

FINAL REPORT

# Economic and Natural Resource Benefits Study of Coastal Erosion Planning and Response Act (CEPRA) Cycle 10–11 Construction Projects

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MARCH 20, 2023

## EXECUTIVE SUMMARY

The Texas Legislature requires the General Land Office (GLO) report the economic and natural resource benefits derived from Coastal Erosion Planning and Response Act construction projects every biennium. To help the GLO meet its reporting requirements, this study provides an overview of the economic and natural resource benefits derived from six construction projects from cycles 10 and 11. These beach restoration, shoreline protection, and natural resources projects include

- #1637: Galveston Island State Park Phase 3 (Cycle 10);
- #1653: South Padre Island Beach Nourishment with BUDM (Cycle 11);
- #1665: Corpus North Beach Harvey Repair (Cycle 10);
- #1685: Causeway Rookery Island Phase 2 (Cycle 11);
- #1693: Babe’s Beach BUDM (2021 BUDM Cycle) (Cycle 11); and
- #1702: Isla Blanca Park Beach Nourishment with BUDM (Cycle 11).

Table E.1 presents a summary of the assessed projects. When viewing the projects as a group, the table shows that the state of Texas receives \$3.0 in economic and financial benefits for every dollar of state funding allocated to these six projects. The benefit cost calculations applied a discount rate of 4.75%, based on an average of 20- to 30-year corporate bond rates existing at the time of study initiation, to convert benefits and costs occurring at different points in time to comparable equivalent values known as discounted present worth. Table E.1 also converts the discounted present worth of benefits and costs to equivalent values at the beginning of 2022 to allow for adding the benefits and costs of the different projects to develop an overall benefit-to-cost ratio.

Like recent studies, the present study examined similar project benefits (those associated with aesthetics, gas sequestration, habitat, non-Texas (federal) project funding, out-of-state visitor spending, pollution abatement, recreation, storm surge protection), calculated benefits over time based on a project’s durability (2 to 20 years), and adopted a Texas accounting stance such that funding from outside Texas represents a financial benefit to the state as money flows into the Texas economy.

Notably, leveraging of federal funding plays a substantial role in the economic benefit calculations for the Galveston Island State Park Phase 3 project with a large source of the funding from the National Fish and Wildlife Foundation, the Isla Blanca Park Beach Nourishment with BUDM project with cost savings from a partnership with the U.S. Army Corps of Engineers for the beneficial use of dredged material from maintenance dredging of the shipping channel, and funding provided by the Federal Emergency Management Agency for the Corpus North Beach Harvey Repair project.

Table E.1 Summary of CEPRA Cycle 10–11 Construction Project Costs and Benefits

CEPRA Project	County	Project Year <sup>1</sup>	Discounted Present Worth, Beginning of Project Year		Discounted Present Worth, Beginning of 2022 <sup>3</sup>		Benefit-to-Cost (B/C) Ratio	
			Cost <sup>2</sup>	Benefits	Cost	Benefits		
#1637: Galveston Island State Park Phase 3 (Cycle 10)	Galveston	2021	\$575,296	\$7,193,585	\$602,623	\$7,535,280	12.5	
#1653: South Padre Island Beach Nourishment with BUDM (Cycle 11)	Cameron	2021	\$1,530,000	\$6,889,481	\$1,602,675	\$7,216,731	4.5	
#1665: Corpus North Beach Harvey Repair (Cycle 10)	Nueces	2023	\$141,208	\$1,647,085	\$141,208	\$1,647,085	11.7	
#1685: Causeway Rookery Island Phase 2 (Cycle 11)	Nueces	2022	\$1,550,394	\$615,430	\$1,550,394	\$615,430	0.4	
#1693: Babe’s Beach BUDM (2021 BUDM Cycle) (Cycle 11)	Galveston	2021	\$12,000,000	\$28,361,072	\$12,570,000	\$29,708,223	2.4	
#1702: Isla Blanca Park Beach Nourishment with BUDM (Cycle 11)	Cameron	2021	\$510,000	\$3,814,534	\$534,225	\$3,995,724	7.5	
<b>Total<sup>4</sup></b>						\$17,001,125	\$50,718,474	3.0
<p>Notes: <sup>1</sup>Project Year represents the year benefits begin to accrue and may not represent the actual construction year.  <sup>2</sup>Texas portion only; dollar values reflect present worth equivalents at the beginning of Project Year.  <sup>3</sup>Dollar values reflect present worth equivalents at the beginning of 2022 with a 4.75% discount rate.  <sup>4</sup>Total B/C Ratio represents the total discounted benefits divided by the total discounted cost of all six projects combined (\$50,718,474 / \$17,001,125 = 3.0).</p>								



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## 1.0 Introduction

### 1.1 Purpose

Texas' coastal resources protect and support crucial industries, including the nation's top waterborne commerce economy, and the economies and livelihood of coastal communities. Erosion of the state's beaches, dunes, and wetlands increase the potential for property and infrastructure damage and can adversely impact tourism and other commercial businesses that provide significant economic value to Texas. To address the impacts of coastal erosion on Texas' natural resources and coastal communities, the 76th Texas Legislature enacted the Coastal Erosion Planning and Response Act (CEPRA) on September 1, 1999.

Per Texas Natural Resource Code (TNRC) 33.606, the Texas General Land Office's (GLO) Coastal Resources Division administers the CEPRA Program, which facilitates an array of coastal erosion remediation and planning projects and studies. In cooperation with federal, state, and local government agencies and non-profit organizations, the CEPRA Program has developed, funded, and implemented over 400 projects with nearly \$155 million of CEPRA funding and \$463 million of matching funds and federal leverage since its inception, resulting in a total allocation of approximately \$618 million over state fiscal years 2000–2021. CEPRA-funded projects include beach and dune restoration, shoreline protection structures, restoration and protection of wetland and benthic habitat, scientific studies, and coastal stewardship initiatives.

The GLO has administered 11, 2-year CEPRA funding cycles that coincide with the Legislative biennium. To assist with the legislative requirement to biennially report the economic and natural resource benefits provided by constructed CEPRA projects, the GLO contracted INTERA-GEC, LLC (Work Order No. D669 under GLO Contract No. 22-004-018) to evaluate representative projects constructed during Cycle 11 (FY20–21). This study will analyze and determine cost-benefit ratios for the following six CEPRA projects, with funds allocated in Cycle 11 or carried forward from Cycle 10 (FY 18–19):

- #1637: Galveston Island State Park Phase 3 (Cycle 10)
- #1653: South Padre Island Beach Nourishment with BUDM (Cycle 11)
- #1665: Corpus North Beach Harvey Repair (Cycle 10)
- #1685: Causeway Rookery Island Phase 2 (Cycle 11)
- #1693: Babe's Beach BUDM (2021 BUDM Cycle) (Cycle 11)
- #1702: Isla Blanca Park Beach Nourishment with BUDM (Cycle 11).

The above projects include three beach restoration projects involving beneficial use of dredge material, one beach restoration post-storm repair project, and two natural resource protection/restoration projects.

### 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 10–11. 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.

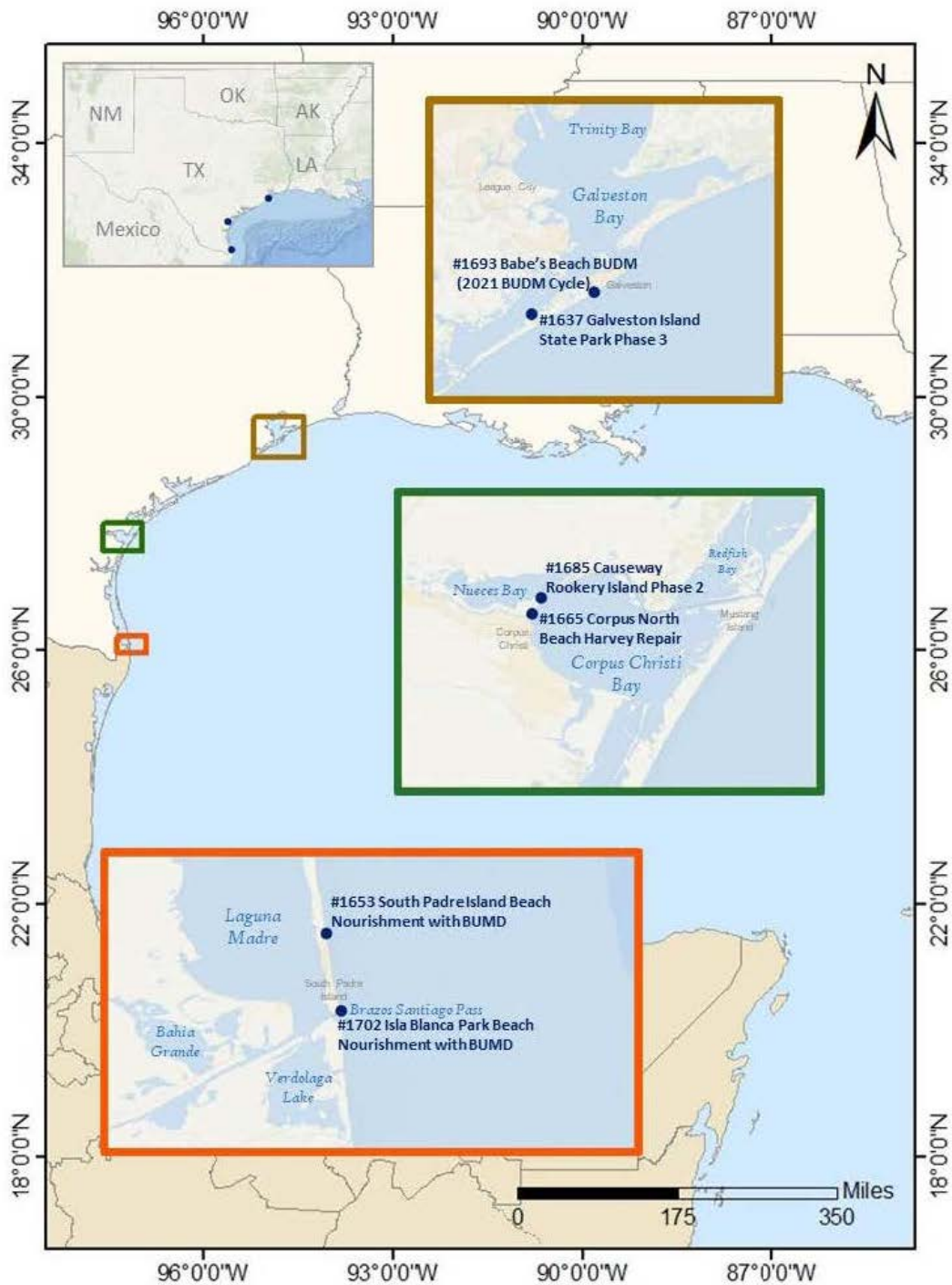


Figure 1.1 Projects' Location Map



## 2.0 Benefit Cost Calculation Methodology

Many of the same individuals who prepared similar studies for the GLO since 2008 (Stites et al., 2008; Krecic et al., 2009; Krecic et al., 2011; Trudnak et al., 2013; Trudnak et al., 2015; Trudnak et al., 2017; and Taylor Engineering, 2019). The following sections summarize principles and concepts applied in this study.

### 2.1 General Concepts

Each coastal restoration/protection project requires methodologies specific to the specific nature of the project. However, most benefit-cost evaluation concepts apply globally to all projects. Usually, benefit-cost analyses help decide whether to proceed with a project and which project represents the best alternative. Instead, these GLO studies focus on economic and engineering performance of projects already completed but apply the same evaluation principles.

For each project, the benefits and costs correspond to the measured differences between conditions without the project (i.e., the owner had not put the project in place) and with the project (i.e., the owner constructed the project). Only differences between the with- and without-project conditions are relevant. Therefore, the period during which the analyses consider benefit and cost effects begins with the year in which the owner installed the project.

Because benefits and costs take place over time, calculations to make such effects at different points in time commensurable and comparable must occur. This requires the use of an appropriate interest rate. The interest rate converts benefits and costs to a single point in time. (One may select any point in time. However, by convention, it usually corresponds with the beginning of the period of analysis). This interest rate includes the effects of inflation. Importantly, note that even without inflation, an interest rate (or “discount rate”, representing what is known as the time value function) proves necessary. Consider that even with zero inflation, an interest rate charge for borrowing money would still exist. One refers to the process of converting benefits and costs to equivalent values at the beginning of the period of analysis as present worth (or present value) calculation or discounting. This study has selected an appropriate discount rate for use in its analyses.

This study expresses benefits and costs in terms of estimated price levels existing when they occur. Furthermore, it assumes most benefits occur throughout the year — represented in this study by assuming the benefits in a year take place at midyear. It treats exceptions to this principle accordingly. Finally, it assumes most implementation costs occur at the beginning of the period of analysis. In the case of recurring annual costs or estimated one-time costs at some other point in time during the period of analysis, it treats present worth calculations accordingly.

Projects that have performed favorably include those with benefits (B) greater than costs (C). For these projects, net benefits are greater than zero ( $[B - C] > 0$ ), and the benefit to cost ratio is greater than 1.0 ( $B/C > 1.0$ ).

This benefit cost evaluation assumes a “Texas” accounting perspective. This means that the analyses include only benefits that accrue within Texas, and only costs incurred within Texas. These evaluations exclude benefits and costs of GLO projects that take place outside of Texas.

The following paragraphs discuss the above and other issues.

### 2.1.1 Inflation

Inflation refers to the change in prices from year to year. The historical Consumer Price Index (CPI) data allows for the adjustment of benefits or costs in a given year’s price level, to reflect price levels current at the time the benefit or cost occurs. Table 2.1 summarizes the CPI data for the period 2015 to present (<https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator/consumer-price-index-1913->).

Table 2.1 Annual Inflation Price Level Adjustments Since 2015

Year	Annual Average CPI	Annual Inflation from Previous Year (%)
2015	237.0	0.1%
2016	240.0	1.3%
2017	245.1	2.1%
2018	251.1	2.4%
2019	255.7	1.8%
2020	258.8	1.2%
2021	271.0	4.7%
2022	294.4	8.6%

Note: 2022 estimate based on change in the CPI from first quarter 2021 to first quarter 2022

For 2023 and beyond, Statista (<https://www.statista.com/statistics/244993/projected-consumer-price-index-in-the-united-states/>) and long-term forecasts by the Federal Open Market Committee of the U.S. Federal Reserve (<https://knoema.com/kyaewad/us-inflation-forecast-2020-2021-and-long-term-to-2060-data-and-charts>) suggest an inflation rate of 2.2%.

By way of an example, adjusting a cost from a 2022 price level to a 2023 price level requires multiplying the value in 2022 prices by 1.022 (1 + 2.2%).

### 2.1.2 Discount Rate

As discussed above, present value factors, based on a given discount rate, convert values at different points in time to comparable values at the same point in time. Sources reviewed for a discount rate to adopt for use in this study included Treasury bond rates, municipal bond rates, and corporate bond rates. This study’s adopted discount rate of 4.75% represents a mid-range value of current and recent corporate bond rates. This is consistent with past GLO studies. Recent 20- to 30-year (yr) High Quality Market (HQM) corporate bond rates range from 4.71 to 4.79% according to U.S. Department of the Treasury 20-Year HQM Corporate Bond Spot Rate (HQMCB20YR), retrieved from the Federal Reserve Bank of St. Louis (<https://fred.stlouisfed.org/series/HQMCB20YR>), and Trading Economics (<https://tradingeconomics.com/united-states/30-year-high-quality-market-hqm-corporate-bond-spot-rate-fed-data.html>) in October 2022.

Because this study assumes benefits accrue throughout the year, present value calculations apply mid-year discounting for most benefit calculations. For example, present worth at the beginning of 2023 of a



benefit occurring during 2023 =  $1 / 1.0475^{0.5} * 2023$  benefit value. Similarly, present worth at the beginning of 2023 of a benefit occurring during 2024 =  $1 / 1.0475^{1.5} * 2024$  benefit value.

### 2.1.3 Accounting Perspective

Like previous studies, this study adopted a “Texas” accounting perspective such that funding from outside Texas (like federal dollars) and spending by visitors from outside the state represent financial benefits to the state because money flows into the Texas economy by both means. As in previous studies of GLO coastal projects, the estimated portion of non-Texas federal costs does not count as a cost because it does not represent an expense incurred within the state. However, it does count as a benefit because it represents a net inflow of money into Texas. Multipliers, to account for secondary effects, apply to both funds provided by entities outside Texas and spending by out-of-state visitors.

For consistency with previous studies’ attempts to estimate the secondary effects of money coming into Texas, an overall average multiplier of 1.75 serves as a general average effect representative of conditions in the Texas economy. A reduction in the multiplier accounts for retail, wholesale, and transportation margins of goods and services remaining in the state’s economy. Adopting a capture rate of 0.8 (80%), representing the portion of spending that the Texas economy captures, on average, yields an overall net multiplier of 1.4 ( $0.8 * 1.75$ ).

As discussed above, federal spending for a project (e.g., for construction and maintenance) represents a financial inflow into the Texas economy. A portion of this federal spending comes from tax revenues originating from individuals and businesses in Texas. Estimating the net amount of federal spending on a project requires a reduction in total federal spending on the project to account for this contribution from Texas. This study applied 10% for this estimated contribution to federal revenues coming from Texas based on the ratio of Texas’ population to the U.S.’s population (a proxy for this adjustment) — approximately 10% (<https://data.census.gov/>). Therefore, an estimated multiplier effect to apply to federal spending on a Texas GLO project equals 1.4 times 0.9 times total federal contribution, which equals 1.26 times total federal contribution. For example, if FEMA contributes \$500,000 to project construction, the estimated amount of this cost originating from Texas equals \$50,000 ( $0.1 * \$500,000$ ). Additionally, Texas receives a benefit of \$630,000 ( $1.4 * 0.9 * \$500,000 = 1.26 * \$500,000$ ).

Out-of-state visitor spending applies the full 1.4 multiplier to estimate the secondary effects of spending by non-Texans visiting project sites within the state. Multiplied by out-of-state visitor spending, this multiplier captures the secondary economic effects brought about by the initial spending. For example, if visitors spend \$1 million in a year, then the total visitor spending benefit for that year equals \$1.4 million, including multiplier effects ( $1.4 * \$1,000,000$ ).

### 2.1.4 Period of Analysis

The period of analysis for a project represents the time during which one estimates benefits and costs. This period for beach restoration projects varies from project to project, depending on the forecasted longevity of each project, and ranges from two to seven years. For natural resource protection/restoration projects, the period of analysis equals 20 years.

### 2.1.5 Caveat

Note that hand calculations may yield slightly different results from those tabulated in this report. This phenomenon occurs because of number rounding in the tables versus calculations performed in MS Excel spreadsheets.

## 2.2 Beach Restoration and Shoreline Protection Projects

Beach nourishment adds large quantities of sand from outside the normal zone of active sediment transport to the beach. This process results in the seaward movement of the beach, typically widening the beach from the “berm” (the part of the beach where beachgoers place their towels and umbrellas) by an additional 50 to 150 feet (ft). This new, wider berm helps dissipate wave energy and increases the distance between upland structures and the sea to protect land and structures from storm damage. Preventing land loss and damage to upland infrastructure forms the basis of storm protection benefits. As intimated above, beaches also have a significant recreational value. Just as narrowing of the beach adversely affects storm damage protection to upland infrastructure, it also negatively affects active and passive recreational opportunities by limiting the space for those activities, and thus, the number of people able to utilize the beach. Therefore, storm damage reduction and visitation benefits represent the benefits considered in this study. The following sections discuss these benefit calculation methodologies. Note that storm damage reduction benefits only accrue for #1665: Corpus North Beach Harvey Repair because other projects’ design lives are extremely short and did not have storms affect them during their period of service.

### 2.2.1 Storm Damage Reduction Benefit

Like previous GLO studies, this study adopted a rigorous engineering approach to develop storm damage reduction benefits, where applicable. Estimating storm damage reduction benefits requires knowledge of background erosion; storm-related erosion; location of damageable elements (e.g., infrastructure and structures) relative to the shoreline; and value of elements. Most information derives from previous studies, property appraisal districts, and site-specific replacement cost estimates. Previous GLO studies serve as a source of background erosion rates and storm information. Storm damage erosion benefits primarily focus on damages triggered by beach erosion.

For determining storm-related erosion, this study applied the USACE Storm Induced Beach Change (SBEACH) cross-shore sediment transport model (Larson and Kraus, 1989a; Larson and Kraus, 1989b; Rosati et al., 1993). The model simulates potential storm-related dune and beach erosion for various return period storms. A two-dimensional cross-shore model, SBEACH applies input parameters describing the physical characteristics of a storm event to predict the adjustment of a pre-storm to a post-storm beach profile. SBEACH simulates wave-induced erosion as well as formation and movement of offshore bars and troughs and accounts for hardbottom or seawall effects on dune and beach erosion. The model accommodates variable grid spaces, time-dependent water levels and wave characteristics, wave refraction and runup, water level setup due to breaking waves (wave setup) and wind (wind setup), and sediment overwash. As SBEACH only simulates beach erosion due to short-term events (storms), model results provide no indication of long-term trends of cross-shore sediment transport. The model neglects simulation of any longshore sediment transport processes.



Model simulations require a pre-storm beach profile, storm information for the duration of a storm event, and sediment transport parameters. The pre-storm beach profile input requirements include a pre-storm beach profile and sediment grain size. The storm information includes wave height and period and water level (storm surge) hydrographs for the duration of the storm event. Simulations did not apply the optional model input of wave direction and wind direction and speed. Additionally, input beach profiles for the SBEACH simulations excluded application of the hardbottom location feature.

The GLO provided representative pre- and post-construction (or design template) profiles. Sediment grain sizes as well as the storm information (wave height, wave period, and water level hydrographs) originate from previous GLO studies. In general, the hydrographs include three normal tide, wave height, and wave period cycles followed by a 36-hour period of storm conditions. The normal conditions follow cosine squared distributions whereas storm conditions follow sine squared distributions. Minor smoothing at the transitions prevents abrupt changes in the water surface elevation. The storms include 1-, 2-, 5-, 10-, 20-, 50-, and 100-yr events characterized by wave height, wave period, and water level hydrographs.

The SBEACH model allows for tuning of four main parameters: the transport rate parameter ( $K$ ), the slope-related sand transport rate parameter ( $\epsilon$ ), the spatial decay coefficient ( $\lambda$ ), and the avalanching angle ( $\Phi$ ). The transport rate parameter governs the magnitude of sediment transport directly and influences the response time of the beach profile. Smaller values of  $K$  lead to longer time scales for equilibrium whereas larger  $K$  values result in faster response times and more beach erosion and larger offshore bars. The slope-related transport rate parameter mainly influences the bar volume with larger values of  $\epsilon$  resulting in more subdued bars. The spatial decay coefficient influences the rate of decay of transport seaward of the break point with smaller values of  $\lambda$  resulting in slower rates of decay. The avalanching angle influences the steepness of the eroded profile with larger values causing steeper profiles. The first two parameters discussed above represent the main calibration parameters (Rosati et al., 1993).

Previous studies considered the values of land, infrastructure, and structures on the affected properties. However, the only CEPR project — #1665: Corpus North Beach Harvey Repair — with storm damage reduction benefits has just upland infrastructure affected by storm erosion. Furthermore, these damageable elements include only slab-on-grade infrastructure susceptible to beach erosion. Consistent with previous GLO studies, this analysis assumes that damage to slab-on-grade structures occurs when the shoreline recedes landward of the seaward edge of the damageable element such that total damage occurs when the shoreline recedes at least halfway through the element's footprint. For example, given erosion extends 25% into a slab-on-grade structure's footprint and the structure appraises at \$500,000, this structure sustains 50% damage or \$250,000 worth of damage.

After modeling the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-yr return period storms for a particular year's shoreline position, one may develop a damage-cumulative probability table like Table 2.2. This table presents an example damage-cumulative probability distribution for a given year's without-project conditions. A series of calculations, captured in the table, helps derive the expected value of average annual damages for a given year. Note the expected average annual damage will not necessarily occur in a particular year. Rather, over a long period, the average damage will approach this expected value.

