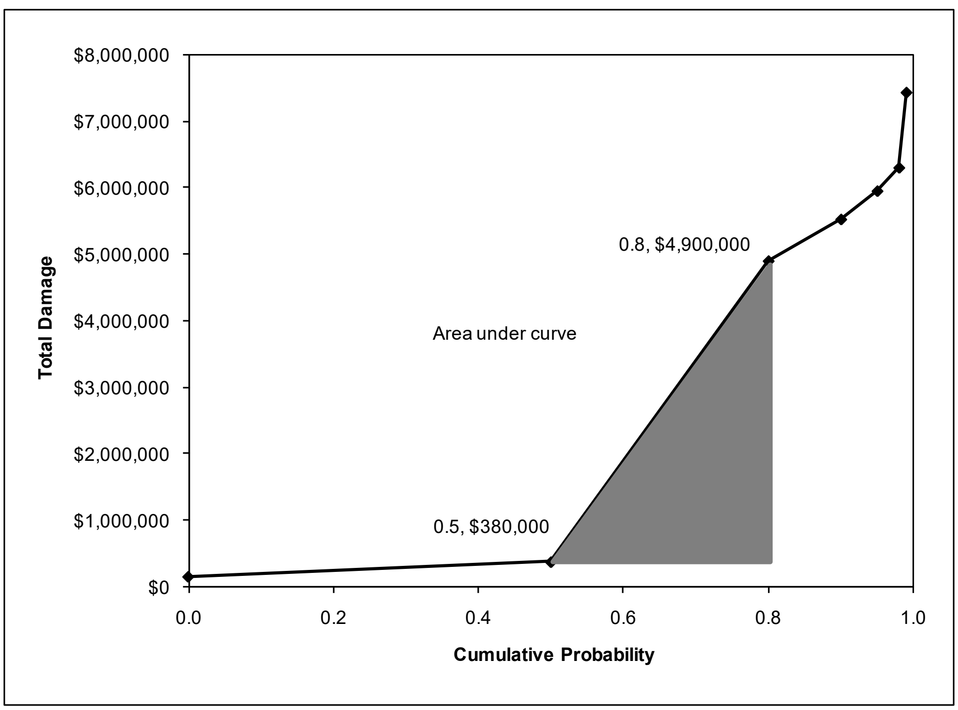

Figure 2.2.2 Example Damage-Cumulative Probability Curve for a Given Year

Table 2.2.1 Example of Total Damage-Cumulative Probability (Year 2, With Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$6,681	$0	$6,681	-	-	-
2	0.50	0.50	$7,467	$0	$7,467	$7,074	0.5	$3,537
5	0.20	0.80	$7,598	$0	$7,598	$7,533	0.3	$2,260
10	0.10	0.90	$10,349	$97,660	$108,009	$57,804	0.1	$5,780
20	0.05	0.95	$10,349	$97,660	$108,009	$108,009	0.05	$5,400
50	0.02	0.98	$10,611	$97,660	$108,271	$108,140	0.03	$3,244
100	0.01	0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
>100	<0.01	>0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
Expected Average Annual Damage in 2016 Prices:								**$22,387**

Table 2.2.2 Example of Total Damage-Cumulative Probability (Year 2, With Project)

Year	Without Project (2016 Prices)	With Project (2016 Prices)	Difference (Benefit)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
2016	$0	$0	$0	$0	$0	$0
2017	$47,517	$22,387	$25,130	$25,658	$24,216	$24,216
2018	$77,113	$24,356	$52,757	$55,050	$49,992	$74,209
2019	$106,892	$25,544	$81,348	$86,751	$75,802	$150,011
2020	$120,404	$44,535	$75,869	$82,526	$69,384	***$219,395***

Notes: [1]Tr = return period; e.g., a 5-yr return period storm has a 20% probability of occurrence in any given year.
Inflation rates: 2.1% for 2016–2017, 2.2%/yr from 2017 through 2019, and 2.0%/yr from 2019 and beyond
Present worth values represent equivalent values, beginning of 2016, 3.93% discount rate (mid-year discounting)

2.2.2 Beach Visitation Benefits

For beach visitation benefits, this study evaluated two categories — spending by out-of-state visitors and recreational enjoyment by all visitors. To develop with- and without-project out-of-state visitor spending estimates requires knowing annual out-of-state visitation, out-of-state visitor spending, and how the with- and without-project conditions affect beach width for each year in the period of analysis. Oden and Butler (2006) report out-of-state visitation by percentage of the total beachgoer population, total number of peak day visitors, and spending for various beach sites throughout Texas — including Galveston Island and South Padre Island beaches — based on site-specific beachgoer surveys. Based on these same surveys, Oden and Butler note that people will visit out-of-state beaches instead of Texas beaches if the Texas beaches become increasingly narrower. Note that Oden et al. (2003) report the number of peak visitor days during the year for South Padre Island. Other project analyses assume a number of peak visitor days based on the traditional Memorial Day to Labor Day period, or no peak period.

New surveys conducted in 2015 revealed updated and enhanced information. Some of the data suggest greater benefits for similar size/scope projects and some suggest reduced benefits, when compared with 2004/2005 survey results. It's hard to say how significant the net result is, or whether the new data revelations tend to offset each other. On the one hand, there is an inherent weakness using data from just one or two days out of a ten-year period to conduct project evaluations. On the other hand, the survey results have enough relative similarity to confirm that we have been using reasonable information for CEPRA project evaluation work. Some relevant key points revealed in the 2015 survey include (a) enhanced beach width sensitivity information, (b) higher levels of visitation than in the 2004/2005 surveys, and (c) lower spending per capita responses than in the 2004/2005 surveys.

All analyses assume beach visitation increases at the same rate as general population growth, approximately 1.4%/year (reflecting a long-term weighted average of Texas and U.S. forecast growth, based on the observation that visitors from outside the state generally approach 10% of all visitors). This growth forecast reflects downward revised projections following the 2010 Census.

This study assumes that out-of-state visitor spending per person is the same for both with- and without-project conditions. Increasing the beach visitation each year by the general population growth rate (1.4%/year) produced estimates of beach population assuming the beach has the capability to accommodate this beach population growth. Because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches. Calculating the beachgoer population each year (adjusted for beach narrowing) and multiplying by the out-of-state spending times the 1.4 multiplier effect produces the value for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.2.3, in bold italic) over the period of analysis.

Oden and Butler (2006) estimated beach visitation with respect to beach width "elasticity," which measures the percentage change in annual visitation given a percentage change in beach width, at South Padre Island and Galveston and Surfside area beaches. Based on 2015 site-specific beachgoer surveys, Taylor Engineering (2015) updated the elasticity relationship with more detailed survey questions. The survey asked visitors how their beach visitation would change for beach width reductions of 50%, 75%, and 100% (i.e., half as wide, quarter as wide, and completely eroded) as well as a 100% increase in beach width (i.e., twice as wide). The combined results from the Galveston area and South Padre Island indicated that visitation would decrease by 50.4%, 54.9%, and 57.0% for the above beach width reductions and increase by 57.8% for the beach width increase (Figure 2.2.3). The survey results provide an improved relationship between visitation and beach width changes and validate a prior general assumption that some minimal level of visitation would likely occur for various activities even with a completely eroded beach, as people may, even with no beach, come to the shore to surf, fish, swim, or view wildlife.

In addition, ensuring the projected beachgoer population would not exceed the beach's capacity in any given year required estimating the maximum number of visitors per day the beach could accommodate. Studies by USACE and Florida Department of Environmental Protection have determined that the average person needs 100 square feet (sf) of dry beach for normal beach activity. The available dry beach surface area divided by 100 sf and multiplied by 2 (estimated average daily turnover rate) yielded the maximum number of visitors per day. Multiplying this result by 365 days produced an estimated maximum annual number of beach visitors for each area. Projections of beach visitation in this study did not exceed maximum capacity for any of the evaluated areas.

Table 2.2.3 Example of Out-of-State Beach Visitor Benefit Calculation

Year	Total Visitation		Out-of-State				Difference (2016 Prices)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
			Visitation		Visitor Spending					
	With Project	Without Project	With Project	Without Project	With Project	Without Project				
2016	172,814	74,310	18,318	7,877	$1,534,889	$660,002	$874,887	$874,887	$858,186	$858,186
2017	163,795	75,350	17,362	7,987	$1,454,785	$669,239	$785,545	$802,042	$756,982	$1,615,168
2018	154,490	76,405	16,376	8,099	$1,372,140	$678,609	$693,531	$723,673	$657,189	$2,272,357
2019	144,892	77,475	15,359	8,212	$1,286,893	$688,113	$598,780	$638,550	$557,958	$2,830,315
2020	134,995	78,560	14,309	8,327	$1,198,990	$697,749	$501,241	$545,223	$458,395	***$3,288,710***

Notes: Out-of-state visitation = 10.6% of total visitation
Out-of-state visitor spending = $59.85 per person (2016 prices)
Multiplier effect = 1.4
Inflation rates: 2.1% for 2016–2017, 2.2%/yr from 2017 through 2019, and 2.0%/yr from 2019 and beyond
Present worth beginning of 2016, 3.93% discount rate, mid-year discounting

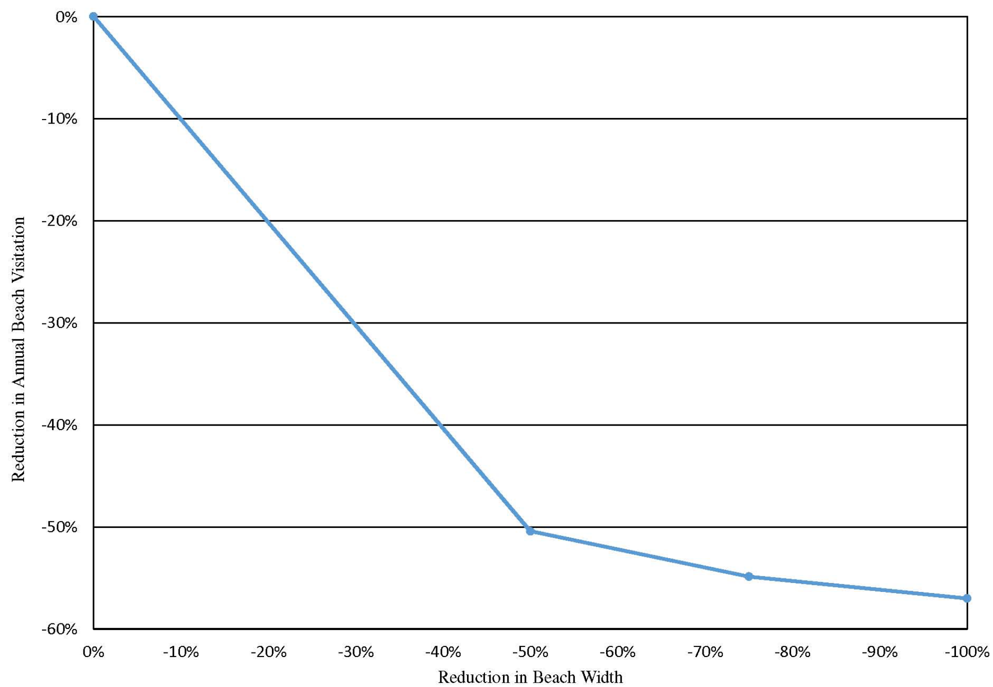

Figure 2.2.3 Relationship between Visitation and Beach Width Change

The other category of visitation benefits includes recreation value for all visitors. Estimating this category of benefits requires knowing the total annual beach visitation with and without the project and the unit day value (UDV). The UDV method (USACE, 2018) relies on expert or informed opinion and judgment to approximate the average "willingness to pay" of visitors (per person per visit) to recreational project sites. The UDV method assigns points to general recreation based on five criteria: (1) recreation experience, (2) availability of opportunity, (3) carrying capacity, (4) accessibility, and (5) environmental. One rates an individual site based on a total of 100 points. Table 2.2.4 presents the guidelines for assigning points. Table 2.2.5 facilitates converting points to dollar values for general recreation.

Assessing both with- and without-project conditions generates the points for each general recreation category in Table 2.2.4. Summing these points and interpolating that point value against the values shown in Table 2.2.5 yields with- and without-project UDVs. Applying the beachgoer population for with- and without-project conditions each year, multiplying by the appropriate UDV, and then taking the difference produces the estimated benefit for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.2.6, in bold italic) over the period of analysis.

This paragraph presents an example of how to assign points to a typical beach area common to the Texas coast. In this example, a beach can accommodate a variety of activities including swimming, surfing, snorkeling, fishing, picnicking, sunbathing, and other active and passive activities. Further, no high quality value activities, defined as activities not common to the region, exist. Accordingly, one could assign a recreation experience value of 8 points to the beach area. Availability of opportunity assigns points based on travel times to the recreational activity. If visitors have a couple beaches within 45 – 60 minutes travel time to choose from, one could assign a value of 8 points for availability of opportunity. A beach area may possess adequate facilities, such as a relatively wide dry beach, to allow beachgoers to enjoy their recreational experience; these conditions may warrant assigning 6 points for carrying capacity. Accessibility measures the ability of visitors to reach the site. Given people can access the beach via good roads, one may assign 10 points for accessibility. Finally, the environmental category judges the site's aesthetics, such as topography, air and water quality, vegetation, climate, adjacent areas, and pests. In this example, the beach may appear average compared to other area beaches. As such, the beach may warrant 6 points for this category. Summing these assigned points over the five categories yields 38 points. Interpolating between 30 and 40 points in Table 2.2.5 produces a UDV of about $7.46. In this hypothetical example, the same point assignment process would be done for conditions without the project. If the points were to total 21, interpolating between 20 and 30 points in Table 2.2.5 results in a UDV of about $5.52.

Table 2.2.4 Guidelines for Assigning Points to General Recreation Projects (USACE, 2018)

Criteria	Judgment Factors				
Recreation Experience Total Points: 30 Point Value:	Two general activities 0 – 4	Several general activities 5 – 10	Several general activities; one high quality value activity 11 – 16	Several general activities; more than one high quality value activity 17 – 23	Numerous high quality value activities; some general activities 24 – 30
Availability of Opportunity Total Points: 18 Point Value:	Several within 1 hr travel time; a few within 30 min travel time 0 – 3	Several within 1 hr travel time; none within 30 min travel time 4 – 6	One or two within 1 hr travel time; none within 45 min travel time 7 – 10	None within 1 hr travel time 11 – 14	None within 2 hr travel time 15 – 18
Carrying Capacity Total Points: 14 Point Value:	Minimum facility for development for public health and safety 0 – 2	Basic facility to conduct activities 3 – 5	Adequate facilities to conduct without deterioration of the resource or activity experience 6 – 8	Optimum facilities to conduct activity at site potential 9 – 11	Ultimate facilities to achieve intent of selected alternative 12 – 14
Accessibility Total Points: 18 Point Value:	Limited access by any means to site or within site 0 – 3	Fair access, poor quality roads to site; limited access within site 4 – 6	Fair access, fair road to site; fair access, good roads within site 7 – 10	Good access, good road to site; fair access, good roads within site 11 – 14	Good access, high standard road to site; good access within site 15 – 18

Criteria	Judgment Factors				
Environmental Total Points: 20 Point Value:	Low aesthetic factors that significantly lower quality 0 – 2	Average aesthetic quality; factors exist that lower quality to minor degree 3 – 6	Above average aesthetic quality; any limiting factors can be reasonably rectified 7 – 10	High aesthetic quality; no factors exist that lower quality 11 – 15	Outstanding aesthetic quality; no factors exist that lower quality 16 – 20

Table 2.2.5 Conversion of Points to Dollar Values for Fiscal Year 2019 (USACE, 2018)

Point Values	General Recreation Values UDV (per person per visit)
0	$4.14
10	$4.92
20	$5.44
30	$6.21
40	$7.77
50	$8.80
60	$9.58
70	$10.10
80	$11.13
90	$11.91
100	$12.43

Table 2.2.6 Example of Recreation Benefit for All Beach Visitors

Year	Number of Visitors		Recreation Value (2017 Prices)		Difference (Benefit)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	75,000	75,000	$534,900	$395,550	$139,350	$139,350	$136,690	$136,690
2017	152,100	152,100	$1,084,777	$802,175	$282,602	$288,537	$272,326	$409,016
2018	154,229	154,229	$1,099,964	$813,406	$286,558	$299,012	$271,542	$680,558
2019	156,389	156,389	$1,115,364	$824,794	$290,570	$309,869	$270,760	$951,318
2020	158,578	158,578	$1,130,979	$836,341	$294,638	$320,491	$269,453	$1,220,771

Notes: UDV (with project) = $7.13 (2016 price level)
UDV (without project) = $5.27 (2016 price level)
Inflation rates: 2.1% for 2016–2017, 2.2%/yr from 2017 through 2019, and 2.0%/yr from 2019 and beyond
Present worth equivalent values at beginning of 2016, mid-year discounting, 3.93% discount rate [mid-year discount factor = $(1/1.0393)^{n+0.5}$, where n = year – 2016]

2.2.3 Period of Analysis

Note that the period of analysis varies between the examined projects. Reasons for these variations include differences in project scale, presence of hard structures, expected life of the project, and observations of project performance.

2.3 Natural Resource Restoration Projects

Natural resource restoration projects may create or enhance conditions (i.e., habitat) supporting an area's natural resources. GLO CEPRA projects may also prevent loss of habitat. Examples of previous GLO natural resource restoration projects include those that created beach and wetland habitat, protected estuarine marsh habitats, and other projects that directly or indirectly created, enhanced, or provided protection for the development and sustainability of natural habitats and the plant and animal communities themselves.

Similar to the prior economic benefits studies, this study quantified natural resource benefits in terms of ecosystem services values, expressed as dollars per acre per year. Estimating these benefits required review of published information on economic benefits of coastal ecosystems, particularly those associated with Texas and other Gulf of Mexico states. In addition to those over-arching concepts presented in Section 2.1, the economic benefit estimates developed in this study for the natural resource projects rest on the assumption that the project sites provide economic benefits in a manner similar to those described in the literature. This assumption served as a surrogate for the extensive on-site interviews and natural resource evaluations described in the literature pertinent to this study. Calculations assumed ecosystem services benefits accrue annually over a project's anticipated lifetime.

Trudnak et al. (2017) described development of ecosystem services values for application in benefit-cost evaluations for GLO CEPRA projects. The GecoServ database (http://www.gecoserv.org/), developed by the Harte Research Institute, Texas A&M University, Corpus Christi, provides a large (worldwide) ecosystem services valuation database listing ecosystem economic services unit area dollar values. Trudnak et al. (2017) identified six ecosystem service categories—*habitat, recreation, disturbance regulation, gas regulation, waste regulation, aesthetics*—that collectively represent the value of GLO CEPRA projects. After filtering to select only data representing Gulf of Mexico ecosystems (with the exception of aesthetic valuation for which there were no Gulf state values reported) and excluding a few early values that recent research has found were less robust than originally assumed, the median value for each ecosystem service provided the values for GLO CEPRA project evaluation. For the current study, we reviewed the GecoServe database and searched for recent literature or data on ecosystem services values. Finding no new values in the GecoServe database or the literature, we applied the Trudnak et al. (2017) ecosystem services values in the present study.

Table 2.2.7 defines the ecosystem services and lists ecosystem service values for marsh and marine open water ecosystems, inflated to 2018 dollars, for each service for marsh ecosystems. Based on the literature for the *habitat* service, we assumed this category provided the basic benefit for commercial and recreational fishing; as a result, the analysis did not use specific commercial and recreational fisheries value estimates. Further, *recreation* included recreational fishing. The marsh values are the median of Gulf state data. The open water values are the single values in the database for habitat (from Washington state) and aesthetics (from New Jersey). Due to the differences between population densities near and likely aesthetic value of open water areas in New Jersey and Texas, we judged the open water aesthetics value inapplicable to the Texas coast and therefore did not apply an aesthetic value for open water areas in the benefit-cost evaluation.

Table 2.2.7 Ecosystem Service Values

Ecosystem Service	Definition[1]	Marsh Per Acre Median Value[2] (2018 dollars)	Open Water Per Acre Value[2,3] (2018 dollars)
Habitat	The physical place where organisms reside (e.g., refugium for resident and migratory species; spawning and nursery grounds)	$56.74	$5.03
Recreation	Opportunities for rest, refreshment, and recreation (e.g., ecotourism; bird watching; outdoor sports)	$92.07	ND[4]
Disturbance Regulation	Dampening of environmental fluctuations and disturbance (e.g., storm surge protection; flood protection)	$591.70	ND
Gas Regulation	Regulation of the chemical composition of the atmosphere and oceans (e.g., biotic sequestration of carbon dioxide and release of oxygen; vegetative	$589.49	ND
Waste Regulation	Removal or breakdown of non-nutrient compounds and materials (e.g., pollution detoxification; abatement of noise pollution)	$2180.90	ND
Aesthetics	Sensory equipment of functioning ecological systems (e.g., proximity of houses to scenery; open space)	$58.73	$476.89
Total Ecosystem Services Per Acre Value		$3569.64	$481.92
Total Ecosystem Services Per Acre Value (less aesthetics)		$3510.90	$5.03

[1]From GecoServ database, http://gecoserv.org/, accessed 04/01/2019
[2]GecoServe values (2012 dollars) converted to 2018 dollars using inflation rates listed in Table 2.1.1
[3]GecoServe database contained only one marine open water value each for habitat (from Washington state) and aesthetics (from New Jersey)
[4]No data

Benefit calculations assume a fixed annual amount of benefit per acre of fully developed habitat created or protected by the project. As for prior GLO CEPRA benefit-cost analyses (Trudnak et al., 2015; Trudnak et al., 2017), we assumed that created marsh habitat initially provides 10% of the per acre ecosystem services value and gradually increases to 100% of the services value over a 15-year period.

Table 2.2.8 provides an example calculation of the total value of ecosystem services for a 50-acre created marsh constructed in 2018 with benefits evaluated over a 21-year (construction year plus 20-year project life) period. The example uses the 2018 ecosystem services value of $3,569.64 per acre (in 2018 dollars) as listed in Table 2.2.7, inflation as given in Table 2.2.1, and annual discount rate of 3.93%. In this example, the project created a cumulative benefit of $1,753,862 in discounted 2018 value.

Table 2.2.8 Example of Benefit Calculation for Created Marsh

Year	Created Marsh			Annual Value of Created Marsh			Beginning of 2018 Discounted Cumulative Value ($)
	Total Area (acres)	Marsh Service (%)	Net Marsh Service Area (acres)	Value (2018 $)	Inflation-Adjusted Value ($)	Beginning of 2018 Discounted Present Worth[1] ($)	
2018	50.00	0%	0.00	0	0	0	0
2019	50.00	10%	5.00	17,105	17,464	16,483	16,483
2020	50.00	16%	8.21	28,101	29,322	26,628	43,111
2021	50.00	23%	11.43	39,097	41,693	36,431	79,542
2022	50.00	29%	14.64	50,093	54,488	45,811	125,353
2023	50.00	36%	17.86	61,088	67,778	54,829	180,182
2024	50.00	42%	21.07	72,084	81,577	63,497	243,679
2025	50.00	49%	24.29	83,080	95,902	71,824	315,503
2026	50.00	55%	27.50	94,076	110,766	79,820	395,323
2027	50.00	61%	30.71	105,072	126,187	87,494	482,817
2028	50.00	68%	33.93	116,068	142,181	94,855	577,672
2029	50.00	74%	37.14	127,064	158,764	101,913	679,585
2030	50.00	81%	40.36	138,060	175,953	108,676	788,262
2031	50.00	87%	43.57	149,056	193,766	115,153	903,415
2032	50.00	94%	46.79	160,052	212,222	121,352	1,024,767
2033	50.00	100%	50.00	171,048	231,338	127,281	1,152,047
2034	50.00	100%	50.00	171,048	235,965	124,917	1,276,964
2035	50.00	100%	50.00	171,048	240,684	122,597	1,399,562
2036	50.00	100%	50.00	171,048	245,498	120,321	1,519,882
2037	50.00	100%	50.00	171,048	250,408	118,086	1,637,969
2038	50.00	100%	50.00	171,048	255,416	115,893	1,753,862

[1]Present worth in 2018, using a mid-year discount factor [1/Discount Rate$^{(n+0.5)}$, where n = (year - 2018)] with the inflation-adjusted value

3.0 BEACH RESTORATION AND SHORELINE PROTECTION BENEFIT ANALYSIS

3.1 Galveston County — #1566 Galveston Seawall Beach Renourishment (between 12th and 61st streets)

3.1.1 Project Description and Background Information

The Galveston Seawall is a large waterfront structure that protects the City of Galveston from coastal inundation. Its' construction occurred in segments between 1902 and 1963. The seawall extends from Fort San Jacinto to roughly 3 miles west of the 61st Street fishing pier between Cove View Boulevard and 7 Mile Road. A riprap revetment protects the seawall's foundation from scour. Since the completion of the first segment in 1904, the seawall has withstood several large storms without any significant damage; this includes Hurricane Ike in 2008 and Hurricane Harvey in 2017.

A groin field is located within the project area extending between 10th and 61st Streets. Construction of the groin field occurred between 1936 and 1939 and an expansion and rehabilitation occurred in 1970 (USACE, 1981). Large storms tend to deplete the sand located between groins. Otherwise, the beaches within the groin field erode slowly, providing space for recreation. Initial restoration of the beach occurred in 1995 placing 710,000 cy of material. The first renourishment project placed 500,000 cy (Songy, 2017) in 2008 following Hurricane Ike. The second renourishment project (CEPRA Project #1566), the focus of this analysis, occurred from January–March 2017. Figure 3.1.1 shows the project location. Substantial development, consisting of access to transportation, hotels, condominiums, businesses, and many tourist attractions and amenities, characterizes the upland area

Per GLO information, CERPA Project #1566 placed approximately 1,000,010 cy of sand, dredged from Bolivar Roads, along roughly 3.6 miles of shoreline from 12th Street to 61st Street. The beach construction template includes a variable width flat berm at elevation +4.5 ft-NAVD88 tying into the seawall; the berm width ranged from 118 – 389 feet (ft), dependent on fill volumes, and averaged 275 ft. Seaward of the berm, the beach face slopes 1V:15H down to +0.5 ft-NAVD88 and then transitions to a shallower slope (1V:50H) that ties into the existing profile.

University of Texas, Bureau of Economic Geology's (UTBEG) Shoreline Change Rate Atlas (UTBEG, 2014) provides the shoreline position envelope and shoreline change rates for three time periods: 1930–2012, 1950–2012, and 2000–2012. The average background erosion rate across the project area is 1.2 ft/yr.

3.1.2 Project Funding

Table 3.1.1 presents the funding breakdown for the project. This analysis treats all costs as though they were incurred at the beginning of 2017 (i.e., the cost reflects 2017 price levels, and is a present worth equivalent value, beginning of 2017). Funding for the beach nourishment project originated from Federal, state, and local sources. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $15,537,626.10 FEMA cost is $1,553,762.61. The resulting cost to Texas for Project #1566 amounts to $5,102,451.61 (present worth, beginning of 2017); this value equals the sum of the CEPRA ($2,756,497), Galveston Park Board ($792,192), and 10% state share of federal costs ($1,553,762.61)

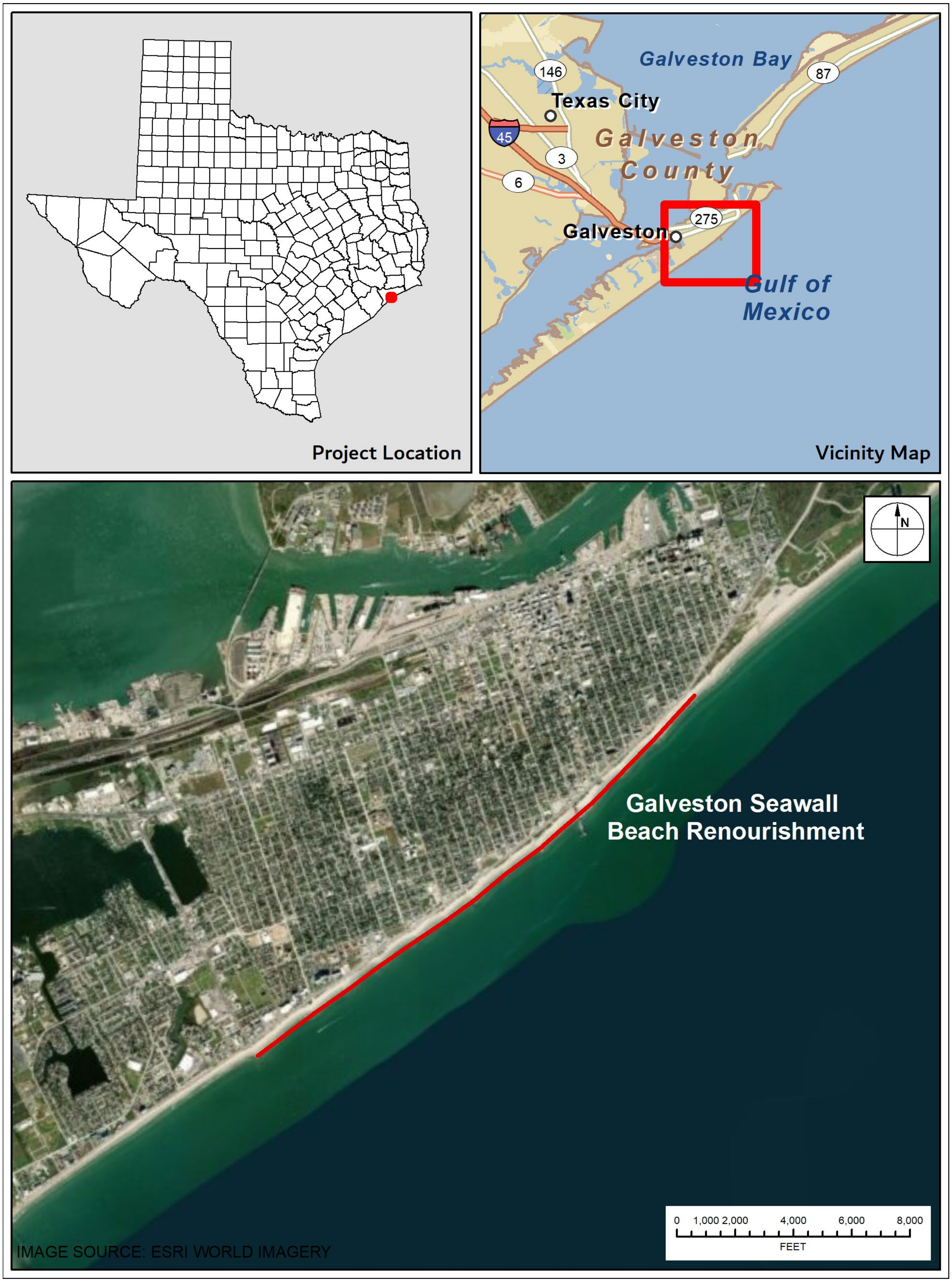

Figure 3.1.1 Location Map — Project #1566 Galveston Seawall Beach Renourishment

Table 3.1.1 Funding for Project #1566 Galveston Seawall Beach Renourishment

Funding Source		Amount ($)
Federal	Federal Emergency Management Agency (FEMA; 81.4% of total project costs) *(Texas portion)*	15,537,626.10 *(1,553,762.61)*
State/Local	TX GLO, CEPRA (78% of non-federal cost; 14.5% of total project cost)	*2,756,497.00*
	Galveston Park Board (22% of non-federal cost; 4.1% of total project cost)	*792,192.00*
	Total Project Funding (100%)	19,086,315.10
	(Texas Total)	*5,102,451.61*

Note: Values in *italics* are costs to the State of Texas
Values represent present worth, beginning 2017

3.1.3 Analysis

Taylor Engineering visited the project area on February 26, 2019, nearly 2 years post-construction. Figure 3.1.2 and Figure 3.1.6 show the project conditions during the site visit. Using Pleasure Pier as a landmark, Figures 3.1.3 – 3.1.6 show a timeline of the project. Figure 3.1.3 and Figure 3.1.4 show the pre- and during construction beach conditions. Figure 3.1.5 captures conditions approximately one-year post-construction (no immediate post-construction imagery is available), and Figure 3.1.6 shows conditions approximately two years post-construction. Of note, the water levels in Figure 3.1.6 are higher than usual, reducing the apparent beach width in the photos as compared to normal conditions, due to a passing weather system and strong onshore winds

As observed during the 2019 site visit, most of the beach nourishment width has been preserved. Aerial photographs collected during the site visit show a significant and consistent beach width throughout much of the project area. From orthoimagery, Taylor Engineering staff measured the approximate distance from the seawall to the wrack line to approximate the berm width. The measured average width of 200 ft is smaller than the average constructed berm width of 275 ft (as expected due to fill equilibration), but still substantially wider than the 60 ft design berm template indicating a large portion of the advance fill remains in the project area.

Absent site-specific data about beach fill evolution and accumulation of offshore sand, this economic benefits study assumed a project lifespan of ten years. The design engineer suggested a ten- to fifteen-year project lifespan dependent on storm activity (Songy, 2017). Assuming a 10-year lifespan (as opposed to 15 years) represents a conservative approach to not overestimate project benefits. In addition, this lifespan appears reasonable based on the apparent two-year project performance and the project's previous nourishment intervals (i.e., 9 years between the first and second nourishments). Using the average berm width of the project (200 ft as discussed above) and an assumed erosion rate of 18 ft/yr (further discussed below), the project would approach pre-construction conditions during the tenth year. Of note, the 18 ft/yr erosion rate is higher than the average approximated erosion rate of 37.5 ft/yr that occurred during the first two years post-construction (i.e., 275 ft – 200 ft / 2 years = 37.5 ft/yr); however, higher initial erosion rates typically occur due to profile equilibration following beach fill placement and reduce with time following construction.

Beach fill placed in front of a storm protection structure (e.g., revetments, seawalls) typically helps protect the structure from damage and prolongs the life of the structures. However, portions of the Galveston Seawall have historically been exposed to direct wave impact without experiencing major structural problems. Naturally, the project helps protect the seawall and rip rap from waves; however, given its size, importance, and historical performance, the assumption that the Galveston Seawall would be damaged absent this nourishment project is not likely within the evaluation period. Therefore, this study did not quantify any potential storm damage protection to the seawall.

For Project #1566, this study calculated economic benefits to the state of Texas from federal spending and beach visitation (recreational benefits and out-of-state visitor spending benefits).

Figure 3.1.2 Project #1566 Two Years Post-construction, 18th Street Looking Southwest (2/26/19)

Figure 3.1.3 Project #1566 Pre-construction Conditions (Source: Google Earth, January 22,2017)

Figure 3.1.4 Project #1566 During Construction (Source: HDR, 2017)

Figure 3.1.5 Project #1566 Post-construction (Source: Google Earth, 3/21/18)

Figure 3.1.6 Project #1566 Conditions Two Years Post-construction (2/16/19)

3.1.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (FEMA) listed in Table 3.1.1 ($15,537,626 x .9 = $13,983,863,49) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as a financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple effect, as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $19,577,408 (i.e., $13,983,863,49 x 1.4) in 2017 prices.

3.1.3.2 Recreational Benefits

The study assumed a project length of 19,272 ft (i.e., the full beach width length [19,122 ft] plus half the tapering length [150 ft]). Based on May 2015 observations, Taylor Engineering (2015) reports 443 peak visitors per 1,000 ft of shoreline on average at Porretto Beach in Galveston, an area with a relatively wide beach width located just east of the project area, and 143 peak visitors per 1,000 ft of shoreline at 57th St. – 61st St., located at the southwestern end of the project area. This analysis assumes the with-project visitation equals that at Porretto Beach and the without-project visitation equals the latter value. Anecdotally, the nourished beach has attracted many visitors, resulting in increased hotel occupancy rates in the project vicinity; thus, the above estimate appears reasonable.

Applying these visitation rates, the study estimates a peak with-project visitation of 8,537 (443 / 1,000 * 19,272) at the beginning of the project. Assuming a daily turnover rate of 2, the daily peak visitation estimate is 17,074. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors visit the beach during off days (17,074 / 5), and 285 off peak days exist during a 365-day year (i.e., 365 – 80). Given the above information, approximately 2,338,910 (17,074 * 80 + 3,414 * 285) visits occurred based on the 2015 visitation estimates, or 2,404,858 (1,546,970 *1.014 * 1.014) visitors after accounting for the general population growth from 2015–2017. The estimated peak without-project visitation equals 2,756 (143 / 1,000 * 19,272), or 5,511 including the daily turnover rate. Incorporating the seasonal effects as described above, approximately 776,237 ((5,511 * 80 + 1,102 * 285) * 1.014 *1.014) visitors visit in 2017 based on the 2015 visitation estimates.