Table 2.2 Example Total Damage-Cumulative Probability (Year 1, without Project)

Tr (years)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	\$0	\$0	\$0	---	---	---
2	0.5	0.5	\$0	\$100,000	\$100,000	\$50,000	0.5	\$25,000
5	0.2	0.8	\$0	\$150,000	\$150,000	\$125,000	0.3	\$37,500
10	0.1	0.9	\$0	\$200,000	\$200,000	\$175,000	0.1	\$17,500
20	0.05	0.95	\$0	\$250,000	\$250,000	\$225,000	0.05	\$11,250
50	0.02	0.98	\$0	\$300,000	\$300,000	\$275,000	0.03	\$8,250
100	0.01	0.99	\$0	\$350,000	\$350,000	\$325,000	0.01	\$3,250
>100	<0.01	>0.99	\$0	\$350,000	\$350,000	\$350,000	0.01	\$3,500
Expected Average Annual Damage								<b>\$106,250</b>

Calculating the expected annual average damage requires several steps. First, the probability of an event occurring each year equals

$$p(x) = \frac{1}{T_r} \quad (2.1)$$

where  $p(x)$  is the probability a certain storm event ( $x$ ) each year (Table 2.2, second column) and  $T_r$  is the return period. One relates return period to cumulative probability by

$$T_r = \frac{1}{1-P(x)} \quad (2.2)$$

where  $P(x)$  is the cumulative probability of  $x$ . One interprets the above equation as the probability an event equals or exceeds an event with a return period of  $T_r$ . For example, storms will equal or exceed a 50-yr storm, on average, 2% of the time [substitute 20 for  $T_r$ , rearrange and solve for  $P(x)$ , subtract the result from 1, and multiply by 100%]. Other values follow from a similar procedure (Table 2.2, third column).

The tabulated “Lot Damage” and “Structure Damage” columns originate from the SBEACH modeling. “Total Damage” simply sums these two damages. For un-modeled events exceeding the 100-yr event, the total damages equal the same total damages as the 100-yr event. The “Average Interval Damage” equals the average of the total damages between adjacent damage values. For example, the 1- and 2-yr total damages equal \$0 and \$100,000. The average of these damages equals \$50,000 (Table 2.2, seventh column). The “Interval Probability” corresponds to the differences between adjacent cumulative probabilities (Table 2.2, third column). Multiplying the values in the “Average Interval Damage” and the “Interval Probability” columns yields the “Expected Value Interval Damage” for each return period event (Table 2.2, last column). Finally, summing the individual results in the last column produces the expected average annual damage for that year.

Repeating the above calculations produces the expected average annual damage for each year of the period of analysis and project condition (i.e., with or without the project). Table 2.3 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 (in this example, two years). The project



benefit for a given year represents the difference in the expected value of storm damage between without- and with-project conditions, including inflation and discounting. The total storm damage reduction benefit equals the cumulative discounted present worth at the end of the period of analysis (Table 2.3, value in last column and row)

Table 2.3 Example of Storm Damage Reduction Benefit Calculation

Year	Without Project (2022 Prices)	With Project (2022 Prices)	Difference (Benefit)	With Inflation <sup>1</sup>	Discounted Present Worth <sup>2</sup>	Cumulative Discounted Present Worth <sup>2</sup>
2023	\$106,250	\$53,000	\$53,250	\$54,422	\$53,173	\$53,173
2024	\$234,000	\$122,000	\$112,000	\$116,982	\$109,116	<b>\$162,289</b>

Notes: Inflation rate = 2.2%

Discount rate = 4.75%

<sup>1</sup>Inflated value for given year; inflation rate factor =  $1+0.022^n$  where  $n = \text{year} - 2022$ ; Ex. Value in 2023 prices equals  $1.022 * \text{value in 2022 prices}$

<sup>2</sup>Present worth, beginning of 2023, based on mid-year discounting; mid-year discount factor =  $(1/(1+0.0475))^{n+0.5}$  where  $n = \text{year} - 2023$ ; Ex. Present worth in 2023 dollars of year 2023 inflated value equals  $(1/1.0475)^{0.5} * (\text{value in With Inflation column})$

Calculating damage-cumulative probability curves for each project year throughout the period of analysis often proves necessary because background erosion (and other processes) can move the shoreline landward every year. Finally, this study, like previous GLO studies, assumes the repair of the preceding year's structural damage before each subsequent year. Of note, probabilistic methods for determining average annual damages applies to future years only; in evaluating projects constructed in prior years, only damages prevented during actual events from construction to the present apply.

## 2.2.2 Beach Visitation Benefits

Recreational enjoyment by all visitors and spending by out-of-state visitors represent the beach visitation benefits addressed by this study. Developing these benefits for each year in the period of analysis requires estimating

- With- and without-project visitor estimates (with population growth and changing beach width);
- Unit day values for with- and without-project conditions;
- Out-of-state visitation percentage of total visitation; and
- Out-of-state visitation spending per person per visit.

Both visitation benefits rely on with- and without project estimates. The following sections discuss development of those estimates and their application in determining recreational enjoyment by all visitors and out-of-state visitor spending as well as other details for benefit determinations.

### 2.2.2.1 With- and Without-Project Visitation Estimates

First, analyses focus on estimating visitation unconstrained (by beach width limitations) based on general population growth. With one exception (noted later in the report), analyses assumed visitation

grows at 1.5% per year, reflecting a long-term weighted average of Texas and U.S. population forecasts (see U.S. Census Bureau and Texas Development Center). Table 2.4 shows an example visitation estimate over a five-year period given an initial estimate of 200,000 annual visitors in 2023 and 1.5% per year population growth rate.

Table 2.4 Example of Unconstrained Visitation Growth Estimate

Year	Unconstrained Annual Visitation
2023	200,000
2024	203,000
2025	206,045
2026	209,136
2027	212,273

Note: Assumes visitation growth rate of 1.5% per year

Next, reductions in beach width and therefore, carrying capacity of the beach, as the beach erodes can constrain the beachgoer population from potentially achieving the values tabulated in Table 2.4. In its analyses, USACE asserts that an average person needs 100 square feet (sf) of dry beach for normal beach activities. Determining the daily carrying capacity of the beach requires dividing the available dry beach surface area by 100 sf and multiplying by two, which corresponds to the average daily turnover rate. Multiplying this result by 365 days produces an annual carrying capacity of the beach. Table 2.5 shows example beach visitation values based on carrying capacity.

Table 2.5 Example of Annual Carrying Capacity of Beach Calculations

Year	Beach Berm Width (ft)	Beach Length (ft)	Dry Beach Area (sf)	Daily Carrying Capacity	Annual Carrying Capacity
2023	100	1,000	100,000	2,000	730,000
2024	50	1,000	50,000	1,000	365,000
2025	25	1,000	25,000	500	182,500
2026	12	1,000	12,000	240	91,250
2027	6	1,000	6,000	120	43,800

Finally, beach visitation can also decrease beyond the beach’s carrying capacity based on beachgoer preference (i.e., beachgoers prefer a wider beach). To determine visitor preference relative to beach width (beach width “elasticity”), Oden and Butler (2006) and Taylor Engineering (2015) conducted site-specific beachgoer surveys at Galveston, Surfside, and South Padre Island beaches. Figure 2.1 shows the different elasticity relationships, which measure the percentage change in annual beach visitation given a percentage change in beach width. With one exception (noted later in this report), analyses rely on the more recent, Taylor Engineering relationship. Table 2.6 shows an example application of the elasticity relationship developed by Taylor Engineering. The more recent survey results support that some minimal level of visitation likely occurs for various activities even with no beach present. Visitors may come to the shore take part in other activities such as surfing, fishing, swimming, and viewing wildlife.

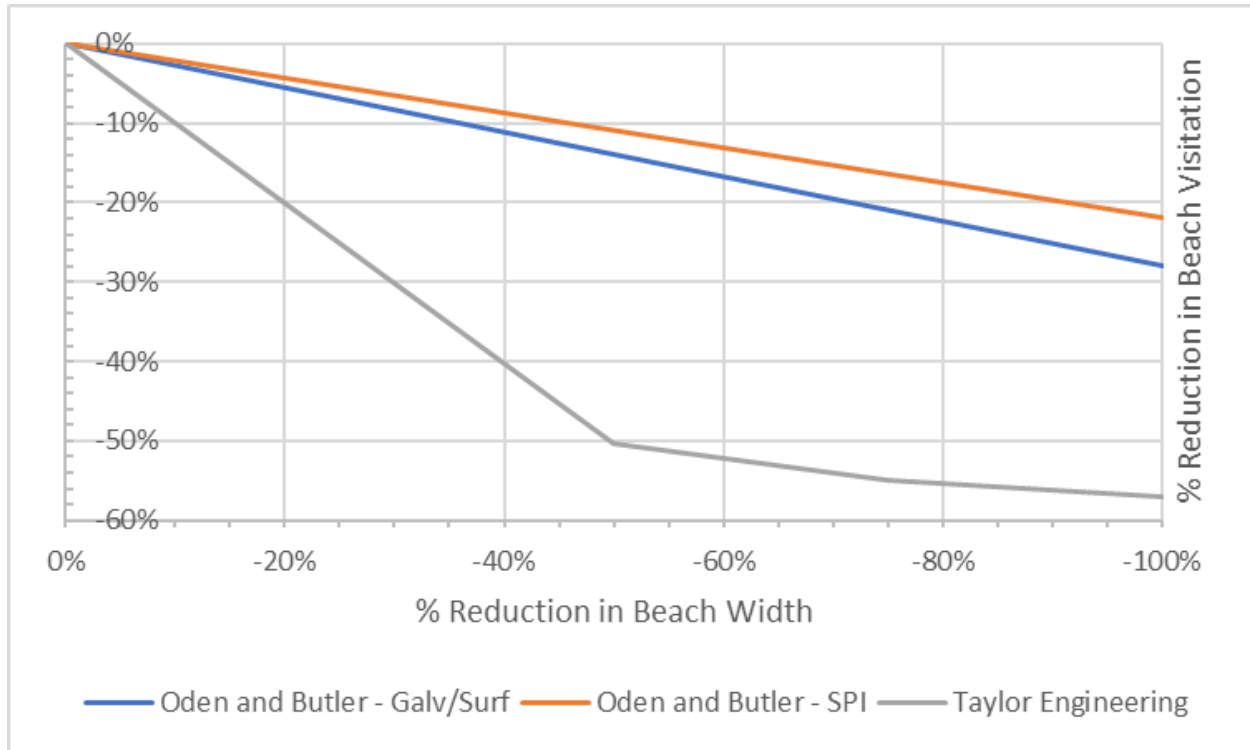


Figure 2.1 Beach Width Elasticity Relationships

Table 2.6 Example of Application of Beach Width Elasticity

Year	Unconstrained Annual Visitation	Beach Berm Width (ft)	% Reduction in Beach Width	% Reduction in Visitation	Reduced Annual Visitation
2023	200,000	100	0%	0.0%	200,000
2024	203,000	50	-50%	-50.4%	100,688
2025	206,045	25	-75%	-54.9%	92,926
2026	209,136	12	-88%	-56.0%	92,120
2027	212,273	6	-94%	-56.5%	92,339

Note: Applies Taylor Engineering elasticity relationship

Table 2.7 completes the example shown in the above tables. Taking the lesser of the unconstrained annual visitation, annual beach carrying capacity, and annual visitation after application of beach width elasticity yields the appropriate visitation estimate for a given year. Analyses apply these calculations for both with- and without-project conditions for each year in the period of analysis. Application of the visitation numbers defined via methods described above serve as input into deriving recreational value benefits for all visitors and out-of-state visitor spending.

Table 2.7 Example of Adjustments to Unconstrained Annual Visitation

Year	Unconstrained Annual Visitation <sup>1</sup>	Annual Carrying Capacity <sup>2</sup>	Annual Visitation Based on Elasticity <sup>3</sup>	Adopted Annual Visitation
2023	200,000	730,000	200,000	200,000
2024	203,000	365,000	100,688	100,688
2025	206,045	182,500	92,926	92,926
2026	209,136	91,250	92,037	91,250
2027	212,273	43,800	92,347	43,800

Notes: <sup>1</sup>From Table 2.4

<sup>2</sup>From Table 2.5

<sup>3</sup>From Table 2.6

### 2.2.2.2 Out-of-State Visitor Spending Benefit

Taylor Engineering (2015) and Lee (2020) provide out-of-state visitation percentages of total visitation; and out-of-state visitation spending per person per visit for the sites assessed in this study. Multiplying the beachgoer population (example shown in Table 2.7) and out-of-state visitor spending for both with and without the project (including multiplier effect), taking the difference between the products, adjusting them for inflation, and discounting yields the benefit for a given year. Summing the discounted values for each year yields the total benefit over the period of analysis (Table 2.8, bold and italicized number). Note that this study assumes that out-of-state visitor spending per person per day does not change relative to with- and without-project conditions.

### 2.2.2.3 Recreation Benefit

With knowledge of annual beach visitation with and without the project over the period of analysis and unit day values (UDV), one may estimate the recreational value benefits of all visitors. The USACE’s UDV method, which relies on “expert or informed opinion and judgment to approximate the average willingness to pay of users of Federal or Federally assisted recreation resources” (USACE, 2022b), helps one assign points to recreation-based activities based on five criteria: (1) recreation experience, (2) availability of opportunity, (3) carrying capacity (different from 100 sf need per person), (4) accessibility, and (5) environmental. Figure 2.2 reproduces USACE’s tabulated guidelines for assigning points to the above criteria for general recreation projects, in which beaches fall. In total, the maximum possible score for a site equals 100 points. Upon establishing the point total, Figure 2.3, reproduced from USACE (2022b), enables converting points to dollar values per visitor per day for general recreation.

Multiplying the beachgoer population (example shown in Table 2.7) and appropriate UDV for both with and without the project, taking the difference between the products, adjusting them for inflation, discounting yields the benefit for a given year. Summing the discounted values for each year yields the total benefit over the period of analysis (Table 2.9, bold and italicized number).



Table 2.8 Example of Out-of-State Visitor Spending Benefit

Year	Out-of-State				Difference (Benefit)	With Inflation <sup>3</sup>	Discounted Present Worth <sup>2</sup>	Cumulative Discounted Present Worth <sup>4</sup>
	Visitation <sup>1,2</sup>		Visitor Spending (2022 prices)					
	With Project	Without Project	With Project	Without Project				
2023	18,000	13,500	\$2,520,000	\$1,890,000	\$630,000	\$643,860	\$629,092	\$629,092
2024	9,062	4,500	\$1,268,669	\$630,000	\$638,669	\$667,079	\$622,224	<b>\$1,251,316</b>

Notes: Out-of-state visitation = 9% of total visitation estimates  
 Out-of-state spending = \$100.00 per person (2022 prices)  
 Inflation rate = 2.2% (2023 and beyond)  
 Discount rate = 4.75%  
 Multiplier effect = 1.4

<sup>1</sup>Assumes total visitation with project equals 200,000 in 2023 and 100,688 in 2024. Multiply by out-of-state visitation percentage to obtain with-project out-of-state visitation.

<sup>2</sup>Assumes total visitation without project equals 150,000 in 2023 and 50,000 in 2024. Multiply by out-of-state visitation percentage to obtain without-project out-of-state visitation.

<sup>3</sup>Inflated value for given year; inflation rate factor =  $1+0.022^n$  where  $n = \text{year} - 2022$ ; Ex. Value in 2023 prices equals  $1.022 * \text{value in 2022 prices}$

<sup>4</sup>Present worth, beginning of 2023, based on mid-year discounting; mid-year discount factor =  $(1/(1+0.0475))^{n+0.5}$  where  $n = \text{year} - 2023$ ; Ex. Present worth, beginning of 2023, of year 2023 inflated value equals  $(1/1.0475)^{0.5} * (\text{value in With Inflation column})$

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Criteria	Judgment factors				
Recreation experience <sup>1</sup>  Total Points: 30  Point Value:	Two general activities <sup>2</sup>  0-4	Several general activities  5-10	Several general activities: one high quality value activity <sup>3</sup>  11-16	Several general activities; more than one high quality high activity  17-23	Numerous high quality value activities; some general activities  24-30
Availability of opportunity <sup>4</sup>  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 <sup>5</sup>  Total Points: 14  Point Value:	Minimum facility for development for public health and safety  0-2	Basic facility to conduct activity(ies)  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 roads to site; fair access, good roads within site  11-14	Good access, high standard road to site; good access within site  15-18
Environmental quality  Total Points: 20  Point Value:	Low aesthetic factors <sup>6</sup> that significantly lower quality <sup>7</sup>  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

<sup>1</sup>Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.

<sup>2</sup>General activities include those that are common to the region and that are usually of normal quality. This includes picnicking, camping, hiking, riding, cycling, and fishing and hunting of normal quality.

<sup>3</sup>High quality value activities include those that are not common to the region and/or Nation, and that are usually of high quality.

<sup>4</sup>Likelihood of success at fishing and hunting.

<sup>5</sup>Value should be adjusted for overuse.

<sup>6</sup>Major esthetic qualities to be considered include geology and topography, water, and vegetation.

<sup>7</sup>Factors to be considered to lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.

Figure 2.2 Guidelines for Assigning Points for General Recreation (Modified from USACE, 2022b)



Point Values	General Recreation Values (1)	General Fishing and Hunting Values (1)	Specialized Fishing and Hunting Values (2)	Specialized Recreation Values other than Fishing and Hunting (2)
0	\$ 4.50	\$ 6.47	\$ 31.51	\$ 18.29
10	\$ 5.35	\$ 7.31	\$ 32.35	\$ 19.41
20	\$ 5.91	\$ 7.88	\$ 32.92	\$ 20.82
30	\$ 6.75	\$ 8.72	\$ 33.76	\$ 22.51
40	\$ 8.44	\$ 9.57	\$ 34.61	\$ 23.91
50	\$ 9.57	\$ 10.41	\$ 37.98	\$ 27.01
60	\$ 10.41	\$ 11.54	\$ 41.36	\$ 29.82
70	\$ 10.97	\$ 12.10	\$ 43.89	\$ 36.01
80	\$ 12.10	\$ 12.94	\$ 47.27	\$ 41.92
90	\$ 12.94	\$ 13.22	\$ 50.64	\$ 47.83
100	\$ 13.50	\$ 13.50	\$ 53.46	\$ 53.46

Figure 2.3 Conversion of Points to Dollar Values for Fiscal Year 2022 (USACE, 2022b)

Table 2.9 Example of Recreation Benefit

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	With Inflation <sup>1</sup>	Discounted Present Worth <sup>2</sup>	Cumulative Discounted Present Worth <sup>2</sup>
	With Project	Without Project	With Project	Without Project				
2023	200,000	150,000	\$2,000,000	\$1,200,000	\$800,000	\$817,600	\$798,847	\$798,847
2024	100,688	50,000	\$1,006,880	\$400,000	\$606,880	\$633,876	\$591,253	<b>\$1,390,101</b>

Notes: UDV (with project) = \$10.00 (2022 prices)  
 UDV (without project) = \$8.00 (2022 prices)  
 Inflation rate = 2.2% (2023 and beyond)  
 Discount rate = 4.75%

<sup>1</sup>Inflated value for given year; inflation rate factor = 1+0.022<sup>n</sup> where n = year – 2022; Ex. Value in 2023 prices equals 1.022 \* value in 2022 prices

<sup>2</sup>Present worth, beginning of 2023, based on mid-year discounting; mid-year discount factor = (1/(1+0.0475))<sup>n+0.5</sup> where n = year – 2023; Ex. Present worth, beginning of 2023, of year 2023 inflated value equals (1/1.0475)<sup>0.5</sup> \* (value in With Inflation column)

## 2.3 Natural Resource Restoration Projects

The natural resource projects sponsored by the CEPRA program create, enhance, and prevent the loss of habitat while potential providing for recreational opportunities, storm surge reduction, gas (e.g., carbon dioxide) sequestration, pollutants removal, and improved area aesthetics.

Like the prior economic benefits studies, this study quantified natural resource benefits in terms of ecosystem services values, expressed as dollars per acre per year, as they changed over a project’s life or

period of analysis. 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 natural resource projects rest on the assumption that the project sites provide economic benefits in a manner like those described in the literature. This assumption served as a surrogate for the extensive onsite 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.

The BlueValue database (<https://www.bluevalue.org/>), developed by the Harte Research Institute, Texas A&M University-Corpus Christi, provides a worldwide database of ecosystem services values. The BlueValue database supersedes the previous version known as GecoServ, which prior GLO studies referenced. Consistent with prior studies, the current study identified six ecosystem service categories—habitat, recreation, storm surge, gas sequestration/storage, pollution abatement, and aesthetics—that represent the value of GLO CEPRA projects. Upon reviewing available ecosystem services values pertaining to Gulf of Mexico states (except for aesthetics for which Gulf state values were unavailable), INTERA-GEC selected the values (expressed as 2019 dollars per hectare per year) pertaining to Texas only, which combined were similar to the average value for all Gulf states. For those categories (habitat and storm surge) that included multiple values based on different calculation methods, analyses adopted the lowest value to yield a conservative ecosystem services valuation.

Table 2.10 defines the ecosystem services and lists ecosystem service values for coastal wetlands and marine open water ecosystems. The BlueValue database did not provide open water values in Texas or other Gulf states for any of the ecosystem services listed. Therefore, this study applied the single open water value for habitat, adjusted for inflation, from the superseded GecoServ database referenced in prior GLO studies (from Washington state). The BlueValue database contained a single open water value for aesthetics (from New Jersey) for the United States; however, due to the differences between population densities near and likely aesthetic value of open water areas in New Jersey and Texas, this study 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 2.10 Ecosystem Service Values

Ecosystem Service	Definition <sup>1</sup>	Coastal Wetlands Value		Open Water Value	
		BlueValue (\$/hectare; 2019 dollars)	Inflated Value (\$/acre; 2022 dollars) <sup>2</sup>	BlueValue (\$/hectare; 2019 dollars)	Inflated Value (\$/acre; 2022 dollars) <sup>2</sup>
Habitat	The physical place where organisms reside (e.g., refugium for resident and migratory species; spawning and nursery grounds)	\$8675.10	\$4,042.03	\$5.12 <sup>3</sup>	\$5.89
Recreation	Opportunities for rest, refreshment, and recreation (e.g., ecotourism; bird watching; outdoor sports)	\$5771.50	\$2,689.15	-	-
Storm Surge	Dampening or reducing environmental impacts from storm surge (e.g., marshes and other coastal habitats absorbing waters from surge)	\$5625.92	\$2,621.31	-	-
Gas Sequestration, Storage, and Production	Regulation of the chemical composition of the atmosphere and oceans (e.g., sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds)	\$1493.45	\$695.85	-	-
Pollution Abatement	Removal or breakdown of non-nutrient compounds and materials, or other forms of potentially harmful pollution (e.g., pollution detoxification;	\$186.83	\$87.05	-	-

Ecosystem Service	Definition <sup>1</sup>	Coastal Wetlands Value		Open Water Value	
		BlueValue (\$/hectare; 2019 dollars)	Inflated Value (\$/acre; 2022 dollars) <sup>2</sup>	BlueValue (\$/hectare; 2019 dollars)	Inflated Value (\$/acre; 2022 dollars) <sup>2</sup>
	absorption of noise pollution)				
Aesthetics	Sensory equipment of functioning ecological systems (e.g., proximity of houses to scenery; open space)	\$87.11	\$40.59	-. <sup>4</sup>	-
Total Ecosystem Services Value		\$21,839.91	\$10,175.98	\$5.12	\$5.89

Notes: <sup>1</sup>From BlueValue database, <http://bluevalue.org/>, accessed 01/20/2022  
<sup>2</sup>BlueValue values (2019 dollars) converted to 2022 dollars per acre using inflation rates listed in Table 2.1 and 1 hectare = 2.47105 acres  
<sup>3</sup> BlueValue database does not provide values for Habitat; this study adjusted the value from the GecoServ database  
<sup>4</sup> BlueValue database contained only one marine open water value for aesthetics (from New Jersey), which was determined to be inapplicable to the Texas coast and, hence, excluded from the study.

Benefit calculations assume a fixed annual amount of benefit per acre of fully developed habitat created or protected by the project. Prior GLO CEPRA benefit-cost analyses (Trudnak et al., 2015; Trudnak et al., 2017) 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. However, the two natural resource projects evaluated in this study provide benefits by protecting existing marsh (with 100% of the services value) and did not create new marsh. Therefore, the present analyses apply the full services value starting at project completion.

Table 2.11 provides an example calculation of the total value of ecosystem services for breakwaters constructed in 2021 to protect existing marsh habitat with benefits evaluated over a 21-year (construction year plus 20-year project life) period. The example uses the 2021 ecosystem services value of \$9,364.76 per acre (adjusted for inflation from the values in Table 2.10), inflation as given in Table 2.1, and an annual discount rate of 4.75%. In this example, the project created a cumulative benefit of \$929,331 (present value, beginning of 2021).



Table 2.11 Example of Benefit Calculation for Protected Marsh

Year	Marsh Lost (acres)				Net Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Cumulative Discounted Present Worth, Beginning of 2021
	With Project		Without Project			Values (2021 Prices) <sup>1</sup>	With Inflation <sup>2</sup>	Discounted Present Worth, Beginning of 2021 <sup>3</sup>	
	Annual	Cumulative	Annual	Cumulative					
2021	0.3	0.3	0.6	0.6	0.3	\$2,809	\$2,809	\$2,745	\$2,745
2022	0	0.3	0.6	1.2	0.9	\$8,428	\$9,153	\$8,538	\$11,283
2023	0	0.3	0.6	1.8	1.5	\$14,047	\$15,591	\$13,883	\$25,166
2024	0	0.3	0.6	2.4	2.1	\$19,666	\$22,307	\$18,963	\$44,129
2025	0	0.3	0.6	3.0	2.7	\$25,285	\$29,312	\$23,788	\$67,916
2026	0	0.3	0.6	3.6	3.3	\$30,904	\$36,614	\$28,366	\$96,282
2027	0	0.3	0.6	4.2	3.9	\$36,523	\$44,223	\$32,707	\$128,989
2028	0	0.3	0.6	4.8	4.5	\$42,141	\$52,149	\$36,820	\$165,810
2029	0	0.3	0.6	5.4	5.1	\$47,760	\$60,402	\$40,714	\$206,524
2030	0	0.3	0.6	6.0	5.7	\$53,379	\$68,994	\$44,396	\$250,920
2031	0	0.3	0.6	6.6	6.3	\$58,998	\$77,934	\$47,875	\$298,795
2032	0	0.3	0.6	7.2	6.9	\$64,617	\$87,234	\$51,158	\$349,953
2033	0	0.3	0.6	7.8	7.5	\$70,236	\$96,905	\$54,253	\$404,206
2034	0	0.3	0.6	8.4	8.1	\$75,855	\$106,960	\$57,167	\$461,372
2035	0	0.3	0.6	9.0	8.7	\$81,473	\$117,411	\$59,906	\$521,279
2036	0	0.3	0.6	9.6	9.3	\$87,092	\$128,269	\$62,479	\$583,758
2037	0	0.3	0.6	10.2	9.9	\$92,711	\$139,548	\$64,891	\$648,649
2038	0	0.3	0.6	10.8	10.5	\$98,330	\$151,262	\$67,148	\$715,797
2039	0	0.3	0.6	11.4	11.1	\$103,949	\$163,424	\$69,257	\$785,054
2040	0	0.3	0.6	12.0	11.7	\$109,568	\$176,047	\$71,224	\$856,278
2041	0	0.3	0.6	12.6	12.3	\$115,187	\$189,147	\$73,053	\$929,331

<sup>1</sup>The marsh ecosystem service value is \$9,364.76/acre (2021 prices)

<sup>2</sup>Inflation adjustments equal 8.6% from 2021 to 2022 and 2.2% annually thereafter

<sup>3</sup>Present worth, beginning of 2021, based on mid-year discounting; mid-year discount factor =  $(1/1.0475)^{n+0.5}$ , where n = year - 2021; discount rate = 4.75%

## 3.0 Beach Restoration and Shoreline Protection Benefit Analysis

This chapter presents the benefit analyses of the following beach-related projects:

- #1653: South Padre Island Beach Nourishment with BUDM (Cycle 11)
- #1665: Corpus North Beach Harvey Repair (Cycle 10)
- #1693: Babe’s Beach BUDM (2021 BUDM Cycle) (Cycle 11)
- #1702: Isla Blanca Park Beach Nourishment with BUDM (Cycle 11).

### 3.1 Cameron County – #1653: South Padre Island Beach Nourishment with BUDM (Cycle 11)

#### 3.1.1 Project Description and Background Information

The City of South Padre Island encompasses approximately four miles of Gulf of Mexico shoreline, extending from approximately one to five miles north of Brazos Santiago Pass in Cameron County. Nourishment of segments of the city’s shoreline occurs periodically with beneficial use of (beach-quality) dredge material (BUDM) derived from federal maintenance dredging of the Brazos Island Harbor jetty and entrance channel segments by the USACE Galveston District. The GLO partners with USACE to facilitate beach nourishment by funding — with City of South Padre Island as the local project sponsor — the incremental cost of placing the dredge material on the beach instead of the permitted offshore dredge material placement area (DMPA).

The latest nourishment, CEPRA Project #1653, placed 269,250 cubic yards (cy) of fill along 2,700 ft of shoreline during May – June 2021 (Figure 3.1). The northern terminus of the placement area (designated DMPA No. 5) lies adjacent to the La Quinta Inn & Suites at the southern boundary of Andy Bowie Park, and the southern terminus lies just north of public access point No. 23, approximately halfway between E. Palmetto Dr. and E. Sunset Dr. The fill template consists of a 150-ft-wide berm at elevation +4.0 ft NAVD88, a 1V:25H foreshore slope above the waterline, and an estimated 1V:40H slope below the waterline; 300-ft-long tapers transition the full template to the existing shoreline at the north and south ends. Figure 3.2 presents representative pre- and post-construction photographs. Figure 3.3 plots representative pre- and post-construction beach profiles towards the center of the placement area. Figure 3.4 shows the authorized fill in plan view and Figure 3.5 shows the authorized fill cross-sectional view.

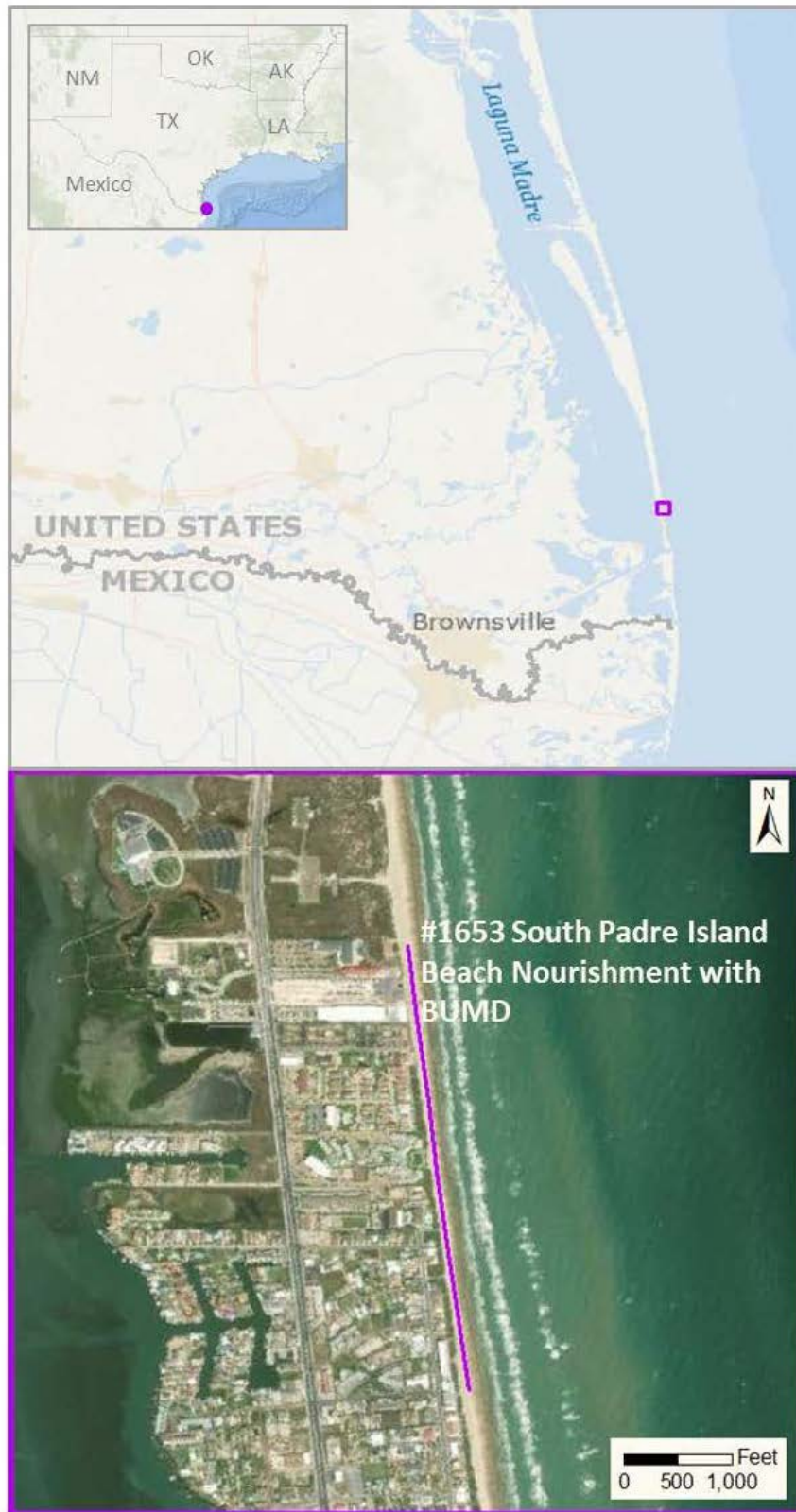


Figure 3.1 Location Map — Project #1653 South Padre Island Beach Nourishment with BUDM

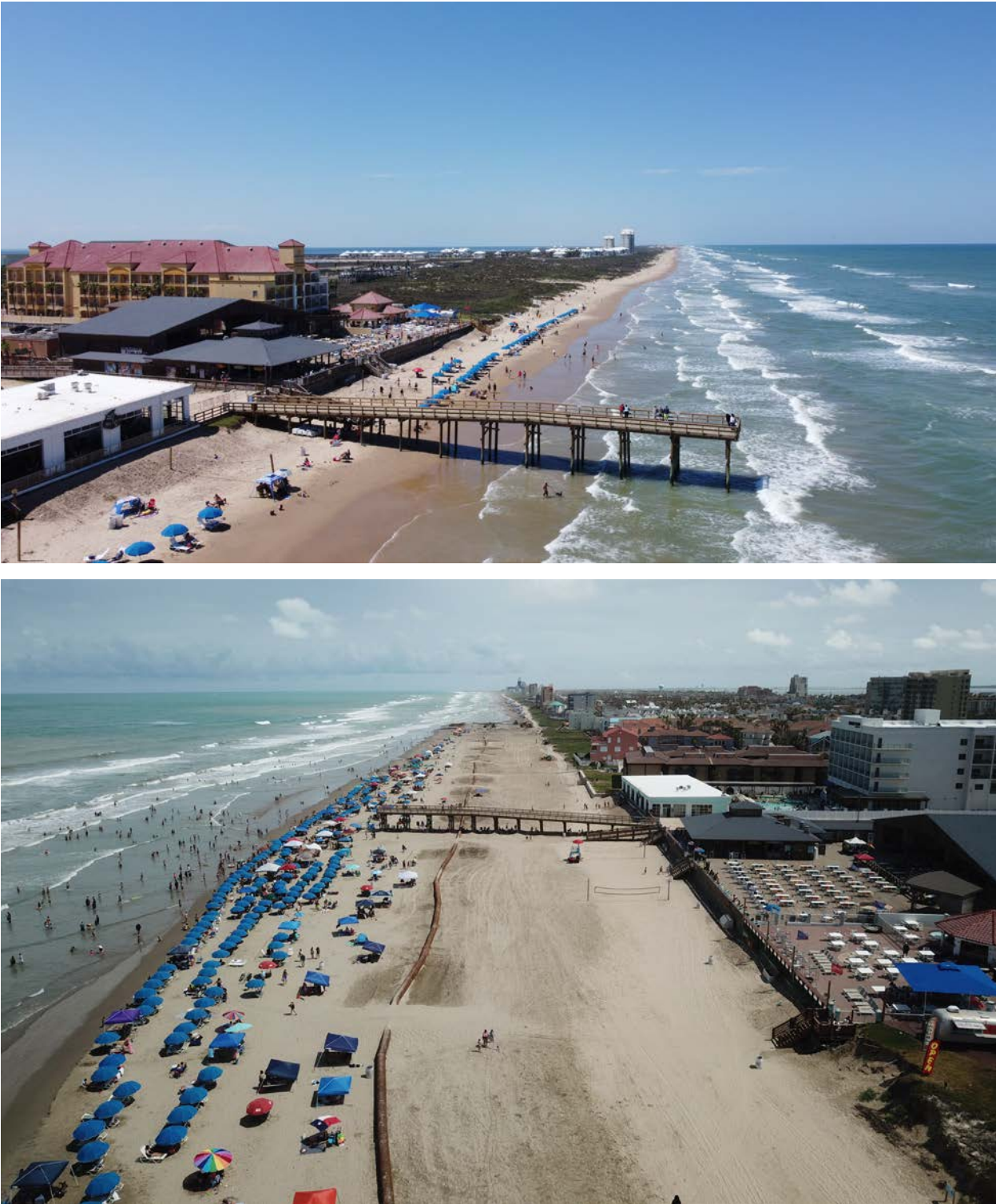


Figure 3.2 Pre- and Post-Construction (Top and Bottom) Conditions

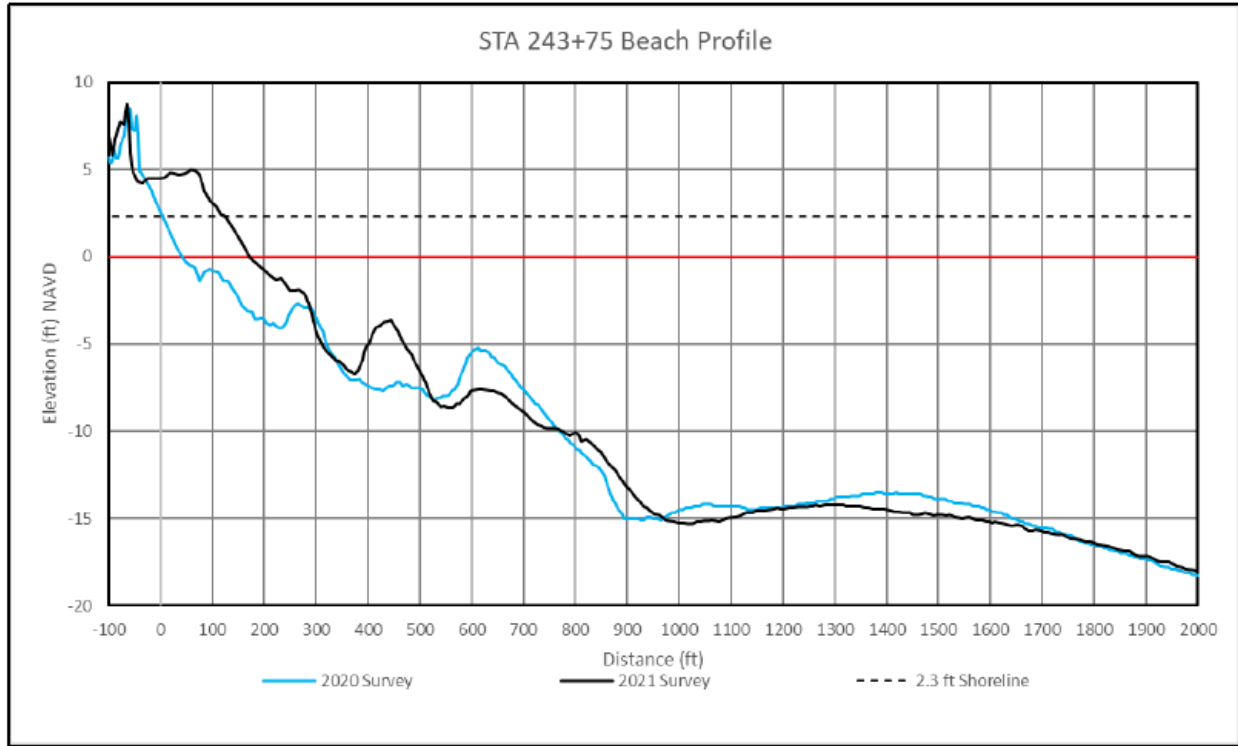


Figure 3.3 Representative Pre- and Post-construction Profiles (HDR, 2021)

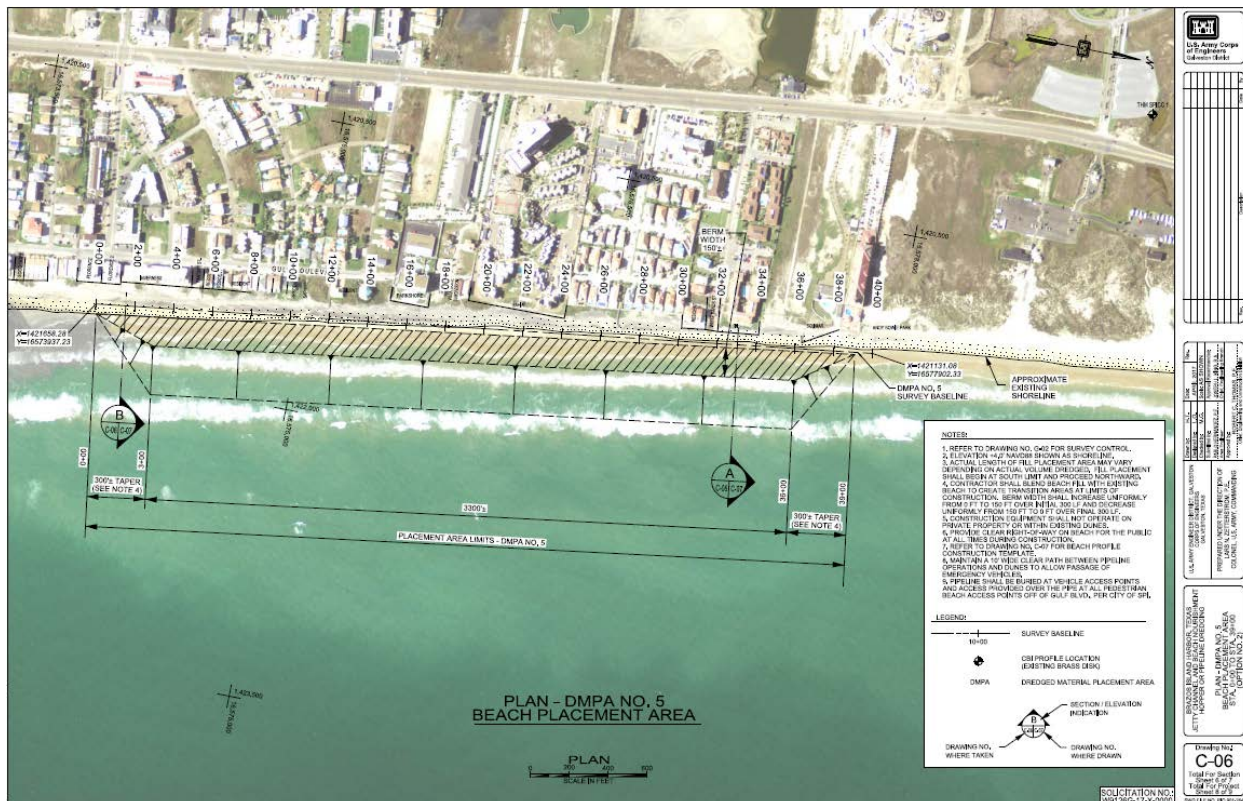


Figure 3.4 Authorized Fill Template Plan View (USACE, 2017)

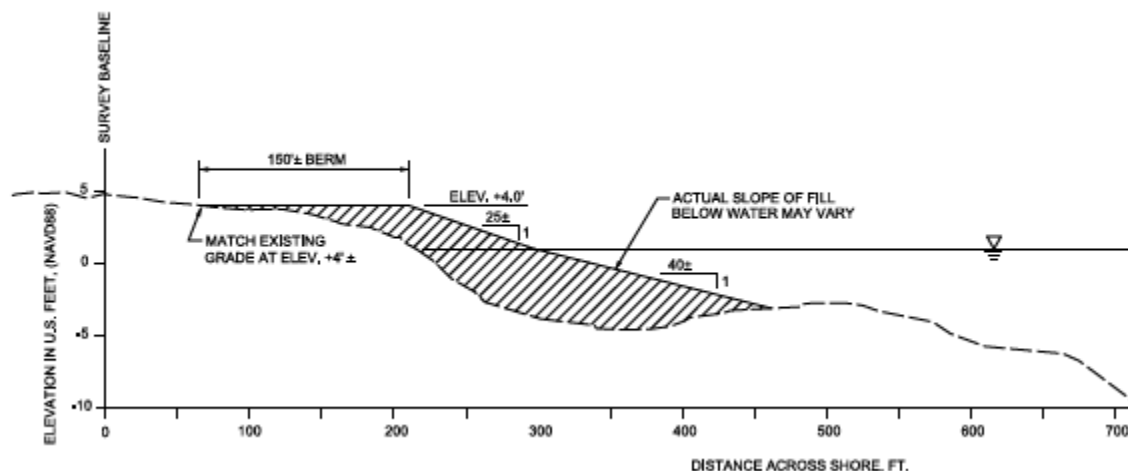


Figure 3.5 Authorized Fill Template Cross Section (USACE, 2017)

### 3.1.2 Project Funding

USACE contributed \$5,868,750 to cover the baseline cost of maintenance dredging the Brazos Island Harbor entrance and jetty channel sections and placing the material in the authorized offshore DMPA. The state/local funding partners contributed \$1,530,000 — cost-shared 75% (\$1,147,500) by GLO (CEPRA) and 25% (\$382,500) by the City of South Padre Island — to cover the total incremental cost of placing the dredged material on the beach rather than the offshore DMPA. This analysis does not consider the federal portion a construction cost for Project #1653 because USACE’s maintenance dredging of the navigation channel would still have occurred without state/local funding for the BUDM nourishment project. Table 3.1 summarizes the project costs, with the summation of the state/local costs representing the total Texas project cost. Of note, USACE has confirmed the actual volume placed in DMPA No. 5 (269,250 cy) exactly matches the projected volume; therefore, no reimbursement to the state/local funding partners is required.

For completeness and informational purposes only, this paragraph explains the funding connection between Project #1653 and Project #1702 (Isla Blanca Park Beach Nourishment with BUDM —Section 3.4). USACE constructed Project #1653 in conjunction with Project #1702, with 75% of the dredge material intended for DMPA No. 5 at the north end of City of South Padre Island and 25% for Isla Blanca Park. The total combined project cost of \$7,908,750 includes the above-mentioned \$5,868,750 federal portion and a \$2,040,000 non-federal portion representing the incremental cost of placing the dredge material on the beach rather than offshore DMPA. USACE split the combined \$2,040,000 non-federal portion in accordance with the projected fill volume of each project. Hence, Project #1653 incurred the non-federal cost of \$1,530,000 ( $\$2,040,000 \times 0.75$ ), included in Table 3.1, and Project #1702 incurred a non-federal cost of \$510,000 ( $\$2,040,000 \times 0.25$ ).



Table 3.1 Funding for Project #1653: South Padre Island Beach Nourishment with BUDM

Funding Source		Amount
State/Local	GLO, CEPRA (75% of non-federal cost, ~26% of total project cost)	\$1,147,500
	City of South Padre Island (25% of non-federal cost, ~8% of total project cost)	\$382,500
Federal	N/A	N/A
Total Cost <b><i>(Texas Only)</i></b>		\$1,530,000 <b><i>(\$1,530,000)</i></b>

Notes: Value in bold italics represents the cost to the State of Texas  
Values represent present worth, beginning of 2021

### 3.1.3 Benefit Analysis

As discussed in the following sections, economic benefits to the state of Texas from beach visitation — spending by out-of-state visitors and recreational enjoyment by all visitors — pertain to Project #1653, starting mid-2021 upon completion of construction. This analysis excludes federal spending as a benefit because USACE would still have conducted maintenance dredging of the navigation channel without state/local funding for the BUDM nourishment project. Additionally, absent immediate pre- and post-storm survey data, this analysis did not quantify storm damage reduction benefits. Although the wider beach provided by the project possibly prevented erosion of the upper beach and dune from Tropical Storm Nicholas in 2021, analysis of Google Earth aerial imagery revealed no noticeable erosion of the dune beyond the project area, such as the dune escarpments and measurable dune loss after Hurricane Harvey in 2017.

As mentioned, the contractor constructed approximately 2,700 ft of beach during May–June 2021. The following assessment of pre-construction, post-construction, and existing conditions support the benefit analysis, which requires estimates of the beachgoer population over the project life.

INTERA-GEC visited the project area on November 3, 2022, approximately 16 months post-construction. Site conditions included a relatively narrow beach width. The south end showed little evidence of remaining fill material above the waterline. The central and northern portions appear to have retained some fill material as evidenced by the beach width near the pier. Fill may exist within the project area within the nearshore; however, survey data documenting such conditions are unavailable. Figures 3.6 – 3.8 show the project conditions during the site visit. Note the line of seaweed (wrack line) gives an idea of the location of recent high tides. However, review of recent tide levels (<https://tidesandcurrents.noaa.gov/>) showed abnormally high tides occurred prior to the site visit; thus, the wrack line does not represent typical mean high tide conditions.