To estimate the effect of beach width "elasticity" (Section 2.2), this analysis reduced the beach width to account for background erosion over the remaining eight years of the project's ten-year lifespan. Given the current beach width of 200 ft and the average pre-construction beach width of 57 ft (discussed below), this analysis applied an erosion rate of 18 ft/yr, which erodes the beach to pre-construction conditions after eight years. Of note, this erosion rate is greater than the above-mentioned 1.2 ft/yr background erosion rate calculated from historical data. However, this historical data includes the influence of the two previous beach fills on the project area and applying the 1.2 ft/yr erosion rate on the 200-ft wide berm would lead to an unrealistic 166-year project life. In reality, the fill erosion rate will diminish with time (i.e., the rate will exceed 18 ft/yr during 2019 and would likely approach the 1.2 ft/yr background erosion rate during the end of the project life; however, this analysis adopts the more simplistic uniform annual erosion rate of 18 ft/yr for the remainder of the project life. The with-project conditions assumed the average post-construction berm width of 275 ft as the starting point in 2017, a berm width of 230 ft at the beginning of 2018, and the approximated average berm width of 200 ft at the beginning of 2019 subject to 18 ft/yr of erosion through 2026.

Pre-construction aerial photography indicates beach widths up to 100 feet wide in some areas. In other areas, the ocean has reached and exposed the rip rap making access unsafe. The without-project conditions assumed the average pre-construction berm width of 57 ft as the starting point in 2017 and applied the historic 1.2 ft/yr background erosion rate. The higher 18 ft/yr erosion rate would erode the without project beach in less than 3.5 years, which is unlikely (absent severe hurricane impacts) due to the groin field throughout the project area stabilizing the remaining beach fill. Table 3.1.2 and Table 3.1.3 show total with-project and without-project visitation adjusted based on the elasticity relationship (Section 2.2).

The visitation numbers derived in Table 3.1.2 and Table 3.1.3 were applied to the UDV developed (see Section 2.2) for with- and without-project conditions to calculate recreation enjoyment benefits. The UDV points assigned to the site with- and without project conditions provides an estimate of its economic benefits. Table 3.1.4 shows a summary of the points assigned for with- and without-project conditions in the project area. Converting the points (54 and 36) to dollars requires interpolating values from Table 2.2.5. The resulting with- and without-project UDVs are $8.72 and $6.83 (2017 dollars) per person per visit. Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. For the first year of analysis (2017, at 2017 price levels), the recreation value for with-project conditions equals $20,960,742 (2,404,858 * $8.72), and the without-project value equals $5,304,801 (776,237 * $6.83). The difference ($15,655,941) yields the recreational benefit for 2017 (assumed mid-year). Table 3.1.5 shows the total recreation value benefit for this project compounding benefits for the total life of the project (ten years). In total, using a mid-year discounting rate of 3.93%, the benefit equals $75,090,037 (present value, beginning of 2017).

3.1.3.3 Out of State Visitor Spending

Taylor Engineering (2015) reported that 10.6% of the visitors in the project vicinity (i.e., near 61st Street) come from out-of-state. Applying this value to the total annual visitation estimates (Table 3.1.2 and Table 3.1.3) yields the number of annual out-of-state visitors. Taylor Engineering (2015) also reports that out-of-state visitors spent $59.08 (2015 dollars) per person per visit to the Galveston area. Inflating this value to 2017 prices yields $61.10 ($59.08 * 1.013 * 1.021). Table 3.1.6 summarizes the benefit to Texas from spending by out-of-state visitors. The present value of this benefit (beginning of 2017) is $65,955,308.

Table 3.1.2 Annual Visitation with Project #1566

Year	Unconstrained Annual Visitation	Beach Width	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2017	2,404,858	275	0%	0%	2,404,858
2018	2,438,526	230	-16%	-16%	2,039,494
2019	2,472,665	200	-27%	-27%	1,798,302
2020	2,507,283	182	-34%	-34%	1,659,365
2021	2,542,385	164	-40%	-40%	1,516,186
2022	2,577,978	146	-47%	-47%	1,368,672
2023	2,614,070	128	-53%	-51%	1,290,780
2024	2,650,667	110	-60%	-52%	1,277,621
2025	2,687,776	92	-67%	-53%	1,263,841
2026	2,725,405	74	-73%	-54%	1,249,425

Notes: Background erosion, -18 ft/yr.
Starting daily peak visitation, 17,074
Out-of-State visitation, 10.6% of total visitation
Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.1.3 Annual Visitation without Project #1566

Year	Unconstrained Annual Visitation	Beach Width	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2017	776,237	57	0%	0%	776,237
2018	787,104	56	-2%	-2%	770,533
2019	798,123	55	-4%	-4%	764,518
2020	809,297	53	-6%	-6%	758,184
2021	820,627	52	-8%	-8%	751,522
2022	832,116	51	-11%	-11%	744,525
2023	843,766	50	-13%	-13%	737,185
2024	855,578	49	-15%	-15%	729,493
2025	867,556	47	-17%	-17%	721,442
2026	879,702	46	-19%	-19%	713,022

Notes: Background erosion, -1.2 ft/yr.
Starting daily peak visitation, 5,511
Out-of-State visitation, 10.6% of total visitation
Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.1.4 UDV Points Assigned to Project #1566

Criteria	Points Assigned (with Project)	Points Assigned (without Project)	Total Possible Points
Recreation Experience	16	10	30
Availability of Opportunity	3	2	18
Carrying Capacity	9	4	14
Accessibility	16	14	18
Environmental	10	6	20
Total	54	36	100

Table 3.1.5 Project #1566 Recreation Benefit for All Visitors

Year	Total Visitation		Recreation Value (2017 Prices)		Difference (2017 Prices)	With Inflation	Beginning of 2017 Discounted Present Worth	Beginning of 2017 Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2017	2,404,858	776,237	$20,960,742	$5,304,801	$15,655,941	$15,655,941	$15,357,082	$15,357,082
2018	2,039,494	770,533	$17,776,233	$5,265,824	$12,241,105	$12,510,409	$11,807,559	$27,164,641
2019	1,798,302	764,518	$15,674,000	$5,224,717	$10,004,254	$10,449,283	$9,489,300	$36,653,941
2020	1,659,365	758,184	$14,463,027	$5,181,426	$8,695,012	$9,281,601	$8,110,164	$44,764,105
2021	1,516,186	751,522	$13,215,075	$5,135,900	$7,405,654	$8,079,175	$6,792,550	$51,556,655
2022	1,368,672	744,525	$11,929,344	$5,088,083	$6,135,949	$6,841,262	$5,534,280	$57,090,934
2023	1,290,780	737,185	$11,250,439	$5,037,920	$5,452,081	$6,212,519	$4,835,615	$61,926,549
2024	1,277,621	729,493	$11,135,747	$4,985,356	$5,281,369	$6,150,391	$4,606,232	$66,532,781
2025	1,263,841	721,442	$11,015,639	$4,930,332	$5,112,994	$6,085,307	$4,385,151	$70,917,932
2026	1,249,425	713,022	$10,889,985	$4,872,791	$4,946,932	$6,017,194	$4,172,105	$75,090,037

Notes: Total visitation estimates derive from Table 3.1.2 and Table 3.1.3.
With-project, UDV dollar value (2017 Prices) = $8.72
Without-project, UDV dollar value (2017 Prices) = $6.83
Multiplier effect = 1.4
Inflation rates: 2.2%/yr 2017 to 2019, 2%/yr 2019 to 2020 and beyond
Present worth beginning of 2017, 3.93% discount rate, mid-year discounting

Table 3.1.6 Project #1566 Out-of-State Visitor Spending Benefit

Year	Out-of-State				Difference (2017 prices)	With Inflation	Beginning of 2017 Discounted Present Worth	Beginning of 2017 Cumulative Discounted Present Worth
	Visitation		Visitor Spending (2017 prices)					
	With Project	Without Project	With Project	Without Project				
2017	254,915	82,281	254,914	82,281	$21,807,074	$14,768,199	$14,486,286	$14,486,286
2018	216,186	81,676	216,186	81,676	$18,494,018	$11,506,899	$10,860,427	$25,346,713
2019	190,620	81,038	190,620	81,038	$16,306,929	$9,374,388	$8,513,156	$33,859,869
2020	175,893	80,367	175,892	80,367	$15,046,996	$8,171,857	$7,140,482	$41,000,351
2021	160,716	79,661	160,715	79,661	$13,748,652	$6,933,909	$5,829,670	$46,830,021
2022	145,079	78,919	145,079	78,919	$12,411,043	$5,659,776	$4,578,509	$51,408,531
2023	136,823	78,141	136,822	78,141	$11,704,683	$5,019,971	$3,907,376	$55,315,907
2024	135,428	77,326	135,427	77,326	$11,585,345	$4,970,354	$3,722,463	$59,038,369
2025	133,967	76,472	133,967	76,472	$11,460,447	$4,918,513	$3,544,344	$62,582,714
2026	132,439	75,580	132,439	75,580	$11,329,731	$4,864,105	$3,372,594	$65,955,308

Notes: Out-of-state visitation = 10.6% of total visitation estimates derive from Tables 3.1.2 and 3.1.3.
Out-of-state spending = $61.10 per person (2017 prices)
Multiplier effect = 1.4
Inflation rates: 2.2%/yr 2017 to 2019, 2%/yr 2019 to 2020 and beyond
Present worth beginning of 2017, 3.93% discount rate, mid-year discounting

3.1.4 *Benefit-Cost Summary*

With total benefits of $160,622,754 and a total project cost of $5,102,452, the resulting B/C ratio for project #1566 equals 31.5. Table 3.1.7 summarizes the results.

Table 3.1.7 Benefit-Cost Summary for Project #1566 Galveston Seawall Renourishment

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Federal Spending Benefit	$19,577,409
Out-of-state Visitor Spending Benefit	$65,955,308
Recreation Benefit	$76,699,104
Total Benefit	**$160,622,754**
Total Cost (Texas portion)	**$5,102,452**
B/C Ratio	**31.5**

Notes: Dollar values reflect present worth equivalents at the beginning of 2017 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2017 (discount factor = 1).
Benefits include mid-year discounting.

3.2 Cameron County — #1574 South Padre Island Beach Nourishment with Beneficial Use of Dredge Material

3.2.1 *Project Description and Background Information*

The City of South Padre Island lies on a barrier island along the Gulf of Mexico in Cameron County, Texas. The City spans an area extending approximately from one to five miles north of Brazos Santiago Pass. During Cycle 8, the GLO and the City of South Padre Island implemented Project #1574 — South Padre Island Beach Nourishment with Beneficial Use of Dredged Material (BUDM). Figure 3.2.1 shows the project extents.

Chronic long-term erosion, storm-related episodic erosion, and upland development characterize the area's beaches. Protecting upland structures and infrastructure from potential storm damage constitutes the major purpose of the project. Upland development in the project area is comprised of single-family homes, multifamily homes, and commercial properties. Shorefront structures generally encroach on the shoreline. Based on the maximum predicted erosive shoreline condition, the present economic analysis considers Gulf-front properties within 200 – 300 ft of the shoreline within the project area. Given the 2016 Cameron Central Appraisal District information, the property values that may be affected by an eroding shoreline (including structures) approach $35 million on South Padre Island.

The project placed approximately 685,000 cy, dredged from the Brazos Inlet Harbor Jetty Channel, along 4,100 ft of shoreline between the entrance to Andy Bowie Park at its northern limit and Goodhope Circle at its southern limit. Construction occurred in two phases, as inclement weather and dredge machinery complications required the contractor to demobilize after four months of operations and then remobilize to complete the job. The first phase (November 2015 – February 2016) dredged 324,344 cy (268,451 cy from the jetty channel and 55,893 cy from the entrance channel) and placed the material along the northernmost 1,700 ft of the beach placement area. The second phase (October – November 2016) dredged 361,127 cy (133,128 from the jetty channel and 227,899 cy from the entrance channel) and placed the material along the remaining 2,400 ft of the beach placement area. Figures 3.2.2 and 3.2.3 present representative pre- and post-construction photographs. Figure 3.2.4 shows condition during construction.

3.2.2 Project Funding

Table 3.2.1 presents the funding breakdown for the project. These costs represent the incremental costs for placing the dredged material on the beach (i.e., the costs exclude the USACE's maintenance dredging costs that would have occurred without beach placement). The Coastal Impact Assistance Program (CIAP) contributed federal funds to the construction of the project through grants awarded to the GLO and the City of South Padre Island, and the GLO and City covered the remaining non-federal costs. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $1,334,476 CIAP cost is $133,447.60. The resulting cost to Texas for Project #1574 amounts to $1,379,963.60; this value equals the sum of the CEPRA ($566,540), City of South Padre Island ($679,976), and 10% state share of federal costs ($133,447.60) This analysis treats all costs as though they were incurred at the beginning of 2016 (i.e., the cost reflects 2016 price levels, and is a present worth equivalent value, beginning of 2016).

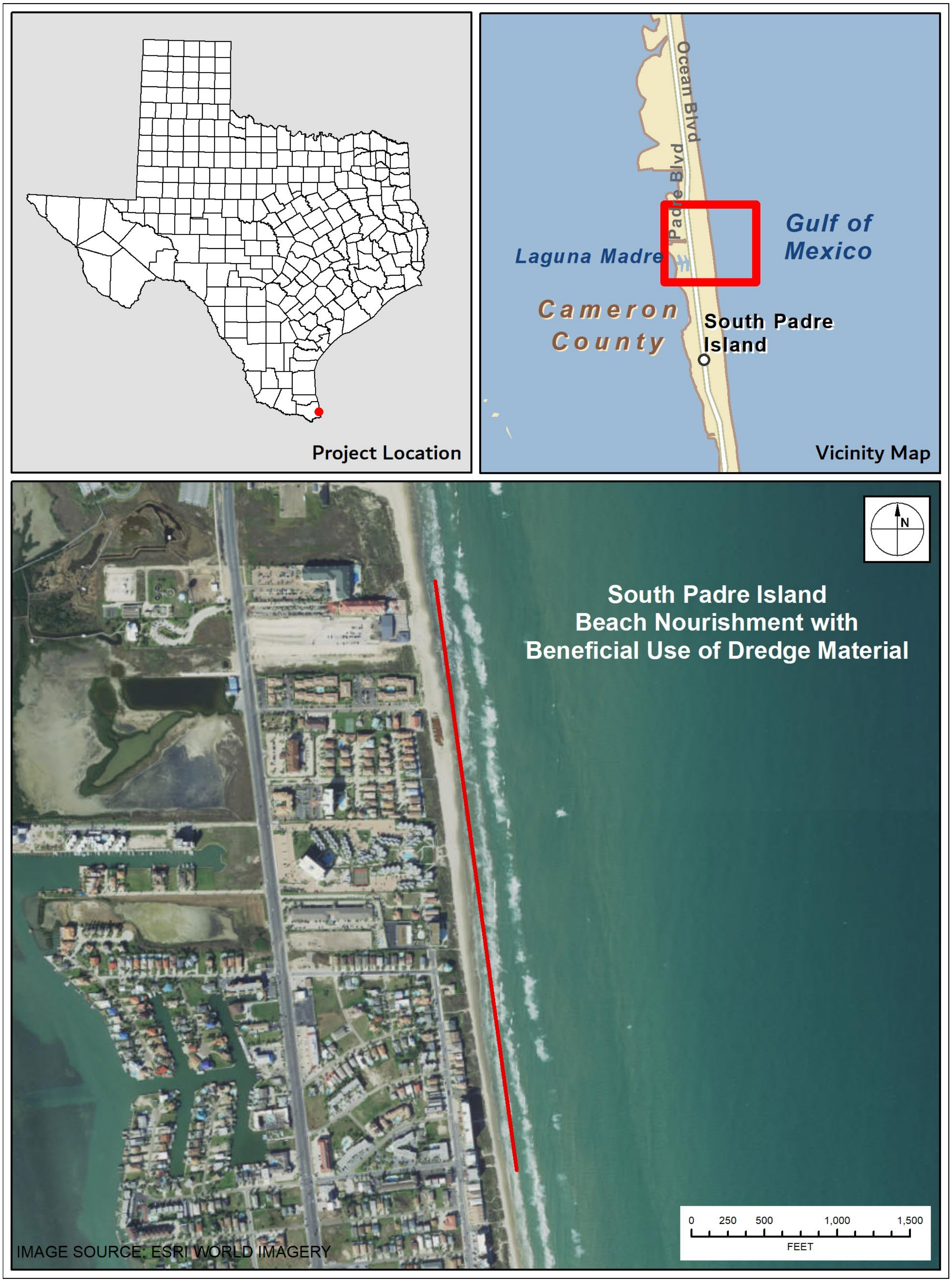

Figure 3.2.1 Location Map — Project#1574 South Padre Island Beach Nourishment with BUDM

Table 3.2.1 Funding for Project #1574 South Padre Island Nourishment with BUDM

Funding Source		Amount ($)
Federal	Coastal Impact Assistance Program (CIAP; 52% of incremental cost) *(Texas portion)*	1,334,476 *(133,447.60)*
State/Local	TX GLO, CEPRA (22% of incremental cost)	*566,540*
	City of South Padre Island (26% of incremental cost)	*679,976*
	Total Incremental Project Funding (100%)	2,580,992.00
	(Texas Total)	*1,379,963.60*

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning of 2016

3.2.3 Analysis

Taylor Engineering visited the project area on February 28, 2019, approximately two years post-construction. Site conditions included a relatively narrow beach with no evidence of remaining fill material above the waterline. Fill may exist within the project area within the nearshore; however, survey data documenting such conditions are unavailable. Figure 3.2.6 shows the project conditions during the site visit near the north end of the project. The narrow beach width is not surprising given the impacts of Hurricane Harvey during late August 2017, evident in analysis of pre- and post-Harvey aerial photographs available from Google Earth Analysis of aerial photographs. Figure 3.2.7 shows conditions in January 2016, during construction of the north end of the project area; the increased width of the nourished beach is evident. Figure 3.2.8 shows condition in December 2017, a few months post-Harvey; the extremely narrow beach, vertical dune escarpment, and reduced width of the dune field clearly indicate the significant erosion caused by the storm. Based on the above information, this analysis assumes a two-year project life for the benefits analysis (i.e., 2016–2017). Economic benefits from the beach project include federal spending, storm damage reduction, and beach visitation as discussed below.

3.2.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (CIAP) listed in Table 1.1 ($1,334,476 x .9 = $1,201,028.40) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $1,681,439.76 (i.e., $1,201,028.40 x 1.4) in 2016 prices.

Figure 3.2.2 Project #1574 Pre-Construction, June 2015 (Source: Texas GLO)

Figure 3.2.3 Project #1574 Post-Construction (Source: Texas GLO)

Figure 3.2.4 Project #1574 During Construction, December 2015 (Source: Texas GLO)

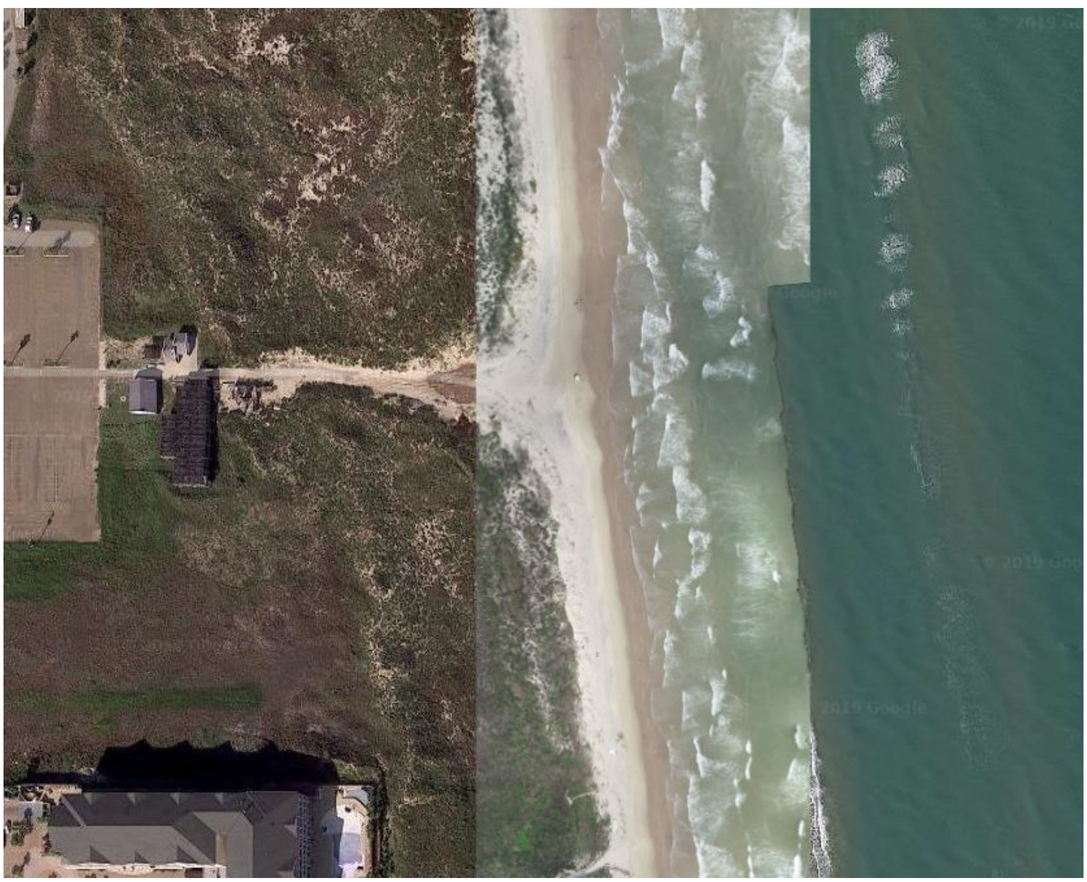

Figure 3.2.5 Project #1574 North End of Construction, 2/28/19 (Orca Circle Beach Access)

Figure 3.2.6 Project #1574 North End During Construction, January 2016 (Source: Google Earth)

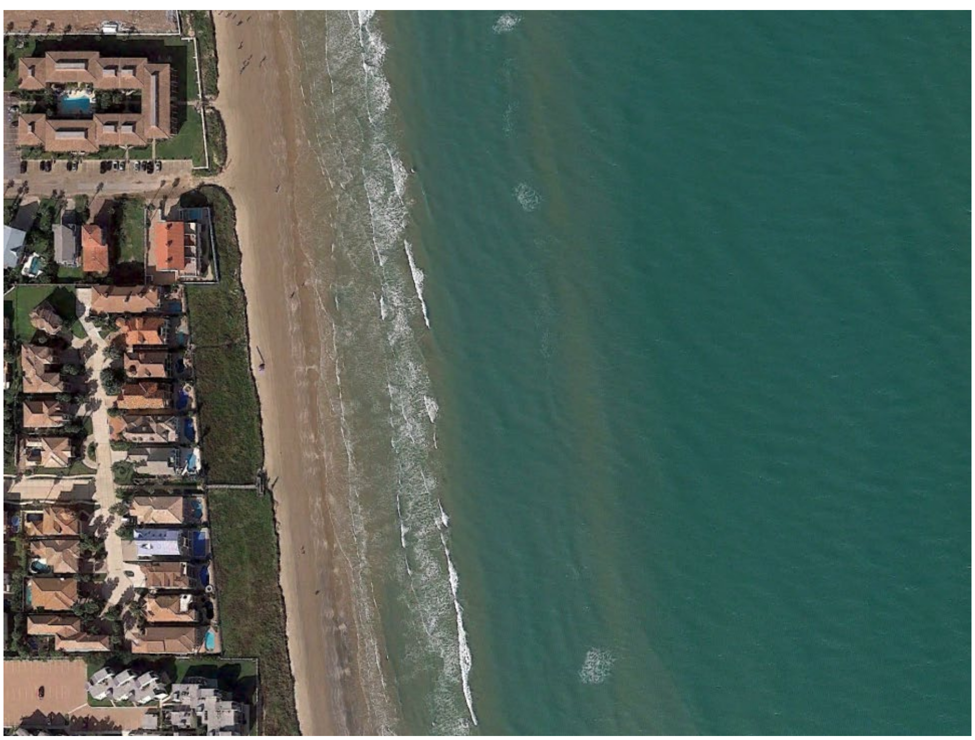

Figure 3.2.7 Project #1574 North End Post-Harvey, December 2017 (Source: Google Earth)

3.2.3.2 Storm Damage Reduction Benefits

Beach restoration and shoreline protection projects protect land, infrastructure, and structures on their landward side against both the ongoing background shoreline erosion and episodic, storm-related erosion. The prevention of land loss and damage to infrastructure and structures form the basis of storm protection benefits to upland properties. As mentioned, Hurricane Harvey caused significant beach erosion in August 2017. Analysis of aerial photographs, available from Google Earth, of South Padre Island show varying levels of storm-induced dune erosion but no damage to upland structures outside of the project area. Thus, Project #1574 did not provide storm damage protection benefits to such structures during Harvey but may have provided land loss prevention benefits. A closer look at the pre-Harvey beach widths and apparent amounts of dune erosion reveals a correlation as discussed below.

Figure 3.2.8 shows the fill placement area (the highlighted segments) as well as the December 2016 shoreline position (red line), and Figure 3.2.9 shows the shoreline position immediately south of the project area. These images show the December 2016 shoreline recedes considerably further landward over a 3,000–4,000 ft stretch of beach immediately south of the project area, indicating very narrow beach widths in this segment. Analysis of the post-Harvey aerial images indicates much greater amounts of dune erosion occurred in this eroded segment, whereas minimal dune erosion (i.e., erosion of the dune face but not the vegetated dune crest) occurred along wider beaches within the project area and further south along the island. Approximately 30–40 ft of dune erosion is apparent in Figures 3.2.10 and 3.2.11, which show pre- and post-Harvey images within the eroded segment. In contrast, Figures 3.2.6 and 3.2.7 show minimal erosion of the vegetated dune within the project area. Given the recessed 2014 and 2015 shoreline positions in the center of the project area and the width of the constructed beach (as indicated by the December 2016 shoreline position), it appears the pre-project conditions within the placement area resembled the eroded conditions to the south; thus, without project construction, the placement area likely would have experienced significant dune erosion during Hurricane Harvey.

Based on the above analysis, this study assumes the project prevented 30 ft of dune loss across the entire 4,100-ft long project area (Phase 1 and 2). Given the Cameron Central Appraisal District information, the land values within the project boundaries equal $23,758,070. Dividing the total land value by the average lot depth (265 ft) and multiplying by 30 ft yields a value of $2,689,582 for the land value protection benefit.

Figure 3.2.8 Shoreline Positions within Project Area (Source: HDR et al., 2017)

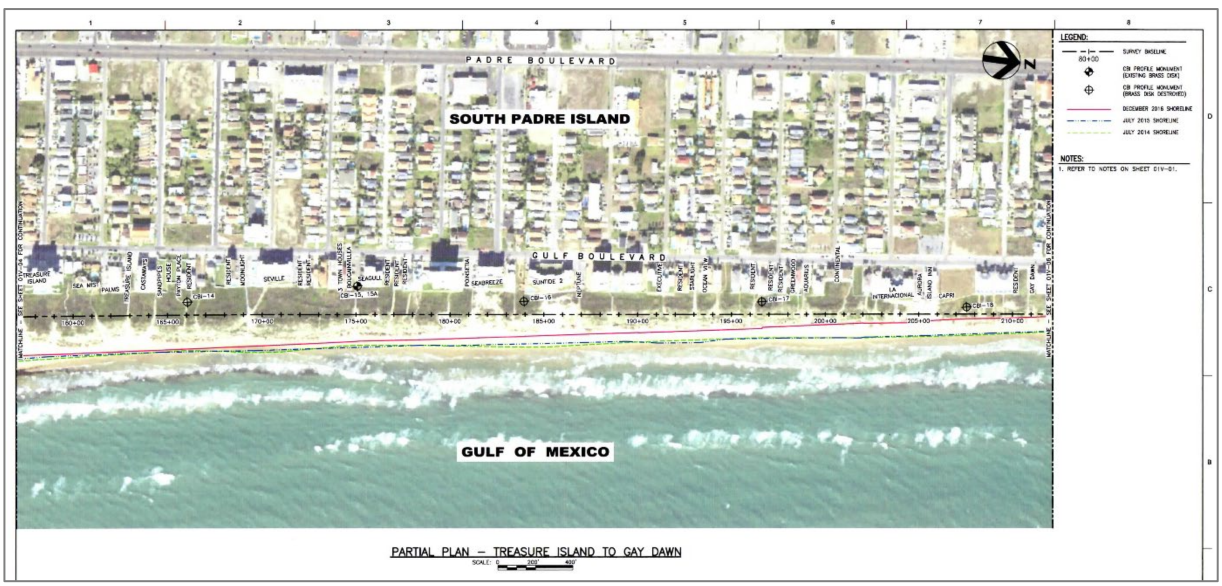

Figure 3.2.9 Shoreline Positions South of Project Area (Source: HDR et al., 2017)

Figure 3.2.10 Project #1574 South End Pre-construction, January 2016 (Source: Google Earth)

Figure 3.2.11 Project #1574 South End Post-Harvey, December 2017 (Source: Google Earth)

3.2.3.3 Beach Visitation Benefits

For beach visitation benefits, this study evaluated two categories — spending by out-of-state visitors and recreational enjoyment by all visitors. Both require estimates of the beachgoer population over the two-year period of analysis. As mentioned, the contractor constructed approximately 1,700 ft of beach during late 2015/early 2016 (Phase 1) before demobilizing. Upon remobilizing in late 2016, the contractor constructed another 2,400 ft of beach (Phase 2). This analysis assumes the benefits for Phase 1 begin at the beginning of 2016 and the benefits of Phase 2 begin at the beginning of 2017.

Taylor Engineering (2015) reports 445 visitors per 1,000 ft of shoreline at the Neptune Circle area closest to the project site. Given the 1,700-ft Phase 1 project length, the project area experiences about 756 peak day visitors. This value increases to 1512 assuming a daily turnover rate of 2. According to Oden and Butler (2005), 104 peak visitor days occur in the South Padre Island area. One-fifth (assumed) of the peak day visitors (302) visit the beach during off peak days; 261 (i.e., 365 – 104) off peak days occur during a 365-day year. Given the above visitor information, approximately 236,070 visits (157,248 [1,512 x 104] + 78,822 [302 x 261]) occurred in 2016 in the Phase 1 project area. Assuming that visitation growth follows the population growth trend of 1.4% per year, annual visitation to the Phase 1 project area in 2016 is estimated at 239,375. Applying the same calculations and assumptions to the 2,400-ft long Phase 2 project area, the project area experiences 2,136 peak (445/1000*2400*2) and 426 non-peak day visitors (445/1000*0.2*2400*2) and a total of 342,729 visitors in 2017 (222,144[2136*104]+111,186[426*261] = 333,330*1.014*1.014 = 342,729).

Increasing the beach visitation each year by the general population growth rate of 1.4% per year produced estimates of beach population for each year of the project life assuming the beach has the capability to accommodate this beach population growth. Because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches. This analysis applied the elasticity relationship (Section 2.2) to estimate the without-project beach visitation estimate, as the pre-project beach widths appear to have eroded 80% compared to the July 2015 beach widths (i.e., 20-ft wide vs 100-ft wide). Additionally, background erosion of 4.6 ft/yr was applied to the 2016 without-project beach width to determine 2017 visitation. The Phase 1 beach widths as of December 2016 (one year post construction) appear about 25% eroded as compared to the Phase 2 immediate post-construction beach widths; thus, the elasticity relationship applies to the Phase 1 visitation estimates for 2017.

This study assumes that out-of-state visitor spending per person is the same for both with- and without-project conditions. Taylor Engineering (2015) reports that 10.2% of visitors to South Padre Island are from out-of-state. Applying this value to the above annual visitation estimates yields 24,416 out-of-state visitors to Phase 1 in 2016 and 34,958 visitors to Phase 2 in 2017. Calculating the beachgoer population each year (adjusted for beach narrowing) and multiplying by the out-of-state spending times the 1.4 multiplier effect produces the value for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit over the period of analysis. Taylor Engineering (2015) reports out-of-state visitors to South Padre Island spend $100.44 per person; adjusted for inflation, the spending equals $101.75 ($100.44*1.013) and $103.88 ($100.44*1.013*1.021) per person in 2016 and 2017 prices, respectively. Table 3.2.4 summarizes the visitor spending benefit ($4,727,283, present value, beginning of 2017).

Table 3.2.2 Project #1574 Total Beach Visitation with Project

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual visitation	Annual Out-of-State Visitation
Phase 1						
2016	239,375	100	0%	0.0%	239,375	24,416
2017	242,726	75	-25%	-25.0%	182,045	18,568
Phase 2						
2017	342,729	100	0%	0.0%	342,729	34,958

Notes: Weighted population growth rate equals 1.4% (proxy for unconstrained visitation growth)
Reduction in visitor per 1% change in beach width = 1% for 0–50% beach width reduction and 0.14% for 50–100% beach width reduction
Beach widths estimated by engineering analysis of available surveys and aerial photography

Table 3.2.3 Project #1574 Total Beach Visitation without Project

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual visitation	Annual Out-of-State Visitation
Phase 1						
2016	239,375	20	-80%	-54.2%	109,634	11,183
2017	242,726	15.4	-85%	-54.8%	109,605	11,180
Phase 2						
2017	342,729	15.4	-85%	-54.8%	154,763	15,786

Notes: Weighted population growth rate equals 1.4% (proxy for unconstrained visitation growth)
Reduction in visitor per 1% change in beach width = 1% for 0–50% beach width reduction and 0.14% for 50–100% beach width reduction.
Erosion rate equals 4.6 ft/yr
2016 beach width estimated by engineering analysis of available surveys and aerial photography
Background erosion rate of4.6 ft/yr used for 2017 beach width

Table 3.2.4 Project #1456-B Out-of-State Visitor Spending Benefit

Year	Total Visitation		Out of State				Difference (Benefit)	Discounted Present Worth	Cumulative Discounted Present Worth
			Visitation		Visitor Spending Benefit				
	With Project	Without Project	With Project	Without Project	With Project	Without Project			
Phase 1									
2016	239,375	109,634	24,416	11,182	$3,477,913	$1,592,809	$1,885,104	$1,849,119	$1,849,119
2017	182,045	109,605	18,568	11,179	$2,700,443	$1,625,822	$1,074,622	$1,014,248	$2,863,367
Phase 2									
2017	342,729	154,763	34,958	15,785	$5,084,128	$2,295,697	$2,788,432	$2,631,774	$2,631,774
								Total	**$5,495,141**

Notes: Total visitation estimates are from Tables 3.1 and 3.2
Out-of-state visitation = 10.2% of total visitation
Out-of-state visitor spending based on $100.44 per person (2015 prices), price levels current during year of spending, multiplier effect of 1.4
Present Worth beginning of 2016, discount rate = 3.93% (mid-year discounting)

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers derived in 6 to the UDV developed (see Section 2.2, Table 2.2.4) for with- and without-project conditions. Table 3.2.5 represents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.2.5 (Section 2.2) results in with- and without-project UDVs of about $9.11 and $7.77 per person per visit (2019 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year in estimated 2019 prices. Converting this benefit to 2017 prices results in a UDV benefit = ($9.11 – $7.77)/ [(inflation factor 2018 to 2019) x (inflation factor 2017 to 2018)]) = ($1.34)/(1.022 x 1.022) = $1.28. Table 3.2.6 presents the recreation value benefit for this project ($3,687,457, present value, beginning of 2017).

Table 3.2.5 UDV Points Assigned to Project #1574

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	12	9	30
Availability of Opportunity	3	3	18
Carrying Capacity	8	3	14
Accessibility	15	15	18
Environmental	16	10	20
Total	54	40	**100**

Table 3.2.6 Project #1574 Recreation Benefit for All Visitors

Year	Total Visitation		Recreation Value		Difference	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
Phase 1								
2016	239,375	109,634	$2,045,337	$798,799	$1,246,538	$1,246,538	$1,222,743	$1,222,743
2017	182,045	109,605	$1,555,479	$798,593	$756,886	$772,780	$729,365	$1,952,107
Phase 2								
2017	342,729	154,763	$2,928,441	$1,127,611	$1,800,830	$1,838,648	$1,735,350	$1,735,350
Total Phase 1 + Phase 2								$3,687,457

Note: Total visitation estimates are from Table 1.9 and Table 1.10
UDV with project equals $8.54 and UDV without project equals $7.29 (2016 price levels)
Estimated increase in prices = 2.1% from 2016 to 2017
Present worth beginning of 2016, discount rate 3.93%, mid-year discounting

3.2.4 Benefit-Cost Summary

Table 3.2.7 summarizes the benefit and cost information for Project #1574. The B/C ratio equals 9.8 with a total estimated benefit of $13,553,631 and cost of $1,379,964. Cost-sharing with project #1574 and taking advantage of relatively small incremental costs (because of large federal cost share on these projects) to place dredged material on the beach appears a worthy strategy.

Table 3.2.7 Benefit-Cost Summary for Project #1574 South Padre Island Nourishment with BUDM

Benefits and Costs	Discounted Present Worth Beginning of 2016
Federal Spending Benefit	$1,681,440
Land Loss Prevention Benefit	$2,689,593
Out-of-State Visitor Spending Benefit	$5,495,141
Recreation Benefit	$3,687,457
Total Benefits	**$13,553,631**
Total Cost (Texas)	**$1,379,964**
B/C Ratio	**9.8**

Notes: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

3.3 Calhoun County — #1604 Indianola Beach Renourishment

3.3.1 Project Description and Background Information

Located on the west shores of Matagorda Bay, south of Magnolia Beach, lies historic Indianola. Founded in 1846, Indianola ranked as the second port in Texas until the devastating September 1875 Hurricane wiped out the town. The town rebuilt, only to be destroyed again in August 1886 by another Hurricane and a catastrophic fire. By 1887, the town was abandoned (Malsch, 2017). Although Indianola did not repopulate into a major port following the 1870's and 1880's Hurricanes, large vessels traveling to Port Lavaca and Port Comfort via the Matagorda Ship Channel still influence the area. The Matagorda Ship Channel lies approximately 1 mile from Indianola Beach allowing for transmission of the ship wakes to the shoreline. The wakes only exasperate the significant erosion occurring at Indianola (CBI, 2019). Figure 3.3.1 provides a location map.