From Figure 3.3, the pre- and post-construction dry beach widths measured approximately 40 and 180 ft, and the November 3, 2022 site visit estimated a beach width of 50 ft at the same location. The currently narrow beach width is unsurprising given the typically rapid fill equilibration that occurs with BUDM projects as well as the passage of Tropical Storm Nicholas close to the project area in 2021. The net northerly longshore transport appeared evident given the wide beach widths visible north of the

project area. While the dispersion of fill onto adjacent properties provides indirect benefit to those properties, this benefit analysis focuses solely on the direct benefits in the project area.

Based on the minimal amount of fill material remaining on the dry beach and the performance of prior BUDM nourishment projects in this area, this economic benefits study assumed a life span of two years for Project #1653.



Figure 3.6 Conditions at Sunset Drive on November 3, 2022, Near South End of the Project Area



Figure 3.7 Conditions on November 3, 2022, Near Center of the Project Area



Figure 3.8 Conditions on November 3, 2022, North of the Project Area

### 3.1.3.1 Out-of-State Visitor Spending Benefit

Taylor Engineering (2015) reports 305 visitors per 1,000 ft of shoreline at the Neptune Circle area (average of morning and afternoon surveys), less than one mile south of the present project site. Applying this value to the 2,700-ft-long project area yields 1,646 peak day visitors assuming a daily turnover rate of two. Oden and Butler (2006) reports 104 peak visitor days occur in the South Padre Island area; one-fifth (assumed) of the peak day visitors (329) visit the beach during off peak days, and 261 (i.e.,  $365 - 104$ ) off peak days occur during a 365-day year. Based on the above visitor information, approximately 257,053 visits ( $171,184 [1,646 * 104] + 85,869 [329 * 261]$ ) to the project area occurred in 2015. Assuming annual visitation growth mirrors the general population growth trend of 1.5% per year, annual visitation to the project area in 2021 equals 281,073 ( $257,053 * 1.015^6$ ).

Given the assumption that the visitation growth does not exceed the beach's capacity, increasing the beach visitation each year by the general population growth rate of 1.5% per year (e.g., visitation in 2nd year =  $1.015 * \text{visitation in 1st year}$ ) produced initial estimates of beach population for each year of the project life. However, because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches as represented by the elasticity relationship (Section 2.2). This analysis estimated the with- and without-project beach visitation estimates considering the beach capacity and elasticity relationship. With approximately the same dry beach widths in the project area in 2022 and in the Neptune Circle area during the 2015 survey (estimated from Google Earth imagery), this analysis assumed the 2022 with-project visitation, adjusted for population growth, is equivalent to the 2015 survey results. Background erosion of -5 ft/yr applied to the 2021 without-project beach width determined 2022 visitation. Tables 3.2 and 3.3 summarize the visitation estimates for with- and without-project conditions. Of note, the with-project beach widths exceed or equal the 2015 beach width throughout the two-year analysis period; thus, visitation reductions via the elasticity relationship are not required. Additionally, the annual visitation estimates do not exceed the carrying capacity of the project area (e.g., 4,860 visitors at any given time in 2021;  $2700 \text{ ft} * 180 \text{ ft} / 100 \text{ sf per visitor} = 4,600 \text{ visitors}$ ) based on USACE's criterion of 100 sf per person.

Taylor Engineering (2015) reports out-of-state visitors to South Padre Island spend \$100.44 per person per day and 21.52% of visitors to the Neptune Circle area originate from outside of Texas. Adjusted for inflation, this spending equals \$114.85 ( $\$100.44 * 271 / 237$ ) in 2021 prices based on the annual average CPI values presented in Table 2.1. Based on the above annual visitation, the project area accommodated 60,431 out-of-state visitors in 2021; adjusting this value for the effects of beach narrowing and annual population growth yields the visitation for any given year. Multiplying the annual out-of-state visitation estimates by the spending per person times the 1.4 multiplier effect produces the annual spending values. The sum of these annual values, adjusted for inflation and discounting, provides the total benefit over the period of analysis. Table 3.4 summarizes the out-of-state visitor spending benefit (\$4,935,004; present value, beginning of 2021).



Table 3.2 Annual Visitation with CEPRA Project #1653

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	281,073	180	260%	0.0%	281,073
2022	285,289	50	0%	0.0%	285,289

Notes: Estimated at mid-year  
 Background erosion = -5 ft/yr; 120-ft beach width reduction from 2021-2022 resulted from typical fill equilibration and erosion from Tropical Storm Nicholas  
 Starting daily peak visitation = 1,646 in 2015 values  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr  
 Beach width change reflects the increase or decrease relative to the 2015 beach width (i.e., conditions represented by the 2015 Taylor Engineering beach user survey data)

Table 3.3 Annual Visitation without CEPRA Project #1653

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	281,073	40	-20%	-20.2%	224,409
2022	285,289	35	-30%	-30.2%	199,018

Notes: Estimated at mid-year  
 Background erosion = -5 ft/yr  
 Starting daily peak visitation = 1,646 in 2015 values  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr  
 Beach width change reflects the increase or decrease relative to the 2015 beach width (i.e., conditions represented by the 2015 Taylor Engineering beach user survey data)

Table 3.4 Out-Of-State Visitor Spending Benefit – CEPRA Project #1653

Year	Out-of-State				Difference (Benefit)	With Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	Visitation		Visitor Spending (2021 prices)					
	With Project	Without Project	With Project	Without Project				
2021	60,431	48,248	9,716,70	7,757,796	\$1,958,90	\$1,958,905	\$1,913,975	\$1,913,975
2022	61,337	42,789	9,862,37	6,880,043	\$2,982,33	\$3,238,814	\$3,021,029	\$4,935,004

Notes: Out-of-state visitation = 21.5% of total visitation estimates derived from tables 3.2 and 3.3  
 Out-of-state spending = \$114.85 per person (2021 prices)  
 Inflation rate = 8.6% (2022)  
 Discount rate = 4.75% (mid-year discounting)  
 Multiplier effect = 1.4  
 Value in bold italics represents the benefit to the State of Texas

### 3.1.3.2 Recreation Benefit

The substantially wider beach created by the project clearly enhances the user experience. As such, this study quantified the economic benefits from the improved recreation value for all visitors. Calculating recreation enjoyment benefits involved applying the visitation numbers derived in Tables 3.2 and 3.3 to the UDV developed (see section 2.2) for with- and without-project conditions. The UDV points assigned to the site with and without the project provides an estimate of its economic benefits. Table 3.5 shows a summary of the points assigned for with- and without-project conditions in the project area. The greater with-project values derive from the substantially wider beach that enhances the user experience under three of the criteria. Converting the points (58 and 42) to dollars requires interpolating values from Figure 2.3. The resulting with- and without-project UDVs equal \$10.24 and \$8.67 (2022 dollars) per person per visit. Taking the difference between the estimated recreation value for all visitors with- and without-project yields the benefit for the year. For the first year of analysis (2021), the recreation value (2022 price levels) with the project equals \$2,878,188 (281,073 \* \$10.24) and without the project equals \$1,945,626 (224,049 \* \$8.67). Adjusting the difference (\$932,561) for 8.6% inflation from 2021 to 2022 yields the recreational benefit for 2021 (\$858,712, assumed mid-year). Table 3.6 shows the total recreation value benefit for this project compounding benefits for the life of the project (two years). In total, applying a discount rate of 4.75% and mid-year discounting, the benefit equals \$1,954,477 (present value, beginning of 2021).

Table 3.5 UDV Points Assigned — CEPRA Project #1653

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	12	5	14
Accessibility	15	15	18
Environmental	16	10	20
Total	58	42	100

Table 3.6 Recreational Enjoyment Benefit for All Users — CEPRA Project #1653

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	Benefit with Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	With Project	Without Project	With Project	Without Project				
2021	281,073	224,409	\$2,878,188	\$1,945,626	\$932,561	\$858,712	\$839,017	\$839,017
2022	285,289	199,018	\$2,921,359	\$1,725,486	\$1,195,873	\$1,195,873	\$1,115,460	<b><i>\$1,954,477</i></b>

Notes: UDV (with project) = \$10.24 (2022 price levels)  
 UDV (without project) = \$8.67 (2022 price levels)  
 Inflation rate = 8.6% (2022)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas



### 3.1.4 Benefit-Cost Summary

Table 3.7 summarizes the benefit and cost information for Project #1653. The B/C ratio equals 4.5 with a total estimated benefit of \$6,889,481 and Texas only cost of \$1,530,000. Cost-sharing with project #1702 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 3.7 Benefit-Cost Summary — #1653: South Padre Island Beach Nourishment Project

Item	Discounted Present Worth (beginning of 2021) <sup>2</sup>
Total Benefit	\$6,889,481
Visitation (Out-of-State Visitor Spending)	\$4,935,004
Visitation (Recreation)	\$1,954,477
Total Cost <sup>1</sup>	\$1,530,000
B/C Ratio	4.5

<sup>1</sup>Texas costs only, assumed to have incurred at the beginning of the first year of project construction (i.e., not discounted)

<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2021 with a 4.75% discount rate with mid-year discounting

## 3.2 Nueces County — #1665: Corpus North Beach Harvey Repair (Cycle 10)

### 3.2.1 Project Description and Background Information

North Beach, which lies inside Corpus Christi Bay just north of downtown Corpus Christi, consists of an approximately 1.5-mile-long beach extending from the Corpus Christi Channel to Rincon Point. In addition to the bayfront beaches, the Texas State Aquarium and the USS Lexington, an aircraft carrier turned museum, are two major tourist attractions in the area. In August 2017, Hurricane Harvey made landfall as a major Category 4 hurricane approximately 30 miles northeast of Corpus Christi. The hurricane caused extensive damage to structures as well as the beach, including the 2016 Beach Monitoring and Maintenance Plan (BMMP) renourishment project. That project included back-passing approximately 80,000 cy of sand from the north end of North Beach and placing it over 3,200 ft of shoreline starting near the USS Lexington and proceeding north (see Trudnak et al., 2017).

Figure 3.10 locates the current project, which includes placing approximately 8,300 cy of beach-compatible sand along a 600-ft-long shoreline segment from near Bridgeport Avenue (station 2+00) to near the Double Tree hotel (station 8+00) (Figure 3.10) including two, 200-ft-long tapers. Figure 3.11 shows a cross section through the main portion of the fill. Structures in this project area include a sidewalk/Beachwalk, a parking lot, a segment of North Shoreline Boulevard, and commercial enterprises further inland. As shown below, storm erosion does not encroach on the commercial buildings. Therefore, analyses exclude them from the structural inventory.

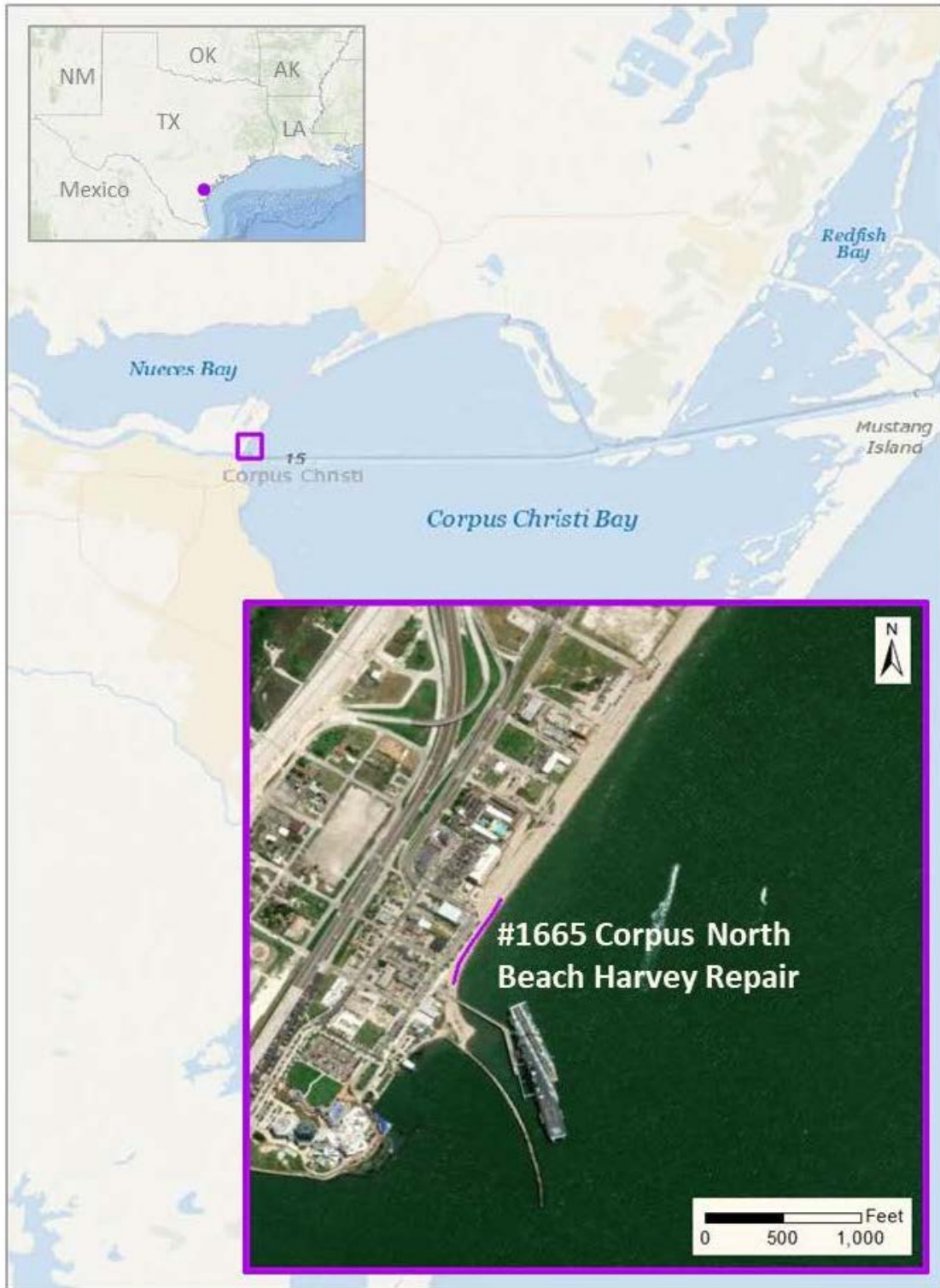


Figure 3.9 Location Map — Project #1665: Corpus North Beach Harvey Repair



Figure 3.10 Corpus North Beach Harvey Repair Plan View (Modified from HDR Construction Drawings)

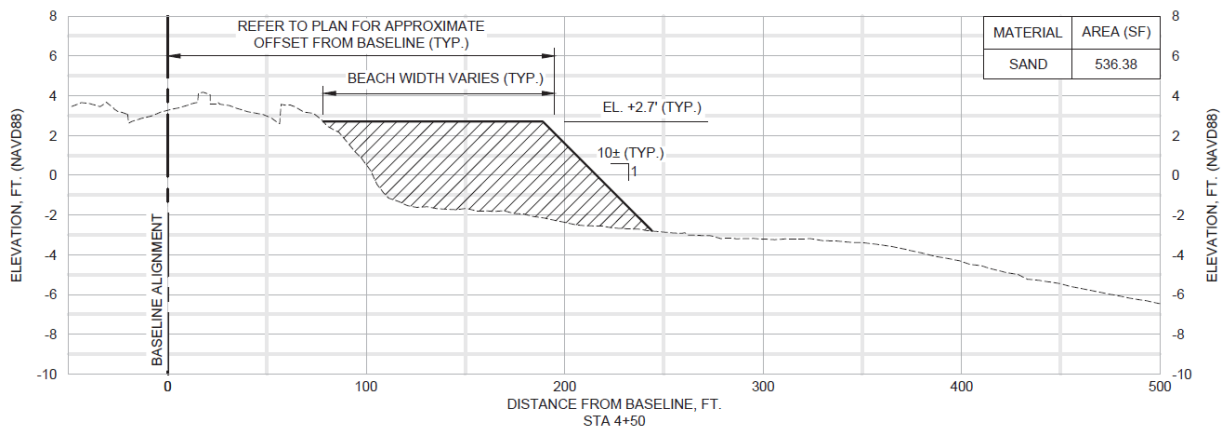


Figure 3.11 Typical Beach Fill Cross Section (Modified from HDR Construction Drawings)

Overall, the sidewalk, parking lot, and roadway segment have a total replacement cost of approximately \$229,000 (2022 prices) for a 600-ft-long segment of sidewalk, a 19-car parking lot, and 350 ft of roadway (Table 3.8). The sidewalk, parking lot, and roadway replacement costs originate from unit costs of \$64.85 per linear foot, \$3,406.52 per car, and \$358.35 per linear foot derived from RSMean construction cost data and escalation indices for items 08 Roads, Railroads & Bridges found in USACE (2022a). Notably, the values applied to represent losses of these features usually correspond to the

replacement costs less depreciation because the damaged elements do not represent new features. Given the present storm damage reduction analysis does not attempt to adjust the replacement costs, application of these replacement costs may lead to a slight overstatement of damages.

Table 3.8 Structure Inventory for Corpus North Beach Harvey Repair

Structure	Replacement Cost (2022 Prices)
Sidewalk/Beachwalk	\$38,911
Parking Lot	\$64,724
Road	\$125,424
Total	\$229,059

Notes: Sidewalk replacement cost = \$64.85/ft \* 600 ft  
 Parking lot replacement cost = \$3,406.52/car \* 19 cars  
 Road replacement cost = \$358.35/ft \* 350 ft

Project construction occurred in late October/early November 2022. Figure 3.12 presents a pre-construction photograph. Figure 3.13 shows post-construction conditions.



Figure 3.12 North Beach Pre-Construction Conditions (Looking North) (August 2022; provided by GLO)



Figure 3.13 North Beach Post-Construction Conditions (Looking North) (December 2022; provided by GLO)

### 3.2.2 Project Funding

Table 3.9 shows that the Federal Emergency Management Agency (FEMA) financially supported most of the project. Recall, costs (funding) originating from national agencies decrease by 90% to account for other states, in this case, incurring those costs. Federal money funds FEMA. States contribute to the federal government through individual and corporate taxes. Like recent GLO CEPRA economic-benefit studies, this study assumes Texas contributes financially to the federal government (and, as such FEMA) in proportion to its share of the national population. Therefore, Texas' total cost is only \$141,207.81 (10%) of the total project cost of \$743,199.00.

Table 3.9 Funding for Project #1665: Corpus Christi North Beach Harvey Repair

Funding Source		Amount
State/Local	GLO, Senate Bill 500 (10% of Project Total)	\$74,319.90
Federal	FEMA (90% of Project Total) Texas (10% of FEMA Funding)	\$668,879.10 <i>(\$66,887.91)</i>
Total Cost <b><i>(Texas Only)</i></b>		\$743,199.00 <b><i>(\$141,207.81)</i></b>

Notes: Value in bold italics represents the cost to the State of Texas  
Values represent present worth, beginning of 2023

### 3.2.3 Benefit Analysis

The economic benefits of this project derive from federal spending, reducing storm damages, and two beach visitation benefit categories — out-of-state visitor spending and recreational enjoyment by all visitors. Estimating these benefits followed similar methodologies as originally applied by Stites et al. (2008) and subsequent GLO CEPRA economic-benefit studies.

This study calculated benefits over a two-year period given the small alongshore placement area and relatively large background erosion rate. The next several paragraphs detail the basis for this period of analysis.

Following a theory based on Pelnard-Consideré (1956), as cited in e.g., Dean and Dalrymple (2002), a beach fill represents a perturbation or a planform anomaly to the local uninterrupted shoreline, which over time, longshore sediment transport smooths. The present project acts as such an anomaly. A linearized approximation of the Pelnard-Consideré “diffusion” equation that describes this process corresponds to

$$\frac{\partial y}{\partial t} = G \frac{\partial^2 y}{\partial x^2} \quad (3.1)$$

where  $y$  is the cross-shore position of the shoreline at time  $t$ , and  $x$  is the alongshore distance. This equation (a form of the well-known heat conduction equation) contains several possible analytical solutions; the boundary conditions (at the lateral ends) specify the solution. The longshore diffusivity parameter ( $G$ ) governs the rate of evolution of the project. In this linearized treatment,

$$G = K \frac{H_0^{2.4} C_{G0}^{1.2} g^{0.4}}{8(s-1)(1-p)C_* \kappa^{0.4} (h_* + B)} \left[ \frac{\cos^{1.2}(\beta_0 - \alpha_0) \cos 2(\beta_0 - \alpha_*)}{\cos(\beta_0 - \alpha_*)} \right] \quad (3.2)$$

where  $K$  is an empirical nondimensional constant,  $H$  is the wave height,  $C_G$  is the wave group velocity,  $g$  is the acceleration due to gravity,  $s$  is the specific gravity of sand (2.65),  $p$  is the sediment porosity (0.35),  $C$  is the wave velocity,  $\kappa$  is the ratio of the breaking wave height to the breaking water depth (0.78),  $h_*$  is the water depth of limiting sediment motion (depth of closure),  $B$  is the height of the berm above the water level,  $\beta$  is the shoreline azimuth, and  $\alpha$  is the direction of the waves. The subscripts  $0$  and  $*$  denote conditions in deep water and at the depth of limiting motion.



Calculating  $G$  requires making several intermediate calculations and assumptions. Trudnak et al. (2017) reports a median sediment size of 0.3 mm characterizes the beaches in the area. Given this size, Dean (2002) suggests a  $K$  value of 0.66. The Hallermeier (1978, 1981) method, as found in the U.S. Army Corps of Engineers' *Coastal Engineering Manual (CEM)* (2006b), allows estimation of the depth of closure ( $h_*$ ) offshore the project area. Hallermeier defined conditions for sediment motion for relatively rare conditions — effective wave height ( $H_e$ ) and period ( $T_e$ ) conditions exceeded only 12 hours per year (or 0.14% of the time).

$$h_* = 2.28H_e - 68.5 \left( \frac{H_e^2}{gT_e^2} \right) \quad (3.3)$$

Analysis of hourly wind data from 2020 and 2021 from the Corpus Christi International Airport (<https://mesonet.agron.iastate.edu/>) allows determination of the effective wave height and period at the site via the Sverdrup-Munk-Bretschneider (SMB) method (e.g., see USACE [2006a]). Applying the SMB method with the hourly wind data from the airport, the fetches from the east to south-southeast, and average water depth of 15 ft, yields effective wave heights and periods near 4 ft and 5 seconds (sec). In turn, these effective conditions result in depths of closure of 7.1 and 7.6 ft. Application of linear wave theory (e.g., see Dean and Dalrymple [1991]) with an effective wave height of 4 ft, and an effective wave period of 4.8 sec yields a wave group velocity of 5.1 feet per second (ft/s) and wave celerity of 10.3 ft/s. Finally, with  $B$  equal to 2.7 ft (based on the project design drawings), assumed shore-normal waves with an average wave height and period of 0.5 ft and 2 sec, and the parameters described above, Equation 2 results in a  $G$  value of 0.008 feet squared per second (ft<sup>2</sup>/s).

Given an initial shoreline like a rectangular planform, engineers may describe the evolution of the shoreline by

$$y(x, t) = \frac{Y}{2} \left\{ \operatorname{erf} \left[ \frac{\gamma}{4} \left( \frac{2x}{L} + 1 \right) \right] - \operatorname{erf} \left[ \frac{\gamma}{4} \left( \frac{2x}{L} - 1 \right) \right] \right\} \quad (3.4)$$

where  $Y$  is the initial width of the planform beach fill,  $L$  is the project length,  $\operatorname{erf} [ ]$  is the error function defined as

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-u^2} du \quad (3.5)$$

and

$$\gamma = \frac{L}{\sqrt{Gt}} \quad (3.6)$$

governs the shoreline evolution rate. The fraction of the placed sand remaining within the placement area at time  $t$  is

$$M(t) = \frac{1}{Y_L} \int_{\frac{-L}{2}}^{\frac{L}{2}} y(x, t) dx = \frac{2}{Y\sqrt{\pi}} \left( e^{-\left(\frac{Y}{2}\right)^2} - 1 \right) + \operatorname{erf} \left( \frac{Y}{2} \right) \quad (3.7)$$

This smoothing or diffusion of the beach fill by longshore sediment transport acts in conjunction with any background erosion present without the beach fill. Therefore, one modifies the above equation by subtracting the proportion of the sand lost based on the background erosion alone.

Given a background erosion rate of -7 feet per year (Trudnak et al., 2017), a 600-ft-long beach fill, a beach fill volume of 8,300 cy, the calculated longshore diffusivity factor (0.008), depth of closure (7.6 ft), and berm height (2.7 ft), the theory predicts the fill will last approximately two years (Figure 3.14). For convenience, this analysis assumed that the beach fill loses 75% its cross-shore width after one year and the remaining 25% after two years. The analysis assumed the first year of the project occurs at the beginning of 2023.

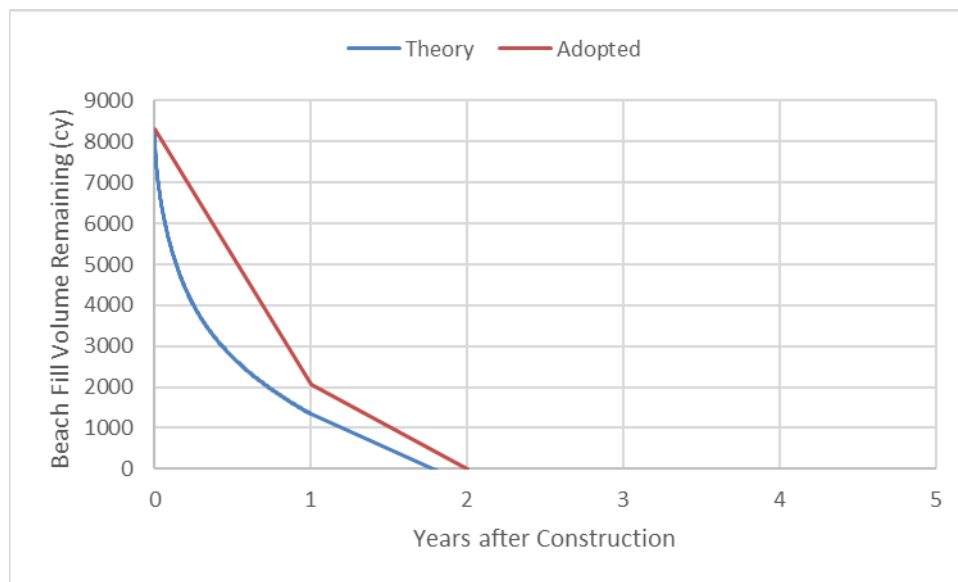


Figure 3.14 Theoretical and Adopted Beach Fill Volume Remaining over Time

### 3.2.3.1 Federal Spending Benefit

Notably, a benefit exists that accounts for federal spending (which represents a net increase inflow of spending to Texas’ economy) that occurs as part of the initial construction of the project. The benefit equates to \$842,788 (0.9 x \$668,879.10 x 1.4 = \$842,788), including the multiplier effect.

### 3.2.3.2 Storm Damage Reduction Benefit

Assessing these benefits necessitated applying SBEACH to with- and without-project conditions. Inputs to the model include a pre-storm profile (with- or without-project), storm information for the duration of a storm event, and sediment transport parameters. The pre-storm beach profile input requires a pre-storm beach profile and sediment grain size. The storm information includes wave height and period and water level (storm surge) hydrographs for the duration of the storm event. Simulations did not apply the optional model input of wave direction and wind direction and speed. Sediment transport



parameters included those shown in Table 3.10. Figure 3.15 presents the first year with- and without-project conditions' profiles that serve as input into SBEACH.

Table 3.10 SBEACH Model Parameters

Parameter	Value
Transport Rate Coefficient (K)	2.00 x 10 <sup>-6</sup> m <sup>4</sup> /N
Eps Parameter (ε)	0.002 m <sup>2</sup> /s
Transport Rate Decay Factor (λ)	0.5 m <sup>-1</sup>
Avalanching Angle (φ)	30°
Landward surf zone depth	1.5 ft
Median grain size	0.3 mm
Overwash Transport Parameter*	0.005
Water Temperature*	20°C
Cross-shore Spacing**	1 ft

Notes: \*Unreported in Trudnak et al. Represents default value.  
 \*\*Unreported in Trudnak et al. Represents value applied in present application.

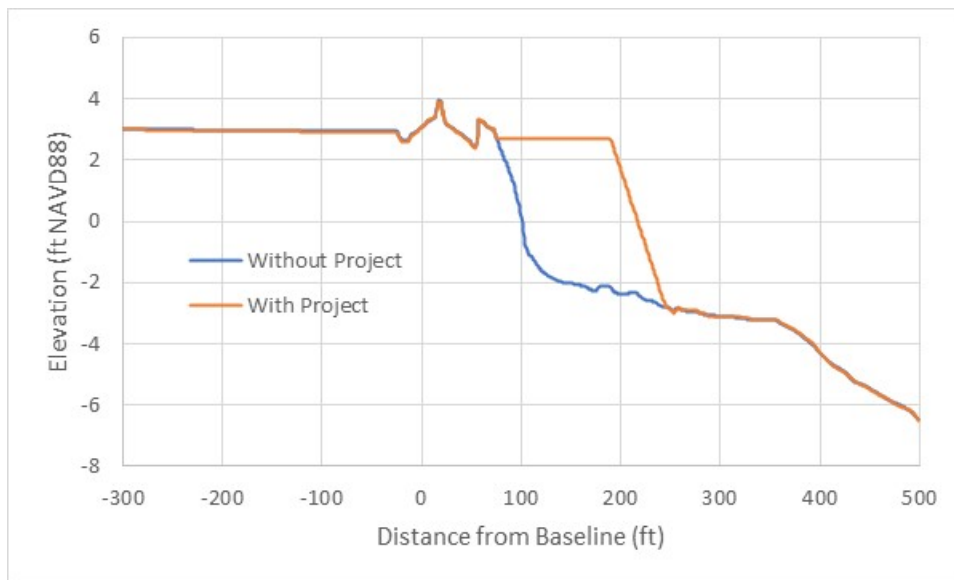


Figure 3.15 Corpus North Beach With- (Post-Construction) and Without- (Pre-Construction) Profiles (Year 1)

This study generated a range of synthetic storms to assess the pre- and post-construction beach profiles. The storms included 1-, 2-, 5-, 10-, 20-, 50-, and 100-yr storms characterized by wave height, wave period, and water level hydrographs. The present analysis applied similar synthetic storms as utilized for assessing #1569 Corpus Christi North Beach BMMP Maintenance Renourishment from CEPRA Cycle 7 (Trudnak et al., 2017). The hydrographs include three normal tide, wave height, and wave period cycles followed by a 36-hour period of storm conditions. The normal conditions follow cosine squared distributions whereas storm conditions followed sine squared distributions. The following figures reproduce the inputted hydrographs.

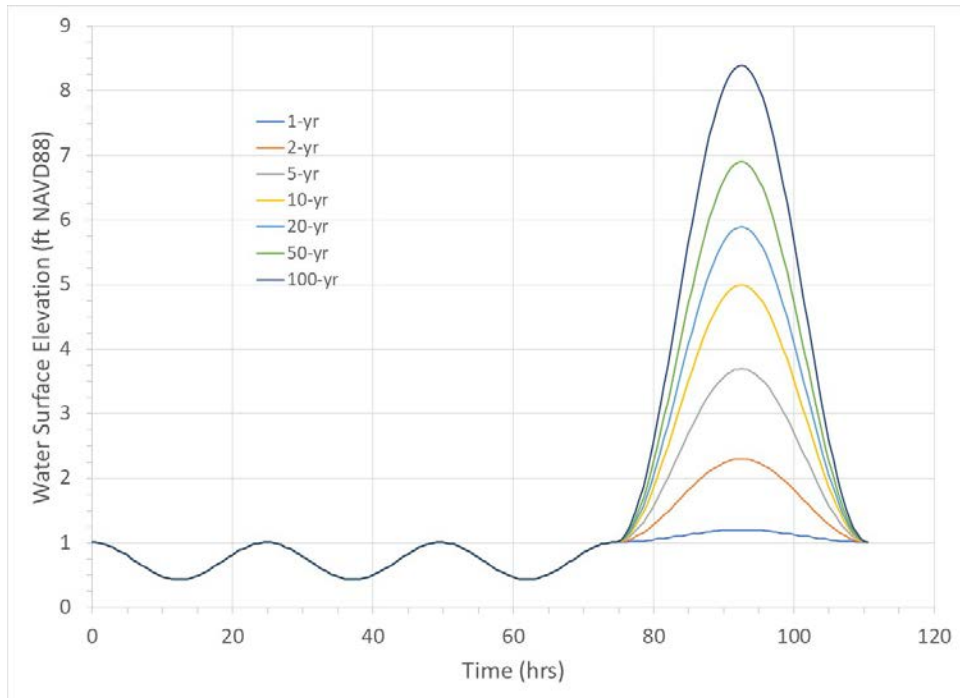


Figure 3.16 Corpus North Beach Synthetic, Time-varying Water Surface Elevations

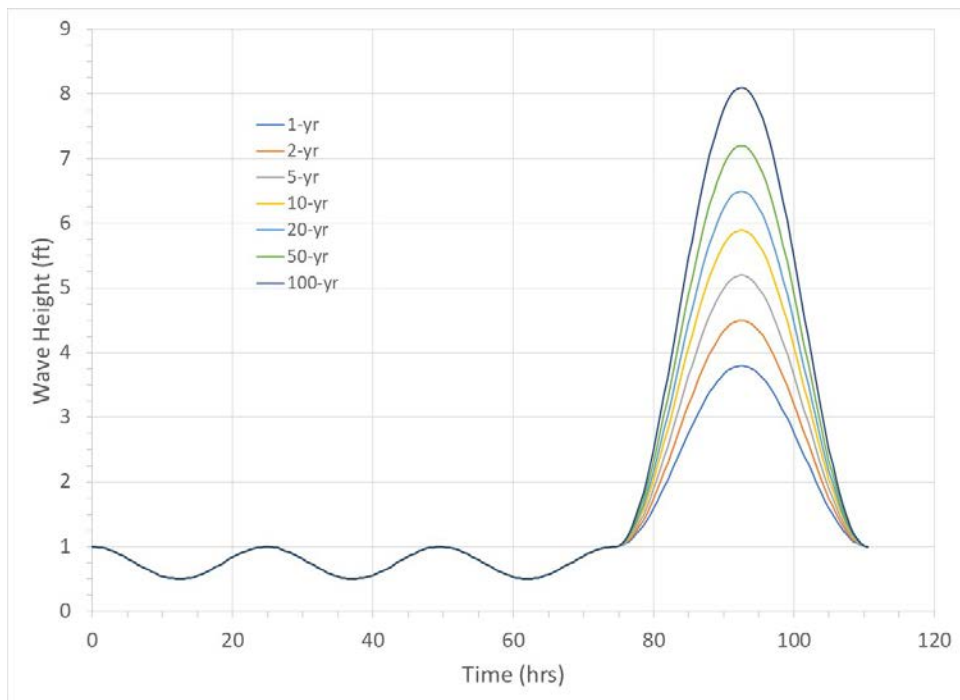


Figure 3.17 Corpus North Beach Synthetic, Time-varying Wave Heights

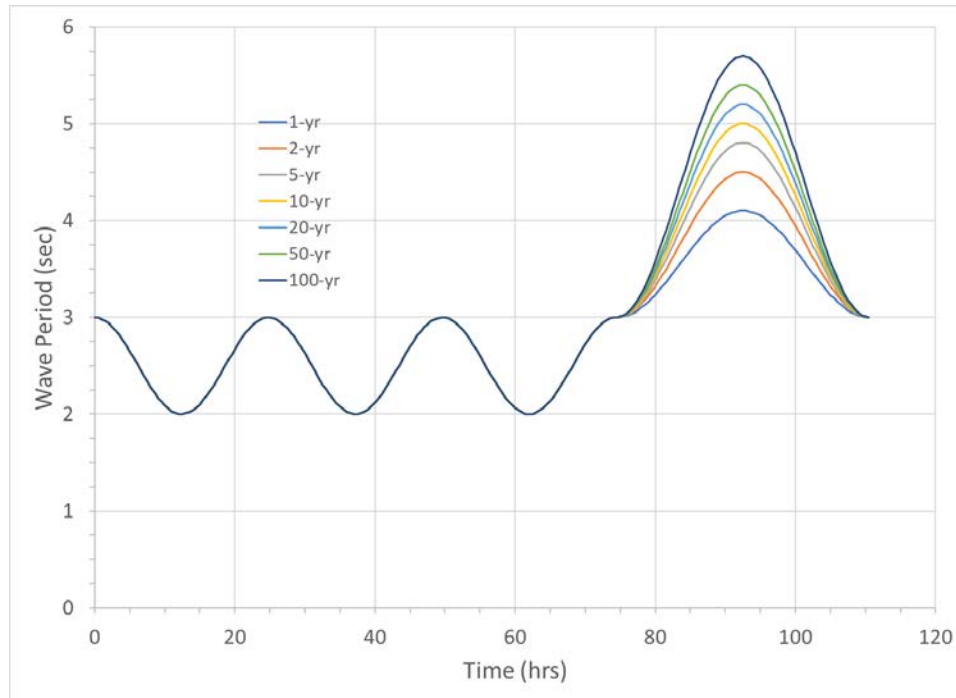


Figure 3.18 Corpus North Beach Synthetic, Time-varying Wave Periods

SBEACH modeling produced post-storm profiles for 1-, 2-, 5-, 10-, 20-, 50-, and 100-yr storms for with- and without-project profiles for the years 2023 and 2024. Figure 3.19 presents typical post-storm profiles for the with- and without-project profiles for the five-year storm at Year 1. Comparing the initial (Figure 3.15) and post-storm (Figure 3.19) profiles, note that the five-year storm undermines the sidewalk, parking lot, and road. Other less frequent storms cause similar levels of erosion (and undermining of the project features).

The methodology outlined in Section 2.2 of this report combined with the site-specific storm response information determines the damage-cumulative probability distribution for the years 2023 and 2024 with and without the project. Notably, this analysis treats the sidewalk, parking lot, and road like slab-on-grade structures such that damage occurs when the shoreline recedes landward of the seaward edge of the element and total damage occurs when the shoreline recedes halfway through the structure. The following table presents the distribution for 2023 without-project conditions. Table 3.11 shows the expected annual total damage for this condition equals approximately \$103,000. A similar procedure results in the values for the 2023 with-project (Table 3.12) and 2024 without- (Table 3.13) and with-project (Table 3.14) conditions. Table 3.15 summarizes the recorded and expected storm damage reduction benefits of the beach fill. The total storm damage reduction benefit over the two-year period equals approximately \$85,000.

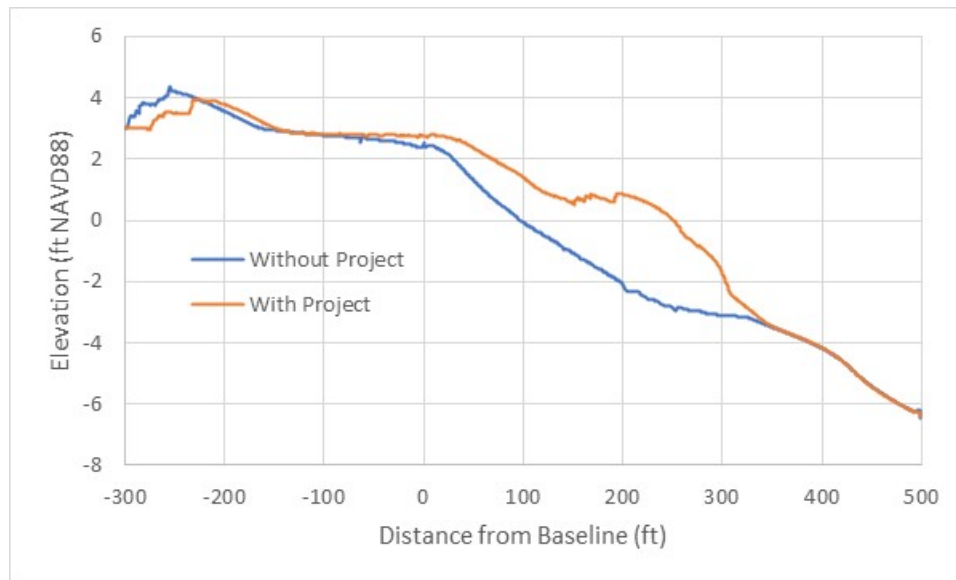


Figure 3.19 Corpus North Beach With- and Without-Project Five-Year Storm Post-Storm Profile (Year 1)

Table 3.11 Corpus North Beach Total Damage-Cumulative Probability (2023, without Project)

Tr (years)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	\$0.00	\$0	\$0	---	---	---
2	0.5	0.5	\$0.00	\$55,944	\$55,944	\$27,972	0.5	\$13,986
5	0.2	0.8	\$0.00	\$229,059	\$229,059	\$142,502	0.3	\$42,750
10	0.1	0.9	\$0.00	\$229,059	\$229,059	\$229,059	0.1	\$22,906
20	0.05	0.95	\$0.00	\$229,059	\$229,059	\$229,059	0.05	\$11,453
50	0.02	0.98	\$0.00	\$229,059	\$229,059	\$229,059	0.03	\$6,872
100	0.01	0.99	\$0.00	\$229,059	\$229,059	\$229,059	0.01	\$2,291
>100	<0.01	>0.99	\$0.00	\$229,059	\$229,059	\$229,059	0.01	\$2,291
Expected Average Annual Damage								<b>\$102,548</b>

Table 3.12 Corpus North Beach Total Damage-Cumulative Probability (2023, with Project)

Tr (years)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	\$0	\$0	\$0	---	---	---
2	0.5	0.5	\$0	\$0	\$0	\$0	0.5	\$0
5	0.2	0.8	\$0	\$177,749	\$177,749	\$88,875	0.3	\$26,662
10	0.1	0.9	\$0	\$183,450	\$183,450	\$180,600	0.1	\$18,060
20	0.05	0.95	\$0	\$183,450	\$183,450	\$183,450	0.05	\$9,173
50	0.02	0.98	\$0	\$183,450	\$183,450	\$183,450	0.03	\$5,504
100	0.01	0.99	\$0	\$183,450	\$183,450	\$183,450	0.01	\$1,835
>100	<0.01	>0.99	\$0	\$183,450	\$183,450	\$183,450	0.01	\$1,835
Expected Average Annual Damage								<b>\$63,067</b>



Table 3.13 Corpus North Beach Total Damage-Cumulative Probability (2024, without Project)

Tr (years)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	\$0	\$0	\$0	---	---	---
2	0.5	0.5	\$0	\$93,416	\$93,416	\$46,708	0.5	\$23,354
5	0.2	0.8	\$0	\$229,059	\$229,059	\$161,237	0.3	\$48,371
10	0.1	0.9	\$0	\$229,059	\$229,059	\$229,059	0.1	\$22,906
20	0.05	0.95	\$0	\$229,059	\$229,059	\$229,059	0.05	\$11,453
50	0.02	0.98	\$0	\$229,059	\$229,059	\$229,059	0.03	\$6,872
100	0.01	0.99	\$0	\$229,059	\$229,059	\$229,059	0.01	\$2,291
>100	<0.01	>0.99	\$0	\$229,059	\$229,059	\$229,059	0.01	\$2,291
Expected Average Annual Damage								<b>\$117,537</b>

Table 3.14 Corpus North Beach Total Damage-Cumulative Probability (2024, with Project)

Tr (years)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	\$0	\$0	\$0	---	---	---
2	0.5	0.5	\$0	\$0	\$0	\$0	0.5	\$0
5	0.2	0.8	\$0	\$200,554	\$200,554	\$100,277	0.3	\$30,083
10	0.1	0.9	\$0	\$200,554	\$200,554	\$200,554	0.1	\$20,055
20	0.05	0.95	\$0	\$206,255	\$206,255	\$203,404	0.05	\$10,170
50	0.02	0.98	\$0	\$206,255	\$206,255	\$206,255	0.03	\$6,188
100	0.01	0.99	\$0	\$217,657	\$217,657	\$211,956	0.01	\$2,120
>100	<0.01	>0.99	\$0	\$217,657	\$217,657	\$217,657	0.01	\$2,177
Expected Average Annual Damage								<b>\$70,792</b>

Table 3.15 Storm Damage Reduction Benefit – CEPRA Project #1665

Year	Without Project (2022 Prices)	With Project (2022 Prices)	Difference (Benefit)	With Inflation	Discounted Present Worth, Beginning of 2023	Cumulative Discounted Present Worth, Beginning of 2023
2023	\$102,548	\$63,067	\$39,481	\$40,349	\$39,424	\$39,424
2024	\$117,537	\$70,792	\$46,745	\$48,824	\$45,541	<b>\$84,965</b>

Notes: Inflation rate = 2.2% (2023 and beyond)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas

### 3.2.3.3 Out-of-State Visitor Spending Benefit

In addition to the storm damage reduction benefits described above, the project also provides beach visitation benefits. The with- and without-project visitation estimates serve as input for estimating the benefits from out-of-state visitor spending and the value of recreation benefits for all visitors.

Determining visitation estimates in the project area from other studies, such as Taylor Engineering (2015), are not applicable given the location of North Beach relative to the Gulf of Mexico and Corpus Christi's relatively dense population. Additionally, no known reliable aerial imagery exists to assist with beach visitor counts. Therefore, this study utilizes annual visitation to other attractions as a proxy for beach visitation.

Based on 2019, pre-pandemic Corpus Christi visitor data, Lee (2020) reports that nature-related visitor trips, the most popular tourist activity in the area in 2019, increased from 20% in 2008 to 50% in 2019. Lee further indicates that 10.5 million people visited the Corpus Christi area with 9% of these visitors originating from out of state and 46% of the visitors representing day trippers. Two of the area's top attractions — the Texas State Aquarium and the USS Lexington museum — boast annual attendances of approximately 600,000 (2019 annual report found at <https://www.texasstateaquarium.org/visit/about/>) and 267,000 visitors (based on overall attendance of approximately eight million visitors since 1992 [8,000,000 visitors / 30 years; <https://usslexington.com/about-the-uss-lexington/the-museum/>]). As per the aquarium's website, most visitors spend approximately two to three hours at the aquarium. Anecdotally, post-pandemic tourism continues to rebound to pre-pandemic levels such that utilizing pre-pandemic visitation likely represents conditions expected in the future.

Given the above visitation data above, one may infer that the day trippers likely visit other area attractions during their one-day stays. Given the assumption that half of the aquarium visitors also visit North Beach beaches, one calculates that 300,000 ( $600,000 * 50\%$ ) people annually visit those beaches. This value is like the annual attendance figure for the museum, which Trudnak et al. (2017) applied to estimate beach visitation. Given the project area equates to approximately 1/12th of North Beach (600 ft / 7,100 ft), this analysis assumes the 2023 unconstrained annual visitation of 25,000 people to the project area ( $300,000 / 12$ ). With an assumed population growth rate of 0.5%, the 2024 unconstrained visitation equals 25,125 annual visitors. Application of a smaller annual growth rate than the weighted population growth rate of 1.5% accounts for the heavily developed and highly urbanized Corpus Christi metro area.

Note that Oden and Butler (2006) and Taylor Engineering (2015) developed beach visitation "elasticity" relationships with beach width based on Galveston, Surfside, and South Padre Island beach user survey results. The two elasticity relationships, which measure the percentage change in annual beach visitation given a percentage change in beach width, show some maximum visitation reductions with no beach present — 22 to 57%. For the present location, these maximum reduction levels appear too low. Therefore, this study adopts an elasticity coefficient of -0.9 for the project area such that no beach present results in a 90% reduction in beach visitors. The lack of a beach constrains the without-project beach visitation (Table 3.16).



Table 3.16 Annual Visitation without CEPRA Project #1665

Year	Unconstrained Annual Visitation	Without Project Beach Width (ft)	Without Project % Reduction in Visitation	Without Project Constrained Annual Visitation
2023	25,000	0	-90.0%	2,500
2024	25,125	0	-90.0%	2,513

With the project, reductions in beach width as the beach erodes (per Pelnard-Considerere analysis) and carrying capacity of the beach constrain the beachgoer population, the latter based on the USACE’s criterion of 100 sf per person and a turnover rate of two. For example, the maximum daily visitation based on the USACE criterion at the beginning of 2023 equals 1,320 people (600 ft [beach length] \* 110 ft [average initial beach width] / 100 sf \* 2). Multiplying by 365 days yields an annual carrying capacity of 481,800 visitors, which is much larger than the unconstrained visitation of 25,000 visitors. Similar calculations yield annual beach carrying capacity at the beginning of 2024. Table 3.17 shows the adopted beach visitation values based on taking the lesser of the projected beachgoer population and carrying capacity.