Due to the severe erosion, local homeowners and Calhoun County began placing rock revetments along the Indianola shoreline. However, with the revetments threatened by scour, the County called for action stating, "since Indianola and Magnolia Beaches are historic assets to the coast and contain thousands of acres of healthy marshes, shoreline protection measures should be considered an environmental emergency project…these areas are critical habitats for environmental, natural resources, ecologic, and historic values to the State of Texas" (Moya, Mahoney, Dixon, 2012). In 2003, TX GLO acted upon the issues in Indianola, constructing a 10-structure groin field. The field can be broken into a northern and southern section, separated by an articulated revetment. Seven groins are in the north segment, and three groins are in the south segment. The area between each groin is referred to as a cell, working from north to south, cells 1 through 6 are located at the north end while cells 7 and 8 are located to the south. The original nourishment of Indianola occurred at the time of the groin field construction. Minimal development characterizes the upland area. The area consists of county campgrounds and a few residential structures.

CERPA Project #1604 nourished the southern 300 ft of cell 7 with approximately 2,453 cy of sand trucked from the Fordyce Murphy Plant located approximately 50 miles inland. Construction occurred during May–June 2017. The fill template includes a flat berm at elevation at +4.0 ft-NAVD88; beyond the berm the beach slopes at 1V:10H tying into the existing bay bottom. While the nourishment plan consisted of a base bid (cell 7) and 4 additive bids (cells 1–4), only the base bid was constructed.

3.3.2 Project Funding

Table 3.3.1 presents the funding breakdown for the project. The summation of the CEPRA and Calhoun Port Authority costs, $207,038, represent the total project costs to the State of Texas; the project did not involve federal funding. This analysis treats all costs as though they were incurred at the beginning of 2017 (i.e., the cost reflects 2017 price levels, and is a present worth equivalent value, beginning of 2017).

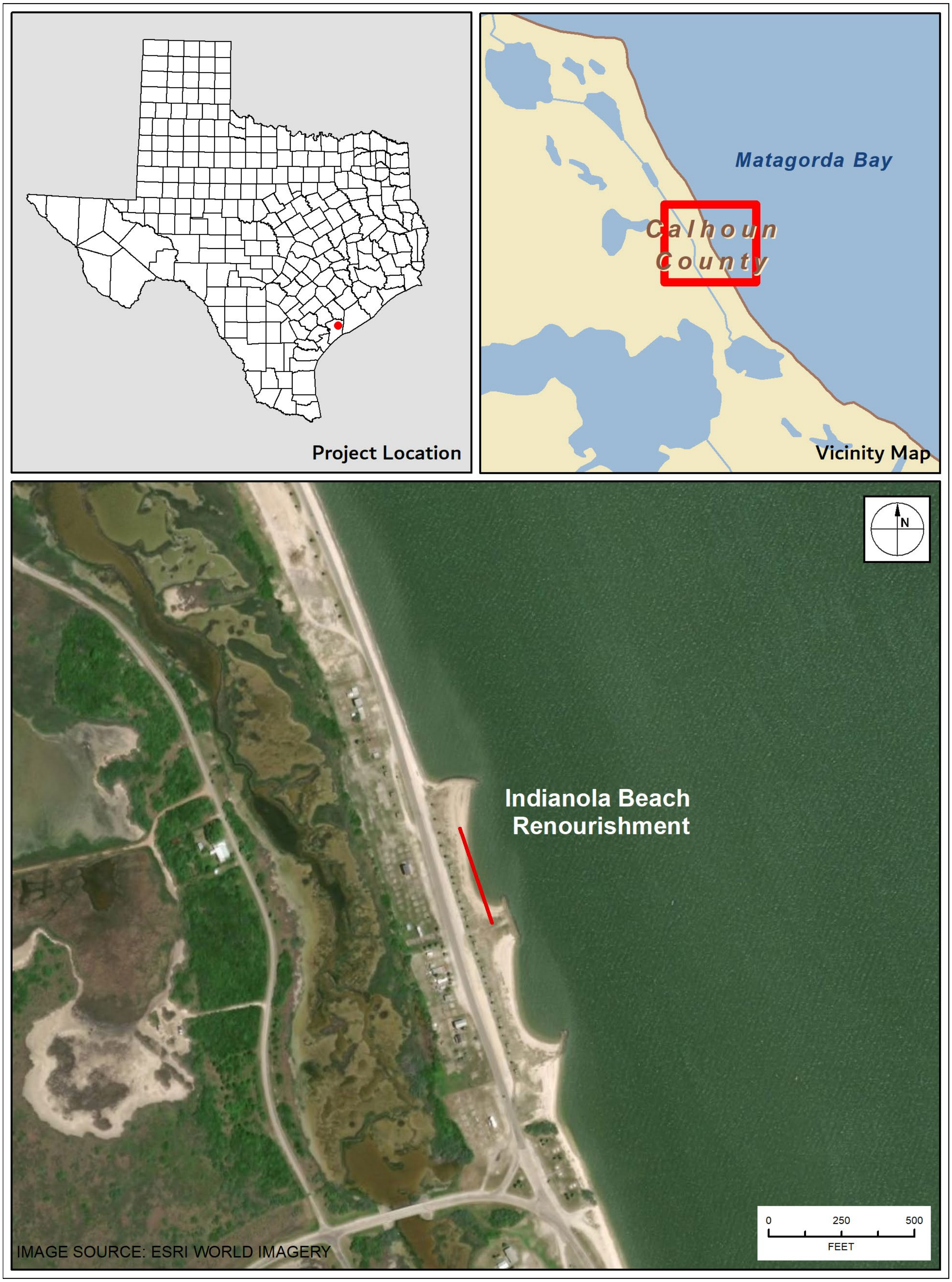

Figure 3.3.1 Location Map — Project #1604 Indianola Beach Renourishment

Table 3.3.1 Funding for Project #1604 Indianola Beach BMMP Maintenance Renourishment

Funding Source		Amount ($)
State/Local	TX GLO, CEPRA (75% of total project cost)	*155,278.74*
	QPP Calhoun Port Authority (25% of total project cost)	*51,759.58*
Total Project Funding (100%)		207,038.32
(Texas Total)		*207,038.32*

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning 2017

3.3.3 Analysis

Taylor Engineering visited the site on February 27, 2019, almost two-years post-construction. Figure 3.3.2 shows the project conditions during the site visit. The fill appears to have remained relatively stable when compared to the pre- and post-construction photograph (Figures 3.3.3 and 3.3.4). The aerial photographs collected during the site visit show a consistent beach width throughout the project area. From orthoimagery, Taylor Engineering staff measured the approximate distance from the beach pavilions to the wrack line to be 85 ft on average. Although Hurricane Harvey passed the project area in 2017, available photo-documentation does not show evidence of significant impacts. Figure 3.3.5 shows the southern extent of the project area and the northern extent of cell 8 post-Hurricane Harvey.

Economic benefits from the project include value gained from recreational enjoyment at the project site. The project also prevented additional erosion of the upland; however, the Calhoun County Property Appraiser does not assign a value to the beach property within the project area. Additionally, this analysis evaluates the benefits of Project #1604 only (i.e., a small-scale beach nourishment project of a single groin cell). The analysis does not represent the benefits of the much larger scale shoreline protection project (i.e., the original groin field and beach fill construction) and maintenance of that project as a whole that provides much greater benefits to the community and nearby habitat.

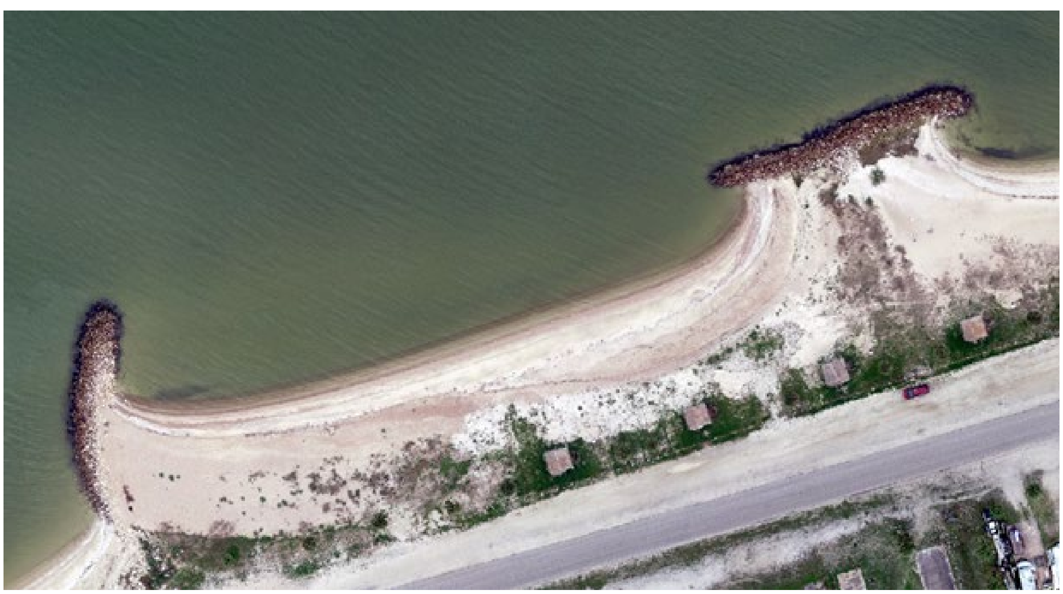

Figure 3.3.2 Project #1604 20 Months Post-construction (2/27/19)

Figure 3.3.3 Project #1604 Pre-construction Conditions

Figure 3.3.4 Project #1604 Post-construction Conditions

Figure 3.3.5 Project #1604 Conditions Post-Hurricane Harvey

3.3.3.1 Recreational Benefits

Absent site-specific beach visitation estimates, this study assumed 100 peak visitors per 1,000 ft of shoreline throughout the project area. Applying this visitation rate, the study estimates a peak visitation of 30 (100 / 1,000 * 300) within the 300-ft long project area. The project area is well known for camping and, hence, visitors spending extended periods of time as opposed to short morning or afternoon beach visits, thus the visitation estimate does not incorporate a daily turnover rate. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (6) visit the beach during off days, and 285 off peak days exist during a 365-day year (i.e., 365 – 80). Given this information, approximately 4,110 (30 * 80 + 6 * 285) visits occur to the project area in 2017. With the lack of commercial development and recreational amenities that typically attract out-of-state visitors, this study did not include out-of-state visitor spending as a benefit for this project.

To estimate the effect of beach width "elasticity" (Section 2.2), this analysis reduced the beach width to account for background erosion over the 7-year project life (beginning in 2017). Published erosion rates range from 5 to 7 ft/yr (CBI, 2019). From analysis of historical aerial photographs, pre- and post-construction survey data, and the conditions observed during the 2019 site visit, this study found the beach/dune system widths measured approximately 60 ft wide before construction, 100 ft wide after construction, and 85 ft wide in 2019; these measurements approximate the distance from the wrack line to the seaward edge of the pavilions. Based on this information, the 2017–2019 erosion occurred at the high end of the published values. This result is not unexpected, as beach fills typically experience higher erosion rates from equilibration that diminish with time. Additionally, though the effects of Hurricane Harvey appear minor from analysis of photographs, the storm may have contributed to the high erosion rate. This analysis assumes erosion of 5 ft/yr (i.e., at the lower end of published values) will occur during 2019 and beyond. Based on 2019 conditions, the 5 ft/yr rate will erode the remainder of the beach fill in 5 years (2019–2023). Thus, the total project life for benefits analysis is 7 years (2017–2023).

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV analysis developed (see Section 2.2, Table 2.2.4) for with- and without-project conditions. Table 1.4 presents a summary of the points assigned for with- and without-project conditions in the Indianola Beach project area. This assignment of points reflects the incremental improvement afforded by the wider re-nourished beach. Converting the points to dollar values with the help of Table 2.2.5 (Section 2.2) results in with- and without-project UDVs of about $7.15 and $6.06 per person per visit (2019 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year in estimated 2019 prices. Converting this benefit to 2017 prices results in a UDV benefit = ($7.15 – $6.06)/ [(inflation factor 2018 to 2019) x (inflation factor 2017 to 2018)]) = ($1.09)/(1.022 x 1.022) = $1.04. Table 1.5 presents the recreation value benefit for this project ($81,242 present value, beginning of 2017).

Table 3.3.2 Annual Visitation with Project #1604

Year	Unconstrained Annual Visitation	Beach Width	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2017	4,110	100	0%	0.0%	4,110
2018	4,168	90	-10%	-10.0%	3,751
2019	4,225	85	-15%	-15.0%	3,591
2020	4,284	80.0	-20%	-20.0%	3,427
2021	4,343	75.0	-25%	-25.0%	3,257
2022	4,403	70.0	-30%	-30.0%	3,082
2023	4,464	65.0	-35%	-35.0%	2,902

Notes: Estimated at mid-year.
Background erosion, -5 ft/yr from 2019–2023.
Starting daily peak visitation, 4,110
Weighted annual population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.3.3 Annual Visitation without Project #1604

Year	Unconstrained Annual Visitation	Beach Width	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2017	2,466	60.0	0%	0%	2,466
2018	2,500	55.0	-8%	-8.3%	2,292
2019	2,535	50.0	-17%	-16.7%	2,113
2020	2,570	45.0	-25%	-25.0%	1,928
2021	2,605	40.0	-33%	-33.3%	1,737
2022	2,641	35.0	-42%	-41.7%	1,541
2023	2,677	30.0	-50%	-50.0%	1,339

Notes: Estimated at mid-year.
Background erosion, -5 ft/yr from 2019–2023.
Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.3.4 UDV Points Assigned to Project #1604

Criteria	Points Assigned (with Project)	Points Assigned (without Project)	Total Possible Points
Recreation Experience	10	8	30
Availability of Opportunity	5	5	18
Carrying Capacity	6	3	14
Accessibility	7	6	18
Environmental	8	6	20
Total	36	28	100

Table 3.3.5 Project #1604 Recreation Benefit for All Visitors

Year	Total Visitation		Recreation Value (2017 Prices)		Difference (2017 Prices)	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2017	4,110	2,466	$28,112	$14,303	$13,810	$13,810	$13,546	$13,546
2018	3,751	2,292	$25,655	$13,292	$12,364	$12,636	$11,926	$25,472
2019	3,591	2,113	$24,564	$12,253	$12,312	$12,859	$11,678	$37,150
2020	3,427	1,928	$23,442	$11,180	$12,263	$13,064	$11,415	$48,565
2021	3,257	1,737	$22,280	$10,073	$12,207	$13,265	$11,153	$59,718
2022	3,082	1,541	$21,082	$8,935	$12,146	$13,463	$10,891	$70,609
2023	2,902	1,339	$19,847	$7,763	$12,084	$13,662	$10,634	$81,242

Notes: Total visitation estimates derive from Table 1.2 and Table 1.3.
With-project, UDV dollar value (2017 Prices) = $6.84
Without-project, UDV dollar value (2017 Prices) = $5.80
Multiplier effect = 1.4
Inflation rates: 2.1% (2017), 2.2% (2018 and 2019), 2.0% 2020 and beyond.
Present worth beginning of 2017, 3.93% discount rate, mid-year discounting

3.3.4 Benefit-Cost Summary

Table 3.3.6 summarizes the project benefits and costs. With benefits equating to $81,242 and costs totaling $207,038, this project has a 0.4 benefit/cost ratio.

Table 3.3.6 Benefit-Cost Summary for Project #1605 Indianola Beach Renourishment

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Recreational Benefit	$81,242
Total Benefits	**$81,242**
Total Cost (Texas)	**$207,038**
B/C Ratio	**0.4**

Note: Dollar values reflect present worth equivalents at the beginning of 2017 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2017 (discount factor = 1).
Benefits include mid-year discounting.

3.4 Galveston County — #1610 Bolivar Beach Restoration Leveraging CIAP

3.4.1 Project Description and Background Information

CEPRA Project #1610, constructed from October–December 2016, included beach and dune restoration along Caplen Beach, located west of Rollover Pass, at the eastern end of the Bolivar Peninsula in Galveston County. This project is part of a long-term effort involving other CEPRA projects to manage the severe erosion problems affecting the Bolivar Peninsula, particularly the erosion caused by Rollover Pass, a man-made inlet that links the Gulf of Mexico with Rollover Bay and East Bay. Chronic long-term erosion, storm-related episodic erosion, and low-density upland development characterize the project area. Figure 3.4.1 provides a location map.

Project #1610 included approximately 2,200 ft of dune restoration and 5,400 ft of beach restoration along a 6,500-ft stretch of Caplen Beach. The dune restoration project area extended from approximately 1,400 ft to 4,350 ft west of Rollover Pass; along this 2,950-ft stretch of beach, three sections of dune totaling 2,200 ft in length were restored. The dune restoration included fill placement, sand fence construction (Figure 3.4.2), and dune plantings (Figure 3.4.3). The beach restoration component included a continuous section extending from 2,500 ft to 7,900 ft west of the Pass. In total, the project placed 105,000 cy trucked from a nearby upland sand source (Figure 3.4.4). Figures 3.4.5 and 3.4.6 show the beach fill during construction and after project completion.

3.4.2 Project Funding

Table 3.4.1 presents the funding breakdown for the project. The Coastal Impact Assistance Program (CIAP) contributed federal funds to the construction of the project through grants awarded to Galveston County, and the GLO covered the remaining non-federal costs. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $3,752,000 CIAP cost is $375,200. The resulting cost to Texas for Project #1610 amounts to $2,375,200; this value equals the sum of the CEPRA ($2,000,000) and 10% state share of federal costs ($375,200). This analysis treats all costs as though they were incurred at the end of 2016 (i.e., beginning of 2017), which is when construction took place. For purposes of this evaluation we are treating these costs as reflecting 2017 prices.

Table 3.4.1 Funding for Project #1610 Bolivar Beach Restoration Leveraging CIAP

<table>
<tr><th colspan="2">Funding Source</th><th>Amount ($)</th></tr>
<tr><td>Federal</td><td>Coastal Impact Assistance Program (CIAP)
(Texas portion)</td><td>3,752,000
(375,200)</td></tr>
<tr><td>State/Local</td><td>TX GLO, CEPRA</td><td>*2,000,000*</td></tr>
<tr><td colspan="2">Total Project Funding (100%)</td><td>5,752,000</td></tr>
<tr><td colspan="2">*(Texas Total)*</td><td>*2,375,200*</td></tr>
</table>

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning of 2017

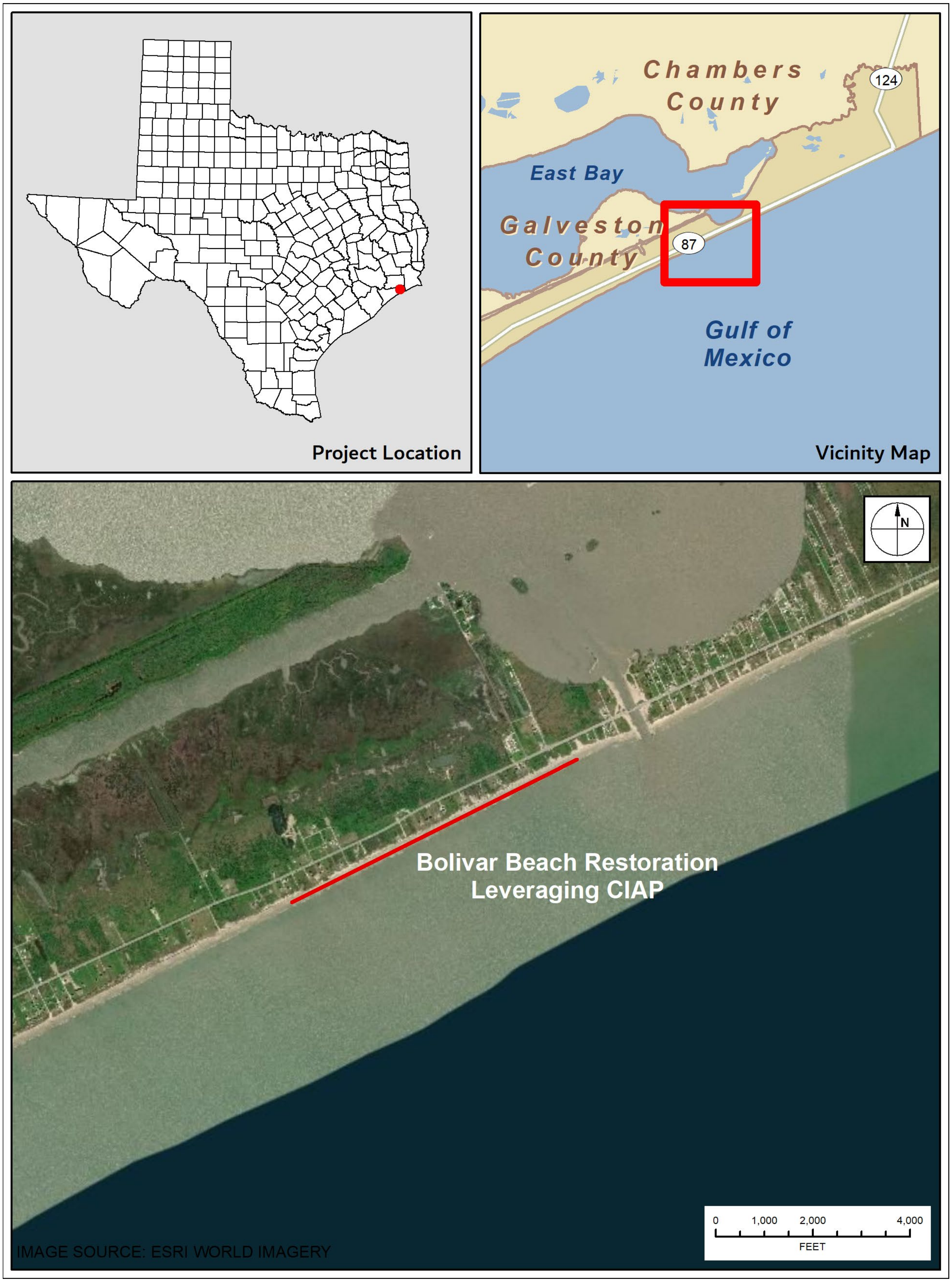

Figure 3.4.1 Location Map — Project #1610 Bolivar Beach Restoration Leveraging CIAP

3.4.3 Analysis

Taylor Engineering visited the site on February 25, 2019, roughly two years post-construction (Figure 3.4.7, 3.4.8, and 3.4.9). Hurricane Harvey impacted the Texas coast during August 2017. The impacts were evident during the site visit, as only minor remnants of the dune restoration were observed. Figures 3.4.10 and 3.4.11 contain post-construction (February 2018) and post-Harvey (January 2018) aerial photographs that show the erosion effects presumably from Hurricane Harvey. Given the apparent effects from the storm, this study adopts a one-year project life. Economic benefits from Project #1610 include federal spending, land loss prevention, and recreational benefits.

3.4.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (CIAP) listed in Table 3.4.1 ($3,752,000 x 0.9 = $3,376,800) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $4,727,520 (i.e., $3,376,800 x 1.4) in 2017 prices.

Figure 3.4.2 Project #1610 Dune Fencing, January 20, 2017

Figure 3.4.3 Project #1610 Dune Plantings, January 20, 2017

Figure 3.4.4 Project #1610 Sand Source, February 2017 (Source: Google Earth)

Figure 3.4.5 Project #1610 During Construction, November 2017 (Source: GLO)

Figure 3.4.6 Project #1610 Post-Construction, December 2016 (Source: GLO)

Figure 3.4.7 Current Project Area Conditions at Beach Access G2, February 25, 2019

Figure 3.4.8 Current Project Area Conditions at Beach Access G5, February 25, 2019

Figure 3.4.9 Current Project Area Conditions at Beach Access G9, February 25, 2019

Figure 3.4.10 Project #1610 Post-Construction, February 2017 (Source: Google Earth)

Figure 3.4.11 Project #1610 Post-Construction, January 2018 (Source: Google Earth)

3.4.3.2 Land Value Protection Benefits

The project may have provided storm damage reduction benefits during Hurricane Harvey; however, lack of pre- and post-storm data in the project vicinity prohibits calculation of such benefits. In lieu of storm damage reduction, this analysis—similar to the current and past analyses for placement of GIWW maintenance dredging materials on Caplen Beach—assumes the project offset the background erosion during this period and thus preserved land values. Given the 2017 Galveston Central Appraisal District information, the land values within the project boundaries equal $5,547,314. Dividing the total land value by the average lot depth (300 ft) and multiplying by the background erosion (5.7 ft per UTBEG) yields a value of $105,399 for the land value protection benefit. Using a mid-year present worth factor, the present worth equivalent = $103,387, as outlined in Table 3.4.2.

Table 3.4.2 Project #1610 Land Value Protection Benefits

Year	Property Values (Land only)	Project Benefit	Discounted Present Worth Benefit (Beginning of 2017)
2017	$2,285,630	$105,399	$103,387

Note: Discount rate is equal to 3.93%
Discounted present worth benefit using mid-year present worth factor
$= 1/(1+.0393)^{.5}$ x $105,399 = $103,387
Average lot depth equals 300 ft per Galveston County property appraisal site
Average background erosion equals 5.7 ft/yr per UTBEG (5.7 x $5,547,314/300 = $105,399)

3.4.3.1 Recreational Benefits

Based on July 2004 observations, Oden and Butler report about 90 peak day visitors to Rollover Pass. Given that Taylor Engineering's 2015 survey does not cover the Caplen Beach area, the Oden and Butler beach visitation estimate remains the most accurate available count. Assuming an average daily turnover rate of 2, the daily visitation estimate increases to 180. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (36) visit the beach during off peak days and 285 (i.e., 365 – 80) off peak days exist during a 365-day year. Given the above visitor information, the estimated number of beach visits occurring in 2004 was approximately 24,660 visits ([180 * 80] + [36 * 285] = 24,660). Increasing this number to a 2017 (i.e., the project base year) value by the rate of general population growth (1.4%), as discussed in Section 2.1, yields 29,545 (i.e., 24,660 * 1.014^{13}). Because of the modest levels of beach use, no overcrowding occurs with or without project (the number of visitors is the same).

Based on 2015 beachgoer surveys, Taylor Engineering (2015) report that out-of-state visitors concentrate in areas with access to transportation, lodging, and other touristic amenities, such as the city of Galveston. The survey did not identify any out-of-state visitors to locations such as Jamaica Beach and Surfside Beach, though budget constraints and adverse weather during implementation of the survey limited the survey duration (i.e., one holiday weekend Saturday). Given the lack of commercial development and recreational amenities, this study did not include out-of-state visitor spending as a benefit for this project.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV analysis developed (see Section 2.2, Table 2.2.4) for with- and without-project conditions. Table 3.4.3 presents a summary of the points assigned for with- and without-project conditions in the project area. This assignment of points reflects the incremental improvement afforded by the wider re-nourished beach and dune enhancements. Converting the points to dollar values with the help of Table 2.2.5 (Section 2.2) results in with- and without-project UDVs of about $6.83 and $5.59 per person per visit (2019 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year in estimated 2019 prices. Converting this benefit to 2017 prices results in a UDV benefit = ($6.83 – $5.59)/ [(inflation factor 2017 to 2019) x (inflation factor 2017 to 2018)]) = ($1.24)/(1.022 x 1.022) = $1.19. Table 3.4.4 presents the recreation value benefit for this project ($34,489 present value, beginning of 2017).

Table 3.4.3 UDV Points Assigned to Project #1610

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	8	6	30
Availability of Opportunity	3	3	18
Carrying Capacity	6	2	14
Accessibility	7	6	18
Environmental	10	5	20
Total	**34**	**22**	**100**

Table 3.4.4 Project #1610 Recreational Benefit for All Users

Year	Total Visitation		Recreation Value		Present Worth (Difference; 2017 Prices)	Discounted Present Worth (Beginning of 2017)
	With Project	Without Project	With Project	Without Project		
2017	29,545	29,545	$193,224	$158,066	$35,158	$34,489

Notes: UDV (with project) equals $6.83 (2019 price levels)/(1.022 x 1.022) = $6.54 (2017 price levels)
UDV (without project) equals $5.59 (2019 price levels)/(1.022 x 1.022) = $5.35 (2017 price levels)
Present worth, beginning of 2017, mid-year discounting, 3.93% discount rate
Discounted present worth = Difference / $1.0393^{(0.5)}$

3.4.4 Benefit-Cost Summary

With total benefits of $4,865,396 and a total project cost of $2,375,200, the resulting B/C ratio for project #1610 equals 2.0. Table 3.4.5 summarizes the results.

Table 3.4.5 Benefit-Cost Summary for Project #1610 Bolivar Beach Restoration Leveraging CIAP

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Federal Spending Benefit	$4,727,520
Prevention of Land Loss Benefit	$103,387
Recreation Benefits	$34,489
Total Benefits	**$4,865,396**
Total Cost (Texas)	**$2,375,200**
B/C Ratio	**2.0**

Note: Dollar values reflect present worth equivalents at the beginning of 2017 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2017 (discount factor = 1).
Benefits include mid-year discounting.

3.5 Galveston County — #1619 GIWW Rollover Bay Reach Beach Nourishment with BUDM

3.5.1 Project Description and Background Information

Rollover Pass, a man-made inlet at the eastern end of the Bolivar Peninsula in Galveston County, links the Gulf of Mexico with Rollover Bay and East Bay. Chronic long-term erosion, storm-related episodic erosion, and low-density upland development characterize the beaches near the Pass. During February 2017 the GLO, in cooperation with USACE and Galveston County, nourished Caplen Beach, west of the Pass, with beach-quality material dredged from the Gulf Intracoastal Waterway Rollover Bay segment. This project is part of a long-term effort involving other CEPRA projects to manage the severe erosion problems affecting the Bolivar Peninsula, particularly the erosion caused by Rollover Pass.

The 2017 project placed approximately 136,000 cy of sand along approximately 3,000 ft of shoreline (Figure 3.5.1), beginning about 1,000 ft west of the edge of the pass. This placement widened the dry beach by roughly 48 ft on average (per comparison of pre- and post-construction aerial images of the project site). Figure 3.5.2 represents post-construction conditions. Based on information obtained from UTBEG (University of Teas Bureau of Economic Geology), the study area's shoreline erodes about 5.7 ft/year. Upland development in the project area, generally comprised of elevated single-family homes, lies a fair distance from the shoreline. Based on the maximum predicted erosive shoreline condition, this analysis includes the first row of Gulf front properties and lots.

3.5.2 Project Funding

Table 3.5.1 presents the funding breakdown for the project. The USACE cost represents the federal cost to dredge the Gulf Intracoastal Waterway (GIWW) and place the material in a Dredge Material Placement Area (DMPA). The state and county costs represent the total incremental cost of placing the dredged material on the beach as opposed to a DMPA. This analysis uses the summation of the CEPRA and Galveston County costs, $171,659, as the total project cost; it excludes the federal cost, because USACE's maintenance dredging of the GIWW would still occur without CEPRA's support for the nourishment project. This analysis treats all costs as though they were incurred at the beginning of 2017 (i.e., the cost reflects 2017 price levels and is a present worth equivalent value, beginning of 2017).

Table 3.5.1 Funding for Project #1619 GIWW Rollover Bay Reach Beach Nourishment with BUDM

Funding Source		Amount ($)
Federal	U.S. Army Corps of Engineers (In-kind dredging contribution, 96% of total project costs)	4,700,000
State/Local	Texas General Land Office, CEPRA (75 % cost-share of incremental cost)	*128,744*
	Galveston County (25% cost-share of incremental cost)	*42,915*
Total Project Cost **(*Texas Total*)**		4,871,659 *171,659*

Notes: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2017

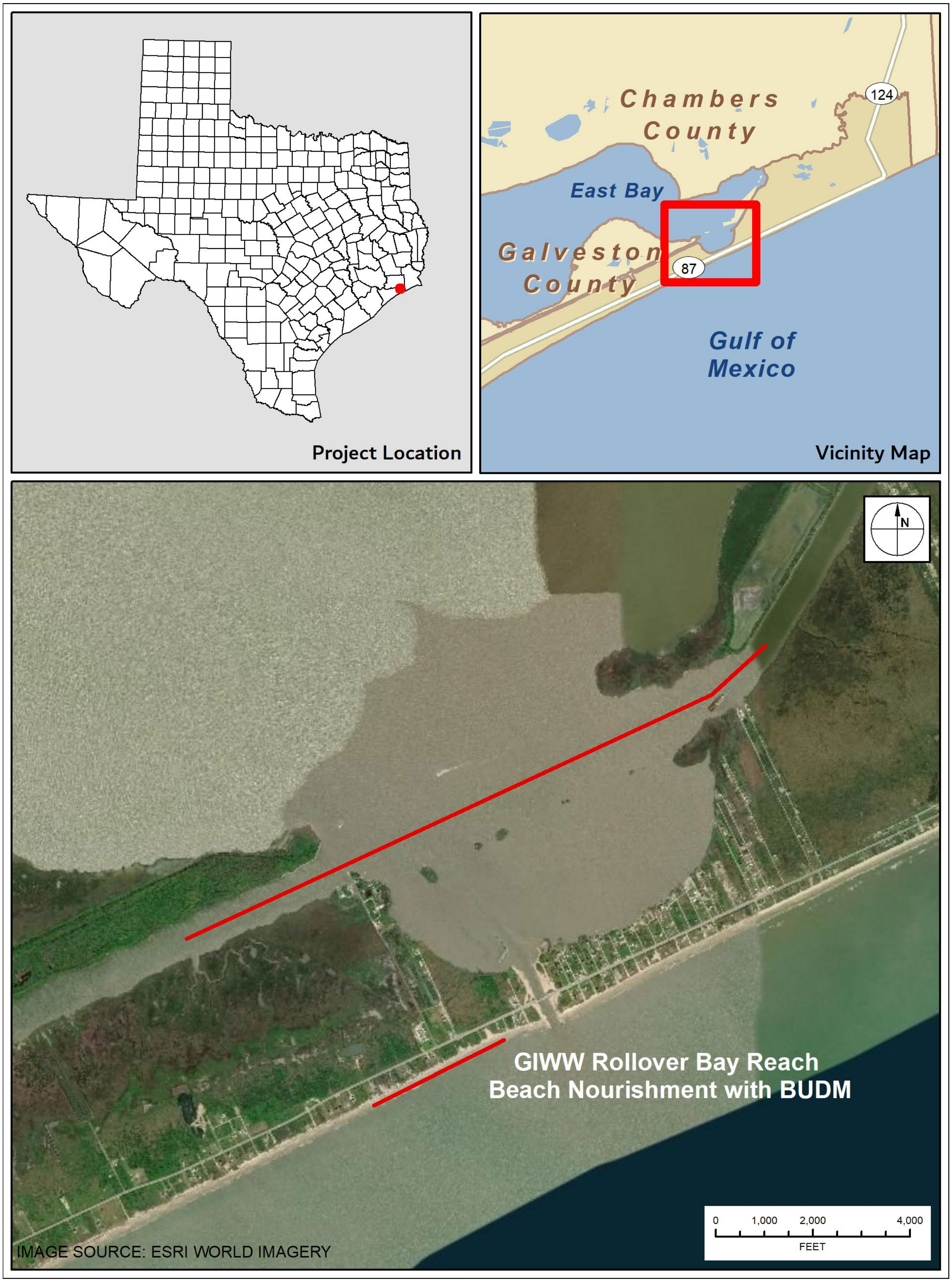

Figure 3.5.1 Location Map-Project #1619 GIWW Rollover Bay Reach Beach Nourishment with BUDM

3.5.3 Analysis

Taylor Engineering visited the site on January 20, 2017 near the time of construction and on February 25, 2019 approximately two-years post-construction. The latter visit, however, occurred after the 2018 beach nourishment with BUDM event and, thus, did not allow for observations of the 2017 project performance. Based on performance of the prior projects (Taylor Engineering, 2013 and Taylor Engineering, 2017), this study assumes that no significant amount of beach fill remained on the dry beach prior to the 2018 project and, thus, adopts a one-year project life for the 2017 project. With the short project length, rapid erosion of the beach fill is expected. Fill material may remain offshore, but lack of data prohibits verification of this. Figure 3.5.2 shows the recent condition at Rollover Reach Beach at the February 25, 2019 site visit conducted by Taylor Engineering. Figures 3.5.3 and 3.5.4 show conditions during the January 20, 2017 site visit. Figures 3.5.5 and 3.5.6 show aerial imagery (obtained from Google Earth) from February 2017 and January 2018.

Figure 3.5.2 Westward View towards Project #1619 Placement Area, February 25, 2019

Figure 3.5.3 Project #1619 Conditions near East End of Project Area, January 20, 2017

Figure 3.5.4 Project #1619 Conditions near West End of Project Area, January 20, 2017

Figure 3.5.5 Project #1619 Aerial Imagery, February 2017 (Source: Google Earth)

Figure 3.5.6 Project #1619 Aerial Imagery, January 2018 (Source: Google Earth)

Economic benefits from the CEPRA #1619 GIWW Rollover Bay Reach with BUDM include land value protection offered from the beach widening as well as value gained from recreational enjoyment at the project site. Though Hurricane Harvey made landfall in Texas during August 2017, this analysis assumes storm damage protection did not occur, because beach erosion in the project area was reportedly relatively minor and much of the fill would likely have been eroded by that time.

3.5.3.1 Land Value Protection Benefits

Though the project did not provide storm damage reduction benefits, the project did offset the background erosion during this period and thus preserved land values. Given the 2017 Galveston Central Appraisal District information, the land values within the project boundaries equal $2,285,630.

Dividing the total land value by the average lot depth (300 ft) and multiplying by the background erosion (5.7 ft per UTBEG) yields a value of $43,427 for the land value protection benefit. Using a mid-year present worth factor, the present worth equivalent = $42,598, as outlined in Table 3.5.2.

Table 3.5.2 Project #1619 Land Value Protection Benefits

Year	Property Values (Land only)	Project Benefit	Discounted Present Worth Benefit (Beginning of 2017)
2017	$2,285,630	$43,427	$42,598

Note: Discount rate is equal to 3.93%

Discounted present worth benefit using mid-year present worth factor = $1/(1+.0393)^{.5}$ x $43,427 = $42,598

Average lot depth equals 300 ft per Galveston County property appraisal site

Average background erosion equals 5.7 ft/yr per UTBEG (5.7/300 x $2,285,630 = $43,427)

3.5.3.2 Recreational Benefits

Based on July 2004 observations, Oden and Butler report about 90 peak day visitors to Rollover Pass. Given that Taylor Engineering's 2015 survey does not cover the Rollover Pass area, this evaluation uses the Oden and Butler beach visitation estimate. Assuming an average daily turnover rate of 2, the daily visitation estimate is 180. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (36) visit the beach during off-peak days and 285 (i.e., 365 – 80) off-peak days exist during a 365-day year. Given this visitor information, the estimated number of beach visits occurring in 2004 was approximately 24,660 visits ([180 * 80] + [36 * 285] = 24,660). Increasing this number to a 2017 (i.e., the project base year) value by the rate of general population growth (1.4%), as discussed in Section 2.1, yields 29,545 annual visitors (i.e., 24,660 * 1.014^{13}). Because of the modest levels of beach use, no overcrowding occurs with or without project (the number of visitors is the same).

Based on 2015 beachgoer surveys, Taylor Engineering (2015) reports that out-of-state visitors concentrate in areas with access to transportation, lodging, and other touristic amenities, such as the city of Galveston. The survey did not identify any out-of-state visitors to locations such as Jamaica Beach and Surfside Beach, though budget constraints and adverse weather during implementation of the survey limited the survey duration (i.e., one holiday weekend Saturday). Given the lack of commercial development and recreational amenities, this study did not include out-of-state visitor spending as a benefit for this project.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV analysis developed (see Section 2.2, Table 2.2.4) for with- and without-project conditions. Table 3.5.3 presents a summary of the points assigned for with- and without-project conditions in the Rollover Bay Reach Beach project area. This assignment of points reflects the incremental improvement afforded by the wider re-nourished beach. Converting the points to dollar values with the help of Table 2.2.5 (Section 2.2) results in with- and without-project UDVs of about $6.21 and $5.59 per person per visit (2019 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year in estimated 2019 prices. Converting this benefit to 2017 prices results in a UDV benefit = ($6.21 – $5.59)/ [(inflation factor 2018 to 2019) x (inflation factor 2017 to 2018)]) = ($0.62)/(1.022 x 1.022) = $0.59. Table 3.5.4 presents the recreation value benefit for this project ($17,389 present value, beginning of 2017).

Table 3.5.3 UDV Points Assigned to Project #1619

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	8	6	30
Availability of Opportunity	3	3	18
Carrying Capacity	5	2	14
Accessibility	7	6	18
Environmental	7	5	20
Total	30	22	100

Table 3.5.4 Project #1619 Recreational Benefit for All Users

Year	Total Visitation		Recreation Value		Present Worth (Difference; 2017 Prices)	Discounted Present Worth (Beginning of 2017)
	With Project	Without Project	With Project	Without Project		
2017	29,545	29,545	$175,793	$158,066	$17,727	$17,389

Notes: UDV (with project) equals $6.21 (2019 price levels)/(1.022 x 1.022) = $5.95 (2017 price levels)
UDV (without project) equals $5.59 (2019 price levels)/(1.022 x 1.022) = $5.35 (2017 price levels)
Present worth, beginning of 2017, mid-year discounting, 3.93% discount rate
Discounted present worth = Difference / $1.0393^{(0.5)}$

3.5.4 Benefit-Cost Summary

Because of the limited visitation and inexpensive land values in the project area, the total project benefits ($59,987) are relatively low as presented in Table 3.5.5. With project costs totaling $171,659, this project has a 0.3 benefit/cost ratio. Although the benefit/cost ratio is low, the project represents a very low-cost alternative (with a unit cost to Texas of $1.26 per cubic yard of beach fill) for mitigating Rollover Pass' erosive effects on Caplen Beach.

Table 3.5.5 Benefit-Cost Summary for Project #1619 GIWW Rollover Bay Reach Beach Nourishment

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Prevention of Land Loss Benefit	$42,598
Recreation Benefit	$17,389
Total Benefits	**$59,987**
Total Cost (Texas)	**$171,659**
B/C Ratio	**0.3**

Note: Dollar values reflect present worth equivalents at the beginning of 2017 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2017 (discount factor = 1).
Benefits include mid-year discounting

4.0 NATURAL RESOURCE RESTORATION BENEFIT ANALYSIS

4.1 Brazoria County — #1529 Follet's Island Habitat Restoration (unofficially County Road 257 Dune Restoration)

4.1.1 Project Description and Background Information

As part of the CEPRA Cycle 7 and 8 projects, the Texas General Land Office partnered with Brazoria County to restore 2.7 miles of beach dune system along the 4.7-mile stretch of Follet's Island beginning about 1.5 miles southwest of San Luis Pass. The beaches and dune systems on Follet's island experience a high rate of background erosion and were also severely impacted by Hurricane Ike in 2008. Follet's Island has experienced erosion rates up to 20 ft/year in certain areas. Paine et al. (2013) estimated an average erosion rate of 6.89 ft/year from 2010 - 2012 aerial photographs. The beach/dune system has historically served as a shoreline protection barrier for CR257, an important hurricane evacuation route. CR257 is Brazoria County's only access route to Follet's Island and Treasure Island, is the only emergency evacuation route for Follet's Island and is one of only two evacuation routes for Galveston Island. Along the project site, the distance from the beach to CR257 averages about 250 ft.

Project #1529, constructed from October 2016–March 2017, placed 52,725 tons of dune core fill and 62,436 tons of cover fill, planted 17,116 linear feet of dune vegetation, and installed five permanent CIAP project signs. The typical vegetation section included bitter panicum (Panicum amarum), sea oats (Uniola paniculate), and/or marshhay cordgrass (Spartina patens) with spacing typically 18 to 26 inches apart. In order to optimize the use of project funds while focusing efforts on the restoration of critical dune areas, the GLO identified four sections of Follet's island based on beach widths, shoreline erosion rates, and the Brazoria County Erosion Response Plan (ERP) dune priority levels. Area One is the southern-most investigation area about seven miles north of the Village of Surfside Beach. This section is 5,700 ft long with beach width ranging from 380 ft to 430 ft prior to construction. Area Two, located 1,000 ft north of Area One, is 3,000 ft long with pre-construction beach width ranging from 290 to 430 ft. Area Three is located north of the previous focus area by 1800 ft and consists of two sections 1,200 ft and 2,400 ft long. Beach widths in this section range from 200 ft to 430 ft. Area Four, located approximately 1.2 miles north of Area Three, is 2,500 ft long with beach width ranging from 340 to 410 ft. Figure 4.1.1 provides a location map.

4.1.2 Project Funding

Table 4.1.1 presents the funding breakdown for the project. The Coastal Impact Assistance Program (CIAP) contributed federal funds to the construction of the project through grants awarded to Galveston County and State of Texas, and the GLO covered the remaining non-federal costs. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the combined $2,141,371 CIAP cost is $214,137. The resulting cost to Texas for Project #1610 amounts to $1,907,520; this value equals the sum of the CEPRA ($1,693,383) and 10% state share of federal costs ($214,137). This analysis treats all costs as though they were incurred at the beginning of 2017 (i.e., the cost reflects 2017 price levels, and is a present worth equivalent value, beginning of 2017).

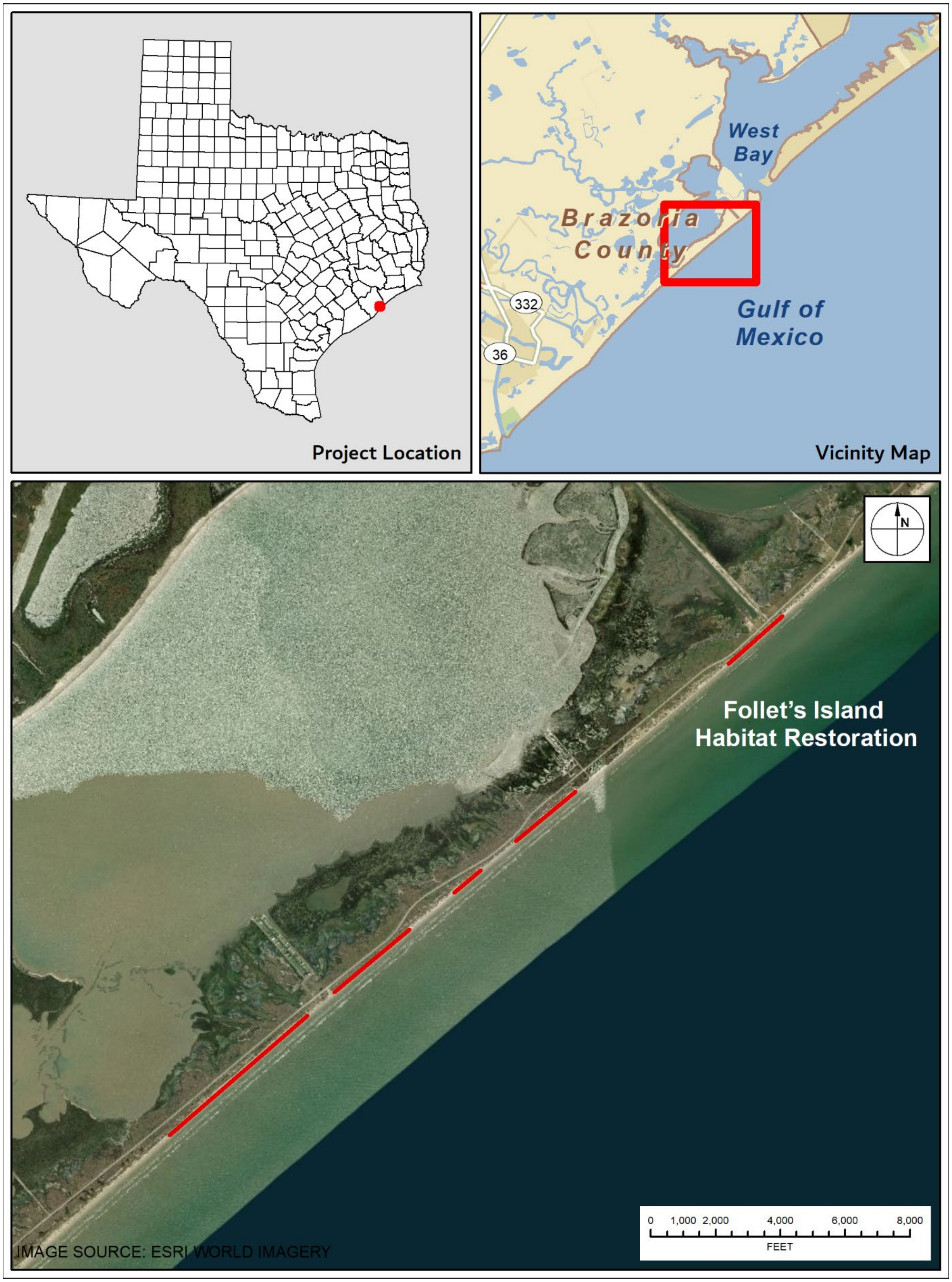

Figure 4.1.1 Location Map-Project #1529 Follet's Island Habitat Restoration

Table 4.1.1 Funding for Project #1529 Follet's Island Habitat Restoration

Funding Source		Amount ($)
Federal	USFWS 2009 State CIAP *(Texas portion)*	2,041,371 *(204,137)*
	USFWS 2009 County CIAP (Texas portion)	100,000 *(10,000)*
State/Local	TX GLO, CEPRA	*1,693,383*
	Total Project Funding (100%)	3,834,754
	(Texas Total)	*1,907,520*

Note: Values in *italics* are costs to the State of Texas
Values represent present worth, beginning of 2017

4.1.3 Analysis

Taylor Engineering visited the site on February 25, 2019, approximately two-years post-construction. Figure 4.1.2 shows aerial imagery collected during the site visit. Much of the dune and dune vegetation remained intact, despite Hurricane Harvey's impacts—Hurricane Harvey made landfall as a category 4 storm at Rockport, Texas, 140 miles southwest of the project area—on the Texas coast in August 2017. A post-storm site visit to the project area in September documented "heavy erosion" of the dune (Mott Macdonald, 2017); immediate post-storm imagery available from Google Earth shows the dunes remained largely intact with a vegetated dune crest remaining, indicating erosion was limited to the dune face and seaward portion of the dune crest. For comparison, Figure 4.1.3 shows aerial imagery of the constructed dune in January 2017, and Figure 4.1.4 shows the planted dune shortly after construction in June 2017. Figure 4.1.5 shows the dune in January 2018 after Hurricane Harvey.

Economics benefits from Project #1529 include federal spending, land loss prevention, and ecosystem protection.

4.1.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (CIAP) listed in Table 4.1.1 ($2,141,371 x 0.9 = $1,927,234) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $2,698,128 (i.e., $1,927,234x 1.4) in 2017 prices.

Figure 4.1.2 Project #1529 Current Conditions, February 2019

Figure 4.1.3 Project #1529 Post-construction, June 2017 (Source: GLO)

Figure 4.1.4 Project #1529 Post-construction, January 2017 (Source: Google Earth)

Figure 4.1.5 Project #1529 Post-Hurricane Harvey, March 2018 (Source: Google Earth)

4.1.3.2 Storm Damage Reduction (Land Loss Prevention) Benefits

Beach restoration and shoreline protection projects protect land, infrastructure, and structures on their landward side against both the ongoing background shoreline erosion and episodic, storm-related erosion. The prevention of land loss and damage to infrastructure and structures form the basis of storm protection benefits to upland properties. Storm damage reduction benefits require estimates of background erosion, storm-related erosion, location of properties, infrastructure, and structures with respect to the shoreline, and value of land, infrastructure, and structures near the shoreline. This study adopted a rigorous engineering approach to develop storm damage reduction benefits. With no structures located landward of the dunes, this analysis calculates storm damage reduction in terms of the value of land loss prevented. Background shoreline erosion in the project area equals 6.89 ft/yr (Jeffrey G. Paine 2013).

Computing storm-induced beach erosion requires applying a numerical model such as Storm-Induced Beach Change (SBEACH) (Larson and Kraus, 1989). This storm erosion model, developed to simulate beach profile change due to cross-shore transport of sediment under changing water levels and breaking waves, provides short-term erosion and recovery predictions on straight beaches. The model assumes that a beach profile evolves to a new equilibrium profile in response to the elevated water levels associated with the storm surge and increased breaking wave heights associated with the storm wave height. Model application requires information on beach profiles, beach sand size, and wave height and period and water level time series (hydrographs) for the duration of the storm.

Estimating project benefits required modeling with- and without-project conditions in SBEACH. Taylor Engineering analyzed various pre- and post-construction profiles within the project area to develop representative initial without- and with-project conditions for SBEACH modeling. This study applied the model parameters shown in Table 4.1.2 presented in King (2007) for the Brazos and Colorado headland area.

Table 4.1.2 SBEACH Model Parameters for Follet's Island Area

Parameter	Value
Transport Rate Coefficient (K)	2.25×10^{-6} m^4/N
Eps Parameter (ε)	0.002 m^2/s
Transport Rate Decay Factor (λ)	0.5 m^{-1}
Avalanching Angle (φ)	35°
Landward surf zone depth	1.6 ft
Median grain size	0.14 mm[†]

(King, 2007)

Taylor Engineering first modeled the effects of synthetic storms for the years 2019 through 2026. This analysis then used a representative pre- and post-construction profile (Figure 4.1.6) with background erosion applied for each successive year. To simulate 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storm events, this study applied a synthetic storm with characteristics corresponding to the return period under consideration. Each synthetic storm consisted of an associated storm tide, wave height, and wave period. This analysis applied storm characteristics (Table 4.1.3) as previously described in Trudnak (2015).

With a typical storm event lasting about 36 hours, distributing the peak storm characteristics over a 36-hour period simulates the passage of a storm and provides a realistic storm model. Before the storm period, three normal tide cycles initialized the model. For a diurnal tide typical of this area, three tidal cycles last about 72 hours. Therefore, each simulation covers a 108-hour time period.

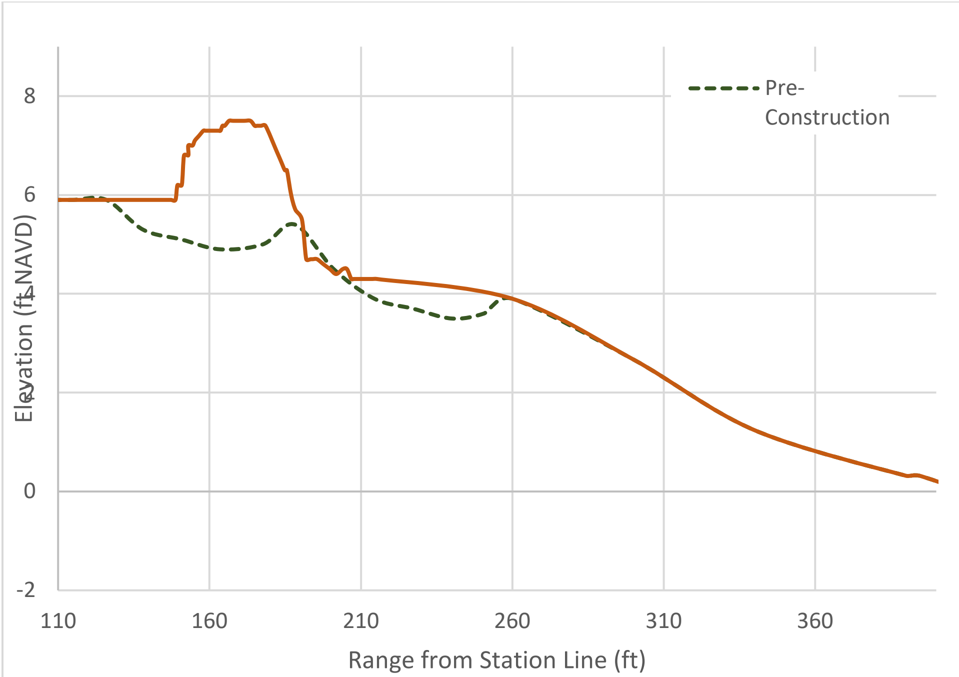

Figure 4.1.6 Project #1529 Representative Pre- and Post- Construction Profiles

Table 4.1.3 Follet's Island Peak Storm Characteristics for Various Return Periods

Return Period (yr)	1	2	5	10	20	50	100
Storm Tide (ft NAVD) †	2.1	2.4	3.2	4.4	6.6	9.4	10.9
Offshore Wave Height (ft)	11.6	13.3	15.8	17.3	19.2	21.5	23.2
Offshore Wave Period (s)	10.1	10.7	11.0	11.8	12.3	12.9	13.4

(Trudnak, 2015)

To develop synthetic time-varying storm surge hydrographs, many authors (e.g., Kriebel, 1989) have applied sine squared distributions such as

$$S(t) = S_p sin^2\left(\pi \frac{t-36}{36}\right) \quad (1.1)$$

where *S* is the storm tide (ft MLT), *t* is time (hours), and S_p is the peak storm tide elevation (ft MLT). The final water surface elevation time series consists of three standard tidal cycles (about 72 hours) developed from a normally varying tide from mean high water (1.23 feet NAVD) to mean low water (-0.22 feet NAVD), followed by the return period specific storm surge hydrograph. Generating the normal tidal cycles requires applying the following equation:

$$S(t) = 1.12cos^2\left(\pi \frac{t-24.8}{24.8}\right) + (0.36) \quad (1.2)$$

Minor smoothing at the transition prevented abrupt changes in the water surface elevation. Figure 4.1.7 shows the final 1-, 2-, 5-, 10-, 20-, 50-, and 100-year hydrographs.

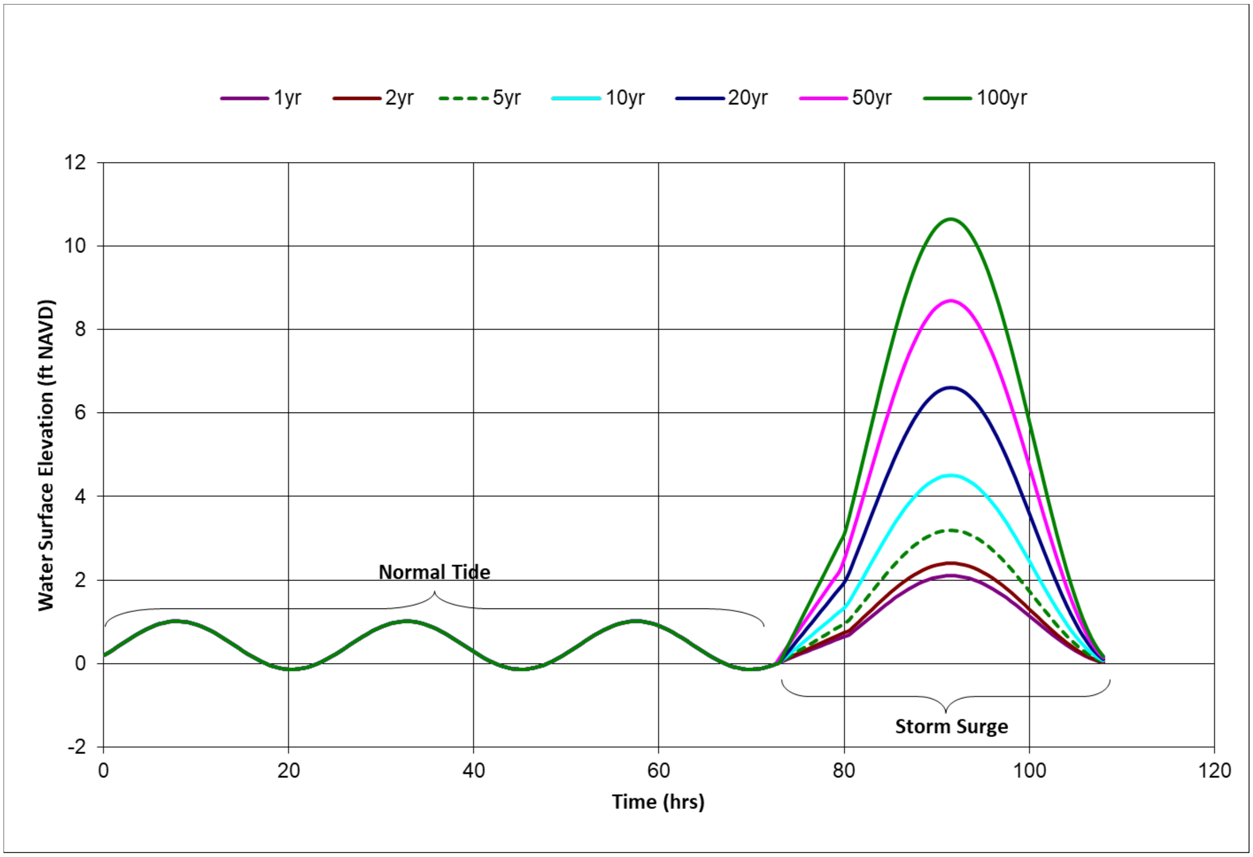

Figure 4.1.7 Follet's Island Synthetic, Time-Varying Water Surface Elevations

As with the storm surge, the temporal wave height variation consisted of two parts. A cosine squared distribution (Equation 1.3) approximated the wave heights during normal conditions over the first 72 hours (3 tidal cycles), followed by a sine squared distribution (Equation 1.4) which approximated the storm wave heights over 36 hours.

$$H(t) = 1.5cos^2\left(\pi\frac{t-24.8}{24.8}\right) = 1.5 \quad (1.3)$$

and

$$H(t) = \left(H_p - H_{min}\right)sin^2\left(\pi\frac{t-36}{36}\right) + H_{min} \quad (1.4)$$

where *H* is the wave height (ft), H_p is the peak wave height (ft), and H_{min} is the minimum wave height following a storm.

Each tidal cycle averaged 24.8 hours, and the wave heights varied from 1.0 to 2.0 ft for 1- and 2-year hydrographs and 1.5 to 3.0 ft for all other return period hydrographs. These conditions represent the relatively calm conditions frequently observed in the Gulf of Mexico. Storm wave heights varied from 2 to 5 ft to the peak wave height (Table 4.1.3) and abate to 2 to 5 ft after storm passage. The 2-to-5-ft values for H_{min} (minimum wave height following a storm) simulate the agitated sea conditions typically found after a storm passes an area. Figure 4.1.8 shows the resulting wave height distributions the model requires.

During the first 72 hours of normal conditions, the wave period varies from three to four seconds for 1-, 2-, and 5-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. The wave period varies from four to five seconds for 10-, 20-, 50-, and 100-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. Similarly, a sine squared distribution approximated the storm wave periods over the final 36 hours with a minimum final wave period of five (1-, 2-, and 5-year return period storms) and six (10-, 20-, 50-, and 100-year storms) seconds. Figure 4.1.9 shows the resulting wave period distributions the model requires.

SBEACH produced post-storm profiles for the 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storms for with- and without-project profiles for 2019 to 2026. Figures 4.1.10 and 4.1.11 present a typical post-storm profile for without- and with-project conditions for the 5-year storm.

CEPRA Project #1382, constructed in 2012, a rock revetment and overwash scour protection to guard against future storms along CR257. Thus, this analysis assumes that storm-induced erosion will not extend landward of the revetment. Using 2019 Brazoria County Appraisal District information, this analysis calculated a total land value of $1,420,886 (2019 prices), or $1,360,371 ($1,420,886/1.022/1.022) adjusted for inflation to 2017 prices, between the pre-project dune and CR257; this value represents the maximum potential land loss from a storm.

The methodology outlined in Section 2.2 and the site-specific information described above produces the damage-cumulative probability distribution for the years 2019 through 2026 with and without the project. Table 4.1.4 presents the damage-cumulative probability distribution for 2019 with project conditions and Table 4.1.5 presents this distribution without project conditions for 2019 without-project conditions. As presented in Table 4.1.6, the estimated 2019–2026 storm damage reduction benefits for Project #1529 equals $1,043,014.

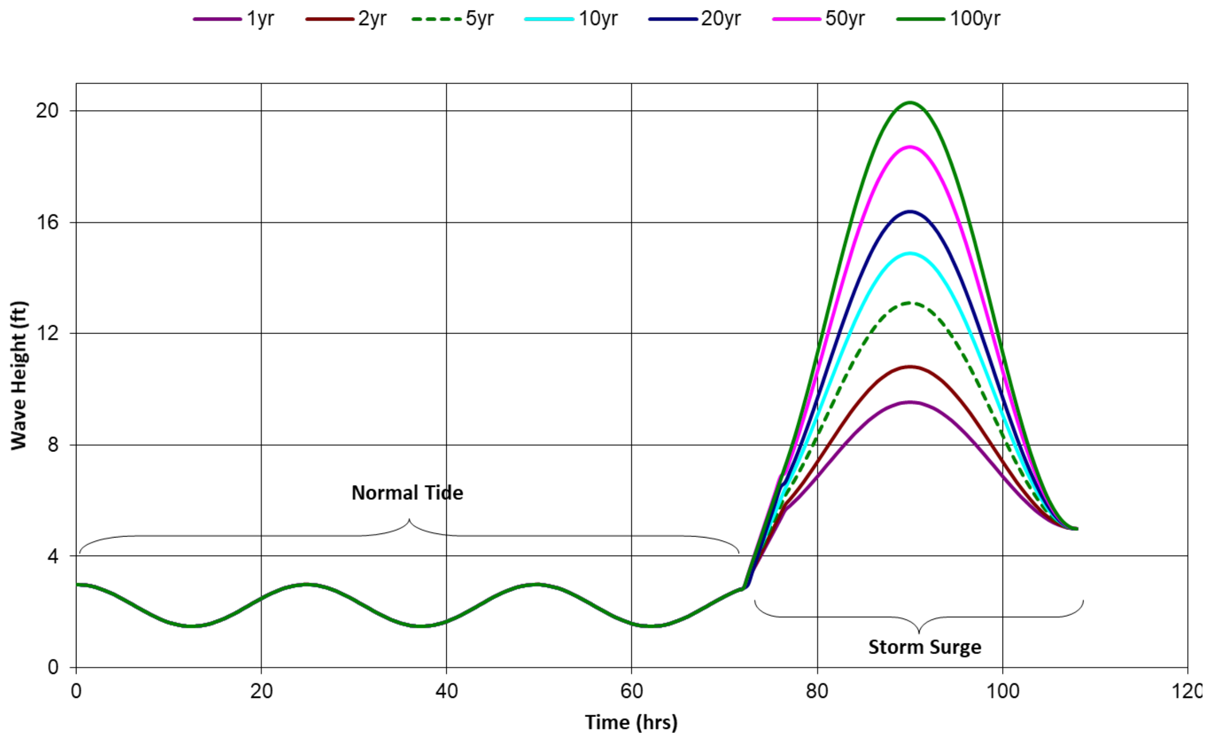

Figure 4.1.8 Follet's Island Synthetic, Time-Varying Wave Heights

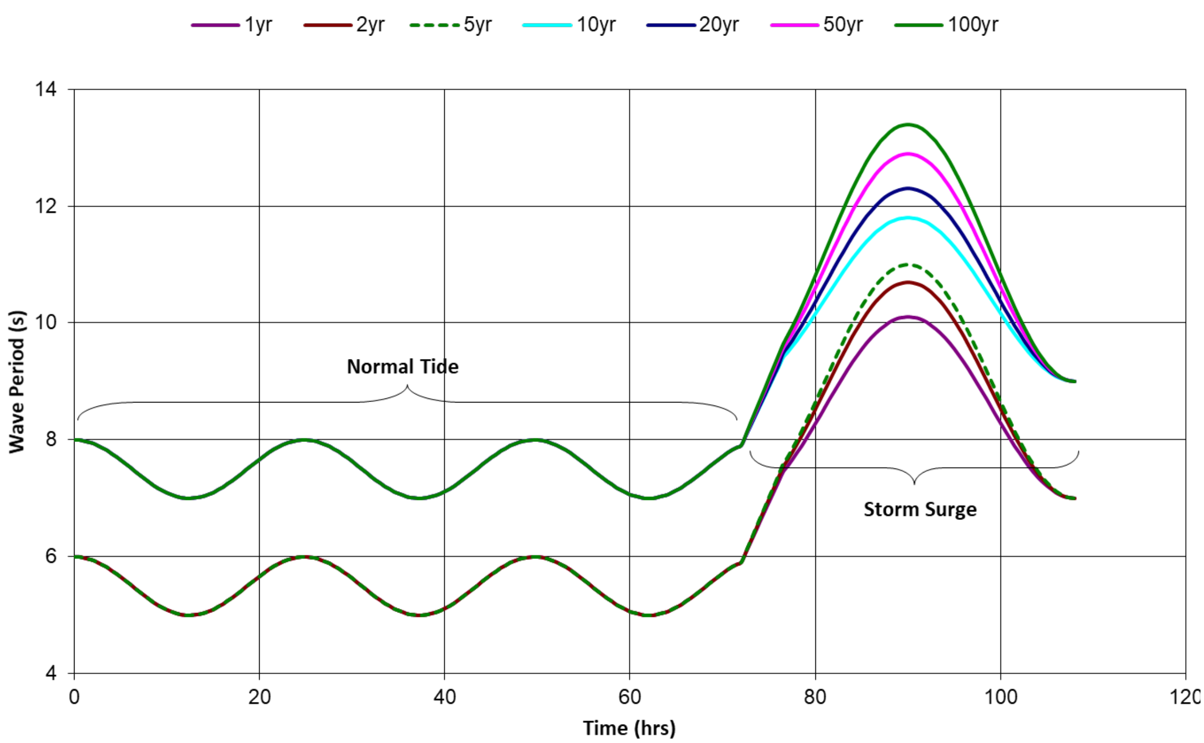

Figure 4.1.9 Follet's Island Synthetic, Time-Varying Wave Periods

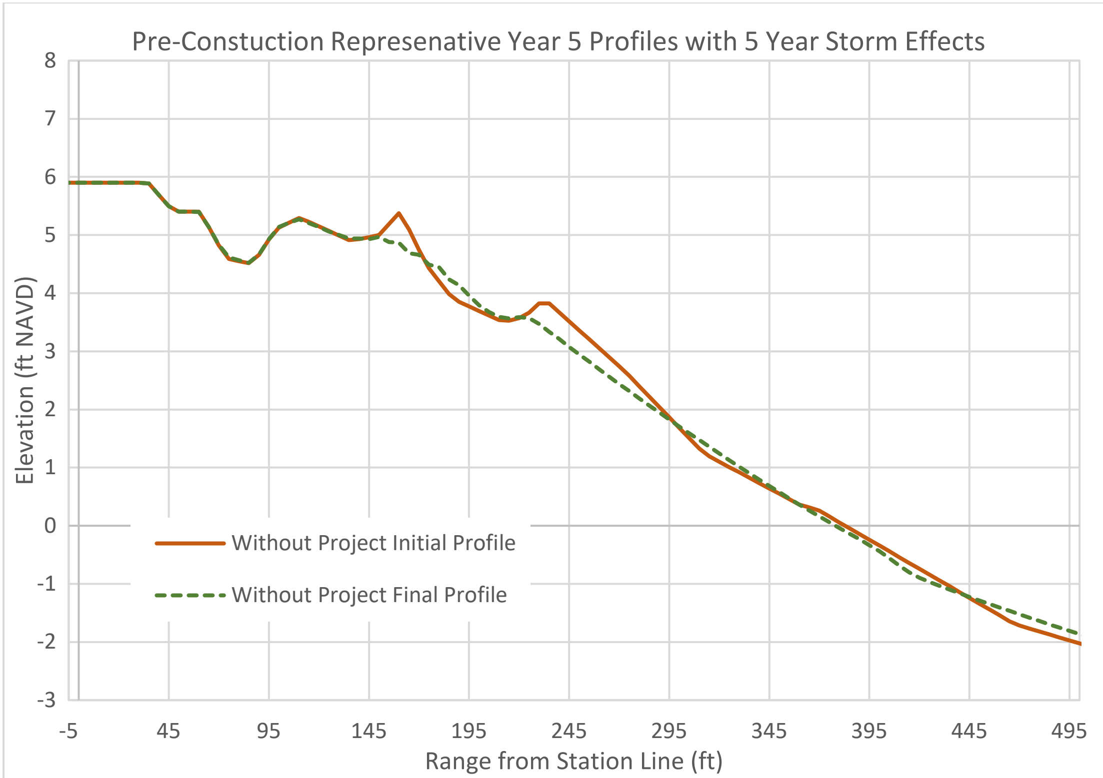

Figure 4.1.10 Project #1529 Typical Pre-Construction Year 5 Profiles with 5 Year Storm Effects

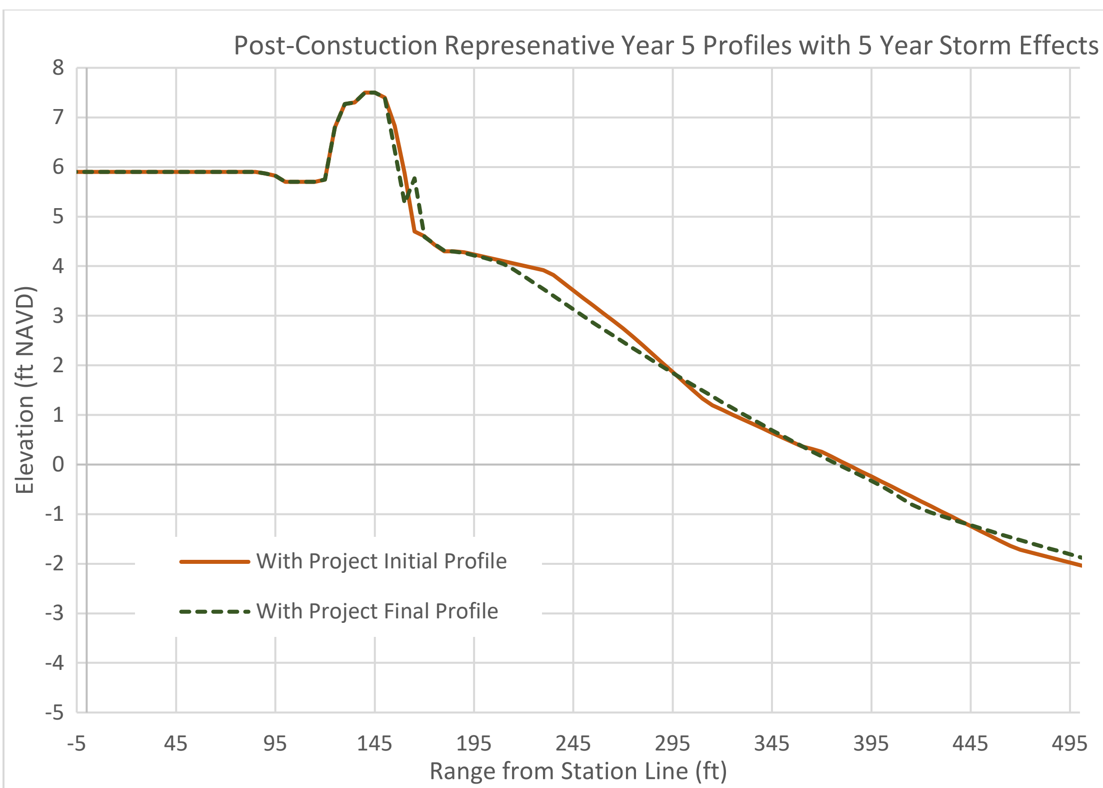

Figure 4.1.11 Project #1529 Typical Post-Construction Year 5 Profiles with 5 Year Storm Effects

Table 4.1.4 Project #1529 Damage-Cumulative Probability Distribution with Project for 2019

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0.00	-	-
2	0.50	0.50	$0	$0	0.50	$0
5	0.20	0.80	$0	$0	0.30	$0
10	0.10	0.90	$107,749	$53,874	0.10	$5,387
20	0.05	0.95	$505,585	$306,667	0.05	$15,333
50	0.02	0.98	$533,077	$519,331	0.03	$15,580
100	0.01	0.99	$593,039	$563,058	0.01	$5,631
>100	<0.01	>0.99	$593,039	$593,039	0.01	$5,930
Expected Average Annual Damage in 2017 Prices:						**$47,862**

Notes: 2019 property values adjusted by inflation to 2017 prices (inflation = 2.2% from 2017–2018 and 2.2% from 2018–2019.