Table 3.17 Annual Visitation with CEPRA Project #1665

Year	Unconstrained Annual Visitation	With Project Beach Width (ft)	With Project % Reduction in Beach Width	With Project % Reduction in Visitation	With Project Constrained Beach Visitation	With Project Area (sf)	Daily Maximum Visitation Based on USACE Criterion	Annual Maximum Visitation Based on USACE Criterion	Adopted With Project Constrained Beach Visitation
2023	25,000	110	0%	0%	25,000	66,000	1,320	481,800	25,000
2024	25,125	28	-75%	-68%	8,166	16,500	333	120,450	8,166

Lee reports that 9% of visitors originate from out of state. These out-of-state visitors spent, on average, \$116 per visitor per day (2019 dollars). Inflating this value to 2022 dollars yields \$133.56 per visitor per day (\$116 \* 1.012 [1.2% inflation rate for 2020] \* 1.047 [4.7% inflation rate for 2021] \* 1.086 [8.6% inflation rate for 2022]). Given that and the visitation numbers presented above, Table 3.18 summarizes the out-of-state visitor spending benefits. The total out-of-state visitor spending benefit over the two-year period equals approximately \$471,000.

Table 3.18 Out-of-State Visitor Spending Benefit – CEPRA Project #1665

Year	Out-of-State				Difference (Benefit)	With Inflation	Discounted Present Worth, Beginning of 2023	Cumulative Discounted Present Worth, Beginning of 2023
	Visitation		Visitor Spending (2022 prices)					
	With Project	Without Project	With Project	Without Project				
2023	2,250	225	\$420,703	\$42,070	\$378,633	\$386,693	\$378,087	\$378,087
2024	735	226	\$137,412	\$42,281	\$95,131	\$99,363	\$92,682	<b><i>\$470,769</i></b>

Notes: Out-of-state visitation = 9% of total visitation estimates derived from tables 3.16 and 3.17  
 Out-of-state spending = \$133.56 per person (2022 prices)  
 Inflation rate = 2.2% (2023 and beyond)  
 Discount rate = 4.75% (mid-year discounting)  
 Multiplier effect = 1.4  
 Value in bold italics represents the benefit to the State of Texas

### 3.2.3.4 Recreation Benefit

Application of the visitation numbers above and the UDV for with- and without-project conditions yields the recreational enjoyment benefit. Table 3.19 presents the points assigned for the various criteria for with- and without-project conditions in the project area. The number of recreational opportunities in the area, like the aquarium and museum, the proximity of the project area to other beaches, the accessibility to the project area, and relatively low aesthetics of the site support the point values assigned to the with- and without-project conditions. The point values assigned for the carrying capacity of the project area differ because the with-project condition affords the beachgoer a dry beach for active and passive recreation. With- and without-project UDVs of \$8.67 and \$7.43 per person per visit result after summing and converting the points to dollars based on Figure 2.3. Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for a year. Table 3.20

Recreational Enjoyment Benefit for All Users — CEPRA Project #1665

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	Benefit with Inflation	Discounted Present Worth, Beginning of 2023	Cumulative Discounted Present Worth, Beginning of 2023
	With Project	Without Project	With Project	Without Project				
2023	25,000	2,500	\$216,650	\$18,565	\$198,085	\$202,443	\$197,800	\$197,800
2024	8,166	2,513	\$70,763	\$18,658	\$52,105	\$54,423	\$50,764	<b><i>\$248,563</i></b>

Notes: UDV (with project) = \$8.67 (2022 prices)  
 UDV (without project) = \$7.43 (2022 prices)  
 Inflation rate = 2.2% (2024)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas



presents the recreation value benefit for the project over the two-year analysis period (approximately \$249,000).

Table 3.19 UDV Points Assigned – CEPRA Project #1665

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	17	17	30
Availability of Opportunity	3	3	18
Carrying Capacity	9	4	14
Accessibility	8	8	18
Environmental	5	2	20
Total	42	34	100

Table 3.20 Recreational Enjoyment Benefit for All Users — CEPRA Project #1665

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	Benefit with Inflation	Discounted Present Worth, Beginning of 2023	Cumulative Discounted Present Worth, Beginning of 2023
	With Project	Without Project	With Project	Without Project				
2023	25,000	2,500	\$216,650	\$18,565	\$198,085	\$202,443	\$197,800	\$197,800
2024	8,166	2,513	\$70,763	\$18,658	\$52,105	\$54,423	\$50,764	<b><i>\$248,563</i></b>

Notes: UDV (with project) = \$8.67 (2022 prices)  
 UDV (without project) = \$7.43 (2022 prices)  
 Inflation rate = 2.2% (2024)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas

### 3.2.4 Benefit-Cost Summary

Table 3.21 shows the benefits and costs as well as benefit-cost ratio for this project. Note that approximately one half of the benefits derive from federal spending.

Table 3.21 Benefit-Cost Summary – #1665: Corpus North Beach Harvey Repair

Item	Discounted Present Worth (beginning of 2023) <sup>2</sup>
Total Benefit	\$1,647,085
Federal Spending	\$842,788
Storm Damage Reduction	\$84,965
Visitation (Out-of-State Visitor Spending)	\$470,769
Visitation (Recreation)	\$248,563
Total Cost <sup>1</sup>	\$141,208

B/C Ratio	11.7
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<sup>1</sup>Texas costs only, assumed to have incurred at the beginning of the first year of project construction (i.e., not discounted)

<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2023 with a 4.75% discount rate

### 3.3 Galveston County – #1693: Babe’s Beach BUDM (2021 BUDM Cycle) (Cycle 11)

#### 3.3.1 Project Description and Background Information

Babe’s Beach, named after former Texas Rep. A.R. “Babe” Schwartz who championed the cause of open beaches in Texas and created in 2015, received the American Shore and Beach Preservation Association’s 2016 Best Restored Beach Award as one of the nation’s top five beach restoration projects. A collaborative effort sponsored by the GLO, Galveston Park Board, City of Galveston and USACE Galveston District, the initial project created a beach fronting the Galveston Seawall west of 61st St., an area depleted of sand for many decades with the seawall’s riprap scour protection lining the shoreline. The project intends to expand Galveston Island’s beach availability for recreational enjoyment, which supports the local tourism industry, and improve the region’s resiliency to storm-induced erosion. The project fronts highly developed uplands including the primary roadway along Galveston Island (FM 3005), hotels and condominiums, and many tourist amenities.

The initial project as well as periodic beach nourishments have occurred through BUDM from the USACE’s required maintenance dredging of the Galveston Entrance Channel. USACE funds the maintenance dredging cost, and the state and local sponsors fund the incremental cost of placing the dredged material on the beach rather than the offshore dredge material disposal area (ODMDS). Figure 3.20 shows the location of the project.

The original 2015 beach restoration project placed 629,188 cy of sand along approximately 4,900 ft of shoreline between 61st St. and 75th St. A second nourishment project in 2019 placed 490,315 cy along an estimated 5,700 ft of shoreline between 61st St. and 77th St. The most recent nourishment, Project #1693, placed 608,948 cy along 9,800 ft of shoreline from 61st St. to just west of 87th St.; dredging occurred from July 2021 to November 2021. The fill template consists of a 200-ft-wide berm (measured from the seawall) at elevation +5.0 ft NAVD88, a 100-ft wide 1V:50H berm slope from +5 ft to +3 ft NAVD88, and 1V:20H foreshore slope extending from +3 ft NAVD88 to the seabed; 500-ft-long tapers transition the full template to the existing shoreline at the east and west ends of the placement area. Figures 3.21 - 3.25 present pre- and post-construction photographs throughout the project area. Figure 3.26 plots representative pre- and post-construction beach profiles towards the center of the placement area. Figures 3.27 and 3.28 show the authorized fill plan view and cross section. Notably, neither the 2015, 2019, nor 2021 projects placed fill within the authorized fill template west of the 91st St. Pier shown in Figure 3.27.



Figure 3.20 Location Map – Project #1693 Babe's Beach BUDM (2021 Cycle)



Figure 3.21 Pre- and Post-construction (Top and Bottom) Photos at Project's East End



Figure 3.22 Pre- and Post-construction (Top and Bottom) Photos in Project's East-Central Area

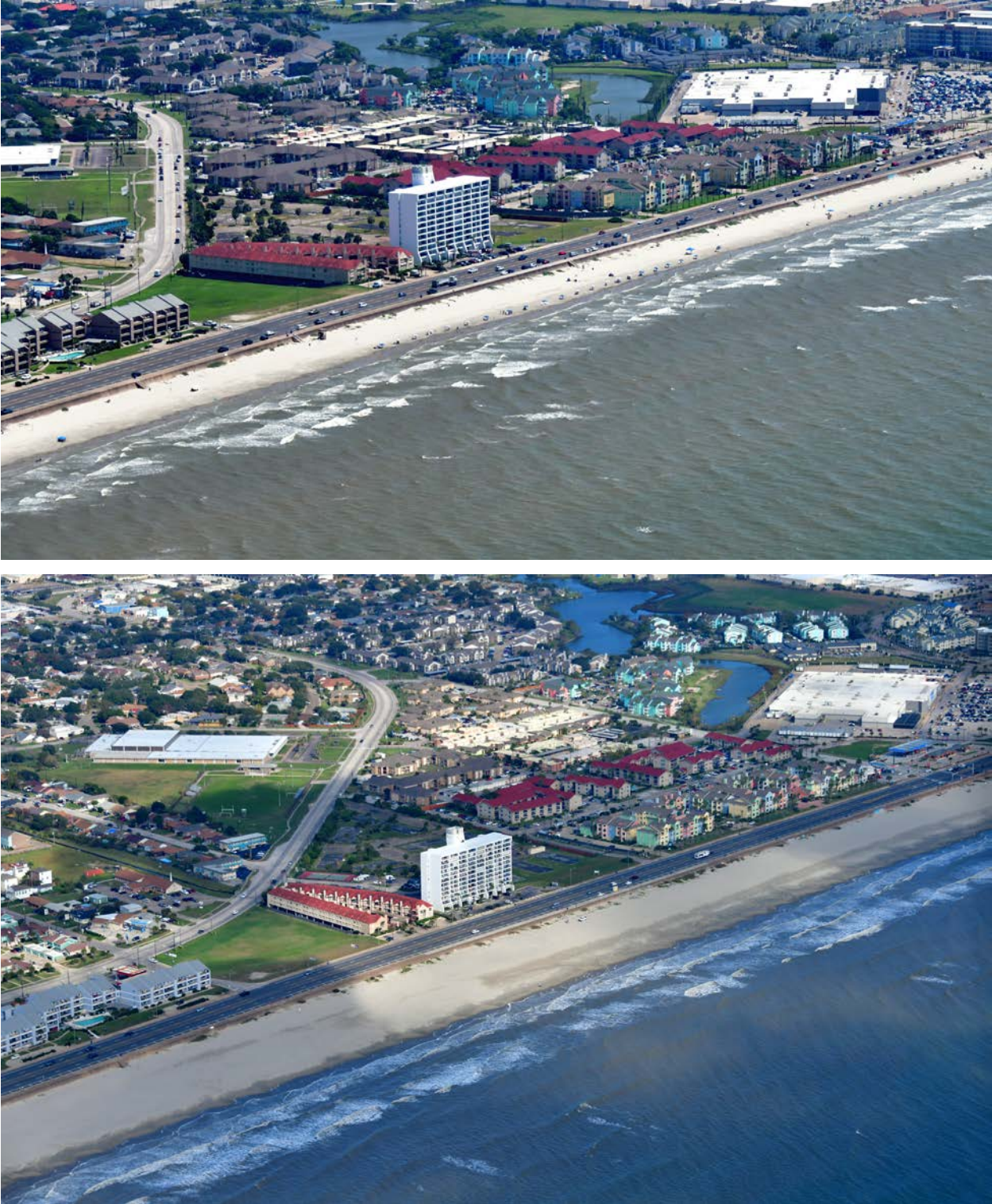


Figure 3.23 Pre- and Post-construction (Top and Bottom) Photos in Project’s Central Area

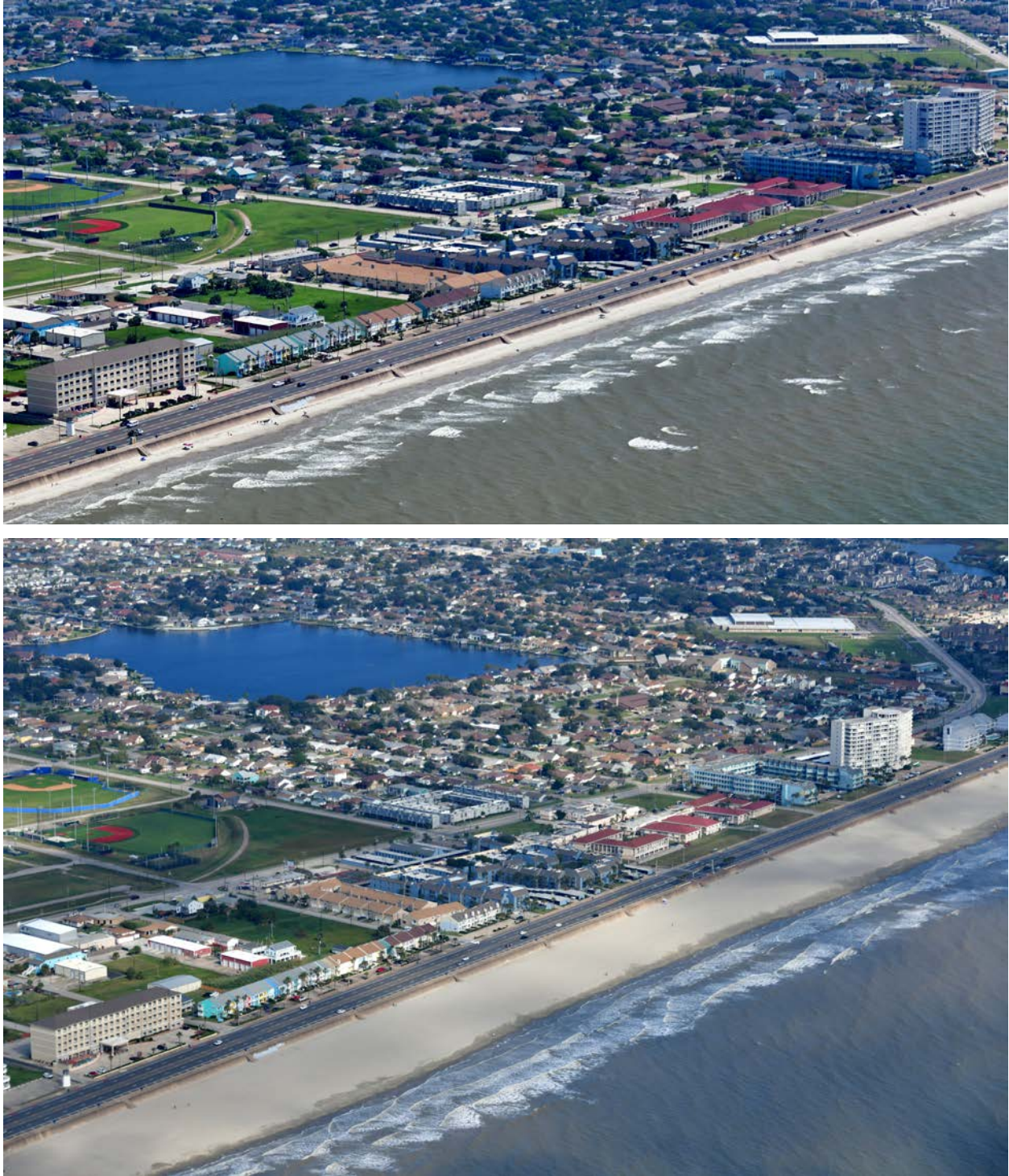


Figure 3.24 Pre- and Post-construction (Top and Bottom) Photos in Project's West-Central Area



Figure 3.25 Pre- and Post-construction (Top and Bottom) Photos at Project's West End

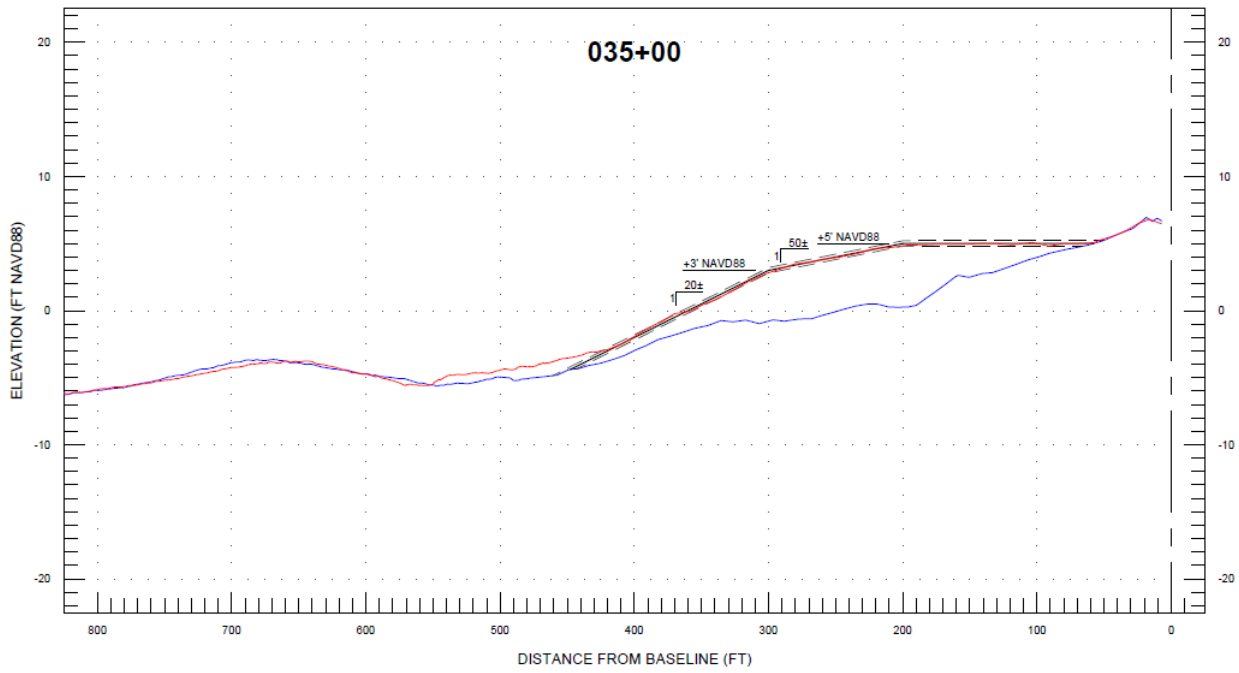


Figure 3.26 Typical Pre- and Post-Construction Profiles (GBA, 2021)



Figure 3.27 Authorized Fill Template Plan View (USACE, 2021)

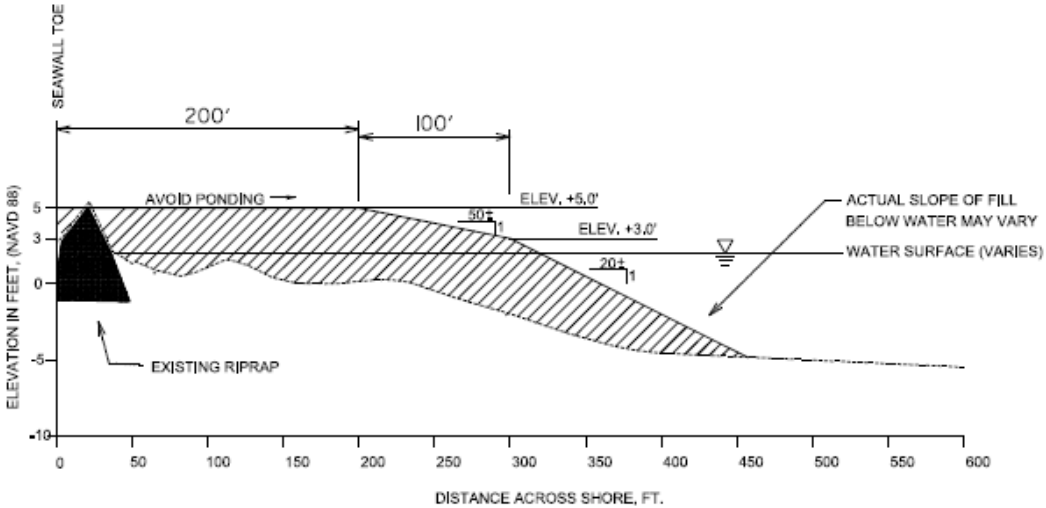


Figure 3.28 Authorized Fill Template Cross Section (USACE, 2021)

**3.3.2 Project Funding**

The USACE contributed \$14,000,000 to cover the baseline cost of maintenance dredging the Galveston Entrance Channel and placing the material in the permitted ODMDS. The state/local funding partners contributed \$12,000,000 to cover the total incremental cost of placing the dredged material on the beach west of 61st St. rather than the ODMDS. The present analysis does not consider the federal portion a construction cost for Project #1693 because USACE’s maintenance dredging of the navigation channel would still have occurred without state/local funding for the BUDM nourishment project. Table 3.22 summarizes the project costs, with the summation of the state/local costs representing the total Texas project cost. Of note, the funding amounts listed in Table 3.22 represent the funds committed for placement of 950,000 cy of dredge material. Because the project only placed 64% of the contracted volume, USACE will reimburse the state/local partners a portion of the funds. The reimbursement amount is currently unknown and, thus, not factored into this analysis.

Table 3.22 Funding for Project #1693: Babe’s Beach BUDM (2021 BUDM Cycle)

Funding Source		Amount
State/Local*	GLO, CEPRA Cycle 11	\$4,038,090.78
	GLO, Gulf of Mexico Energy Security Act (GOMESA)	\$5,000,000.00
	Galveston Park Board	\$2,961,909.22
Federal	N/A	N/A
<b>Total Cost (Texas Only)</b>		<b>\$12,000,000.00 (\$12,000,000.00)</b>

Notes: Value in bold italics represents the cost to the State of Texas  
 Values represent present worth, beginning of 2021  
 \*Because a lower volume of beach quality material was placed on the beach than originally budgeted, USACE will likely reimburse GLO a portion of the funds; the reimbursement amount is currently unknown and not factored into this analysis.

### 3.3.3 Benefit Analysis

As discussed in the following sections, economic benefits to the state of Texas from beach visitation (recreational benefits and out-of-state visitor spending benefits) pertain to Project #1693, starting mid-2021 upon completion of construction. This analysis excludes federal spending as a benefit of Project #1693 because USACE’s maintenance dredging of the ship channel would have occurred without the state’s support for the BUDM nourishment project (i.e., USACE would have disposed of the dredge material offshore). Additionally, while the presence of a sandy beach provides some level of storm protection, this analysis assumes Project #1693 does not provide measurable storm damage reduction benefits. The Galveston Seawall — at over 10 miles long, 17 ft high, and 16 ft thick and protected from scour by a riprap revetment — has fixed the shoreline and protected City of Galveston for decades. Constructed incrementally from 1902–1963, the seawall has endured numerous hurricanes, including Hurricane Ike in 2008 which devastated nearby unprotected beaches. For most of its existence, the portion of the seawall west of 61st St. (i.e., the project area) has existed without a protective beach and without major structural concerns for the seawall or its protective riprap. A presumption that the project prevents measurable damage to the robust seawall and upland infrastructure would yield an unrealistically high benefit-cost ratio.

As mentioned, the contractor constructed 9,800 ft of beach during July – November 2021. The following assessment of pre-construction, post-construction, and existing conditions support the benefit analysis.

Analysis of the pre- and post-construction beach profiles (GBA, 2021), spaced 100 ft apart throughout the project area, revealed average pre- and post-construction beach widths of approximately 125 ft and 300 ft. These widths represent the approximate distance from the dune toe, or landward extent of fill where no dune existed, to the mean high water shoreline (+1.23 ft NAVD88). The pre-construction survey represents conditions approximately two years after construction of the 2019 nourishment project. Given the assumption that all Babe’s Beach nourishment projects have the same authorized fill template, the 125-ft pre-construction beach widths indicate the 2019 fill eroded rapidly (i.e., 175 ft during the first two years post-construction). Analysis of Google Earth aerial imagery reveals the 2015 project performed similarly the first two years, but the erosion slowed with time as an approximately 75-ft wide beach remained after four years. These varying erosion rates suggest the beach initially erodes rapidly from fill equilibration as sand disperses alongshore (evidenced in aerial imagery with substantial beach growth west of the project area) but reaches a reduced and more consistent erosion rate once the fill equilibrates.