Table 4.1.5 Project #1529 Damage-Cumulative Probability Distribution without Project for 2019

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0.00	-	-
2	0.50	0.50	$0	$0	0.50	$0
5	0.20	0.80	$475	$238	0.30	$71
10	0.10	0.90	$970,230	$485,352	0.10	$48,535
20	0.05	0.95	$1,201,744	$1,085,987	0.05	$54,299
50	0.02	0.98	$1,262,430	$1,232,087	0.03	$36,963
100	0.01	0.99	$1,360,371	$1,311,400	0.01	$13,114
>100	<0.01	>0.99	$1,360,371	$1,360,371	0.01	$13,604
Expected Average Annual Damage in 2017 Prices:						**$166,586**

Notes: 2019 property values adjusted by inflation to 2017 prices (inflation = 2.2% from 2017–2018 and 2.2% from 2018–2019.

Table 4.1.6 Project #1529 2019–2026 Storm Damage Reduction Benefit

Year	Without Project (2017 Prices)	With Project (2017 Prices)	Difference	Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
2019	$166,586	$47,862	$118,724	$124,006	$112,613	$112,613
2020	$198,739	$58,908	$139,831	$148,973	$130,171	$242,784
2021	$185,493	$66,783	$118,710	$129,000	$108,456	$351,240
2022	$204,097	$77,320	$126,777	$140,521	$113,676	$464,916
2023	$229,554	$68,733	$160,821	$181,821	$141,523	$606,439
2024	$277,352	$105,003	$172,350	$198,753	$148,853	$755,292
2025	$234,216	$119,305	$114,911	$135,165	$97,402	$852,693
2026	$316,820	$88,038	$228,782	$274,488	$190,320	$1,043,014

Notes: Inflation rate = 2.0% for years 2020–2026
Discount rate 3.93%
Discounted present worth beginning of 2017, using mid-year present worth factor
The values for each year are a result of a process similar to that described and shown in Tables 4.1.4 and 4.1.5 for 2019

The above analysis pertains to the potential land loss prevention benefit for 2019–2026 based on the probability of occurrence of future storms but does not directly address the annual land loss from background erosion. This study assumes the project offsets the background erosion that would have occurred during the 10-year project life without construction of the dune. That is, the project prevented 6.89 ft of land loss each year across the project area. As mentioned above, the total land value within the project area between the dune and CR257 equals $1,360,371 (2017 prices). Dividing the total land value by the average lot depth (254 ft) and multiplying by the background erosion (6.89 ft per yr) yields a value of $36,901 (2017 prices) for the annual land value protection benefit. Using a mid-year present worth factor, the present worth equivalent = $36,197 for 2017, as outlined in Table 4.1.7. The cumulative land loss benefits for 2017–2026 equals $16,134. The total land loss prevention benefit for 2017–2026 equals $1,377,281 (1,043,014 [Table 4.1.6] + 334,267 [Table 4.1.7] = 52,700).

Table 4.1.7 Project #1529 Land Loss (Background Erosion) Prevention Benefit

Year	Project Benefit (2017 Prices)	Inflation-Adjusted Value ($)	2017 Discounted Present Worth ($)	Cumulative Discounted Present Worth ($)
2017	36,901	36,901	36,197	36,197
2018	36,901	37,713	35,594	71,791
2019	36,901	38,543	35,002	106,793
2020	36,901	39,314	34,352	141,145
2021	36,901	40,100	33,714	174,859
2022	36,901	40,902	33,088	207,947
2023	36,901	41,720	32,474	240,420
2024	36,901	42,554	31,870	272,291
2025	36,901	43,406	31,279	303,570
2026	36,901	44,274	30,698	334,267

Note: Inflation rates 2.2%/yr for 2017 to 2019 and 2.0%/yr for years 2019-2026
Discount rate 3.93% (mid-year discounting)
Discounted present worth beginning of 2017, using mid-year present worth factor

4.1.3.3 Ecosystem Services Benefit

The land between the project area shoreline and State Road 257 includes a number of small, isolated wetlands mapped in an agency-approved wetland delineation effort as part of project permitting. This study assumes Project #1529 provided ecosystem services benefits by preventing erosion of the wetlands. The ecosystem services benefits analysis rest on several assumptions:

- The berm will prevent further erosion of the wetlands landward of the pre-project dune toe.
- Ecosystem services benefits will accrue from the berm preventing marsh erosion.
- Benefits began the beginning of the first year construction was completed (early 2017) and for the rest of the subsequent 10-year project life.

Wetland losses were estimated by first identifying the pre-project toe of dune in Google Earth. That line was converted to a shapefile in ArcMap and then regressed landward by 6.98 ft/yr—the annual background erosion (Paine et al 2013)—to represent the landward extent of erosion each year of the without-project life. Project construction plan view sheets were converted from .pdf to .jpg format, imported to ArcMap, and scale corrected and georectified using baseline northing and easting data provided in the plans in ArcMap. The wetlands on the plan views, delineated as part of the project permitting process, were then digitized. The ten without-project erosion limit lines were then intersected with the wetlands to estimate the wetlands impacted each year of the expected project life, 2017–2026 (inclusive). The areas of wetland lost each year formed the basis for the calculation of without and with-project wetland benefits.

We evaluated the Follet's Island project applying the per acre marsh and open water ecosystem services values described in Section 2.3, adjusted to 2017 price levels, as the berm was constructed during a short period at the end of 2016 and the beginning of 2017. The minimal loss of wetlands during construction was not included in the benefits evaluation. Table 4.1.8 details the annual ecosystem services benefits ($103,721) from marsh protection in discounted present worth (beginning of 2017) over the estimated project life.

Table 4.1.8 Project #1529 Shoreline Protection Ecosystem Services Benefits – Erosion Protection

Year	Marsh Lost (acres)				Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2017 Cumulative Discounted Present Worth ($)
	With Project		Without Project						
	Annual	Cumulative	Annual	Cumulative		Value (2017 $)	Inflation-Adjusted Value ($)	Beginning of 2017 Discounted Present Worth[1] ($)	
2017	0.00	0.00	0.17	0.17	0.17	598	598	587	587
2018	0.00	0.00	0.28	0.45	0.45	1,586	1,621	1,530	2,117
2019	0.00	0.00	0.41	0.86	0.86	3,001	3,135	2,847	4,963
2020	0.00	0.00	0.55	1.41	1.41	4,934	5,257	4,593	9,557
2021	0.00	0.00	0.74	2.15	2.15	7,517	8,169	6,868	16,425
2022	0.00	0.00	0.93	3.08	3.08	10,772	11,940	9,659	26,083
2023	0.00	0.00	1.14	4.22	4.22	14,747	16,672	12,977	39,061
2024	0.00	0.00	1.38	5.60	5.60	19,556	22,552	16,890	55,951
2025	0.00	0.00	1.62	7.22	7.22	25,224	29,670	21,381	77,331
2026	0.00	0.00	1.86	9.08	9.08	31,722	38,060	26,389	103,721

4.1.4 Benefit-Cost Summary

Table 4.1.9 summarizes the project benefits and costs. With benefits summing to $4,179,129 and project costs totaling $1,907,520, this project has a 2.2 B/C ratio.

Table 4.1.9 Benefit-Cost Summary for Project #1529 Follet's Island Habitat Restoration

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Federal Spending Benefit	$2,698,128
Land Loss Prevention Benefit	$1,377,281
Ecosystem Services Benefit	$103,721
Total Benefits	**$4,179,129**
Total Cost (Texas)	**$1,907,520**
B/C Ratio	**2.2**

Notes:
Texas costs only, assumed incurred at the beginning of the first year of project construction
Values represent present worth equivalents at the beginning of 2017 with a 3.93% discount rate.

4.2 Jefferson County — #1530 McFaddin National Wildlife Refuge Beach Ridge

4.2.1 Project Description and Background Information

The McFaddin National Wildlife Refuge (NWR) contains 58,861 acres of marsh, wetlands, and coastal prairies along the Texas Gulf Coast in western Jefferson, Chambers, and eastern Galveston County (Figure 4.2.1). The NWR extends from the coast inland to or beyond the Gulf Intracoastal

Waterway (GIWW). Rapid coastline erosion, as much as 40 ft per year, has occurred along the NWR section of the Texas coast. Erosion (exacerbated by Hurricane Ike) removed the beach dune system that historically protected interior wetlands from inundation with saline Gulf waters during episodic high water levels, typically occurring more frequently than tropical storm or hurricane storm surges (Salt Bayou Marsh Work Group, 2013; LJA, 2016).

As part of the CEPRA Cycle 7 project, the Texas General Land Office partnered with the Coastal Impact Assistance Program (CIAP) and Jefferson county to restore the beach and dune (or beach ridge) along the Gulf of Mexico shoreline in the McFAddin National Wildlife Refuge. This Pilot Project placed approximately 535,000 cy along 3 miles of beach extending eastward from White's Levee to restore the beach and minimize inundation of the landward marsh. The project, constructed from April – May 2017, advanced the shoreline 80 – 120 ft seaward throughout the project area and constructed a beach ridge with a crest elevation of 8 ft NAVD88. In addition to beach nourishment, Project #1530 also included vegetative plantings. Five rows of intermixed bitter panicum and sea oats along a length of 15,312 linear feet for a total number of 38,320 plants were placed in March of 2018.

4.2.2 Project Funding

Funding for Project #1530 originated from federal, state and county sources, as listed in Table 4.2.1. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. Accordingly, the Texas share of the total federal cost ($9,788,707) is $978,870. The resulting cost to Texas for Project #1530 amounts to $2,590,695 (present worth, beginning of 2017); this value equals the sum of the CEPRA and Jefferson County contributions and the 10% state share of federal costs.

Table 4.2.1 Funding for Project #1530 McFaddin NWR Beach Ridge Restoration

Funding Source		Amount ($)
Federal	CIAP to Jefferson County *(Texas portion)*	2,788,857 *(278,886)*
	CDBG to Jefferson County (*Texas portion*)	430,101 *(43,010)*
	CIAP to State (*Texas portion*)	6,569,750 *(656,975)*
State/Local	Texas GLO, CEPRA	*1,500,454*
	Jefferson County	*111,370*
Total Project Cost		11,400,532
Texas Total		*2,590,695*

Note: Values in *italics* are costs to the State of Texas
Values represent present worth, beginning of 2017

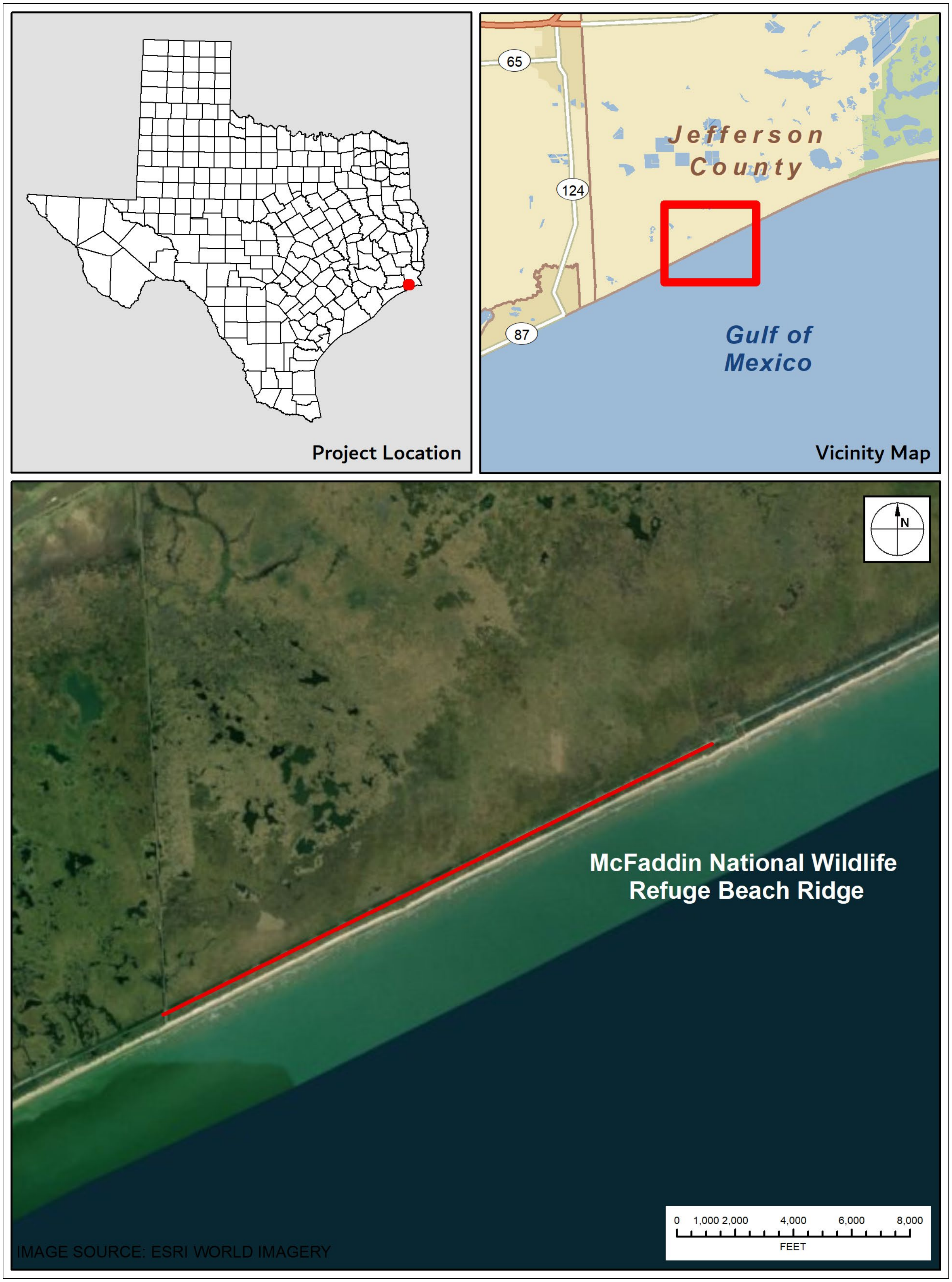

Figure 4.2.1 Location Map — Project #1530 McFaddin NWR Beach Ridge Restoration

4.2.3 Analysis

Project #1530 McFaddin NWR Beach Ridge Restoration dredging and onshore beach placement construction began in April 2017 and was completed in May 2017. Figures 4.2.2 and 4.2.3 show pre-construction conditions, and Figures 4.2.4–4.2.6 show post-construction conditions. As typical for analyses of other similar projects, we assumed a 10-yr project lifetime for this analysis, with 2017 (the construction completion year) as the first year of the project life. Economics benefits from Project #1530 include federal spending, land loss prevention, and ecosystem protection.

4.2.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (CIAP and CDBG) listed in Table 4.2.1 ([$2,788,857+ $430,101 + $6,569,750]) x 0.9 = $8,809,837) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $12,333,772 (i.e., $8,809,837 x 1.4) in 2017 prices.

4.2.3.2 Storm Damage Reduction (Land Loss Prevention) Benefits

Beach restoration and shoreline protection projects protect land, infrastructure, and structures on their landward side against both the ongoing background shoreline erosion and episodic, storm-related erosion. The prevention of land loss and damage to infrastructure and structures form the basis of storm protection benefits to upland properties. Storm damage reduction benefits require estimates of background erosion; storm-related erosion; location of properties, infrastructure, and structures with respect to the shoreline; and value of land, infrastructure, and structures near the shoreline. This study adopted a rigorous engineering approach to develop storm damage reduction benefits. With no structures existing within the project area, the storm damage reduction benefits equal the loss of land value prevented by the project. Using background erosion (i.e., shoreline change) data from UTBEG, this analysis calculated a background shoreline erosion rate within the project area of 21.17 ft/yr.

Computing storm-induced beach erosion requires applying a numerical model such as Storm-Induced Beach Change (SBEACH) (Larson and Kraus, 1989). This storm erosion model, developed to simulate beach profile change due to cross-shore transport of sediment under changing water levels and breaking waves, provides short-term erosion and recovery predictions on straight beaches. The model assumes that a beach profile evolves to a new equilibrium profile in response to the elevated water levels associated with the storm surge and increased breaking wave heights associated with the storm wave height. Model application requires information on beach profiles, beach sand size, and wave height and period and water level time series (hydrographs) for the duration of the storm.

Using information from the Jefferson County Appraisal District, the land within the project area was valued on average at $250 per acre in 2019 prices. This value was used to assess the land loss prevention benefit.

Figure 4.2.2 Project #1530 Pre-Construction Conditions, April 2017 (Source: GLO)

Figure 4.2.3 Project #1530 Pre-Construction Conditions, April 2017 (Source: GLO)

Figure 4.2.4 Project #1530 Post-Construction Aerial View (Source: GLO)

Figure 4.2.5 Project #1530 Post-Construction Conditions, May 2017 (Source: GLO)

Figure 4.2.6 Project #1530 Post-Construction Conditions, May 2017 (Source: GLO)

Estimating project benefits required modeling with- and without-project conditions in SBEACH. Taylor Engineering analyzed various pre- and post-construction profiles within the project area to develop representative initial without- and with-project profiles (Figure 4.2.7) for SBEACH modeling. This study applied the model parameters shown in Table presented in King (2007).

Table 4.2.2 SBEACH Model Parameters for McFaddin NWR Area

Parameter	Value
Transport Rate Coefficient (K)	2.25 x 10^{-6} m^4/N
Eps Parameter (ε)	0.002 m^2/s
Transport Rate Decay Factor (λ)	0.5 m^{-1}
Avalanching Angle (φ)	35°
Landward surf zone depth	1.6 ft
Median grain size	0.14 mm[†]

(King, 2007)

Taylor Engineering first modeled the effects of synthetic storms for the years 2019 through 2026. This analysis then used a representative pre- and post-construction profile (Figure 4.2.7) with background erosion applied for each successive year. To simulate 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storm events, this study applied a synthetic storm with characteristics corresponding to the return period under consideration. Each synthetic storm consisted of an associated storm tide, wave height, and wave period. This analysis applied storm characteristics (Table 4.2.3) as previously described in (Trudnak et al., 2015).

With a typical storm event lasting about 36 hours, distributing the peak storm characteristics over a 36-hour period simulates the passage of a storm and provides a realistic storm model. Before the storm period, three normal tide cycles initialized the model. For a diurnal tide typical of this area, three tidal cycles last about 72 hours. Therefore, each simulation covers a 108-hour time period.

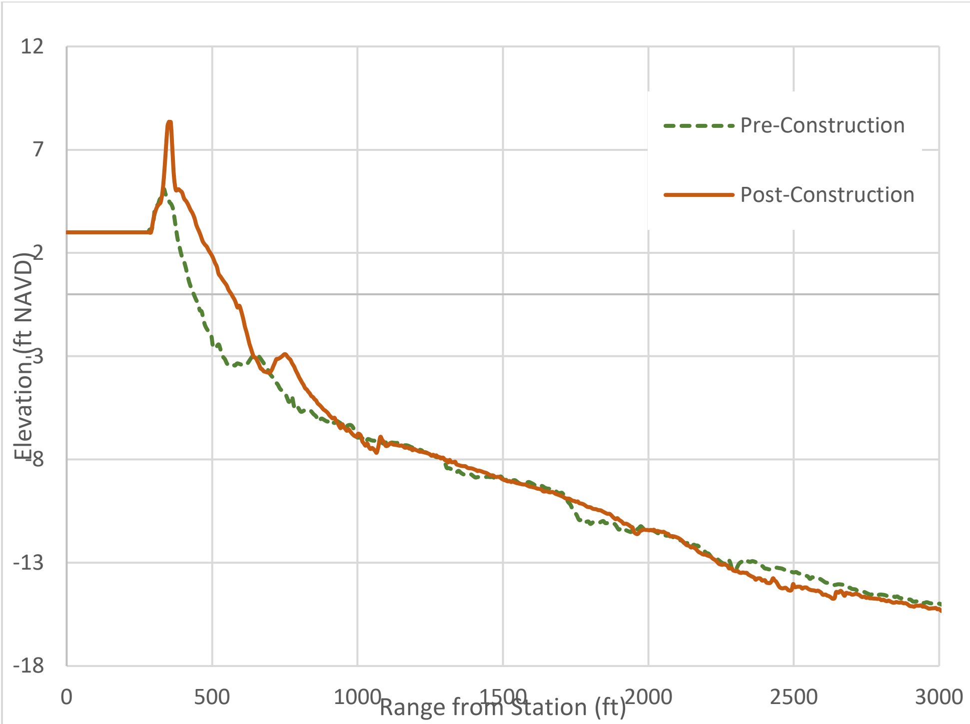

Figure 4.2.7 Project #1530 Representative Pre- and Post-Construction Profiles

Table 4.2.3 McFaddin NWR Peak Storm Characteristics for Various Return Periods

Return Period (yr)	1	2	5	10	20	50	100
Storm Tide (ft NAVD) †	2.1	2.4	3.2	4.4	6.6	9.4	10.9
Offshore Wave Height (ft)	11.6	13.3	15.8	17.3	19.2	21.5	23.2
Offshore Wave Period (s)	10.1	10.7	11.0	11.8	12.3	12.9	13.4

(Trudnak, 2015)

To develop synthetic time-varying storm surge hydrographs, many authors (e.g., Kriebel, 1989) have applied sine squared distributions such as

$$S(t) = S_p sin^2\left(\pi\frac{t-36}{36}\right) \qquad (1.1)$$

where *S* is the storm tide (ft MLT), *t* is time (hours), and S_p is the peak storm tide elevation (ft MLT). The final water surface elevation time series consists of three standard tidal cycles (about 72 hours) developed from a normally varying tide from mean high water (1.23 feet NAVD) to mean low water (-0.22 feet NAVD), followed by the return period specific storm surge hydrograph. Generating the normal tidal cycles requires applying the following equation:

$$S(t) = 1.12cos^2\left(\pi\frac{t-24.8}{24.8}\right) + (0.36) \qquad (1.2)$$

Minor smoothing at the transition prevented abrupt changes in the water surface elevation. Figure 4.2.8 shows the final 1-, 2-, 5-, 10-, 20-, 50-, and 100-year hydrographs.

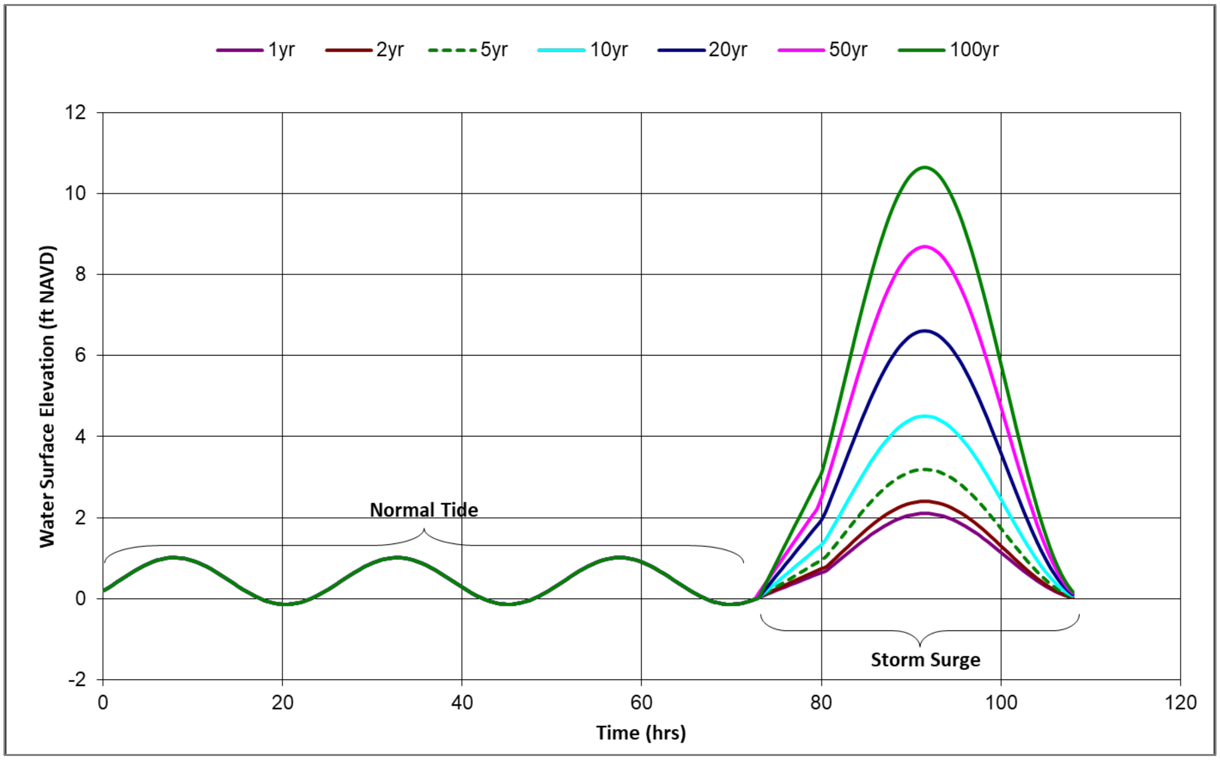

Figure 4.2.8 McFaddin NWR Synthetic, Time-Varying Water Surface Elevations

As with the storm surge, the temporal wave height variation consisted of two parts. A cosine squared distribution (Equation 1.3) approximated the wave heights during normal conditions over the first 72 hours (3 tidal cycles), followed by a sine squared distribution (Equation 1.4) which approximated the storm wave heights over 36 hours:

$$H(t) = 1.5cos^2\left(\pi\frac{t-24.8}{24.8}\right) = 1.5 \quad (1.3)$$

and

$$H(t) = \left(H_p - H_{min}\right)sin^2\left(\pi\frac{t-36}{36}\right) + H_{min} \quad (1.4)$$

where H is the wave height (ft), H_p is the peak wave height (ft), and H_{min} is the minimum wave height following a storm.

Each tidal cycle averaged 24.8 hours, and the wave heights varied from 1.0 to 2.0 ft for 1- and 2-year hydrographs and 1.5 to 3.0 ft for all other return period hydrographs. These conditions represent the relatively calm conditions frequently observed in the Gulf of Mexico. Storm wave heights varied from 2 to 5 ft to the peak wave height and abate to 2 to 5 ft after storm passage. The 2-to-5-ft values for H_{min} (minimum wave height following a storm) simulate the agitated sea conditions typically found after a storm passes an area. Figure 4.2.9 shows the resulting wave height distributions the model requires.

During the first 72 hours of normal conditions, the wave period varies from three to four seconds for 1-, 2-, and 5-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. The wave period varies from four to five seconds for 10-, 20-, 50-, and 100-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours.

Similarly, a sine squared distribution approximated the storm wave periods over the final 36 hours with a minimum final wave period of five (1-, 2-, and 5-year return period storms) and six (10-, 20-, 50-, and 100-year storms) seconds. Figure 4.2.10 shows the resulting wave period distributions the model requires.

SBEACH produced post-storm profiles for the 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storms for with- and without-project profiles for 2019 to 2026 Figures 4.2.11 and 4.2.12 presents a typical post-storm profile for without- and with-project conditions for the 5-year storm.

The methodology outlined in Section 2.2 and the site-specific information described above produces the damage-cumulative probability distribution for the years 2019 through 2026 with and without the project. Table 4.2.4 presents the damage-cumulative probability distribution for 2019 with project conditions, and Table 4.2.5 presents this distribution for 2019 without project conditions. As presented in Table 4.2.6, the estimated 2019–2026 storm damage reduction benefits for Project #1530 equal $36,566.

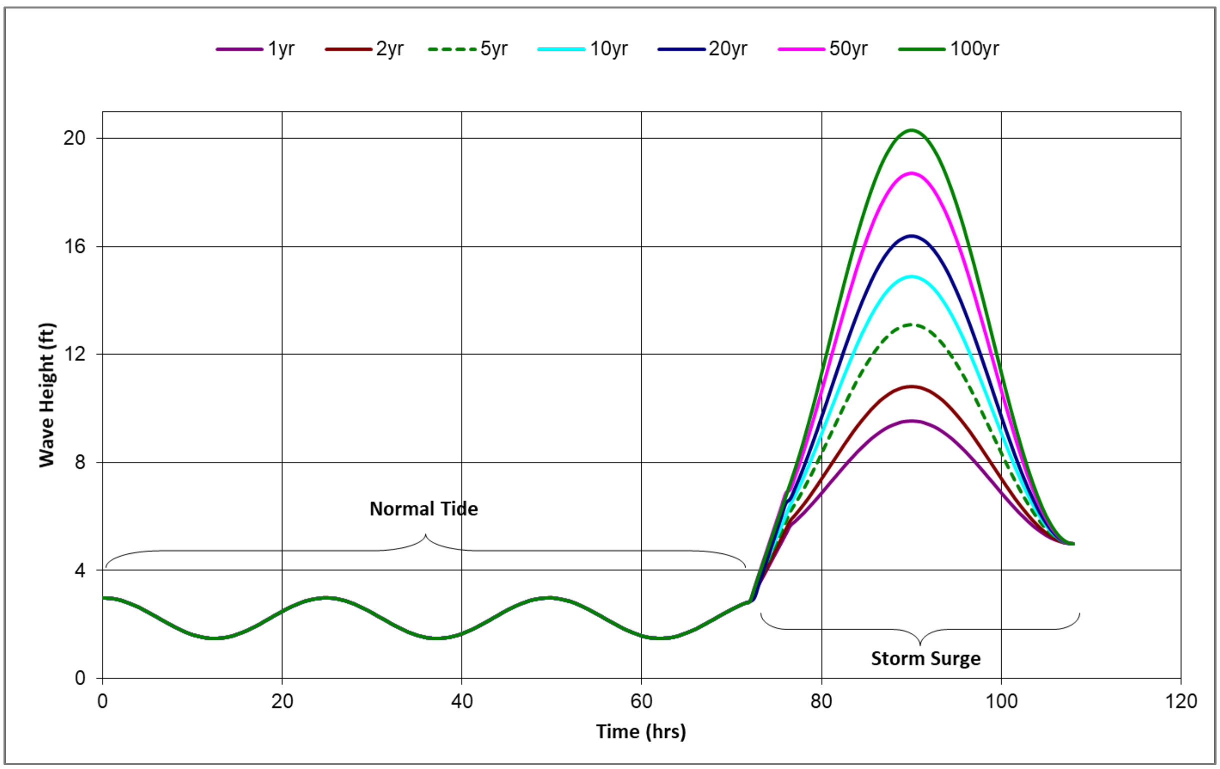

Figure 4.2.9 McFaddin NWR Synthetic, Time-Varying Wave Heights

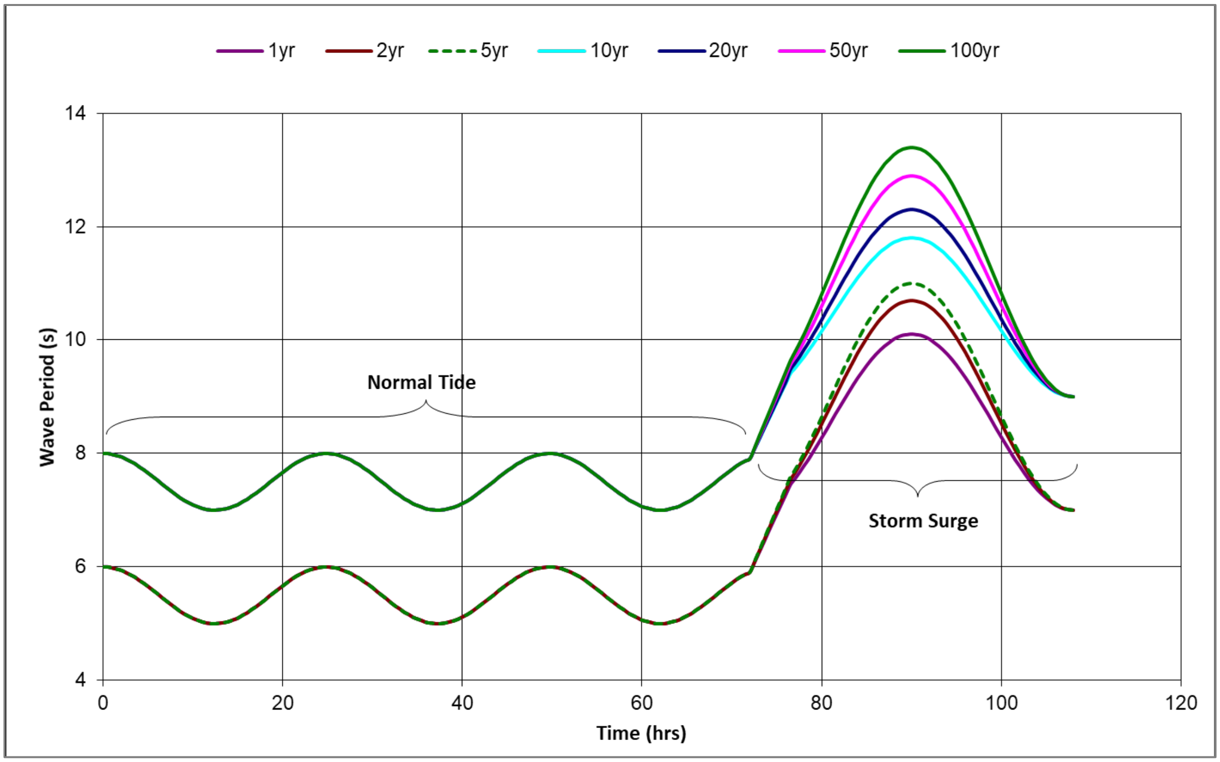

Figure 4.2.10 McFaddin NWR Synthetic, Time-Varying Wave Periods

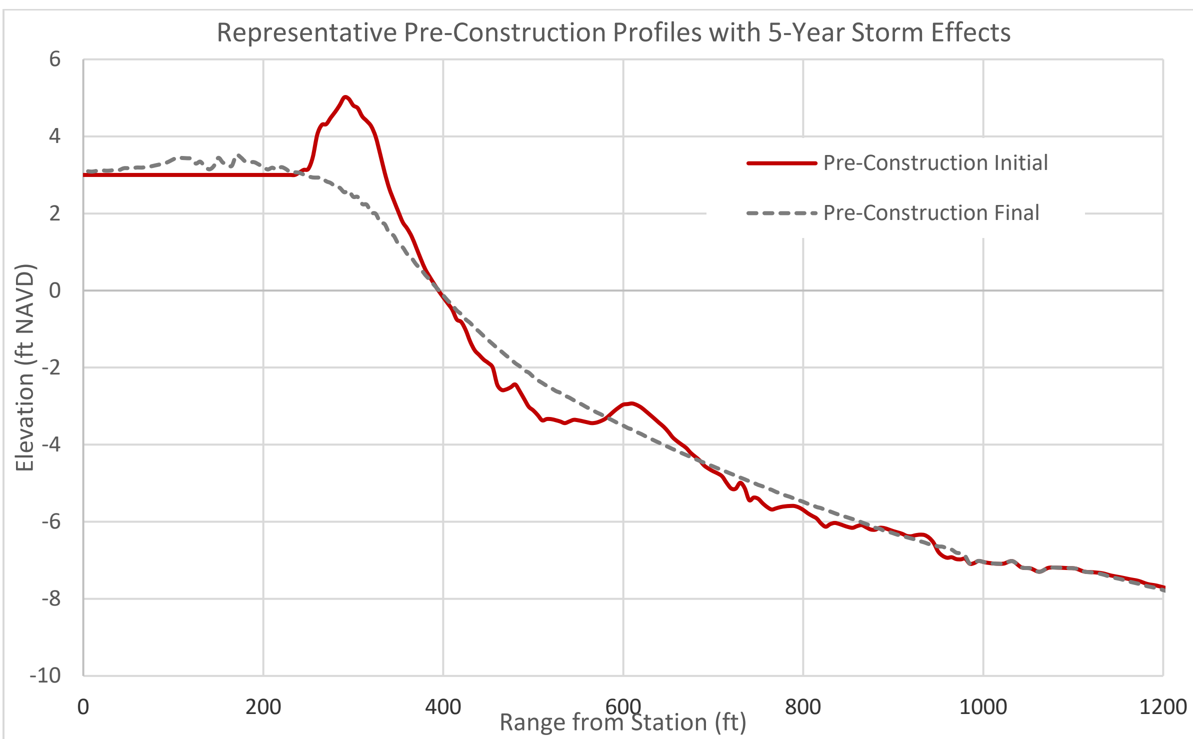

Figure 4.2.11 Project #1530 Typical Pre-Construction Year 5 Profiles with 5 Year Storm Effects

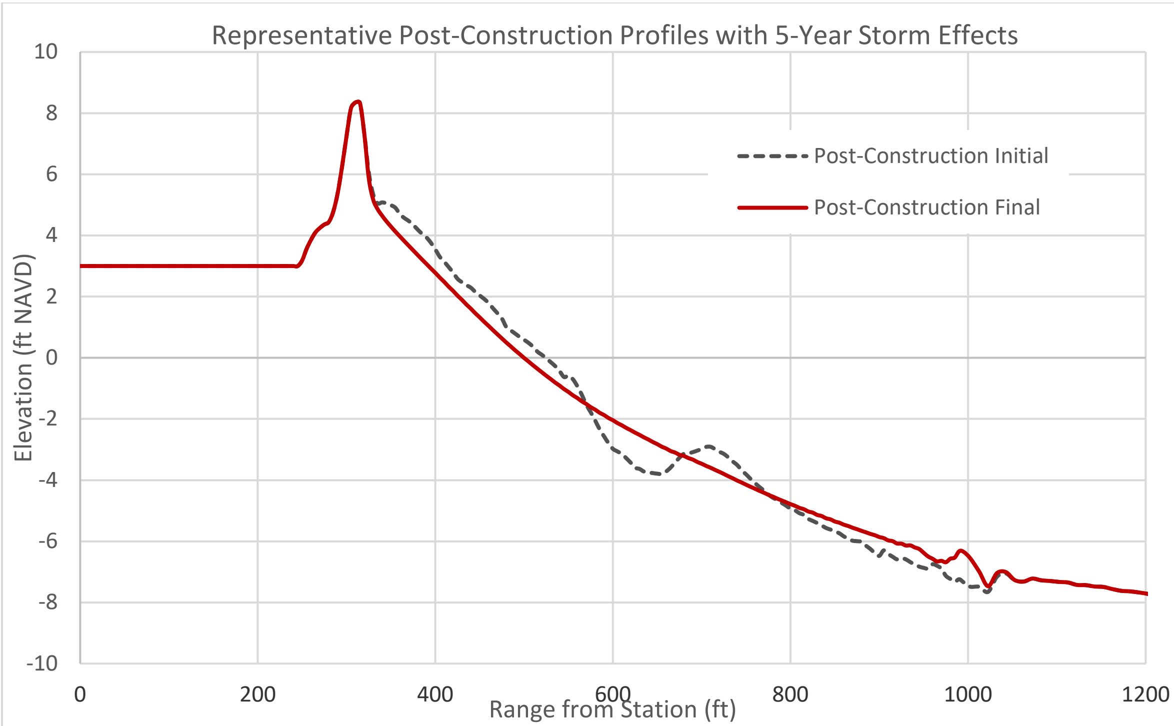

Figure 4.2.12 Project #1530 Typical Post-Construction Year 5 Profiles with 5 Year Storm Effects

Table 4.2.4 Project #1530 Damage-Cumulative Probability Distribution with Project for 2019

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$4,595	$2,297	-	-
2	0.50	0.50	$1,689	$3,142	0.50	$1,571
5	0.20	0.80	$3,208	$2,449	0.30	$735
10	0.10	0.90	$8,094	$5,651	0.10	$565
20	0.05	0.95	$8,192	$8,143	0.05	$407
50	0.02	0.98	$8,306	$8,249	0.03	$247
100	0.01	0.99	$8,686	$8,496	0.01	$85
>100	<0.01	1.0	$8,686	$8,686	0.01	$87
Expected Average Annual Damage in 2017 Prices:						**$3,697**

Notes: 2019 property values adjusted by inflation to 2017 prices (inflation = 2.2% from 2017–2018 and 2.2% from 2018–2019.

Table 4.2.5 Project #1530 Damage-Cumulative Probability Distribution without Project for 2019

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$3,315	$1,657.26	-	-
2	0.50	0.50	$12,405	$7,860	0.50	$3,930
5	0.20	0.80	$7,506	$9,956	0.30	$2,987
10	0.10	0.90	$7,699	$7,603	0.10	$760
20	0.05	0.95	$10,185	$8,942	0.05	$447
50	0.02	0.98	$16,506	$13,346	0.03	$400
100	0.01	0.99	$14,643	$15,575	0.01	$156
>100	<0.01	1.0	$14,643	$14,643	0.01	$146
Expected Average Annual Damage in 2017 Prices:						**$8,827**

Notes: 2019 property values adjusted by inflation to 2017 prices (inflation = 2.2% from 2017–2018 and 2.2% from 2018–2019.

Table 4.2.6 Project #1530 Storm Damage Reduction Benefit

Year	Without Project (2017 Prices)	With Project (2017 Prices)	Difference	Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
2019	$8,827	$3,697	$5,130	$5,358	$4,866	$4,866
2020	$9,748	$4,282	$5,466	$5,824	$5,089	$9,954
2021	$11,374	$6,343	$5,031	$5,467	$4,596	$14,550
2022	$13,513	$8,050	$5,463	$6,055	$4,898	$19,448
2023	$15,158	$9,702	$5,456	$6,169	$4,801	$24,250
2024	$17,037	$11,477	$5,560	$6,412	$4,802	$29,052
2025	$18,044	$13,535	$4,510	$5,305	$3,822	$32,874
2026	$19,806	$15,368	$4,438	$5,325	$3,692	$36,566

Notes: Inflation rates 2.2%/yr for 2017 to 2019 and 2.0%/yr for years 2019-2026
Discount rate 3.93% (mid-year discounting)
Discounted present worth beginning of 2017, using mid-year present worth factor
The values for each year are a result of a process similar to that described and shown in Tables 4.2.4 and 4.2.5 for 2019

The above analysis pertains to the potential land loss prevention benefit for 2019–2026 based on the probability of occurrence of future storms but does not directly address the annual land loss from background erosion. This study assumes the project offsets the background erosion that would have occurred during the 10-year project life without construction of the beach and dune restoration. That is, the project prevented 21.17 ft of land loss each year across the project area. As mentioned above, the land value equals $250 per acre in 2019 prices, or $239.35 per acre adjusted for inflation to 2017 prices. Assuming a project length of 15,312 ft, the land lost per year from background erosion equals 7.44 acres

(21.17 x 15,312 / 43,560 = 7.44) valued at $1,860 (7.44 x $250) in 2019 prices, or $1,781 (7.44 x $239.35) in 2017 prices. Using a mid-year present worth factor, the present worth equivalent = $1,747 for 2017, as outlined in Table 4.2.7. The cumulative land loss benefits for 2017–2026 equals $16,134. The total land loss prevention benefit for 2017–2026 equals $52,700 (36,566 [Table 4.2.6] + 16,134[Table 4.2.7] = 52,700).

Table 4.2.7 Project #1530 Land Loss (Background Erosion) Prevention Benefit

Year	Project Benefit (2017 Prices)	Inflation-Adjusted Value ($)	2017 Discounted Present Worth ($)	Cumulative Discounted Present Worth ($)
2017	$1,781	$1,781	$1,747	$1,747
2018	$1,781	$1,820	$1,718	$3,465
2019	$1,781	$1,860	$1,689	$5,155
2020	$1,781	$1,898	$1,658	$6,813
2021	$1,781	$1,936	$1,627	$8,440
2022	$1,781	$1,974	$1,597	$10,037
2023	$1,781	$2,014	$1,567	$11,605
2024	$1,781	$2,054	$1,538	$13,143
2025	$1,781	$2,095	$1,510	$14,653
2026	$1,781	$2,137	$1,482	$16,134

Note: Inflation rates 2.2%/yr for 2017 to 2019 and 2.0%/yr for years 2019-2026
Discount rate 3.93% (mid-year discounting)
Discounted present worth beginning of 2017, using mid-year present worth factor

4.2.3.3 Habitat Restoration Benefit

Taylor Engineering estimated the McFaddin NWR beach ridge restoration project benefit as the value of emergent wetland acreage protected from conversion to marine open water due to the project's minimization of saline water intrusion into the marsh system. The benefit estimate required determination of the amount of wetland that would be lost with and without the beach and dune restoration. To estimate wetland loss, we delineated the wetland area likely influenced by overwash salinity increases, determined the amount of emergent wetland converted to open water during the berm's project life, and estimated the economic value of wetlands based on per acre ecosystem services values. With the project, wetlands are lost during the construction year, but are protected thereafter for the expected 10-year project life. Without the project, wetlands are lost for each year of the analysis period, including the construction year and the 10 years during which the project would have prevented erosion of the wetlands landward of the beach ridge.

Taylor Engineering applied a geographic information system (GIS) analysis of National Wetlands Inventory (NWI) data to delineate and quantify the area of emergent wetland vegetation likely influenced by saline overwash entering the marsh. We assumed that overwash moved north and east through the marsh, bounded on the south by the newly-constructed berm, on the west by the unpaved road extending from the end of the project to the GIWW, on the north by the GIWW, and on the east by Perkins levee. We obtained NWI Texas wetlands data for this area as a shapefile from the Texas Natural Resources Information System. The NWI wetlands data are based on interpretation of 2010 aerial images. We did not attempt to account for any wetland loss occurring between the 2010 image date and project construction.

Comparison of the ecosystem value differences between the with-project and without-project conditions provides the project benefit value. For the without-project condition, we assumed that the annual wetland loss rate given above remains unchanged for the analysis period. The with-project condition assumed that ecosystem services benefits would begin the year following construction completion, as the reduction of saltwater entering the system and displacement of residual saltwater with fresh water during the wet season would eliminate emergent vegetation loss due to salinity effects.

We estimated the economic services value of the emergent vegetation marsh and open water (expressed as dollars/acre) as the sum of habitat, recreation, disturbance regulation, gas regulation, and waste regulation values (Section 2.3). We did not include the aesthetics value because most of the area benefitting from the project is remote and offers only limited human aesthetic experience. Marsh ecosystem services values at 2018 prices totaled $3,510 (Section 2.3). Adjusting values to 2017 levels provided values of $3,435.

Based on the above assumptions and analyses, we calculated the annual acreage of emergent wetlands lost for with- and without-project conditions. Subtracting the respective acreages acreage lost with the project (i.e., salinity-related loss during construction and permanent loss due to direct berm impact) from the acreage lost without the project (i.e., salinity-related loss) provided the net project benefit in terms of protected wetland acreage. We assumed a 10-year ecosystem services benefit life for the project (Table 4.2.8). Net acreage protected in each year is multiplied by the ecosystem services per acre value (2017 prices). This value is then converted to an inflation-adjusted amount, reflecting the price levels estimated to exist in each year. This amount is then converted to a present value, at the beginning of 2017. Finally, the annual benefit present values are accumulated for the 11-year evaluation period.

Table 4.2.8 McFaddin Island Beach Ridge Restoration Ecosystem Services Value-Marsh Erosion Prevention

Year	Marsh Lost (acres)				Net Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2017 Discounted Cumulative Value of Marsh Preserved ($)
	With Project		Without Project						
	Annual Loss	Cumulative	Annual	Cumulative		Value (2017 $)	Inflation-Adjusted Value ($)	Beginning of 2017 Discounted Present Worth[1] ($)	
2017	2.85	2.85	2.850	2.850	0.00	0	0	0	0
2018	0.00	2.85	1.640	4.490	1.64	5,634	5,758	5,434	5,434
2019	0.00	2.85	1.760	6.250	3.40	11,680	12,200	11,079	16,513
2020	0.00	2.85	2.020	8.270	5.42	18,619	19,837	17,333	33,846
2021	0.00	2.85	2.570	10.840	7.99	27,448	29,828	25,077	58,924
2022	0.00	2.85	2.870	13.710	10.86	37,308	41,352	33,452	92,376
2023	0.00	2.85	3.180	16.890	14.04	48,232	54,530	42,445	134,821
2024	0.00	2.85	4.010	20.900	18.05	62,008	71,507	53,554	188,375
2025	0.00	2.85	5.200	26.100	23.25	79,871	93,949	67,701	256,076
2026	0.00	2.85	6.190	32.290	29.44	101,136	121,342	84,134	340,210
2027	0.00	2.85	6.860	39.150	36.30	124,703	152,608	101,812	442,022

[1]Present worth in 2017, using a mid-year discount factor [1/Discount Rate$^{(n+0.5)}$, where n = (year - 2017)] with the inflation-adjusted value

4.2.4 Benefit-Cost Summary

Table 4.2.9 summarizes the project benefits and costs. With benefits summing to $12,828,494 and project costs totaling $2,590,695, this project has a 5.0 B/C ratio.

Table 4.2.9 Benefit-Cost Summary for Project #1530 McFaddin NWR Beach Ridge Restoration

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Federal Spending Benefit	$12,333,772
Land Loss Prevention	$52,700
Ecosystem Services Benefit	$442,022
Total Benefits	**$12,828,494**
Total Cost (Texas)	**$2,590,695**
B/C Ratio	**5.0**

Notes:
Texas costs only, assumed incurred at the beginning of the first year of project construction
Values represent present worth equivalents at the beginning of 2017 with a 3.93% discount rate

4.3 Galveston County — #1572 Dickinson Bayou Wetland Restoration

4.3.1 Project Description and Background Information

A combination of regional land subsidence, both natural and human-induced, as well as sea level rise have contributed to erosion of marshes in Galveston Bay (Coplin and Galloway,1999). As cessation of groundwater withdrawal has slowed regional subsidence, several marsh creation projects in Galveston Bay and vicinity have begun to restore marsh and eroded shorelines within the bay. The Dickinson Bayou Wetland Restoration Project protects shoreline and created marsh on the west side of the bayou about 2.75 miles upstream of its confluence with Dickinson Bay (Figure 4.3.1).

The restoration project created north and south berms (about 880 ft and 2,000 ft long) to protect the shoreline and allow for marsh creation. Open water behind the berms was backfilled with sediment from Dickinson Bayou to create about nine acres of estuarine marsh. A small (110-ft long) breakwater protects a tidal channel at the south end of the project area. Project construction began in May 2016 and was completed in August 2016. Figure 4.3.2 shows the project components.

4.3.2 Project Funding

Table 4.3.1 presents the funding breakdown for the project. The USFWS and CMP contributed federal funds to the construction of the project, and the GLO, Texas Parks and Wildlife Department, and Coastal Conservation Association covered the remaining non-federal costs. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. Accordingly, the resulting cost to Texas for Project #1572 amounts to $767,156; this value equals the sum of the non-federal costs ($706,835) and 10% state share of federal costs ($60,322). This analysis treats all costs as though they were incurred at the beginning of 2016), the year when construction took place. For purposes of this evaluation we are treating these costs as reflecting 2016 prices.

Table 4.3.1 Funding for Project #1572 Dickinson Bayou Wetland Restoration

Funding Source		Amount ($)
Federal	USFWS NCWD[2] *(Texas portion[3])*	436,605 *(43,661)*
	CMP Cycle 18[2] *(Texas portion)*	166,610 *(16,661)*
State	Texas GLO, CEPRA	627,687
	Texas Parks and Wildlife Department	36,485
Private	Coastal Conservation Association	42,663
Total Project Cost ***(Texas Total)***		1,310,050 *(767,156)*

Notes: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016

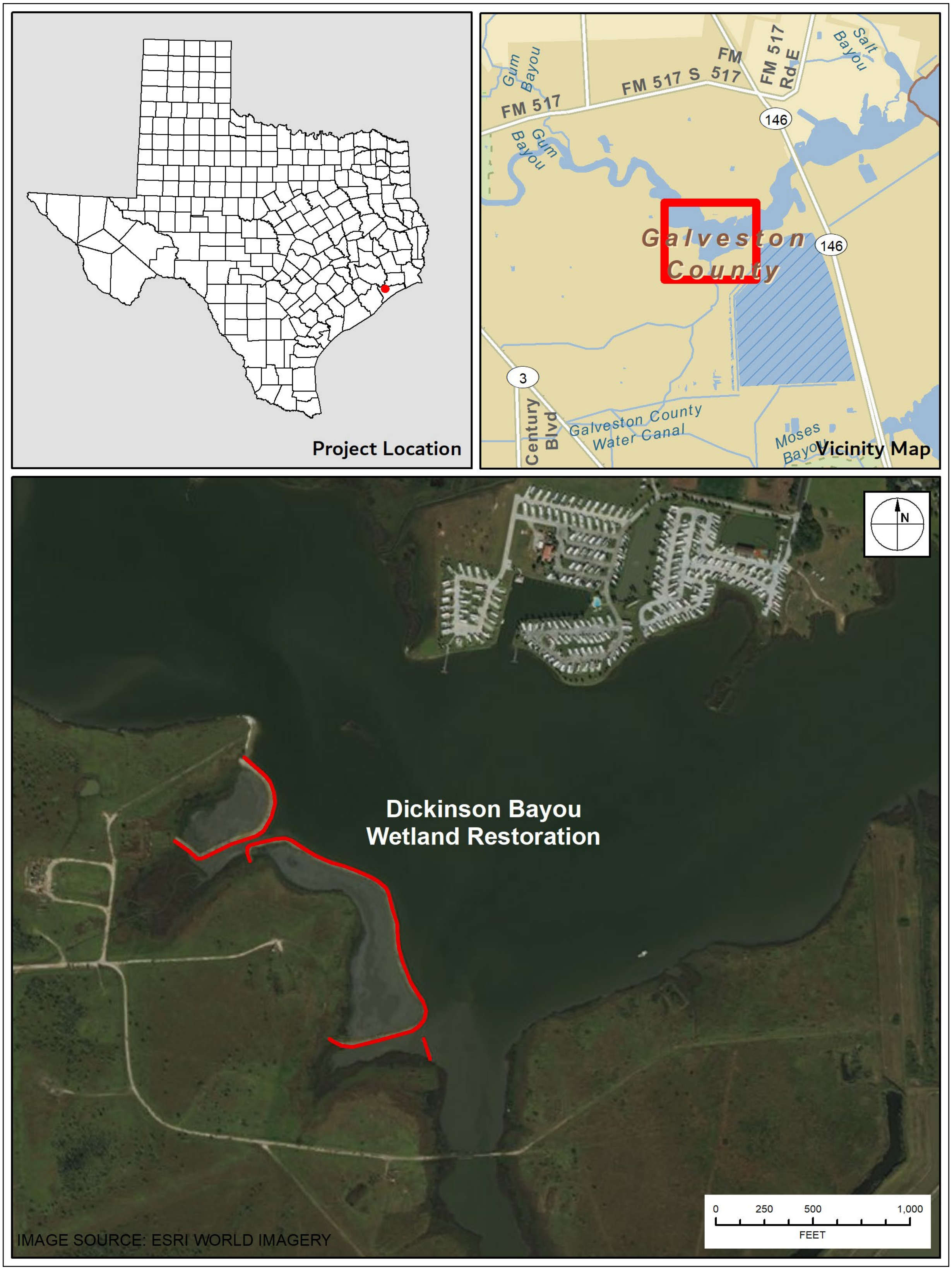

Figure 4.3.1 Location Map — Project #1572 Dickinson Bayou Wetland Restoration

Figure 4.3.2 Dickinson Bayou Wetland Restoration Project Features

4.3.3 Analysis

Benefits for Project #1614 include federal spending and ecosystem services benefits

4.3.3.1 <u>Federal Spending Benefit</u>

This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). A multiplier of 1.26 applied to the federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy. Federal funding provided $603,215 of the $1,310,050 total project cost (Table 4.3.1).

The non-Texas portion of the federal contributions (USFWS and CMP) listed in Table 4.3.1 $542,893.50 ($436,605x0.9 + 166,610x0.9 = $542,893.50) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $760,051 (i.e., $542,893.50 x 1.4) in 2016 prices

4.3.3.2 Ecosystem Services Benefits

The ecosystem services benefits analysis for the Dickinson Bayou wetland restoration rest on several assumptions:

- The berms and created marsh will prevent further erosion of the shoreline from its 2016 location.
- Created marsh ecosystems develop full ecosystem function over several years as vegetation becomes established and soil column value benefits occur when the created marshes have settled, vegetation becomes established, and benthic and soil column communities develop. As for previous GLO economic evaluations, full ecosystem services value will develop over a 15-year period (Trudnak et. al., 2015).
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Trudnak et. al., 2015).
- Ecosystem services benefits will accrue from 1) the breakwater's prevention of marsh erosion and 2) development of the new marsh.
- Benefits began following completion of the project in August 2016 (i.e., project benefits occurred for the last 1/3 of 2016 and for the subsequent 20-year project life.
- The project created marsh over open water; open water ecosystem services were lost and replaced by marsh ecosystem services.

Consistent with prior Texas GLO cost-benefit evaluations, we began project evaluation with the construction year (2016) and considered 2017 as the first year of the 20-year project life. Thus, the evaluation covered a 21-year period. We evaluated the Dickinson Bayou project applying the per acre marsh and open water ecosystem services values described in Section 2.3, adjusted to 2016 price levels ($3,421 per acre) to correspond to the project construction year.

The berms and created marsh will protect wetlands present landward of the 2016 shoreline. Our examination of aerial imagery available on Google Earth from 1968 to 2016 indicated an annual erosion rate of 1.0 ft/yr. Applying that erosion rate to the shoreline visible in a 02/07/2016 aerial image gave the without-project shoreline. Overlying without-project shoreline on currently available National Wetlands Inventory mapped data resulted in an estimated 1.3 acres of without-project marsh loss. Assuming that aerial marsh loss occurred in proportion to annual amount of shoreline retreat, we estimated annual without-project erosion of 0.062 acres/year over the 21-year evaluation period. With-project marsh loss of 0.04 acres occurred during the first 2/3 of the construction year; no marsh loss occurred thereafter. Subtracting annual with-project marsh loss from without-project marsh loss gave the net annual amount of marsh preserved by the project.

We determined the amount of created marsh as the area between the seaward edge of the low-level berms and the 2016 shoreline. GIS analysis indicated that the project created 9.08 acres of marsh. Because the created marsh does not initially provide full ecosystem services value, we considered the marsh as providing 0% of its full ecosystem services value during the construction year, 10% of ecosystem value during the first year following construction, and then adding an additional 6.4% of ecosystem value for the next 14 years. Thereafter, the created marsh provided 100% ecosystem value. The net annual value of created marsh therefore equaled marsh acres*percent service value*value/acre.

Marsh creation resulted in the loss of 9.08 acres of open water estuarine habitat. We assumed that the open water habitat was completely lost during the construction year.

The net ecosystem value for the project consisted of the sum of erosion prevention and marsh creation values minus the lost open water value.

Tables 4.3.2 and 4.3.3 detail the annual ecosystem services benefits from marsh protection and marsh creation. Table 4.3.4 details the value of lost open water ecosystem services. The net value of ecosystem services—the sum of the discounted value of marsh erosion prevented ($35,171) and marsh created ($318,501) less the value of open water habitat lost ($756)—resulting from this project equals $352,917 ($318,501 + $35,171 - $756 = $352,916) in discounted present worth (beginning of 2016).

Table 4.3.2 Project #1572 Ecosystem Services Value – Marsh Erosion Prevention

Year	Marsh Lost (acres)				Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			2016 Discounted Cumulative Value ($)
	With Project		Without Project						
	Annual Loss	Cumulative	Annual	Cumulative		Value (2016 $)	Inflation-Adjusted Value ($)	2016 Discounted Present Worth[1] ($)	
2016	0.04	0.04	0.062	0.062	0.02	70	70	69	69
2017	0.00	0.04	0.062	0.123	0.08	281	287	271	340
2018	0.00	0.04	0.062	0.185	0.14	492	514	467	807
2019	0.00	0.04	0.062	0.247	0.21	704	750	656	1,462
2020	0.00	0.04	0.062	0.308	0.27	915	995	836	2,299
2021	0.00	0.04	0.062	0.370	0.33	1,126	1,249	1,010	3,309
2022	0.00	0.04	0.062	0.432	0.39	1,337	1,513	1,178	4,487
2023	0.00	0.04	0.062	0.494	0.45	1,548	1,787	1,338	5,825
2024	0.00	0.04	0.062	0.555	0.51	1,759	2,071	1,492	7,317
2025	0.00	0.04	0.062	0.617	0.58	1,970	2,366	1,640	8,958
2026	0.00	0.04	0.062	0.679	0.64	2,181	2,672	1,782	10,740
2027	0.00	0.04	0.062	0.740	0.70	2,392	2,989	1,919	12,659
2028	0.00	0.04	0.062	0.802	0.76	2,603	3,318	2,049	14,708
2029	0.00	0.04	0.062	0.864	0.82	2,814	3,658	2,174	16,882
2030	0.00	0.04	0.062	0.925	0.88	3,025	4,011	2,294	19,176
2031	0.00	0.04	0.062	0.987	0.95	3,236	4,377	2,408	21,584
2032	0.00	0.04	0.062	1.049	1.01	3,447	4,756	2,518	24,102
2033	0.00	0.04	0.062	1.111	1.07	3,659	5,148	2,622	26,724
2034	0.00	0.04	0.062	1.172	1.13	3,870	5,554	2,722	29,446
2035	0.00	0.04	0.062	1.234	1.19	4,081	5,974	2,817	32,263
2036	0.00	0.04	0.062	1.296	1.25	4,292	6,409	2,908	35,171

[1]Present worth beginning of 2016, using a mid-year discount factor [1/(Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

Table 4.3.3 Project #1572 Ecosystem Services Value - Marsh Creation

Year	Marsh Area Created		Annual Value of Created Marsh			2016 Discounted Cumulative Value ($)
	Total (acres)	Net Marsh Service (acres)	Value (2016 $)	Inflation-Adjusted Value ($)	2016 Discounted Present Worth[1] ($)	
2016	9.08	0.00	0	0	0	0
2017	9.08	0.91	3,106	3,171	2,993	2,993
2018	9.08	1.49	5,103	5,325	4,836	7,829
2019	9.08	2.08	7,100	7,572	6,616	14,445
2020	9.08	2.66	9,097	9,895	8,319	22,764
2021	9.08	3.24	11,094	12,308	9,957	32,721
2022	9.08	3.83	13,091	14,814	11,531	44,252
2023	9.08	4.41	15,087	17,416	13,043	57,295
2024	9.08	4.99	17,084	20,115	14,495	71,791
2025	9.08	5.58	19,081	22,916	15,889	87,680
2026	9.08	6.16	21,078	25,820	17,226	104,905
2027	9.08	6.75	23,075	28,832	18,507	123,413
2028	9.08	7.33	25,072	31,953	19,736	143,148
2029	9.08	7.91	27,069	35,188	20,912	164,060
2030	9.08	8.50	29,065	38,539	22,038	186,098
2031	9.08	9.08	31,062	42,011	23,114	209,212
2032	9.08	9.08	31,062	42,851	22,685	231,897
2033	9.08	9.08	31,062	43,708	22,264	254,160
2034	9.08	9.08	31,062	44,582	21,850	276,011
2035	9.08	9.08	31,062	45,474	21,444	297,455
2036	9.08	9.08	31,062	46,384	21,046	318,501

[1]Present worth in 2016, using a mid-year discount factor [1/(Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

Table 4.3.4 Project #1572 Ecosystem Services Value – Open Water Loss

Year	Open Water Lost (acres)	Annual Value of Open Water Lost			2016 Discounted Cumulative Value ($)
		Value (2016 $)	Inflation-Adjusted Value ($)	2016 Discounted Present Worth[1] ($)	
2016	9.08	44	44	43	43
2017	9.08	44	45	42	85
2018	9.08	44	46	41	127
2019	9.08	44	47	41	167
2020	9.08	44	48	40	207
2021	9.08	44	49	39	247
2022	9.08	44	50	39	285
2023	9.08	44	51	38	323
2024	9.08	44	52	37	360
2025	9.08	44	53	36	397
2026	9.08	44	54	36	432
2027	9.08	44	55	35	468
2028	9.08	44	56	34	502
2029	9.08	44	57	34	536
2030	9.08	44	58	33	569
2031	9.08	44	59	33	602
2032	9.08	44	60	32	634
2033	9.08	44	62	31	665
2034	9.08	44	63	31	696
2035	9.08	44	64	30	726
2036	9.08	44	65	30	756

[1]Present worth beginning of 2016, using a mid-year discount factor [1/(Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

4.3.4 Benefit-Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a benefit-cost ratio of 1.5 (Table 4.3.5) in 2016 dollars.

Table 4.3.5 Benefit-Cost Summary for Project #1572 Dickinson Bayou Wetland Restoration

Benefits and Costs	Discounted Present Worth (Beginning of 2016)
Federal Spending Benefit	$760,051
Ecosystem Services Benefit	$352,916
Total Benefits	**$1,112,967**
Total Cost (Texas Cost)	**$767,156**
B/C Ratio	**1.5**

Note: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

4.4 Galveston County — #1596 Virginia Point Wetland Protection & Restoration

4.4.1 Project Description and Background Information

A combination of regional land subsidence, both natural and human-induced, as well as sea level rise have contributed to erosion of marshes in Galveston Bay (Coplin and Galloway,1999). As cessation of groundwater withdrawal has slowed regional subsidence, several marsh creation projects in Galveston Bay and vicinity have begun to restore marsh-eroded shorelines within the bay. The Virginia Point Shoreline Protection Project created marsh and protects shoreline on the west side of Galveston Bay between the Virginia Campsites and the Malone Superfund Site (Figure 4.4.1).

The project constructed approximately 6,025 linear feet of 58 segmented, limestone rip rap breakwaters at Virginia Point between March and October 2016. The final breakwater layout was comprised of five cells. The first cell is the southernmost cluster of breakwaters near the Virginia Point Campsites, and progressing northward to the fifth cell of breakwaters, near the Malone Superfund Site (Figure 4.4.2).

4.4.2 Project Funding

Funds for project execution included support from the federal, Texas, and non-governmental organization (NGO) sources listed in Table 4.4.1. As described in Section 2.1, we assume that Texas taxpayers support 10% of the federal costs; thus, any costs that originate from national agencies or organizations are decreased by 90%. Accordingly, the Texas share of the CIAP cost is $198,504 and the National Fish and Wildlife Federation (NFWF)—a NGO predominantly funded by Congressional appropriations and agreements with federal agencies—cost is $187,451. The resulting cost to Texas for Project #1572 amounts to $450,579; this value equals the sum of the CEPRA and 10% state share of the federal and NGO costs ($64,624 + $198,504 + $187,451 = $450,579). This analysis treats all costs as though they were incurred at the beginning of 2016 (i.e., the cost reflects 2016 price levels, and is a present worth equivalent value, beginning of 2016).

Table 4.4.1 Funding for Project #1596 Virginia Point Wetland Protection & Restoration

Funding Source		Amount ($)
Federal	CIAP *(Texas Portion[2])*	1,985,041 *(198,504)*
State	Texas GLO, CEPRA	*64,624*
NGO	NFWF *(Texas Portion[2])*	1,874,507 *(187,451)*
Total Project Cost		3,924,172
Texas Total		*450,579*

Notes: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016.

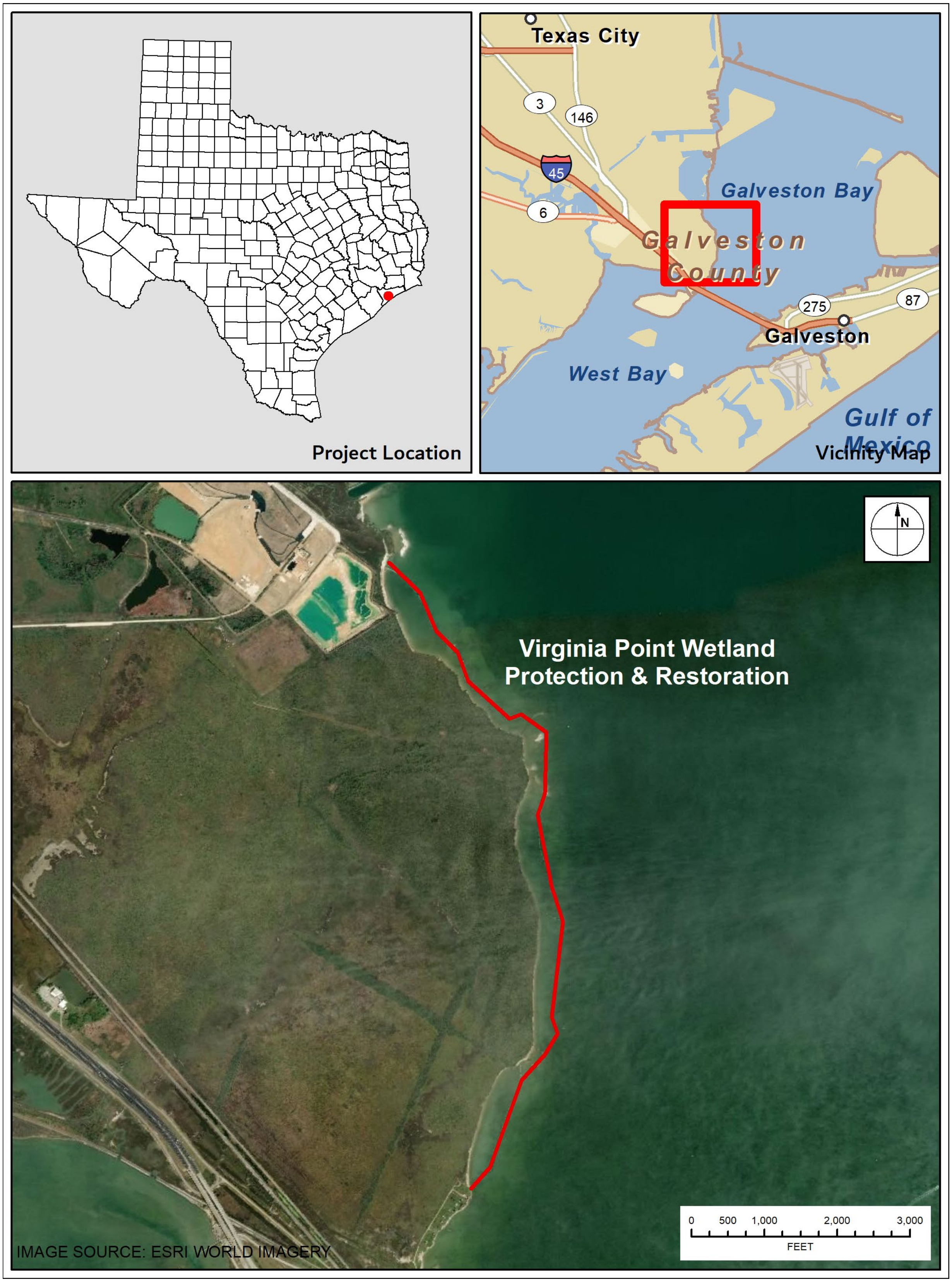

Figure 4.4.1 Location Map — Project #1596 Virginia Point Wetland Protection & Restoration Project

Figure 4.4.2 Virginia Point Wetland Protection & Restoration Project Features (Source: TX GLO)

4.4.3 Analysis

Economics benefits from Project #1572 include federal spending and ecosystem protection.

4.4.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (CIAP and NFWF) listed in Table 4.4.1 ($1,985,041x0.9 + $1,874,507*0.9 = $3,473,593) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $4,863,030 (i.e., $3,473,593 x 1.4) in 2017 prices.

4.4.3.2 Ecosystem Services Benefits

The ecosystem services benefits analysis for Project#1572 rests on several assumptions:

- The breakwaters will prevent further erosion of the shoreline from its 2016 location and accumulate sediments to bring bottom elevations up to create suitable marsh depths.
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015).
- Ecosystem services benefits will accrue from the breakwater's prevention of marsh erosion
- Benefits began following completion of the project in August 2016 (i.e., project benefits occurred for the last 1/3 of 2016 and for the subsequent 20-year project life.
- Volunteers planted 3.04 acres of marsh vegetation in 2018; this marsh creation is not included in the benefits analysis, because the planting was not funded as part of Project #1572.