INTERA visited the project area on November 21, 2022, one year after construction completion. Figures 3.29 – 3.31 show project conditions during the site visit within an hour of high tide. Figures 3.32 – 3.33 show conditions immediately west of the project area near Galveston Fishing Pier. A substantial and consistent beach width of approximately 200 ft remained throughout most of the project area, with the beach slightly narrowing to approximately 165 ft at 81st St. and 140 ft at the west end of the project (just west of 87th St.). Beyond the project area, the beach (created from the fill dispersing) width continues to narrow towards the Galveston Fishing Pier and rapidly decreases within the first 400 ft west of the pier; no beach is evident approximately 700 ft west of the pier. The 61st St. groin has impounded a substantial amount of fill dispersed to the east, with a beach width approaching 300 ft.

Note that the observed 200-ft beach width suggests that Project #1693 has initially performed similarly to both the 2015 and 2019 nourishment projects.

Absent site-specific data about beach fill evolution and longevity other than the information discussed above, this economic benefits study assumed a life span of seven years for Project #1693. This estimate appears reasonable based on the performance of the 2015 project, assuming the volume of fill remaining after four years (i.e., prior to the 2019 nourishment project) was sufficient to last another three years. To model the varying erosion rate from fill equilibration, this analysis applied shoreline retreats of 100 ft during the first year, 75 ft during the second year, and 25 ft/yr thereafter. This study assumed a project length of 9,800 ft (inclusive of tapers given the rapid fill equilibration that fills in the tapers). Of note, Taylor Engineering (2017) estimated a background erosion rate of -8.7 ft/yr in the project area. This estimate assumed, given that no beach had existed in front of the seawall since its construction, all the long-term (1930–2012) shoreline recession (262 ft) documented in the University of Texas Bureau of Economic Geology (UTBEG) Shoreline Change Rate Atlas occurred entirely within the 30 years prior to the construction of the seawall (262 ft / 30 yrs = 8.7 ft/yr). Like the prior study, this analysis did not apply the 8.7 ft/yr background erosion rate because such a rate on a 200-ft wide beach would lead to an unrealistic (without groins to retain the fill) 23-year project life.



Figure 3.29 Existing Conditions on November 21, 2022 at East End of Project



Figure 3.30 Existing Conditions on November 21, 2022 in Center of Project Looking East



Figure 3.31 Existing Conditions on November 21, 2022 in Center of Project Looking West



Figure 3.32 Existing Conditions on November 21, 2022 at West End of Fill Taper



Figure 3.33 Existing Conditions on November 21, 2022 West of Project



### 3.3.3.1 Out-of-State Visitor Spending Benefits

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 like the project area. Applying this value to the 9,800-ft-long project area yields about 8,682 peak day visitors assuming a daily turnover rate of two ( $443 / 1000 * 9800 * 2$ ). 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 (1,736) 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 information, approximately 1,189,320 ( $8,682 * 80 + 1,736 * 285$ ) visits occurred based on the 2015 visitation estimates. Should annual visitation growth mirror the general population growth trend of 1.5% per year, annual visitation to the project area in 2021 after project construction equals 1,300,454 ( $1,189,320 * 1.015^6$ ).

Given the assumption that visitation growth does not exceed the beach's capacity, increasing the beach visitation each year by the general population growth rate of 1.5% per year (e.g., visitation in 2nd year =  $1.015 * \text{visitation in 1st year}$ ) produces initial estimates of beach population for each year of the project life. However, because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches as represented by the elasticity relationship (Section 2.2). This analysis estimated beach visitation with and without the project considering the beach capacity and elasticity relationship. As mentioned, this analysis eroded the beach 100 ft during the first year and 75 ft during the second year to represent fill equilibration, and 25 ft/yr thereafter; these erosion rates completely erode the beach by the end of the assumed seven-year project life. Note this analysis assumes when the beach above mean high water completely erodes, sand accessible at low tide may still provide recreation opportunities; thus, no modifications to the elasticity relationship to account for the armored shoreline is necessary. Tables 3.23 and 3.24 summarize the visitation estimates for with- and without-project conditions. Note that the visitation estimates do not exceed the carrying capacity of the project area (e.g., 19,600 visitors in 2022 at any given time;  $9800 \text{ ft} * 200 \text{ ft} / 100 \text{ sf per visitor} = 19,600 \text{ visitors}$ ) based on USACE's criterion of 100 sf per person) based on USACE's criterion of 100 sf per person.

Taylor Engineering (2015) reports out-of-state visitors to the Galveston area spend \$59.08 (2015 dollars) per person per day and 10.6% of the beachgoers near 61st St. traveled from out-of-state. Adjusted for inflation, this spending equals \$67.56 ( $\$59.08 * 271/237$ ) in 2021 prices based on the annual average CPI values presented in Table 2.1. Based on the above annual visitation, the project area accommodated 137,848 out-of-state visitors in 2021 ( $1,300,454 * 10.6\%$ ); adjusting this value for the effects of beach narrowing and annual population growth yields the visitation for any given year. Multiplying the annual out-of-state visitation estimates by the spending per person times the 1.4 multiplier effect produces the annual spending values. The sum of these annual values, adjusted for inflation and discounting, provides the total benefit over the period of analysis. Table 3.25 summarizes the visitor spending benefit (\$10,302,341, present value, beginning of 2021).

Table 3.23 Annual Visitation with CEPRA Project #1693 (61st St. – 87th St.)

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	1,300,454	300	0.0%	0.0%	1,300,454
2022	1,319,961	200	-33.3%	-33.6%	876,454
2023	1,339,760	125	-58.3%	-51.9%	644,425
2024	1,359,857	100	-66.7%	-53.4%	633,693
2025	1,380,254	75	-75.0%	-54.9%	622,495
2026	1,400,958	50	-83.3%	-56.4%	610,818
2027	1,421,972	25	-91.7%	-56.3%	621,402

Notes: Estimated at mid-year  
 Background erosion = -100 ft in year 1 and -75 ft in year 2 due to fill equilibration, -25 ft/yr thereafter  
 Starting daily peak visitation = 4,341 in 2015 values  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr

Table 3.24 Annual Visitation without CEPRA Project #1693 (61st St. – 87th St.)

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	1,300,454	125	-58.3%	-51.9%	625,518
2022	1,319,961	100	-66.7%	-53.4%	615,102
2023	1,339,760	75	-75.0%	-54.9%	604,232
2024	1,359,856	50	-83.3%	-55.6%	603,776
2025	1,380,254	25	-91.7%	-56.3%	603,171
2026	1,400,958	0	-100.0%	-57.0%	602,412
2027	1,421,972	0	-100.0%	-57.0%	611,448

Notes: Estimated at mid-year  
 Background erosion = -25 ft/yr  
 Starting daily peak visitation = 4,341 in 2015 values  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr



Table 3.25 Out-Of-State Visitor Spending Benefit — CEPR Project #1693

Year	Out-of-State				Difference (2021 prices)	With Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	Visitation		Visitor Spending (2021 prices)					
	With Project	Without Project	With Project	Without Project				
2021	137,848	66,305	\$13,038,215	\$6,271,392	\$6,766,823	\$6,766,823	\$6,611,619	\$6,611,619
2022	92,904	65,201	\$8,787,232	\$6,166,971	\$2,620,261	\$2,845,603	\$2,654,259	\$9,265,878
2023	68,309	64,049	\$6,460,938	\$6,058,011	\$402,928	\$447,206	\$398,220	\$9,664,097
2024	67,171	64,000	\$6,353,302	\$6,053,376	\$299,926	\$340,209	\$289,205	\$9,953,303
2025	65,984	63,936	\$6,241,031	\$6,047,323	\$193,708	\$224,559	\$182,237	\$10,135,540
2026	64,747	63,856	\$6,124,030	\$6,039,756	\$84,274	\$99,846	\$77,354	\$10,212,894
2027	65,869	64,813	\$6,230,153	\$6,130,273	\$99,881	\$120,939	\$89,447	<b><i>\$10,302,341</i></b>

Notes: Out-of-state visitation = 10.6% of total visitation estimates derive from tables 3.23 and 3.24.  
 Out-of-state spending = \$67.56 per person (2021 prices)  
 Inflation rate = 8.6% (2022), 2.2% (2023 and beyond)  
 Discount rate = 4.75% discount rate (mid-year discounting)  
 Multiplier effect = 1.4  
 Value in bold italics represents the benefit to the State of Texas

### 3.3.3.2 Recreation Benefits

The widened beach clearly accomplished the project’s goal of expanding Galveston Island’s beach availability for recreational enjoyment; thus, this study determined the economic benefits from the improved recreation value for all visitors. Calculating recreation enjoyment benefits involved applying the visitation numbers derived in Tables 3.23 and 3.24 to the UDV developed (see section 2.2) for with- and without-project conditions. The UDV points assigned to the site with- and without project conditions provides an estimate of its economic benefits. Table 3.26 shows a summary of the points assigned for with- and without-project conditions in the project area; the greater with-project values derive from the substantially wider beach that enhances the user experience under three of the criteria. Converting the points (54 and 35) to dollars requires interpolating values from Figure 2.3. The resulting with- and without-project UDVs are \$9.91 and \$7.60 (2022 dollars) per person per visit. Taking the difference between the estimated recreation value for all visitors with and without the project yields the benefit for the year. For the first year of analysis (2021), the recreation value with the project (at 2022 price levels) equals \$12,887,499 (1,300,454 \* \$9.91) and without the project equals \$4,753,937 (625,518 \* \$7.60). The difference (\$8,133,562) yields the recreational benefit for 2021 (assumed mid-year). Table 3.27 shows the total recreation value benefit for this project compounding benefits for the life of the project (seven years). In total, applying a discount rate of 4.75% and mid-year discounting, the benefit equals \$18,058,731 (present value, beginning of 2022).

Table 3.26 UDV Points Assigned — CEPRA Project #1693

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	16	7	30
Availability of Opportunity	3	3	18
Carrying Capacity	9	5	14
Accessibility	16	14	18
Environmental	10	6	20
Total	54	35	100

Table 3.27 Recreational Benefit for All Users — CEPRA Project #1693

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	With Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	With Project	Without Project	With Project	Without Project				
2021	1,300,454	625,518	\$12,887,499	\$4,753,937	\$8,133,562	\$7,489,468	\$7,317,689	\$7,317,689
2022	876,454	615,102	\$8,685,659	\$4,674,775	\$4,010,884	\$4,010,884	\$3,741,184	\$11,058,873
2023	644,425	604,232	\$6,386,252	\$4,592,163	\$1,794,089	\$1,833,559	\$1,632,713	\$12,691,586
2024	633,693	603,776	\$6,279,898	\$4,588,698	\$1,691,200	\$1,766,431	\$1,501,612	\$14,193,197
2025	622,495	603,171	\$6,168,925	\$4,584,100	\$1,584,825	\$1,691,741	\$1,372,906	\$15,566,103
2026	610,818	602,412	\$6,053,206	\$4,578,331	\$1,474,875	\$1,609,010	\$1,246,556	\$16,812,659
2027	621,402	611,448	\$6,158,094	\$4,647,005	\$1,511,089	\$1,684,785	\$1,246,073	<b><i>\$18,058,731</i></b>

Notes: UDV (with project) = \$9.91 (2022 prices)  
 UDV (without project) = \$7.60 (2022 prices)  
 Inflation rate = 8.6% (2022), 2.2% (2023 and beyond)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas



### 3.3.4 Benefit-Cost Summary

The out-of-state visitor spending and recreational value combine for a benefit of \$28,361,072, accrued throughout the seven-year project life (Table 3.28). With project costs totaling \$12,000,000, this project has a 2.4 B/C ratio. Of note, this B/C ratio will likely improve substantially upon factoring in the reimbursement from USACE due (as mentioned in Section 3.3.2) to the placed fill volume totaling only 67% of the budgeted volume. For example, a \$2,000,000 reimbursement would increase the B/B ratio to 2.8 and a \$3,000,000 reimbursement would increase the B/C ratio to 3.2

Table 3.28 Benefit-Cost Summary — #1693: Babe’s Beach BUDM (2021 BUDM Cycle)

Item	Discounted Present Worth (beginning of 2021) <sup>2</sup>
Total Benefit	\$28,361,072
Visitation (Out-of-State Visitor Spending)	\$10,302,341
Visitation (Recreation)	\$18,058,731
Total Cost <sup>1</sup>	\$12,000,000
B/C Ratio	2.4

Notes: <sup>1</sup>Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)

<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2021 with a 4.75% discount rate

## 3.4 Cameron County — #1702 Isla Blanca Park Beach Nourishment with BUDM (Cycle 11)

### 3.4.1 Project Description and Background Information

Isla Blanca Park lies at the southern tip of South Padre Island, immediately north of Brazos Santiago Pass in Cameron County. Nourishment of the Isla Blanca Park beach occurs periodically with beneficial use of beach-quality dredge material derived from federal maintenance dredging of the Brazos Island Harbor jetty and entrance channel segments by the USACE Galveston District. The GLO partners with USACE to facilitate beach nourishment by funding — with Cameron County as the local project sponsor — the incremental cost of placing the dredge material on the beach as opposed to the permitted offshore DMPA.

The latest nourishment, CEPRA Project #1702, placed 85,998 cy of fill along 1,500 ft of shoreline during May – June 2021. The southern terminus of the fill placement template (designated DMPA No. 1) began approximately 652 feet north of the Brazos Santiago Pass north jetty and terminated approximately 2,152 ft north of the jetty (Figure 3.34). The fill template consists of a 150-ft-wide berm at elevation +4.0 ft NAVD88, a 1V:25H foreshore slope above the waterline, and an estimated 1V:40H slope below the waterline; 300-ft-long tapers transition the full template to the existing shoreline at the north and south ends. Figure 3.35 presents representative pre- and post-construction aerial imagery and Figure 3.36 shows beach conditions immediately prior to construction. Figure 3.37 plots representative pre- and post-construction beach profiles towards the center of the placement area. Figures 3.38 and 3.39 show the authorized fill plan view and cross section.

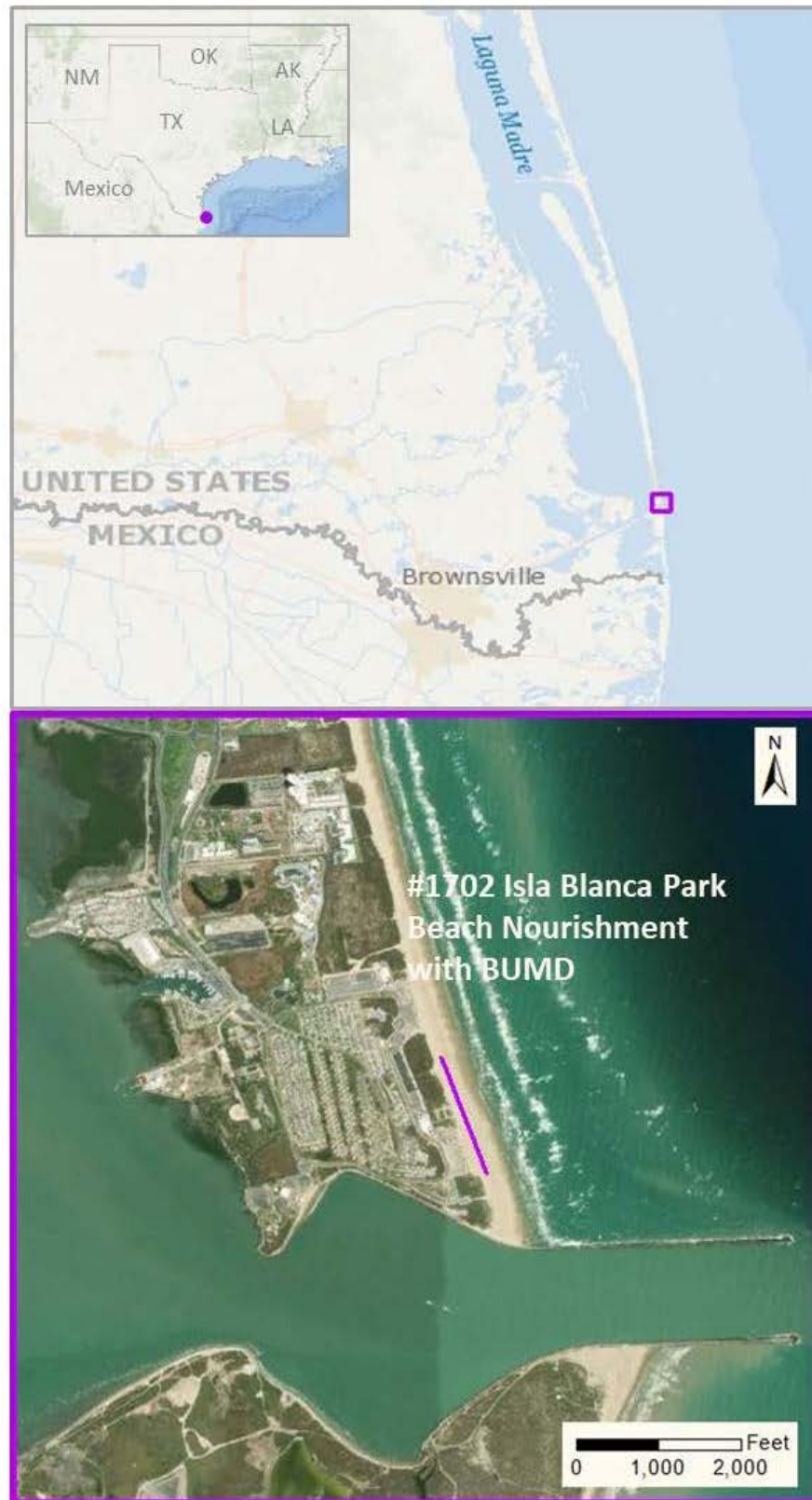


Figure 3.34 Location Map — Project #1702 Isla Blanca Park Beach Nourishment with BUMD



Figure 3.35 Pre- and Post-Construction (Feb. and Sep. 2021) Conditions (source: Google Earth)



Figure 3.36 Conditions Immediately Before Construction (source: GLO)

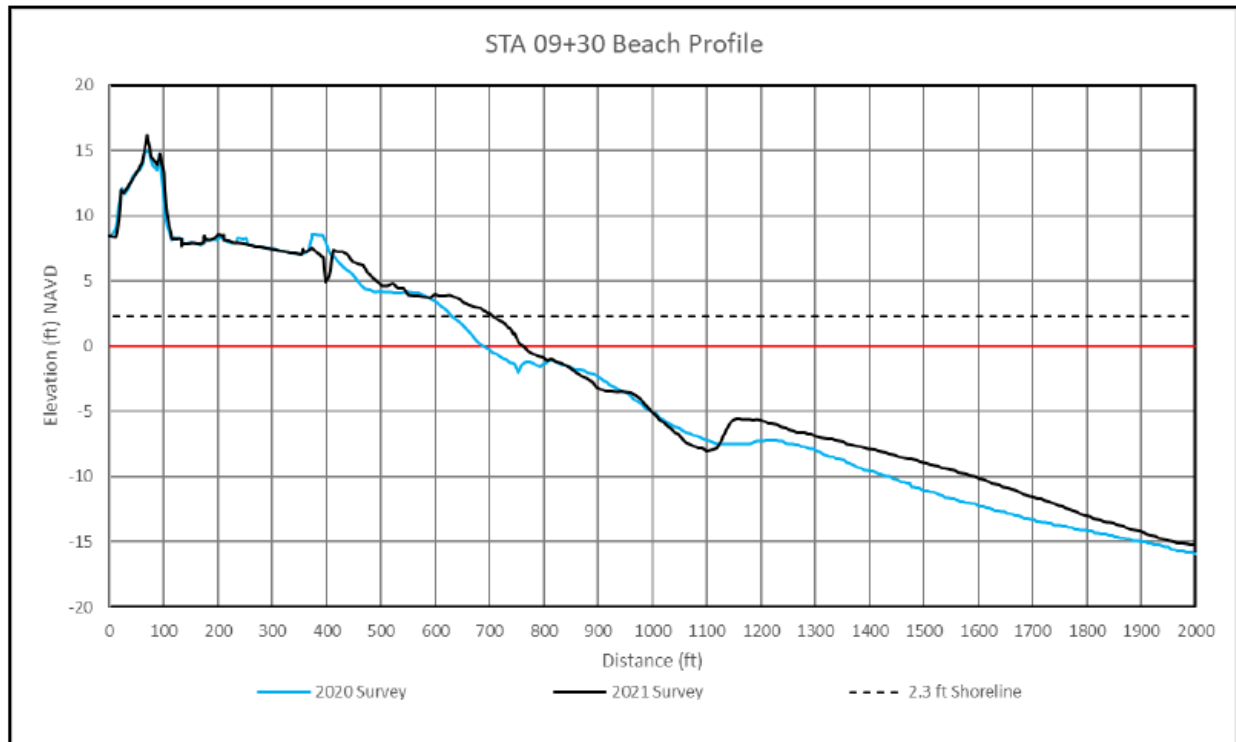


Figure 3.37 Representative Pre- and Post-construction Profiles (HDR, 2021)

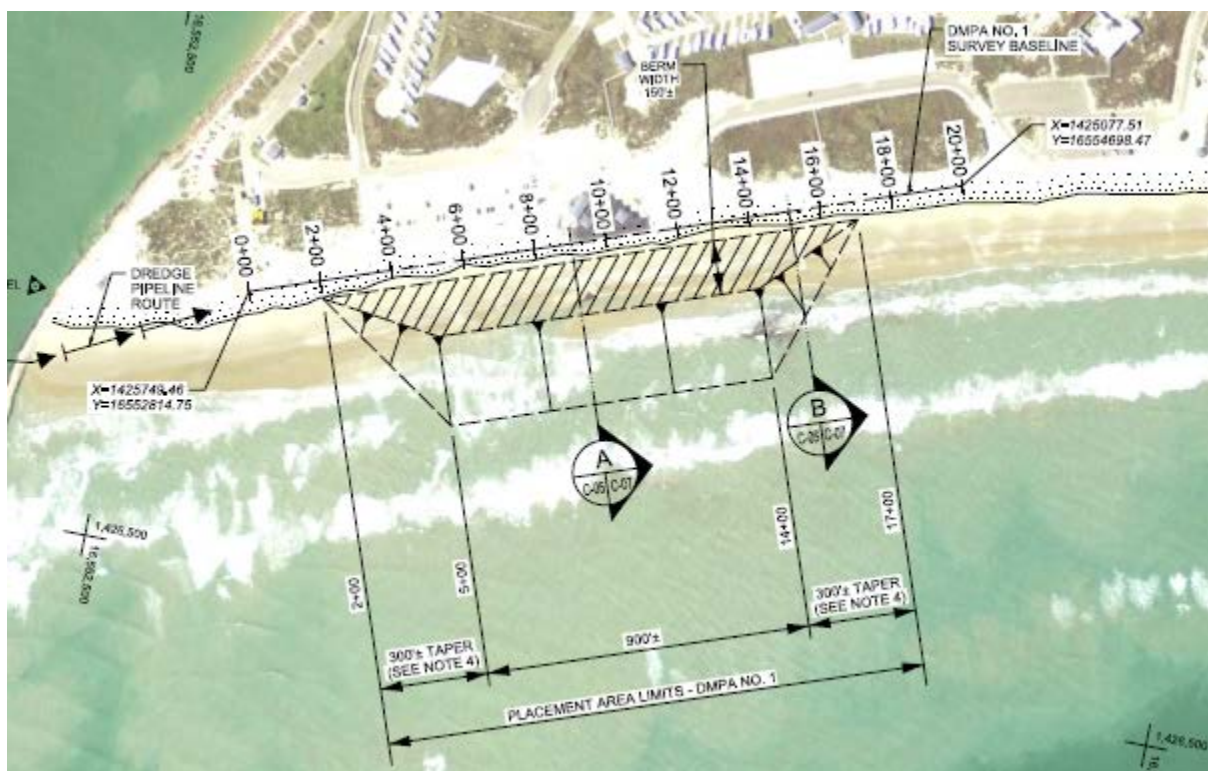


Figure 3.38 Authorized Fill Template Plan View (USACE, 2017)

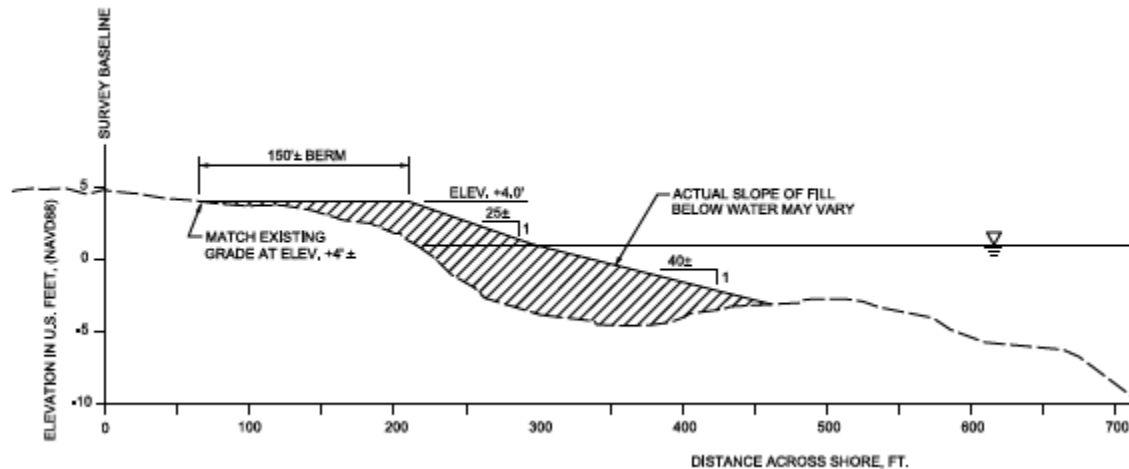


Figure 3.39 Authorized Fill Template Cross Section (USACE, 2017)

### 3.4.2 Project Funding

The USACE contributed \$5,868,750 to cover the baseline cost of maintenance dredging the Brazos Island Harbor entrance and jetty channel sections and placing the material in an authorized offshore DMPA. The state/local funding partners contributed \$510,000 — cost-shared 75% (\$382,500) by GLO (CEPRA) and 25% (\$127,500) by Cameron County — to cover the total incremental cost of placing 89,750 cy of the dredged material on the beach rather than the offshore DMPA. This analysis does not consider the federal portion a construction cost for Project #1702 because USACE’s maintenance dredging of the navigation channel would still have occurred without state/local funding for the BUDM nourishment project. Table 3.29 summarizes the project costs with the summation of the state/local costs representing the total Texas project cost. Notably, USACE has confirmed the actual volume placed in Isla Blanca Park (85,998 cy) was 3,752 cy less than the projected 89,750 cy volume; therefore, USACE will reimburse the state/local sponsors for the under-run. This analysis does not account for the slight reimbursement amount, which USACE has not yet determined.