Consistent with prior Texas GLO cost-benefit evaluations, we began project evaluation with the construction year (2016) and considered 2017 as the first year of the 20-year project life. Thus, the evaluation covered a 21-year period.

The breakwaters will protect wetlands present landward of the 11,197-ft long project area shoreline. Our examination of aerial imagery available on Google Earth from January 22, 1995 and January 22, 2017 indicated an annual erosion rate of 5.4 ft/yr. Applying that erosion rate to the shoreline visible in the January 22, 2017 aerial image moved the without-project shoreline 108 ft further landward (5.4 ft/yr x 20 years) resulting in an estimated 27.8 acre loss, or 1.39 acres per year. Adjusting marsh ecosystem services values (see Section 2.3) to 2016 price levels provided a value of $3,421/acre for this project evaluation. Breakwater construction resulted in a loss of 4.78 acres of open water estuarine habitat in 2016. Open water ecosystem services, adjusted to 2016 price level, were valued at $4.82/acre. Loss of benefits were calculated based on those dates.

Table 4.4.2 details the annual ecosystem services benefits from marsh protection, and Table 4.4.3 details the value of lost open water ecosystem services. The net value of ecosystem services—the discounted value of marsh erosion prevented ($764,122) less the value of open water habitat lost ($398)—resulting from this project equals $763,724 ($764,122 - $398 = $763,724) in discounted present worth (beginning of 2016).

Table 4.4.2 Project #1596 Ecosystem Services Value – Marsh Erosion Prevention

Year	Marsh Lost (acres)				Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2016 Discounted Cumulative Value ($)
	With Project		Without Project						
	Annual Loss	Cumulative	Annual	Cumulative		Value (2016 Price Levels)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	1.39	1.39	1.39	1.39	0.00	0	0	0	0
2017	0.00	1.39	1.39	2.78	1.39	4,750	4,849	4,577	4,577
2018	0.00	1.39	1.39	4.17	2.78	9,499	9,912	9,002	13,579
2019	0.00	1.39	1.39	5.56	4.17	14,249	15,195	13,278	26,856
2020	0.00	1.39	1.39	6.94	5.55	18,999	20,666	17,375	44,231
2021	0.00	1.39	1.39	8.33	6.94	23,748	26,349	21,315	65,546
2022	0.00	1.39	1.39	9.72	8.33	28,498	32,251	25,103	90,649
2023	0.00	1.39	1.39	11.11	9.72	33,248	38,379	28,743	119,392
2024	0.00	1.39	1.39	12.50	11.11	37,997	44,738	32,239	151,631
2025	0.00	1.39	1.39	13.89	12.50	42,747	51,337	35,595	187,226
2026	0.00	1.39	1.39	15.27	13.88	47,497	58,182	38,816	226,042
2027	0.00	1.39	1.39	16.66	15.27	52,246	65,281	41,905	267,947
2028	0.00	1.39	1.39	18.05	16.66	56,996	72,640	44,865	312,813
2029	0.00	1.39	1.39	19.44	18.05	61,746	80,267	47,702	360,514
2030	0.00	1.39	1.39	20.83	19.44	66,495	88,170	50,417	410,931
2031	0.00	1.39	1.39	22.22	20.83	71,245	96,357	53,015	463,946
2032	0.00	1.39	1.39	23.60	22.21	75,995	104,836	55,499	519,445
2033	0.00	1.39	1.39	24.99	23.60	80,744	113,617	57,873	577,318
2034	0.00	1.39	1.39	26.38	24.99	85,494	122,706	60,139	637,458
2035	0.00	1.39	1.39	27.77	26.38	90,244	132,113	62,302	699,759
2036	0.00	1.39	1.39	29.16	27.77	94,993	141,848	64,363	764,122

[1]Present worth, beginning of 2016, using a mid-year discount factor [(1/Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

Table 4.4.3 Project #1596 Ecosystem Services Value – Open Water Habitat Loss

Year	Open Water Lost (acres)	Annual Value Lost			2016 Discounted Cumulative ($)
		Value (2016 $)	Inflation-Adjusted Value ($)	2016 Discounted Present Worth[1] ($)	
2016	4.78	23	23	23	23
2017	4.78	23	24	22	45
2018	4.78	23	24	22	67
2019	4.78	23	25	21	88
2020	4.78	23	25	21	109
2021	4.78	23	26	21	130
2022	4.78	23	26	20	150
2023	4.78	23	27	20	170
2024	4.78	23	27	20	190
2025	4.78	23	28	19	209
2026	4.78	23	28	19	228
2027	4.78	23	29	18	246
2028	4.78	23	29	18	264
2029	4.78	23	30	18	282
2030	4.78	23	31	17	300
2031	4.78	23	31	17	317
2032	4.78	23	32	17	334
2033	4.78	23	32	17	350
2034	4.78	23	33	16	367
2035	4.78	23	34	16	382
2036	4.78	23	34	16	398

[1]Present worth beginning of 2016, using a mid-year discount factor [(1/Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

4.4.4 Benefit-Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a benefit-cost ratio of 12.5 (Table 4.4.4) in 2016 dollars.

Table 4.4.4 Benefit-Cost Summary for Project #1596 Virginia Point Wetland Protection & Restoration

Benefits and Costs	Beginning of 2016 Discounted Present Worth
Federal and NGO Spending Benefit	$4,863,030
Ecosystem Services Benefit	$763,724
Total Benefits	**$5,626,754**
Total Cost (Texas)	**$450,579**
B/C Ratio	**12.5**

Note: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

4.5 Galveston County — #1601 West Galveston Island Bayside Marsh Restoration

4.5.1 Project Description and Background Information

A combination of regional land subsidence, both natural and human-induced, as well as sea level rise have contributed to erosion of marshes in Galveston Bay (Coplin and Galloway, 1999). As cessation of groundwater withdrawal has slowed regional subsidence, several marsh creation projects in Galveston Bay have begun to restore marsh along the bay side of Galveston Island. The West Galveston Island Marsh Restoration Project (Project) is a continuation of these restoration efforts.

Initial marsh restoration efforts began in the 1990's at Carancahua Cove, where Texas Parks and Wildlife Department (TPWD) and volunteers, installed rectangular terraces made of dredged material and geotextile breakwaters in order to decrease wave action. Marsh grasses were planted on top of the terraces to promote marsh growth. In 2010, additional restoration efforts began. Due to the fine sands of the terraced grid and wave action, the geotextile breakwater and terraced grid slowly eroded away. TPWD and partners worked to restore the original 200-acre grid of inter-tidal marsh.

The West Galveston Island Marsh Restoration Project built two rock breakwaters (5,415 linear feet) to protect against wave action generated in the West Bay and created 75-acres of marsh habitat by constructing emergent mounds in intertidal areas and open water. The mounds, created with material hydraulically dredged from a nearby borrow area in West Galveston Bay, provide a platform for growing marsh vegetation. The construction contract was executed on July 21, 2016, the rock breakwaters were finished in February 2017, the dredged material placement was finished in June 2017, and maintenance observations were conducted on June 26th and 27th, 2018. Figure 4.5.1 provides a location map and Figure 4.5.2 shows project details.

4.5.2 Project Funding

Table 4.5.1 presents the funding breakdown for the project. The USFWS and CMP contributed federal funds to the construction of the project, and the GLO, Texas Parks and Wildlife Department, and Coastal Conservation Association covered the remaining non-federal costs. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the resulting cost to Texas for Project #1572 amounts to $767,156; this value equals the sum of the non-federal costs ($706,835) and 10% state share of federal costs ($60,322). This analysis treats all costs as though they were incurred at the beginning of 2016), the year when construction took place. For purposes of this evaluation we are treating these costs as reflecting 2016 prices.

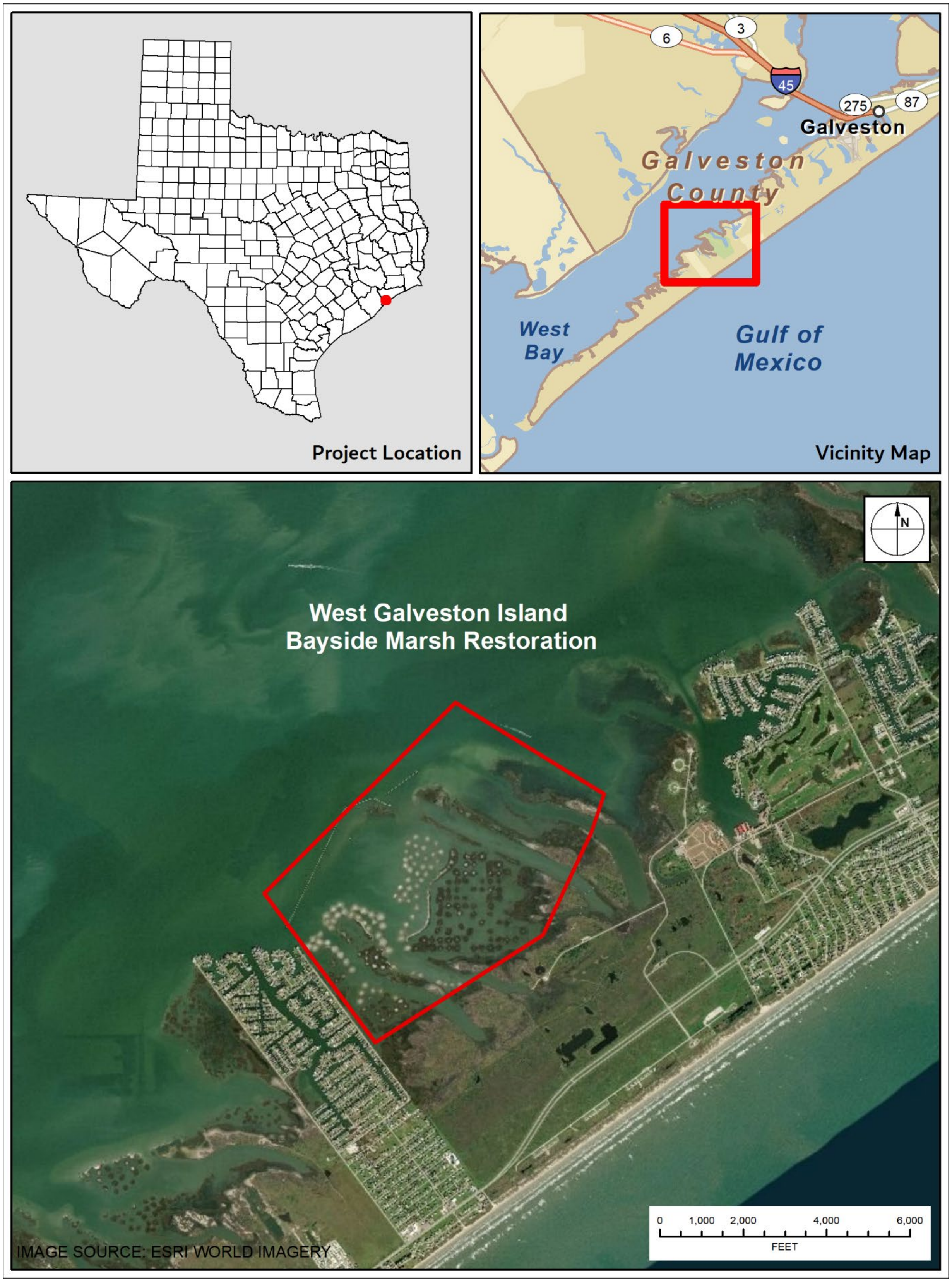

Figure 4.5.1 Location Map — Project #1601 West Galveston Island Bayside Marsh Restoration

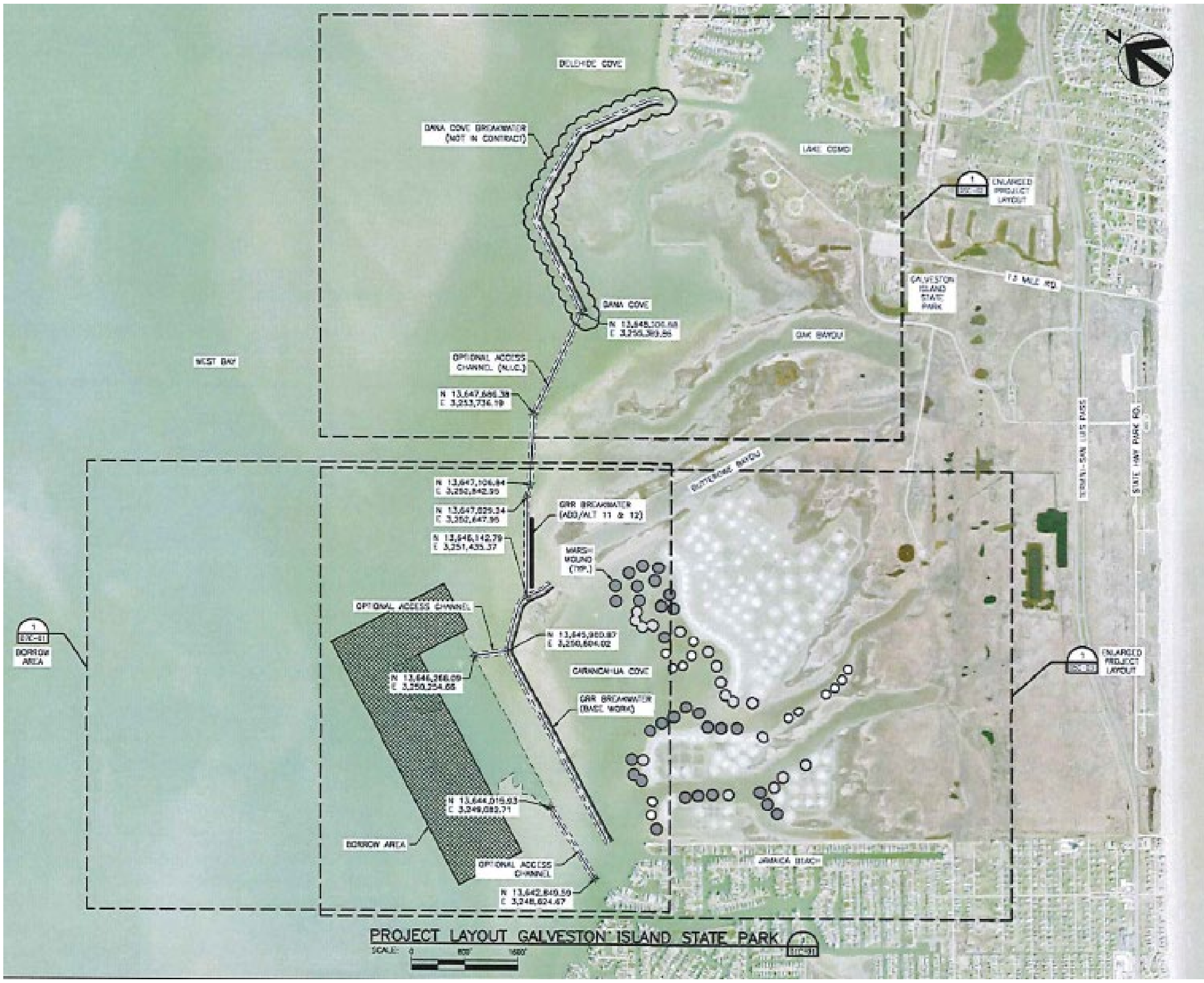

Figure 4.5.2 Project #1601 Plan View Drawing (Detail from HDR project record drawing dated April 2016)

Table 4.5.1 Funding for Project #1601 West Galveston Island Bayside Marsh Restoration

Funding Source		Amount
Federal	State 2009 CIAP *(Texas portion)*	$2,490,029 *($249,003)*
	NFWF *(Texas portion)*	$4,857,887 *($485,789)*
State/Local	TX GLO, CEPRA	*$50,778*
Total Project Funding (100%)		$7,398,694
(Texas Total)		*$785,570*

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning of 2016

4.5.3 Analysis

Benefits for Project #1601 include federal spending and ecosystem services benefits

4.5.3.1 <u>Federal Spending Benefit</u>

The non-Texas portion of the federal contributions (CIAP and NFWF)) listed in Table 4.5.1 ([$2,490,029 x 0.9] + [$4,857,887 x 0.9] = $6,613,124) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $9,258,374 (i.e., $6,613,124x1.4) in 2016 prices.

4.5.3.2 <u>Ecosystem Services Benefit</u>

The ecosystem services benefits analysis for the West Galveston Island Marsh Restoration rests on several assumptions:

- The breakwaters and created marsh will prevent further erosion of the shoreline from its 2016 location.
- Created marsh ecosystems develop full ecosystem function over several years as vegetation becomes established and soil column value benefits occur when the created marshes have settled, vegetation becomes established, and benthic and soil column communities develop. As for previous GLO economic evaluations, full ecosystem services value will develop over a 15-year period (Taylor, 2015).
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015).
- Full ecosystem value benefits occur when the marsh mounds have settled and developed a vegetation community as well as a full benthic community and marsh soil column.
- The project created breakwaters over open water which caused open water ecosystem services lost, assumed to beginning accruing in 2017.
- Benefits began the beginning of the first year construction was completed (early 2017) and for the rest of the subsequent 20-year project life.
- Ecosystem services benefits will accrue from 1) the breakwater’s prevention of marsh erosion and 2) development of new marsh on the mounds;
- The newly constructed breakwaters serve to protect the new marsh areas, not the pre-existing areas.

Consistent with prior Texas GLO cost-benefit evaluations, we began project evaluation with the construction year (2016) and considered 2017 as the first year of the 20-year project life. Thus, the evaluation covered a 21-year period.

The shoreline erosion rate considers multiple locations for erosion, including the islands at the tip of Butterowe Bayou and the previously constructed marsh boundaries. Using Google Earth imagery, the shoreline was mapped around the 3 northern islands for the available years beginning November 28, 2011, the time that the area was at its most full and vegetated state. Shorelines were traced for approximately six years, including the project year (2017) and the most recent imagery (March 21, 2018). Transects were made across each island and marsh boundary in the direction of wave action at that island shoreline. The distances were measured from the November 2011 shoreline back to the March 2018 shoreline and averaged over the 6.33 years in between to get the annual shoreline erosion rate of 9.98 ft/yr. Assuming that aerial marsh loss occurred in proportion to annual amount of shoreline retreat, we estimated annual without-project erosion of 0.57 acres/year.

We determined the amount of created marsh as the newly installed marsh mounds seaward of the 2016 shoreline and within the terraced grid. The Performance Monitoring at the West Galveston Island Marsh Restoration Project Report (HDR, 2018) stated the project restored 75 acres of intertidal marsh complex within the Carancahua Cove, through construction of 81 marsh mounds and 5,415 linear foot of breakwater. Because the created marsh does not initially provide full ecosystem services value, we considered the marsh as providing 0% of its full ecosystem value during the construction year, 10% of ecosystem value during the first year following construction, and then adding an additional 6.4% of ecosystem value for the next 14 years. Thereafter, the created marsh provided 100% ecosystem value.

Marsh creation resulted in the loss of 2.49 acres of open water estuarine habitat. We assumed that the open water habitat was completely lost during the construction year.

Tables 4.5.2 and 4.5.3 detail the annual ecosystem services benefits from marsh protection and marsh creation. Table 4.5.4 details the value of lost open water ecosystem services. The net value of ecosystem services—the sum of the discounted value of marsh erosion prevented ($310,954) and marsh created ($2,587,511) less the value of open water habitat lost ($756)—resulting from this project equals $2,898,270 ($310,954 + $2,587,511 - $195 = $2,898,270) in discounted present worth (beginning of 2016).

Table 4.5.2 Project #1601 Ecosystem Services Value – Erosion Prevention

Year	Marsh Lost (acres)				Net Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2016 Discounted Cumulative Value of Marsh Preserved ($)
	With Project		Without Project						
	Annual Loss	Cumulative	Annual	Cumulative		Values (2016 $)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	0.57	0.57	0.57	0.57	0.00	0	0	0	0
2017	0.00	0.57	0.57	1.13	0.57	1,933	1,973	1,863	1,863
2018	0.00	0.57	0.57	1.70	1.13	3,866	4,034	3,663	5,526
2019	0.00	0.57	0.57	2.26	1.70	5,799	6,184	5,403	10,929
2020	0.00	0.57	0.57	2.83	2.26	7,731	8,410	7,070	17,999
2021	0.00	0.57	0.57	3.39	2.83	9,664	10,722	8,674	26,673
2022	0.00	0.57	0.57	3.96	3.39	11,597	13,124	10,215	36,889
2023	0.00	0.57	0.57	4.52	3.96	13,530	15,618	11,697	48,586
2024	0.00	0.57	0.57	5.09	4.52	15,463	18,206	13,119	61,705
2025	0.00	0.57	0.57	5.65	5.09	17,396	20,891	14,485	76,190
2026	0.00	0.57	0.57	6.22	5.65	19,328	23,677	15,796	91,986
2027	0.00	0.57	0.57	6.78	6.22	21,261	26,565	17,053	109,039
2028	0.00	0.57	0.57	7.35	6.78	23,194	29,560	18,258	127,297
2029	0.00	0.57	0.57	7.91	7.35	25,127	32,664	19,412	146,709
2030	0.00	0.57	0.57	8.48	7.91	27,060	35,880	20,517	167,225
2031	0.00	0.57	0.57	9.04	8.48	28,993	39,212	21,574	188,799
2032	0.00	0.57	0.57	9.61	9.04	30,925	42,662	22,585	211,384
2033	0.00	0.57	0.57	10.17	9.61	32,858	46,235	23,551	234,935
2034	0.00	0.57	0.57	10.74	10.17	34,791	49,934	24,473	259,409
2035	0.00	0.57	0.57	11.30	10.74	36,724	53,763	25,353	284,762
2036	0.00	0.57	0.57	11.87	11.30	38,657	57,724	26,192	310,954

[1]Present worth at beginning of 2016, applying a mid-year discount factor [$(1/1.0393)^{n+0.5}$, where n = (year - 2016)] (discount rate = 3.93%) to the inflation-adjusted value

Table 4.5.3 Project #1601 Ecosystem Services Value – Marsh Created

Year	Marsh Area Created		Annual Value of Created Marsh			Beginning of 2016 Discounted Cumulative Discounted Present Worth ($)
	Total (acres)	Net Marsh Service (acres)	Values (2016 $)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	0	0.00	0	0	0	0
2017	75.00	7.50	25,235	25,765	24,317	24,317
2018	75.00	12.32	41,458	43,259	39,285	63,603
2019	75.00	17.14	57,680	61,511	53,748	117,350
2020	75.00	21.96	73,903	80,387	67,585	184,936
2021	75.00	26.79	90,125	99,994	80,891	265,827
2022	75.00	31.61	106,348	120,353	93,679	359,505
2023	75.00	36.43	122,570	141,486	105,963	465,469
2024	75.00	41.25	138,793	163,416	117,760	583,228
2025	75.00	46.07	155,015	186,167	129,082	712,310
2026	75.00	50.89	171,238	209,763	139,942	852,252
2027	75.00	55.71	187,460	234,228	150,355	1,002,607
2028	75.00	60.54	203,683	259,587	160,333	1,162,940
2029	75.00	65.36	219,905	285,868	169,888	1,332,828
2030	75.00	70.18	236,128	313,095	179,033	1,511,861
2031	75.00	75.00	252,350	341,298	187,780	1,699,641
2032	75.00	75.00	252,350	348,124	184,293	1,883,934
2033	75.00	75.00	252,350	355,086	180,871	2,064,804
2034	75.00	75.00	252,350	362,188	177,512	2,242,316
2035	75.00	75.00	252,350	369,432	174,215	2,416,531
2036	75.00	75.00	252,350	376,821	170,980	2,587,511

[1]Present worth at beginning of 2016, applying a mid-year discount factor [$(1/1.0393)^{n+0.5}$, (discount rate = 3.93%) where n = (year - 2016)] to the inflation-adjusted value

Table 4.5.4 Project #1601 Ecosystem Services Value – Open Water Loss

Year	Open Water Lost (acres)	Annual Value Lost			Beginning of 2016 Discounted Cumulative Value ($)
		Value (2016 $)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	0.00	0	0	0	0
2017	2.49	12	12	12	12
2018	2.49	12	13	11	23
2019	2.49	12	13	11	34
2020	2.49	12	13	11	45
2021	2.49	12	13	11	56
2022	2.49	12	14	11	66
2023	2.49	12	14	10	77
2024	2.49	12	14	10	87
2025	2.49	12	14	10	97
2026	2.49	12	15	10	107
2027	2.49	12	15	10	116
2028	2.49	12	15	9	126
2029	2.49	12	16	9	135
2030	2.49	12	16	9	144
2031	2.49	12	16	9	153
2032	2.49	12	17	9	162
2033	2.49	12	17	9	171
2034	2.49	12	17	8	179
2035	2.49	12	18	8	187
2036	2.49	12	18	8	195

[1]Present worth in 2016, using a mid-year discount factor [(1/Discount Rate)$^{n+0.5}$, where n = (year - 2016)] with the inflation-adjusted value

4.5.4 Benefit-Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a benefit-cost ratio of 15.5 (Table 4.5.5) in 2016 dollars.

Table 4.5.5 Benefit-Cost Summary-Project #1601 West Galveston Island Bayside Marsh Restoration

Benefits and Costs	Discounted Present Worth (Beginning of 2016)
Federal Spending Benefit	$9,258,374
Ecosystem Services Benefit	$2,898,270
Total Benefits	**$12,156,643**
Total Cost (Texas)	**$785,570**
B/C Ratio	**15.5**

Note: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

4.6 Matagorda County — #1612 Mad Island Wildlife Management Area Shoreline Protection Phase 2

4.6.1 Project Description

The Mad Island Wildlife Management Area (WMA), Matagorda County Texas, includes 7,200 acres of marsh and upland habitat within the Gulf Coast Prairies and Marshes Ecoregion. This project, the second phase of protection efforts for the shoreline of the WMA along the Gulf Intracoastal Waterway (GIWW), constructed approximately 3,010 linear feet of rock breakwater to protect the adjacent freshwater and brackish marshes within the WMA that would otherwise be impacted by saline water or lost completely if the long-term erosion rate were to continue unabated. The Phase 2 breakwater connected to the east end of the Phase 1 breakwater and extended east to the boundary of the WMA. Phase II completed the GIWW shoreline protection effort (Figure 4.6.1).

4.6.2 Project Funding

Funds for project execution included support from Texas sources listed in Table 4.6.1. Lacking an allocation of funding sources to project activity (e.g., engineering and design, construction) by expenditure date, we assumed that all project expenditures occurred in 2017, the year of breakwater construction.

Table 4.6.1 Funding for Project #1612 Mad Island WMA Shoreline Protection Phase 2

Funding Source		Amount ($)
State	Texas Parks and Wildlife Department (in-kind)	*$440,050*
	Texas GLO, CEPRA	*$440,050*
Total Project Cost		***$880,100***
Texas Total		***$880,100***

Notes: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2017.

4.6.3 Analysis

4.6.3.1 <u>Ecosystem Services Benefits</u>

The ecosystem services benefits analysis for the Mad Island Wildlife Management Area Shoreline Protection Phase 2 Project rests on several assumptions:

- The breakwater will prevent further erosion of the shoreline from its 2017 location.
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015).
- The project created breakwater over open water; open water ecosystem services were lost and not replaced.
- Ecosystem services benefits will accrue from the breakwater’s prevention of marsh erosion.
- Benefits began following completion of the project in December 2017 (i.e., project benefits occurred beginning January 1, 2018 and for the subsequent 20-year project life.

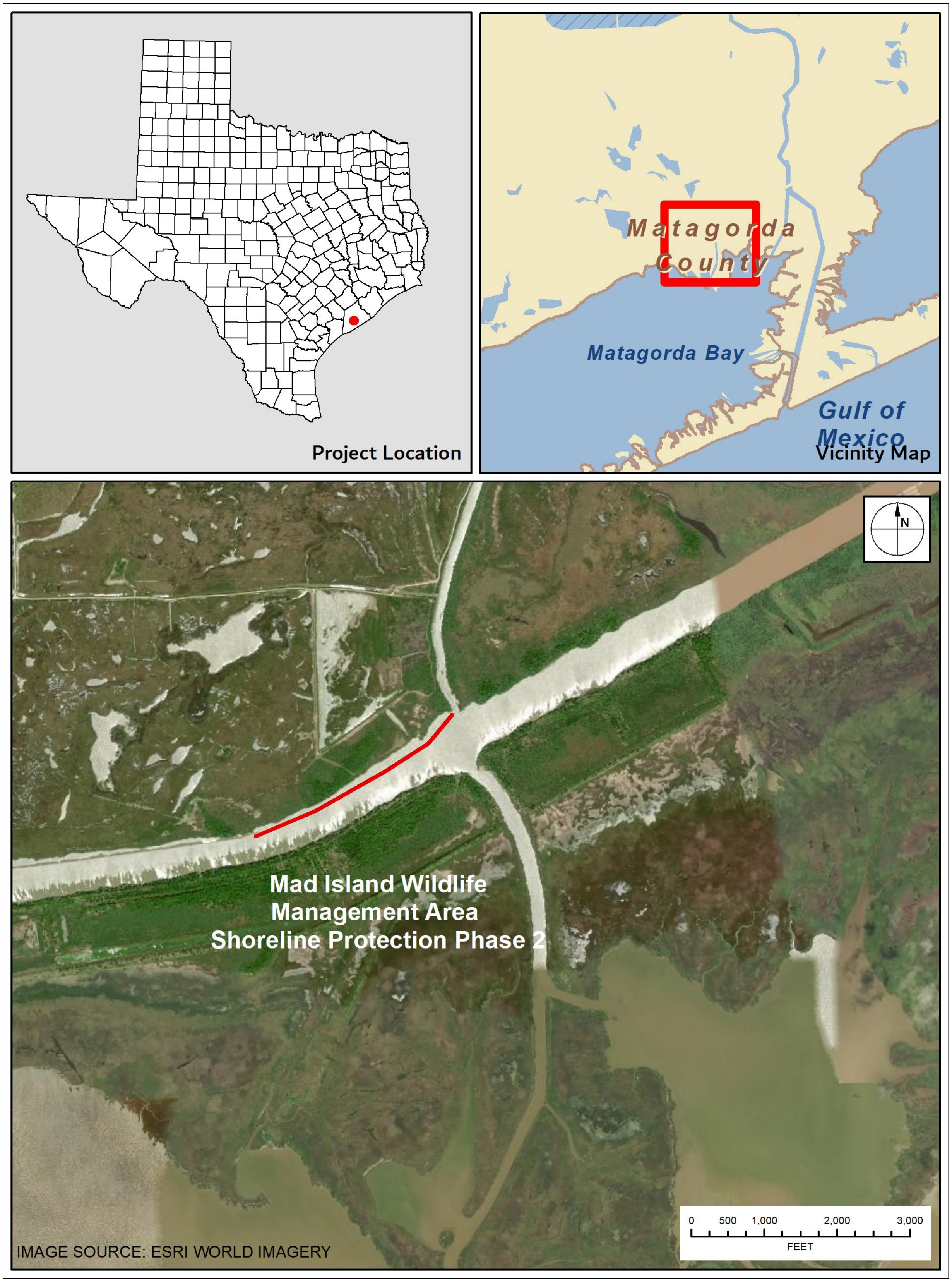

Figure 4.6.1 Location Map — Project #1612 Mad Island WMA Shoreline Protection Phase 2

Consistent with prior Texas GLO cost-benefit evaluations, we began project evaluation with the construction year (2017) and considered 2018 as the first year of the 20-year project life. Thus, the evaluation covered a 21-year period. We evaluated the Mad Island project applying the per acre marsh and open water ecosystem services values described in Section 2.3, adjusted to 2017 price levels to correspond to the project construction year.

TPWD estimated shoreline erosion rates of 1-3 ft/yr due to boat and barge wake action (Raasche and Nelson 2019). For this analysis we mapped the project shoreline visible in February 3, 1995 and August 29, 2017 images on Google Earth. We exported the maps to ARCMap and measured the distance between shorelines at 16 shore-perpendicular control lines along the 3,010 ft project area. The average distance between the two shorelines was divided by the number of years between them (22) to obtain an average erosion rate of 2.49 ft/year or 0.17 acres/year. A without-project shoreline was then created based on the average erosion rate. Since the entire eroded area was wetland, the area of wetland lost was calculated as the total area lost with a 2.49 ft/year erosion rate over a 20-year period, 3.44 acres. This 22-year erosion estimate was compared to a longer term estimate based on 1964 (the earliest year with useful aerial photographs) and 2017 aerials. The more recent erosion rate estimate (ft/year erosion) for the current period was slightly but not significantly higher than the longer-term average.

The benefits were estimated assuming that the unattenuated erosion would continue to erode freshwater marsh along the shorelines of the GIWW at the estimated long-term rate, and that the breakwater, constructed in 2017, would completely eliminate the erosion, preserving the marshes behind it. The benefits are attained for the marsh preserved for the project life, assumed to be 20 years. Adjusting marsh ecosystem services values (see Section 2.3) to 2017 price levels provided a value of $3,493/acre for this project evaluation.

With a base width of 13.5 to 18.5 ft over a 3,010 ft length (data from GLO), breakwater construction resulted in the loss of 1.24 acres of open water habitat. We assumed this loss occurred in 2017. The project did not replace open water habitat. Open water ecosystem services, adjusted to 2017 price level, were valued at $4.92/acre.

Table 4.6.2 details the annual ecosystem services benefits from marsh protection, and Table 4.6.3 details the value of lost open water ecosystem services. The net value of ecosystem services—the discounted value of marsh erosion prevented ($95,436) less the value of open water habitat lost ($105)—resulting from this project equals $95,331 ($95,436- $105 = $95,331) in discounted present worth (beginning of 2017).

Table 4.6.2 Project #1612 Ecosystem Services Value – Erosion Prevention

Year	Marsh Lost (acres)				Net Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2017 Discounted Cumulative Value of Marsh Preserved ($)
	With Project		Without Project						
	Annual Loss	Cumulative	Annual	Cumulative		Values (2017 $)	Inflation-Adjusted Value ($)	Beginning of 2017 Discounted Present Worth[1] ($)	
2017	0.17	0.17	0.17	0.17	0.00	0	0	0	0
2018	0.00	0.17	0.17	0.34	0.17	594	607	573	573
2019	0.00	0.17	0.17	0.51	0.34	1,188	1,240	1,126	1,699
2020	0.00	0.17	0.17	0.68	0.51	1,781	1,898	1,658	3,357
2021	0.00	0.17	0.17	0.85	0.68	2,375	2,581	2,170	5,527
2022	0.00	0.17	0.17	1.02	0.85	2,969	3,291	2,662	8,189
2023	0.00	0.17	0.17	1.19	1.02	3,563	4,028	3,135	11,325
2024	0.00	0.17	0.17	1.36	1.19	4,156	4,793	3,590	14,914
2025	0.00	0.17	0.17	1.53	1.36	4,750	5,587	4,026	18,941
2026	0.00	0.17	0.17	1.70	1.53	5,344	6,412	4,446	23,386
2027	0.00	0.17	0.17	1.87	1.70	5,938	7,266	4,848	28,234
2028	0.00	0.17	0.17	2.04	1.87	6,532	8,153	5,234	33,468
2029	0.00	0.17	0.17	2.21	2.04	7,125	9,072	5,603	39,071
2030	0.00	0.17	0.17	2.38	2.21	7,719	10,025	5,958	45,029
2031	0.00	0.17	0.17	2.55	2.38	8,313	11,012	6,297	51,325
2032	0.00	0.17	0.17	2.72	2.55	8,907	12,034	6,621	57,946
2033	0.00	0.17	0.17	2.89	2.72	9,500	13,093	6,931	64,878
2034	0.00	0.17	0.17	3.06	2.89	10,094	14,190	7,228	72,106
2035	0.00	0.17	0.17	3.23	3.06	10,688	15,325	7,511	79,617
2036	0.00	0.17	0.17	3.40	3.23	11,282	16,500	7,781	87,397
2037	0.00	0.17	0.17	3.57	3.40	11,875	17,716	8,038	95,436

[1]Present worth at beginning of 2017, applying a mid-year discount factor [$(1/1.0393)^{n+0.5}$, where n = (year - 2017)] (discount rate = 3.93%) to the inflation-adjusted value

Table 4.6.3 Project #1612 Ecosystem Services Value – Open Water Loss

Year	Open Water Lost (acres)	Annual Value Lost			Beginning of 2017 Discounted Cumulative Value ($)
		Value (2017 $)	Inflation-Adjusted Value ($)	Beginning of 2017 Discounted Present Worth[1] ($)	
2017	1.24	6	6	6	6
2018	1.24	6	6	6	12
2019	1.24	6	6	6	18
2020	1.24	6	7	6	23
2021	1.24	6	7	6	29
2022	1.24	6	7	5	34
2023	1.24	6	7	5	40
2024	1.24	6	7	5	45
2025	1.24	6	7	5	50
2026	1.24	6	7	5	55
2027	1.24	6	7	5	60
2028	1.24	6	8	5	65
2029	1.24	6	8	5	70
2030	1.24	6	8	5	75
2031	1.24	6	8	5	79
2032	1.24	6	8	5	84
2033	1.24	6	8	4	88
2034	1.24	6	9	4	93
2035	1.24	6	9	4	97
2036	1.24	6	9	4	101
2037	1.24	6	9	4	105

[1]Present worth in 2017, using a mid-year discount factor [(1/Discount Rate)$^{n+0.5}$, where n = (year - 2017)] with the inflation-adjusted value

4.6.4 Benefit Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a benefit-cost ratio of 0.1 (Table 4.6.4).

Table 4.6.4 Benefit-Cost Summary-Project #1612 Mad Island WMA Shoreline Protection Phase 2

Benefits and Costs	Discounted Present Worth (Beginning of 2017)
Ecosystem Services Benefit	$95,331
Total Benefits	**$95,331**
Total Cost (Texas)	**$880,100**
B/C Ratio	**0.1**

Note: Dollar values reflect present worth equivalents at the beginning of 2017 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2017 (discount factor = 1).
Benefits include mid-year discounting.

4.7 Nueces County — #1614 Shamrock Island Protection & Habitat Enhancement Phase 2

4.7.1 Project Description and Background Information

Shamrock Island lies off the western shoreline of Mustang Island on the east side of Corpus Christi Bay in Nueces County, Texas (Figure 4.7.1). The island originated as a spit connected to Mustang Island. In 1970, Hurricane Celia breached the spit, creating Shamrock Island. By eliminating predator access, this separation allowed the island to function as an avian sanctuary. However, this also separated the island from its historical sediment source, which has led to erosion of the island. Currently, Shamrock Island is 110 acres with about 72 acres of marshes, scrub, and shorelines; the remaining area consists of intersecting lagoons. The island provides protected areas for bird roosting within the island boundaries. The Nature Conservancy acquired the island in 1995 as a sanctuary for over nineteen species of birds.

A 13-mile fetch (from Nueces Bay Causeway with westerly winds) allows waves to build to the east across the bay and erode Shamrock Island. A series of projects have constructed breakwaters to protect much of the north and western sides of the island from the open waters of Corpus Christi Bay. A 1999 project near the north end of the island constructed a 3,510-ft geotube breakwater and related feeder beach on the north and northeast sides of the island. That project was followed by construction projects in 2005–2006 and 2013–2014 creating 27 stone breakwaters around much of the northern and western sides of the island (except along the southwest area). The project also filled in two gaps in the island’s beaches caused by storms.

The 2016 project evaluated here completed the western erosion barrier with three breakwaters extending south over 1,000 ft—three breakwater sections totaling 914 ft and related gaps between sections—from an existing breakwater. The project also filled hurricane-related breaches along the island’s southwest and northern shorelines. The project is the second phase of a multi-phase project to protect the island and provide a source of sand to offset potential future erosion (Figure 4.7.2).

4.7.2 Project Funding

Funds for project execution included support from The Nature Conservancy (TNC) (a national non-governmental organization) and Texas sources listed in Table 4.7.1. Consistent with our treatment of federal funding, we treated the TNC funding as a national, out-of-state source, for which Texans accounted for 10% of the funding in rough proportion to the Texas proportion of the national population. Lacking an allocation of funding sources to project activity (e.g., engineering and design, construction) by expenditure date, we assumed that all project expenditures occurred in 2016. This analysis uses the summation ($1,140,357) of the CEPRA and State Surface Damage Fund contributions and the Texas portion of The Nature Conservancy contribution as the total project cost.

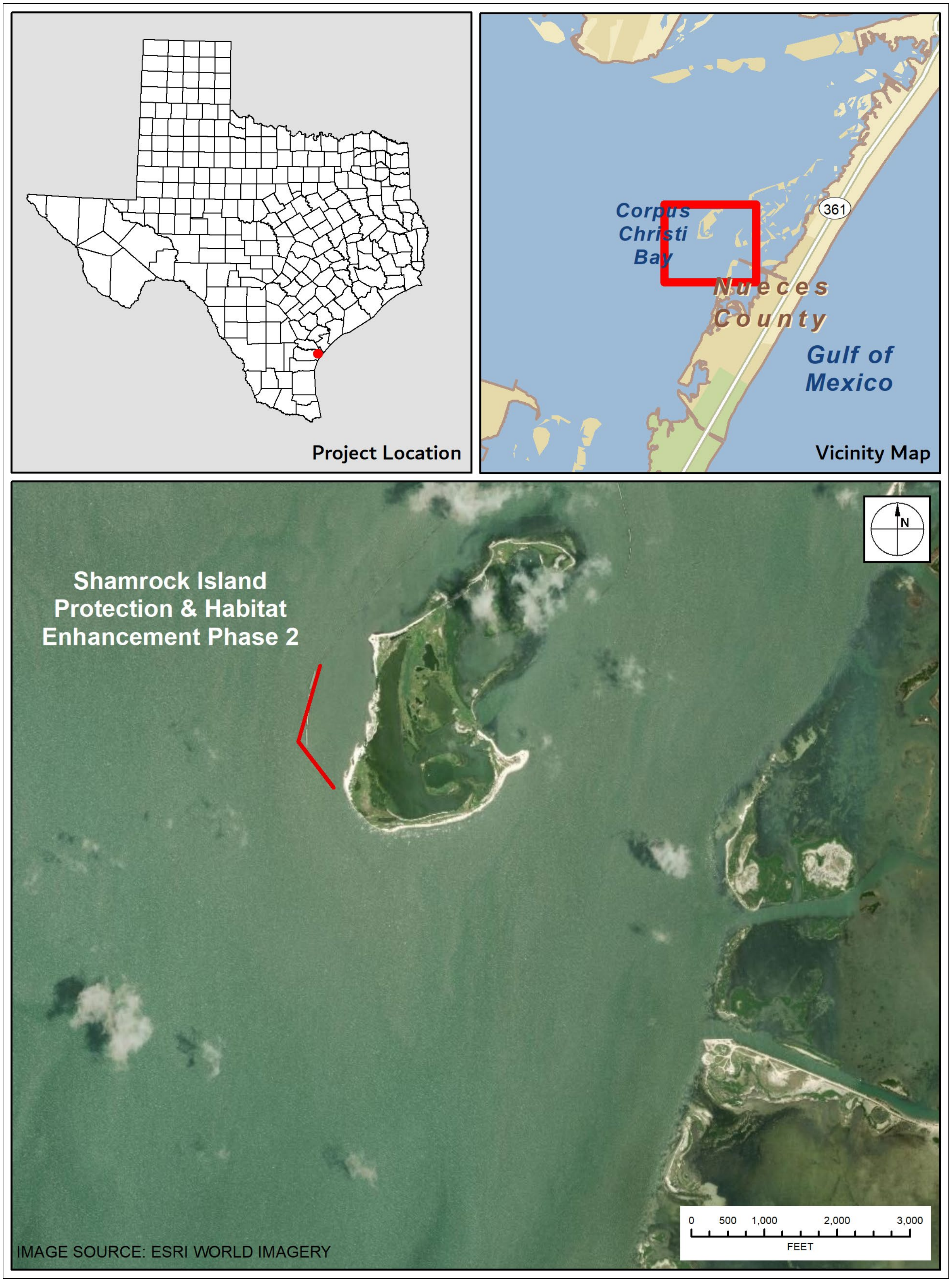

Figure 4.7.1. Location Map-Project #1614 Shamrock Island Protection & Habitat Enhancement Phase 2

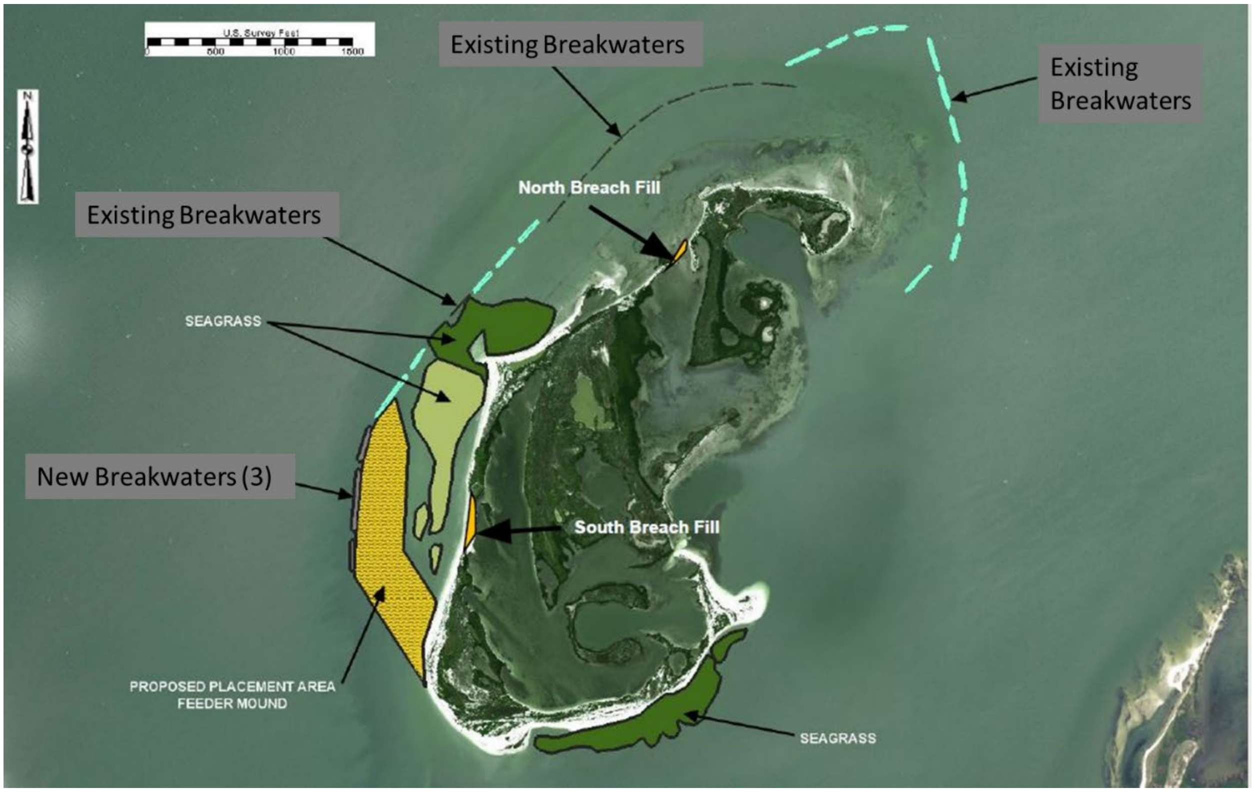

Figure 4.7.2 Shamrock Island, Second Phase Breakwaters and Beach Fill

(Figure revised from Maristany (2017), feeder mounds were not constructed)

Table 4.7.1. Funding for Project #1614 Shamrock Island Protection & Habitat Enhancement Phase 2

Funding Source		Amount ($)
Federal	The Nature Conservancy (Cash and In-Kind Services) (Texas portion)	713,217 *(71.322)*
State	Texas GLO, CEPRA	69,316
	State Surface Damage Fund	999,719
Total Project Cost ***(Texas Total)***		1,782,252 (1,140,357)

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning of 2016

4.7.3 Analysis

Benefits for Project #1614 include federal spending and ecosystem services benefits.

4.7.3.1 Federal Spending Benefit

The non-Texas portion of the federal contributions (TNC) listed in Table 4.7.1 ($713,217 x .9 = $641,895) represents the total non-Texas funding for the project. This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). Additionally, a multiplier of 1.4 (Section 2.1) accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy. Hence, the estimated total non-Texas spending benefit for this project is equal to $858,653 (i.e., $641,895 x 1.4) in 2016 prices.

4.7.3.2 Ecosystem Services Benefit

The ecosystem services benefits analysis for the Shamrock Island Shoreline Protection Project rest on several assumptions:

- Erosion rates are based on project area shoreline erosion from 2005 (the date after which the previous breakwater construction began and altered the island hydrodynamics) to 2016.
- The breakwaters will prevent further erosion of the shoreline from its 2016 location.
- The 2016 breach fill repaired two shoreline segments behind the existing breakwaters (300-ft long north fill segment) and the 2016 project breakwaters (375-ft long south fill segment). We considered the breakwaters as providing shoreline erosion protection benefits and did not assign additional benefit value to the breach repairs.
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015).
- Ecosystem services benefits will accrue beginning January 1, 2017, as construction began in November 2016 and completed in December 2016.

Consistent with prior Texas GLO cost-benefit evaluations for similar projects, we began project evaluation with the construction year (2016) and considered 2017 as the first year of the 20-year project life. Thus, the evaluation covered a 21-year period Given the late 2016 project completion, natural resources benefits began in 2017. We evaluated the project applying the per acre marsh and open water ecosystem services values described in Section 2.3, adjusted to 2016 price levels to correspond to the project construction year. The breakwaters will protect all island components within their approximate area of influence (Figure 4.7.2) landward of the January 2017 shoreline. We compared shoreline locations visible on Google Earth images taken June 27, 2005 and January 2, 2017 to determine an annual rate of erosion. Shoreline recession at five shore-perpendicular transects (Figure 4.7.3) overlain on the images indicated an average erosion rate of 12.8 ft/yr across the 1,290 ft of shoreline protected by the project. Multiplying that erosion rate by the 1,290 ft of protected shoreline resulted in the average annual loss rate of 0.38 acres. We assumed that all the eroded area was marsh. Considering the project location facing a large expanse of open water, we assumed that the project provided little aesthetic value and evaluated the project with the "without aesthetics" ecosystem services value described in Section 2.3.

Breakwater construction in open water caused a permanent loss of open water habitat. The three breakwater footprints totaled 1.15 acres. We evaluated the lost habitat at the open water ecosystem services value given in Section 2.3.

The net ecosystem value for the project consisted of the sum of erosion prevention over the 20-year project period following construction less the habitat benefit value of the open water filled by the breakwaters. Tables 4.7.2 and 4.7.3 detail the annual ecosystem services benefits of erosion prevention and annual value of lost open water ecosystem services. Table 4.7.4 details the net annual ecosystem services benefits. Notably, this project provides some ecosystem services benefits that cannot readily be converted to dollars, (e.g. brown pelican population viability benefits). Consequently, the marsh ecosystem service values applied in this evaluation may underestimate the value of the Shamrock Island as an avian sanctuary.

Table 4.7.2 details the annual ecosystem services benefits from marsh protection, and Table 4.7.3 details the value of lost open water ecosystem services. The net value of ecosystem services—the discounted value of marsh erosion prevented ($205,264) less the value of open water habitat lost ($96)—resulting from this project equals $205,168 ($205,264 - $96 = $205,168) in discounted present worth (beginning of 2016). Notably, this project provides some ecosystem services benefits that cannot readily be converted to dollars, (e.g. brown pelican population viability benefits). Consequently, the marsh ecosystem service values applied in this evaluation may underestimate the value of the Shamrock Island as an avian sanctuary.

Table 4.7.2 Project #1614 Ecosystem Services Value – Erosion Prevention

Year	Marsh Lost				Habitat Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2016 Discounted Cumulative Value of Habitat Preserved ($)
	With Project		Without Project						
	Annual (acres)	Cumulative (acres)	Annual (acres)	Cumulative (acres)		Value (2016$)	Inflation Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	0.38	0.38	0.38	0.38	0.00	$0	$0	$0	$0
2017	0	0.38	0.38	0.76	0.38	$1,276	$1,303	$1,229	$1,229
2018	0	0.38	0.38	1.14	0.76	$2,552	$2,663	$2,418	$3,648
2019	0	0.38	0.38	1.52	1.14	$3,828	$4,082	$3,567	$7,214
2020	0	0.38	0.38	1.90	1.52	$5,104	$5,551	$4,667	$11,882
2021	0	0.38	0.38	2.28	1.90	$6,379	$7,078	$5,726	$17,607
2022	0	0.38	0.38	2.65	2.28	$7,655	$8,663	$6,743	$24,351
2023	0	0.38	0.38	3.03	2.65	$8,931	$10,310	$7,721	$32,072
2024	0	0.38	0.38	3.41	3.03	$10,207	$12,018	$8,660	$40,732
2025	0	0.38	0.38	3.79	3.41	$11,483	$13,791	$9,562	$50,294
2026	0	0.38	0.38	4.17	3.79	$12,759	$15,629	$10,427	$60,721
2027	0	0.38	0.38	4.55	4.17	$14,035	$17,536	$11,257	$71,978
2028	0	0.38	0.38	4.93	4.55	$15,311	$19,513	$12,052	$84,030
2029	0	0.38	0.38	5.31	4.93	$16,587	$21,562	$12,814	$96,844
2030	0	0.38	0.38	5.69	5.31	$17,862	$23,685	$13,543	$110,387
2031	0	0.38	0.38	6.07	5.69	$19,138	$25,884	$14,241	$124,628
2032	0	0.38	0.38	6.45	6.07	$20,414	$28,162	$14,909	$139,537
2033	0	0.38	0.38	6.83	6.45	$21,690	$30,520	$15,546	$155,083
2034	0	0.38	0.38	7.20	6.83	$22,966	$32,962	$16,155	$171,238
2035	0	0.38	0.38	7.58	7.20	$24,242	$35,489	$16,736	$187,974
2036	0	0.38	0.38	7.96	7.58	$25,518	$38,104	$17,290	$205,264

[1]Present worth beginning of 2016, using a mid-year discount factor [1/Discount Rate(n+0.5), where n = (year - 2016)] with the inflation-adjusted value

Table 4.7.3 Project #1614 Ecosystem Services Value – Open Water Loss

Year	Open Water Lost (acres)	Annual Value Lost			Beginning of 2016 Discounted Cumulative Open Water Loss ($)
		Value (2016 $)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	1.15	6	6	5	5
2017	1.15	6	6	5	11
2018	1.15	6	6	5	16
2019	1.15	6	6	5	21
2020	1.15	6	6	5	26
2021	1.15	6	6	5	31
2022	1.15	6	6	5	36
2023	1.15	6	6	5	41
2024	1.15	6	7	5	46
2025	1.15	6	7	5	50
2026	1.15	6	7	5	55
2027	1.15	6	7	4	59
2028	1.15	6	7	4	63
2029	1.15	6	7	4	68
2030	1.15	6	7	4	72
2031	1.15	6	7	4	76
2032	1.15	6	8	4	80
2033	1.15	6	8	4	84
2034	1.15	6	8	4	88
2035	1.15	6	8	4	92
2036	1.15	6	8	4	96

[1]Present worth beginning of 2016, using a mid-year discount factor [1/(Discount Rate)$^{(n+0.5)}$, where n = (year - 2016)] with the inflation-adjusted value

4.7.4 Benefit-Cost Summary

With total benefits of $1,103,821 and a total project cost of $1,140,357, the resulting B/C ratio for project #1614 equals 1.0. Table 4.7.4 summarizes the results.

Table 4.7.4 Benefit-Cost Summary for Project #1614 Shamrock Island Protection & Habitat Enhancement Phase 2

Benefits and Costs	Discounted Present Worth (Beginning of 2016)
Federal Spending Benefit	$858,653
Ecosystem Services Benefit	$205,168
Total Benefits	**$1,103,821**
Total Cost (Texas)	**$1,140,357**
B/C Ratio	**1.0**

Note: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

4.8 Galveston County — #1627 Moses Lake Shoreline Protection Phase 3

4.8.1 Project Description and Background Information

The Moses Lake Shoreline Protection Project Phase 3 constructed nearly 6,000 ft of breakwater to protect 6,700 ft of eroding shoreline along the Texas City Prairie Preserve (Figure 4.8.1), a 2,303-acre property comprising coastal prairie habitat and wetlands that provide a home for wintering and migrating grassland songbirds and support migratory and year-round populations of waterfowl, shorebirds, and wading birds. Birds such as the brown pelican, white ibis, peregrine falcon, white-tailed hawk, Forster's terns, and seaside sparrows have been sighted at the preserve. The Nature Conservancy, which founded the preserve in 1995 to protect and restore the coastal habitat, manages the preserve to improve resiliency and water quality (The Nature Conservancy 2019).

Historically, the combination of subsidence and wave action have led to rapid erosion of the preserve's shoreline along Moses Lake. Erosion of three or more feet (ft) per year occurs, destroying essential habitat for plants and animals (Lightbody 2016). Phase 1 and Phase 2 of the Moses Lake Shoreline Protection Project constructed approximately 1,600 ft and 2,400 ft of living shorelines in 2002 and 2012 to combat the rapid erosion along the central to southern sections of the western shore of Moses Lake and protect the preserve's habitat. Phase 3 of the project occurred in 2018 with construction of two breakwater segments; a 4,860-ft long segment spans from the center of the western shoreline to the northern end, and a 1,110-ft long segment lies along the southern end of the western shore.

4.8.2 Project Funding

Table 4.8.1 presents the funding breakdown for the project. The summation of the CEPRA and Galveston Bay Foundation costs, $1,983,400, represent the total project costs to the State of Texas; funding did not include any federal or other non-Texas sources. This analysis treats all costs as though they were incurred at the beginning of 2018 (i.e., the cost reflects 2018 price levels and is a present worth equivalent value, beginning of 2018).

Table 4.8.1 Funding for Project #1627 Moses Lakes Shoreline Protection Phase 3

Funding Source		Amount ($)
State/Local	TX GLO, CEPRA (38% of total project cost)	*750,000*
	QPP Galveston Bay Foundation (62% of total project cost)	*1,233,400*
	Total Project Funding (100%)	*1,983,400*

Note: Values in italics are costs to the State of Texas
Values represent present worth, beginning 2018

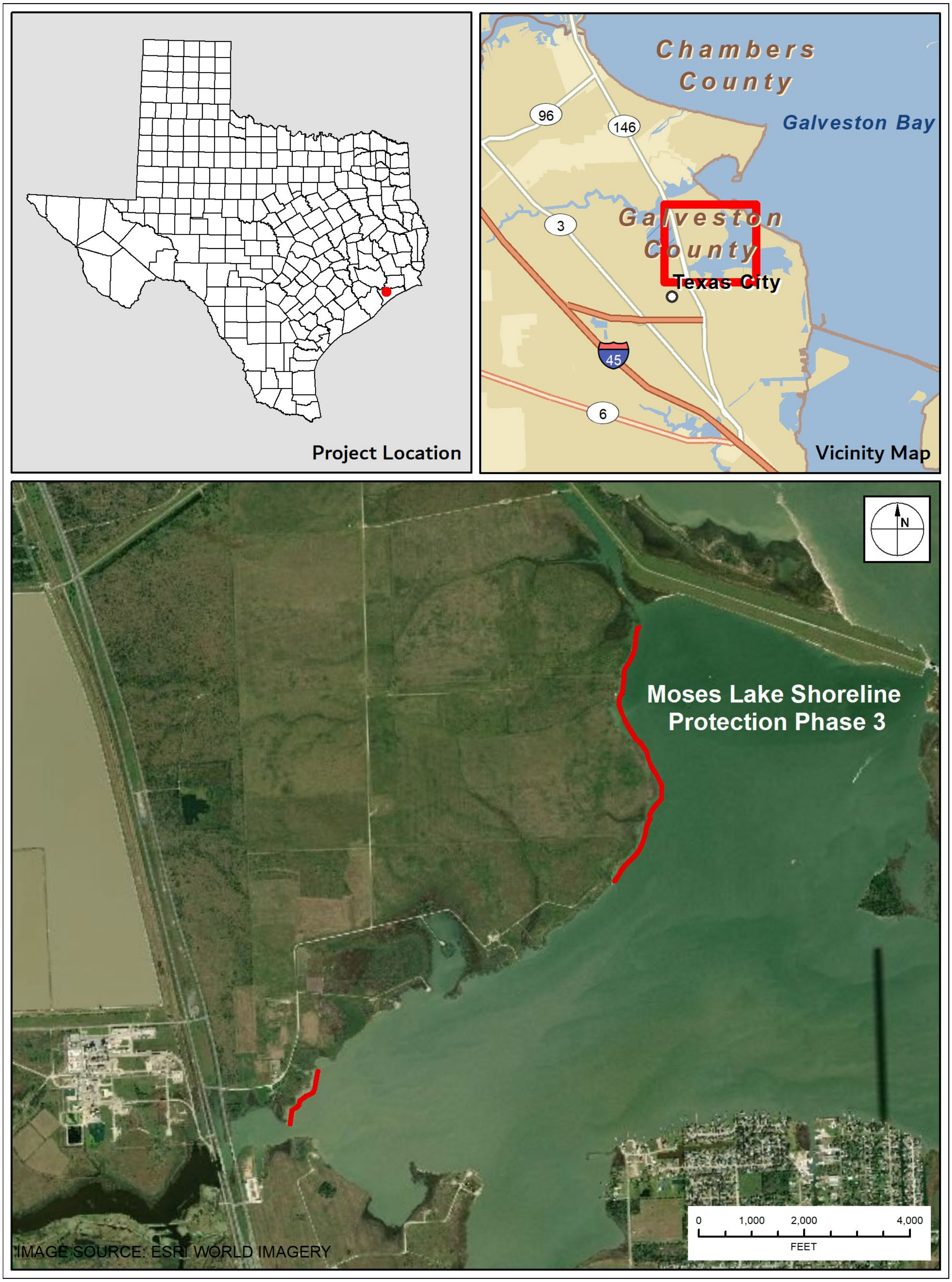

Figure 4.8.1 Location Map—Project #1627 Moses Lake Shoreline Protection Phase 3

4.8.3 Analysis

Taylor Engineering visited the site on February 25, 2019, a few months after completion of construction. Figure 4.8.2 shows the project conditions in the southern segment during the site visit; the pre-existing erosion scarp is evident along the shoreline, and the calm waters in the lee of the breakwaters demonstrates the project's intended purpose of reducing wave-induced erosion. Due to inclement weather conditions, Taylor Engineering could not visit the northern segment, which can only be reached by boat. Staff also could not capture orthoimagery due to high winds.

Figure 4.8.2 Project #1627 One Year Post-construction

4.8.3.1 Ecosystem Service Benefits

This analysis adopts a 25-year project life based on the performance of the adjacent Phase 1 and Phase 2 projects. The projects have performed as expected, eliminating erosion and developing an estuarine marsh. Because the lake elevation is controlled, sea level rise should not affect the performance of the breakwaters. Land subsidence in the area has ceased, thus the breakwaters should remain at the constructed elevation and perform effectively for a long period.

Based on an average erosion rate of 3 ft/yr along the 6,670 ft-long total project length, the Phase 3 shoreline would lose about 0.46 acres of coastal prairie habitat each year without the project. This analysis values the loss of land due to coastal erosion based on a willingness to pay estimate of

$3,500 per acre (American Farmland Trust, 2010). Given the above information, the benefit equals $1,610/yr ($3,500 per acre x 0.46 acres), in 2010 prices, or $1,849/yr adjusted for inflation to 2018 prices. Over the 25-year project life, the land loss prevention benefit equals $36,612 (discounted present worth at the beginning of 2018, mid-year discounting, 3.93% discount rate) as shown in Table 4.8.2.

The preserve uplands provide annual groundwater recharge services valued at $221/acre annually (American Farmland Trust and Texas A&M, 2010) in 2010 prices, or $253.83/acre adjusted for inflation to 2018 prices. Based on the 0.46 acre/yr erosion rate, the benefit (2018 prices) equals $116/yr. As shown in Table 4.8.3, the benefit grows annually from $116 in 2018 to $2,919 in the 25th year, because the benefit is additive each year, meaning the loss of service prevented each year continues throughout the remainder of the project life. The accumulation of benefits over the 25-year project life equals $27,811 (discounted present worth at the beginning of 2018, mid-year discounting, 3.93% discount rate).

The Nature Conservancy also uses the property for beef cattle grazing; thus, shoreline erosion results in loss of grazing benefits. Dunn et al (2010) reported that beef production profitability from northern mixed grass prairie ranged from $20.43 per hectare ($8.27 per acre) to 23.01 per hectare ($9.31 per acre). High quality prairie (in the natural system sense) results in a low profit per unit area grazed, as the rangeland maintained in “higher” condition results from lower grazing herd densities. Assuming the Nature Conservancy maintains the current high-quality prairie habitat, this analysis used a value of $9.31 (2010 prices) per acre per year to determine the benefit; adjusted for inflation, the value equals $10.69 per acre per year in 2018 prices. Over a 25-year project life, the net benefit (discounted present worth at the beginning of 2018, mid-year discounting, 3.93% discount rate) resulting from the protection of grazing lands summed to $1,172 (Table 4.8.4).

Table 4.8.2 Project #1627 Upland Land Value Protection Benefit

Year	Annual With-Project Benefit	Benefit with Inflation	Discounted Present Worth	Cumulative Present Worth
2018	$1,849	$1,849	$1,814	$1,814
2019	$1,849	$1,890	$1,784	$3,598
2020	$1,849	$1,928	$1,751	$5,348
2021	$1,849	$1,966	$1,718	$7,066
2022	$1,849	$2,006	$1,686	$8,752
2023	$1,849	$2,046	$1,655	$10,407
2024	$1,849	$2,087	$1,624	$12,031
2025	$1,849	$2,128	$1,594	$13,625
2026	$1,849	$2,171	$1,564	$15,190
2027	$1,849	$2,214	$1,535	$16,725
2028	$1,849	$2,259	$1,507	$18,232
2029	$1,849	$2,304	$1,479	$19,710
2030	$1,849	$2,350	$1,451	$21,162
2031	$1,849	$2,397	$1,424	$22,586
2032	$1,849	$2,445	$1,398	$23,984
2033	$1,849	$2,494	$1,372	$25,356
2034	$1,849	$2,543	$1,346	$26,703
2035	$1,849	$2,594	$1,321	$28,024
2036	$1,849	$2,646	$1,297	$29,321
2037	$1,849	$2,699	$1,273	$30,594

Year	Annual With-Project Benefit	Benefit with Inflation	Discounted Present Worth	Cumulative Present Worth
2038	$1,849	$2,753	$1,249	$31,843
2039	$1,849	$2,808	$1,226	$33,069
2040	$1,849	$2,864	$1,203	$34,272
2041	$1,849	$2,922	$1,181	$35,453
2042	$1,849	$2,980	$1,159	$36,612

Table 4.8.3 Project #1627 Groundwater Recharge Service Benefit

Year	Land Loss without Project (acres)	Benefit Value (2018 Prices)	Benefit Value with Inflation	Discounted Present worth	Cumulative Present Worth
2018	0.46	$116.76	$117	$115	$115
2019	0.92	$233.52	$239	$225	$340
2020	1.38	$350.29	$365	$332	$671
2021	1.84	$467.05	$497	$434	$1,105
2022	2.30	$583.81	$633	$532	$1,638
2023	2.76	$700.57	$775	$627	$2,265
2024	3.22	$817.34	$922	$718	$2,982
2025	3.68	$934.10	$1,075	$805	$3,788
2026	4.14	$1,050.86	$1,234	$889	$4,677
2027	4.60	$1,167.62	$1,398	$969	$5,646
2028	5.06	$1,284.38	$1,569	$1,047	$6,693
2029	5.52	$1,401.15	$1,746	$1,121	$7,813
2030	5.98	$1,517.91	$1,929	$1,191	$9,004
2031	6.44	$1,634.67	$2,119	$1,259	$10,264
2032	6.90	$1,751.43	$2,316	$1,324	$11,588
2033	7.36	$1,868.19	$2,519	$1,386	$12,974
2034	7.82	$1,984.96	$2,730	$1,445	$14,419
2035	8.28	$2,101.72	$2,949	$1,502	$15,921
2036	8.74	$2,218.48	$3,175	$1,556	$17,477
2037	9.20	$2,335.24	$3,409	$1,607	$19,085
2038	9.66	$2,452.01	$3,651	$1,656	$20,741
2039	10.12	$2,568.77	$3,901	$1,703	$22,444
2040	10.58	$2,685.53	$4,160	$1,747	$24,192
2041	11.04	$2,802.29	$4,428	$1,790	$25,981
2042	11.50	$2,919.05	$4,704	$1,830	$27,811

Table 4.8.4 Project #1627 Grazing Land Benefit

Year	Land Loss without Project (acres)	Benefit Value (2018 Prices)	Benefit Value with Inflation (2018 Prices)	Discounted Present worth	Cumulative Present Worth
2018	0.46	$5	$5	$5	$5
2019	0.92	$10	$10	$9	$14
2020	1.38	$15	$15	$14	$28
2021	1.84	$20	$21	$18	$47
2022	2.30	$25	$27	$22	$69
2023	2.76	$30	$33	$26	$95
2024	3.22	$34	$39	$30	$126

Year	Land Loss without Project (acres)	Benefit Value (2018 Prices)	Benefit Value with Inflation (2018 Prices)	Discounted Present worth	Cumulative Present Worth
2025	3.68	$39	$45	$34	$160
2026	4.14	$44	$52	$37	$197
2027	4.60	$49	$59	$41	$238
2028	5.06	$54	$66	$44	$282
2029	5.52	$59	$74	$47	$329
2030	5.98	$64	$81	$50	$379
2031	6.44	$69	$89	$53	$432
2032	6.90	$74	$98	$56	$488
2033	7.36	$79	$106	$58	$547
2034	7.82	$84	$115	$61	$607
2035	8.28	$89	$124	$63	$671
2036	8.74	$93	$134	$66	$736
2037	9.20	$98	$144	$68	$804
2038	9.66	$103	$154	$70	$874
2039	10.12	$108	$164	$72	$945
2040	10.58	$113	$175	$74	$1,019
2041	11.04	$118	$187	$75	$1,095
2042	11.50	$123	$198	$77	$1,172

4.8.4 Benefit-Cost Summary

With total benefits of $65,595 and a total project cost of $1,983,400, the resulting B/C ratio for project #1609 equals 0.03. Table 4.8.5 summarizes the results.

Table 4.8.5 Benefit-Cost Summary for Project #1627 Moses Lake Shoreline Stabilization Phase 3

Benefits and Costs	Discounted Present Worth (Beginning of 2018)
Land Loss Prevention Benefit	$36,612
Groundwater Recharge Protection Benefit	$27,811
Grazing Land Loss Prevention Benefit	$1,172
Total Benefits	**$65,595**
Total Costs (Texas)	**$1,983,400**
B/C Ratio	**0.03**

Note: Dollar values reflect present worth equivalents at the beginning of 2018 with a 3.93% discount rate.
Costs considered as taking place at the beginning of 2018 (discount factor = 1).
Benefits include mid-year discounting.

5.0 CONCLUSIONS

This study finds the state of Texas receives $11.00 in economic and financial benefits for every Texas dollar invested in these projects. Table 5.1.1 presents a summary of the assessed CEPRA Cycles 7–9 projects, which is a representative sampling of the CEPRA program.

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the Virginia Point Wetland Protection & Restoration reflects contributions from the National Fish and Wildlife Foundation (NFWF) and Coastal Impact Assistance Program (CIAP), which covered 98.4% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.26 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits, as described by the following examples. The Virginia Point Wetland Protection & Restoration experienced federal spending benefits ($4,863,030 discounted present worth) from NFWF and CIAP funding as mentioned above. Similarly, Follet's Island Habitat Restoration experienced federal spending benefits ($2,698,128 discounted present worth) from funding by U.S. Fish and Wildlife Service (USFWS) and CIAP. Funding provided by the Federal Emergency Management Agency (FEMA) led to significant federal spending benefits for the Galveston Seawall Beach Nourishment ($19,577,409 discounted present worth).

Overall, the direct and positive net benefits (B/C ratio greater than one) from the 13 evaluated projects combined indicate that these coastal erosion control projects yield high returns on investment for the state of Texas. Preserving Texas' coastal assets proves a worthy public investment strategy for the Texas taxpayers and citizens.

Table 5.1.1 Summary of CEPRA Cycles 7–9 Projects, Costs, and Benefits

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[3] ($)	Discounted Benefits ($)	
#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).

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Thomas Durnin

From: Michael Trudnak <mtrudnak@taylorengineering.com>
Sent: Thursday, August 29, 2019 11:07 AM
To: Thomas Durnin
Subject: RE: Work Order No. B523 CEPRA Economic-Natural Resources Benefit-Cost Study Final Report
Attachments: 2019 Economic and Natural Resource Benefit Study Final Report C2019-004.pdf

Thomas,

The final report is attached. I kept the May 2019 date, because we didn't make any changes. I just changed "Draft" to "Final" on page ii.

Thanks,

Mike

Michael Trudnak, P.E. | **Senior Coastal Engineer**

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From: Michael Trudnak
Sent: Tuesday, July 23, 2019 1:47 PM
To: Thomas Durnin <Thomas.Durnin@GLO.TEXAS.GOV>
Subject: RE: Work Order No. B523 CEPRA Economic-Natural Resources Benefit-Cost Study Final Report

Thomas,

That's great to hear. I'll finalize the report. Best of luck with all the ongoing projects.

Michael Trudnak, P.E. | **Senior Coastal Engineer**

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From: Thomas Durnin <Thomas.Durnin@GLO.TEXAS.GOV>
Sent: Tuesday, July 23, 2019 11:18 AM
To: Michael Trudnak <mtrudnak@taylorengineering.com>
Subject: Work Order No. B523 CEPRA Economic-Natural Resources Benefit-Cost Study Final Report

Mike, I don't believe I conveyed this, but we do not have any edits regarding the draft report sent to us back on May 10th. So at this point, it's good to go in terms of issuing the final version of the report.