For completeness and informational purposes only, this paragraph explains the funding connection between Project #1702 and Project #1653 (South Padre Island Beach Nourishment with BUDM — Section 3.1). USACE constructed Project #1702 in conjunction with Project #1653, with 25% of the total dredge material intended for Isla Blanca Park and 75% for the north end of City of South Padre Island. The total combined project cost of \$7,908,750 included the above-mentioned \$5,868,750 federal portion and a \$2,040,000 non-federal portion representing the incremental cost of placing the dredge material on the beach (including both projects) rather than offshore. USACE split the combined \$2,040,000 non-federal portion in accordance with the projected fill volume of each project. Hence, Project #1702 incurred the non-federal cost of \$510,000 (i.e., \$2,040,000 \* 0.25) included in Table 3.29, and Project #1653 incurred a non-federal cost of \$1,530,000 (i.e., \$2,040,000 \* 0.75).

Table 3.29 Funding for Project #1702: Isla Blanca Park Beach Nourishment with BUDM

Funding Source		Amount
State/Local	GLO, CEPRA (75% of non-federal cost)	\$382,500
	Cameron County (25% of non-federal cost)	\$127,500
Federal	N/A	N/A
Total Cost <i>(Texas Only)</i>		\$510,000 <i>(\$510,000)</i>

Notes: Value in bold italics represents the cost to the State of Texas  
Values represent present worth, beginning of 2021

### 3.4.3 Benefit Analysis

As discussed in the following sections, economic benefits to the state of Texas from beach visitation — spending by out-of-state visitors and recreational enjoyment by all visitors — pertain to Project #1702, starting mid-2021 upon completion of construction. This analysis excludes federal spending as a benefit of Project #1702 because USACE would still have conducted maintenance dredging of the navigation channel without state/local funding for the BUDM nourishment project. Additionally, in 2017, Cameron County commenced park renovations that included demolition of the original unprotected beachfront pavilions, dune restoration, and construction of new facilities further landward. These renovations removed the vulnerable structures that potentially could have been damaged in the without-project scenario. Given the substantial beach widths protecting the current parking lot and boardwalk from erosion in 2021 prior to construction, Project #1702 does not result in any measurable storm damage reduction benefits.

As mentioned, the contractor constructed approximately 1,500 ft of beach during May–June 2021. The following assessment of pre-construction, post-construction, and existing conditions support the benefit analysis. Note both beach visitation benefits require estimates of the beachgoer population over the project life.

INTERA-GEC visited the project area on November 3, 2022, approximately 16 months post-construction. Site conditions included a relatively wide beach, eroded since construction but still retaining fill above the waterline. Additional fill may exist within the project area within the nearshore; however, survey data documenting such conditions are unavailable. Figures 3.40 and 3.41 show the project conditions during the site visit. Note the line of seaweed (wrack line) gives an idea of the location of recent high tides. However, review of recent tide levels (tidesandcurrents.com) showed abnormally high tides occurred prior to the site visit; thus, the wrack line does not represent typical mean high tide conditions.

Estimation of beach width via analysis of Google Earth aerial imagery yielded pre-construction and post-construction beach widths of approximately 140 ft and 255 ft, resulting in a beach width increase of 115 ft. Similarly, HDR (2021), which analyzed pre-construction (summer 2020) and post-construction (summer 2021) beach profiles along South Padre Island, documented a beach width increase of approximately 115 ft in the project area, as calculated by the average change at two beach profiles (74.5 ft at STA 9+30 and 156 ft at STA 15+00) within the project area. Absent site-specific data about beach fill evolution and longevity other than the information gathered from the site visit and the data discussed



above, this economic benefits study assumed a life span of five years (i.e., 2021–2025) for Project #1702.



Figure 3.40 Conditions on November 3, 2022 looking Northwards from Center of Project Area



Figure 3.41 Conditions on November 3, 2022 Looking Southwards from North End of Project Area

### 3.4.3.1 Out-of-State Visitor Spending Benefit

Taylor Engineering (2015) reports 421 visitors per 1,000 ft of shoreline at Isla Blanca Park (average of morning and afternoon surveys). Applying this value to the 1,500-ft-long project area yields about 1,262 peak day visitors assuming a daily turnover rate of two ( $421 / 1000 * 1500 * 2$ ). According to Oden and Butler (2006), 104 peak visitor days occur in the South Padre Island area. One-fifth (assumed) of the peak day visitors (252) 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 197,020 visits ( $131,248 [1,262 * 104] + 65,772 [252 * 261]$ ) to the project area occurred in 2015. Assuming annual visitation growth mirrors the general population growth trend of 1.5% per year, annual visitation to the project area in 2021 equals 215,430 ( $197,020 * 1.015^6$ ).

Given the assumption that the visitation growth does not exceed the beach's capacity, increasing the beach visitation each year by the general population growth rate of 1.5% per year (e.g., visitation in 2nd year =  $1.015 * \text{visitation in 1st year}$ ) produced initial estimates of beach population for each year of the project life. However, because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches as represented by the elasticity relationship (Section 2.2). This analysis estimated the with- and without-project beach visitation estimates considering the beach capacity and elasticity relationship. For the without-project scenario, as estimated from Google Earth imagery, the starting 2021 without-project (i.e., pre-construction) beach width of 140 ft on average is slightly less than the estimated 2015 beach width of 155 ft. For the with-project scenario, the average 175-ft-wide beach estimated during the November 2022 site visit indicates the beach has eroded 80 ft ( $255 - 175$ ) since construction (high erosion rates are typical the first year after construction due to fill equilibration) but remains wider than in 2015. For the remainder of the project life, this analysis reduced the beach width by the background erosion rate of -2.7 ft/yr.

Note that available historic shoreline change data is insufficient to accurately represent the expected performance of the nourishment project. Data obtained from UTBEI indicates average shoreline recession of approximately -1 ft/yr from the 1950s–2019 and shoreline advance of 1 ft/yr from 2000–2019. However, these results include the effects past BUDM nourishments that have helped stabilize the shoreline. HDR (2021) documents a shoreline erosion rate of -2.7 ft/yr from 2005–2008, in between past nourishment events; a single beach profile (i.e., STA 9+30) located near the south project taper serves as the basis of this rate. Given the lack of more information, this study adopted a rate of -2.7 ft/yr. Of note, the with-project beach widths exceed the 2015 beach width throughout the five-year analysis period; thus, no visitation reductions via the elasticity relationship occurred. Tables 3.30 and 3.31 summarize the visitation estimates for with- and without-project conditions. Notably, the annual visitation estimates do not exceed the carrying capacity of the project area (e.g., 3,825 visitors in 2021 at any given time;  $1500 \text{ ft} * 255 \text{ ft} / 100 \text{ sf per visitor} = 3,825 \text{ visitors}$ ) based on USACE's criterion of 100 sf per person.

Taylor Engineering (2015) reports out-of-state visitors to South Padre Island spend \$100.44 per person and 8.7% of visitors to Isla Blanca Park originate from outside of Texas. Adjusted for inflation, the spending equals \$114.85 ( $\$100.44 * 271 / 237$ ) in 2021 prices based on the annual average CPI values presented in Table 2.1. Based on the above annual visitation, the project area accommodated 18,742 out-of-state visitors in 2021; adjusting this value for the effects of beach narrowing and annual population growth yields the visitation for any given year. Multiplying the annual out-of-state visitation



estimates by the spending per person times the 1.4 multiplier effect produces the annual spending values. The sum of these annual values, adjusted for inflation and discounting, provides the total benefit over the period of analysis. Table 3.2.4 summarizes the visitor spending benefit (\$2,012,295, present value, beginning of 2021).

Table 3.30 Annual Visitation with CEPRA Project #1702

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	215,430	255	64.5%	0.0%	215,430
2022	218,661	175	12.9%	0.0%	218,661
2023	221,941	167.3	7.9%	0.0%	221,941
2024	225,270	164.6	6.2%	0.0%	225,270
2025	228,649	161.9	4.5%	0.0%	228,649

Notes: Estimated at mid-year.  
 Background erosion, -2.7 ft/yr; 85-ft beach width reduction from 2021-2022 resulted from typical fill equilibration  
 Starting daily peak visitation = 1,262 in 2015  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr  
 Beach width change reflects the increase or decrease relative to the 2015 beach width (i.e., conditions represented by the 2015 beach user survey data)

Table 3.31 Annual Visitation without CEPRA Project #1702

Year	Unconstrained Annual Visitation	Beach Width (ft)	Beach Width Change	Elasticity (Visitation Change)	Constrained Annual Visitation
2021	215,430	140	-9.7%	-9.8%	194,415
2022	218,661	137.3	-11.4%	-11.5%	193,492
2023	221,941	134.6	-13.2%	-13.3%	192,497
2024	225,270	131.9	-14.9%	-15.0%	191,429
2025	228,649	129.2	-16.6%	-16.8%	190,286

Notes: Estimated at mid-year.  
 Background erosion, -2.7 ft/yr.  
 Starting daily peak visitation = 1,262 in 2015.  
 Weighted population growth rate (proxy for unconstrained visitation growth) = 1.5%/yr  
 Beach width change reflects the increase or decrease relative to the 2015 beach width (i.e., conditions represented by the 2015 beach user survey data)

Table 3.32 Out-Of-State Visitor Spending Benefit – CEPRA Project #1702

Year	Out-of-State				Difference (2021 prices)	With Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	Visitation		Visitor Spending (2021 prices)					
	With Project	Without Project	With Project	Without Project				
2021	18,742	16,914	\$3,013,592	\$2,719,619	\$293,973	\$293,973	\$287,231	\$287,231
2022	19,024	16,834	\$3,058,790	\$2,706,707	\$352,082	\$382,361	\$356,651	\$643,881
2023	19,309	16,747	\$3,104,673	\$2,692,789	\$411,884	\$457,147	\$407,072	\$1,050,953
2024	19,598	16,654	\$3,151,241	\$2,677,849	\$473,393	\$536,974	\$456,472	\$1,507,425
2025	19,892	16,555	\$3,198,509	\$2,661,859	\$536,650	\$622,119	\$504,871	<b><i>\$2,012,295</i></b>

Notes: Out-of-state visitation = 8.7% of total visitation estimates derive from Tables 3.30 and 3.31.

Out-of-state spending = \$114.85 per person (2021 prices)

Inflation rate = 8.6% (2022), 2.2% (2023 and beyond)

Discount rate = 4.75% (mid-year discounting)

Multiplier effect = 1.4

Value in bold italics represents the benefit to the State of Texas

### 3.4.3.2 Recreation Benefits

The substantially wider beach created by the project clearly enhances the user experience. As such, this study quantified the economic benefits from the improved recreation value for all visitors. Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers derived in tables 3.30 and 3.31 to the UDV developed (see Section 2.2) for with- and without-project conditions. Table 3.33 presents a summary of the points assigned for with- and without-project conditions in the project area; the greater with-project values derive from the substantially wider beach that enhances the user experience under three of the criteria. Converting the points to dollar values with the help of Figure 2.3 (Section 2.2) results in with- and without-project UDVs of \$10.47 and \$9.99 (2022 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 (2021), the recreation value with the project (2022 price levels) equals \$2,255,552 (215,430 \* \$10.47) and without the project equals \$1,942,206 (194,415 \* \$9.99). Adjusting the difference (\$313,346) for 8.6% inflation and discounting from 2021 to 2022 yields the recreational benefit for 2021 (\$281,915, assumed mid-year). In total, the benefit equals \$1,802,239 (present value, beginning of 2021) (Table 3.35).

Table 3.33 UDV Points Assigned — CEPRA Project #1702

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	12	10	30
Availability of Opportunity	3	3	18
Carrying Capacity	12	10	14
Accessibility	18	18	18
Environmental	16	14	20
Total	61	55	100



Table 3.34 Recreational Benefit for All Users — CEPRA Project #1702

Year	Total Visitation		Recreation Value (2022 Prices)		Difference (Benefit)	With Inflation	Discounted Present Worth, Beginning of 2021	Cumulative Discounted Present Worth, Beginning of 2021
	With Project	Without Project	With Project	Without Project				
2021	215,430	194,415	\$2,255,552	\$1,942,206	\$313,346	\$288,532	\$281,915	\$281,915
2022	218,661	193,492	\$2,289,381	\$1,932,985	\$356,396	\$356,396	\$332,431	\$614,345
2023	221,941	192,497	\$2,323,722	\$1,923,045	\$400,677	\$409,492	\$364,637	\$978,982
2024	225,270	191,429	\$2,358,577	\$1,912,376	\$446,201	\$466,050	\$396,181	\$1,375,163
2025	228,649	190,286	\$2,393,955	\$1,900,957	\$492,998	\$526,257	\$427,075	<b><i>\$1,802,239</i></b>

Notes: UDV (with project) = \$10.47 (2022 prices)  
 UDV (without project) = \$9.99 (2022 prices)  
 Inflation rate = 8.6% (2022), 2.2% (2023 and beyond)  
 Discount rate = 4.75% (mid-year discounting)  
 Value in bold italics represents the benefit to the State of Texas

### 3.4.4 Benefit Cost Summary

With total benefits of \$3,814,534 and a total project cost of \$510,000, the resulting B/C ratio for CEPRA Project #1702 equals 7.5 (Table 3.35).

Table 3.35 Benefit-Cost Summary — #1702: Isla Blanca Park Beach Nourishment with BUDM

Benefits and Costs	Discounted Present Worth (beginning of 2021) <sup>2</sup>
Total Benefit	\$3,814,534
Visitation (Out-of-State Visitor Spending)	\$2,012,295
Visitation (Recreation)	\$1,802,239
Total Cost <sup>1</sup>	\$510,000
B/C Ratio	7.5

Notes: <sup>1</sup>Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)  
<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2021 with a 4.75% discount rate

## 4.0 Natural Resource Restoration Benefit Analysis

This chapter presents the benefit analyses of the following natural resource-related projects:

- #1637: Galveston Island State Park Phase 3 (Cycle 10); and
- #1685 Causeway Rookery Island Phase 2 (Cycle 11).

### 4.1 Galveston County – #1637: Galveston Island State Park Phase 3 (Cycle 10)

#### 4.1.1 Project Description and Background Information

CEPRA Project # 1637 included the construction of three rock breakwaters within Galveston Island State Park (GISP) — at Butterowe Bayou, Oak Bayou, and Dana Cove — to protect approximately 87 acres of existing estuarine emergent marsh, 12 acres of existing sand and mud flats, and 311 acres of shallow open water that, in part, supports critical sea grass beds. Designed to shelter the habitat from waves over a 25-year project life, the breakwaters will also provide hard substrate habitat, similar to that of oyster reefs. Construction of the breakwaters, totaling 7,550 linear feet (825 ft at Butterowe Bayou, 2,500 ft at Oak Bayou, and 4,225 ft at Dana Cove) — occurred from July–October 2021.

The National Fish and Wildlife Foundation (NFWF), a project funding stakeholder, describes GISP as one of the last remaining strips of land on Galveston Island that represents a complete beach to bay transitional ecosystem commonly found on barrier islands (<https://www.nfwf.org/sites/default/files/gulf/Documents/tx-galveston-island-iii-17.pdf>). Project #1637 complements prior project phases, funded by the Gulf Environmental Benefit Fund, that constructed adjacent breakwaters and restored marsh habitat in the central and western portions of GISP. Combined, the projects protect over two miles of GISP shoreline and 150 acres of estuarine emergent marsh. Such marsh protection/restoration projects, which began in the 1990s in Galveston Bay, are important for combatting the adverse effects of long-term subsidence and wave-induced erosion, which have destroyed important habitat and feeding grounds for numerous bird species and estuarine-dependent species including shrimp, red drum, and blue crab. Since the 1950s, Galveston Bay has lost over 20% (35,000 acres) of its emergent wetlands and 70% (1,800 acres) of its seagrasses (NFWF).

Figure 4.1 provides a location map. Figure 4.2 shows typical breakwater details. Figures 4.3–4.4 show typical post-construction conditions in December 2021. Figure 4.5 shows pre- and post-construction aerials taken from Google Earth.

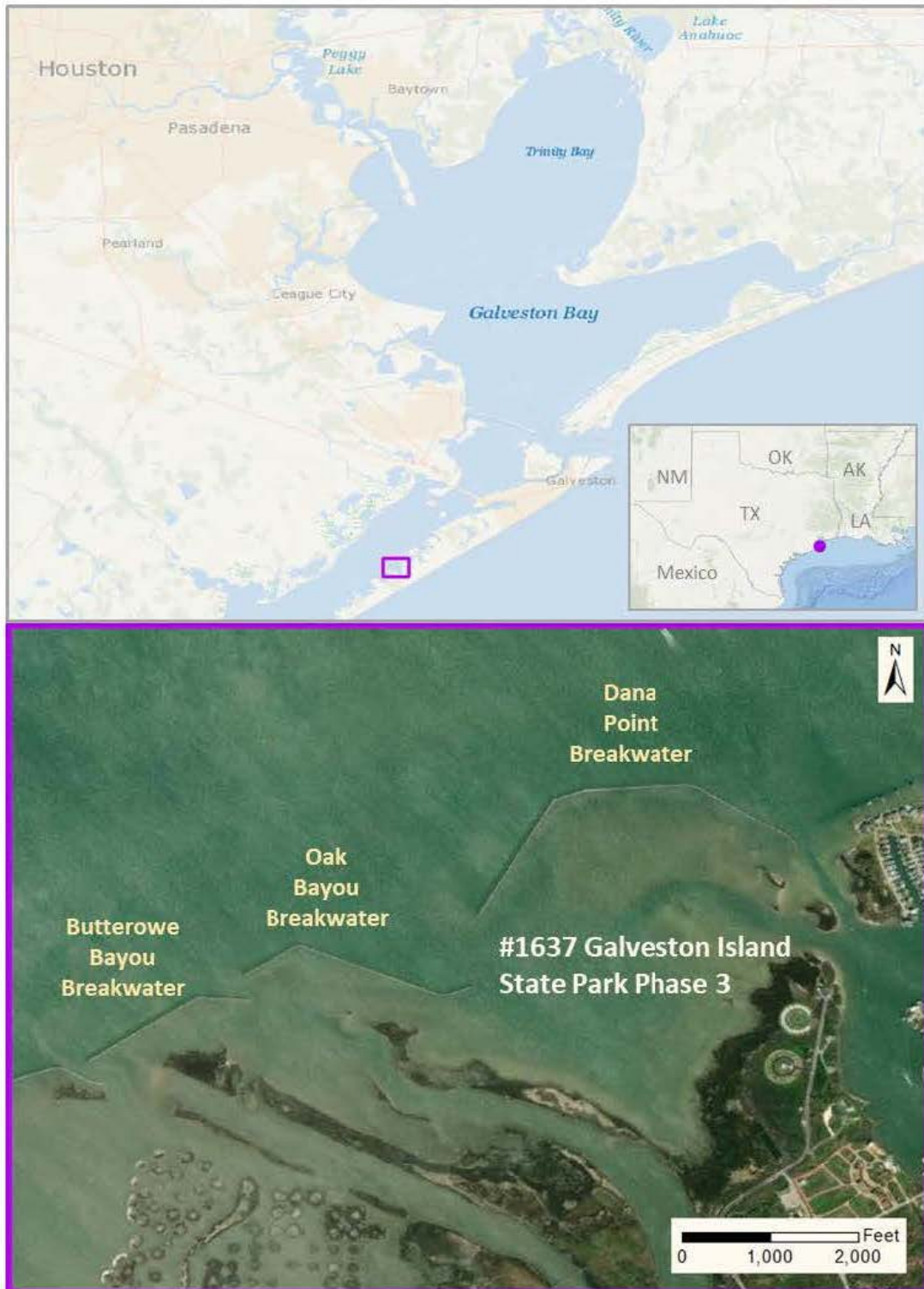


Figure 4.1 Location Map — Project #1637 Galveston Island State Park Phase 3

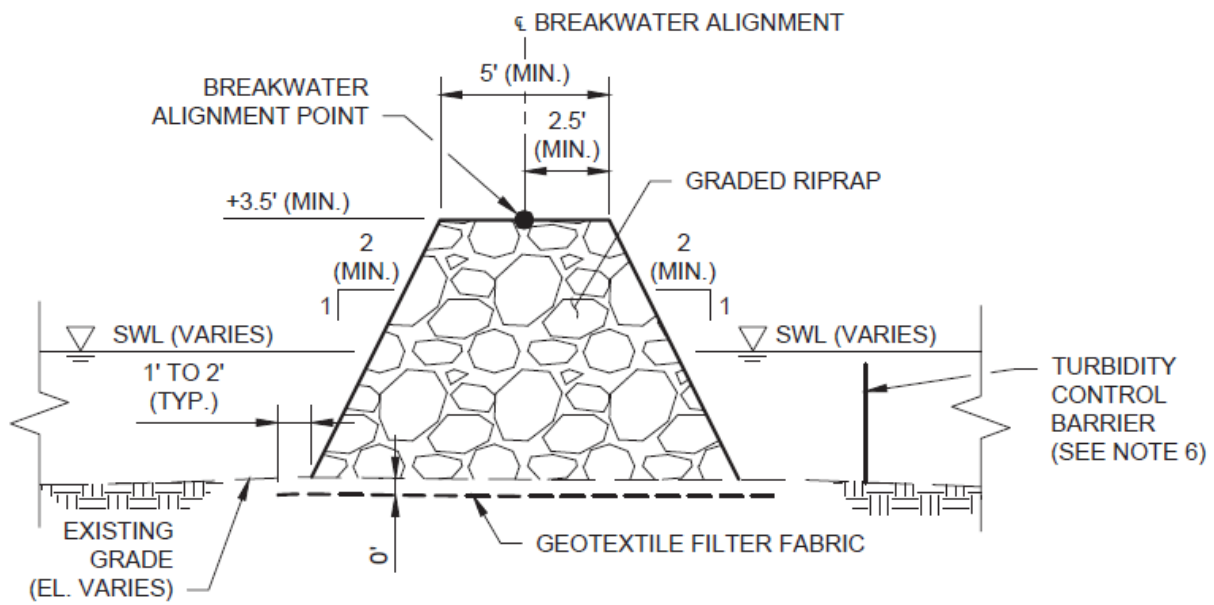


Figure 4.2 Typical Breakwater Section (HDR, 2020)



Figure 4.3 Typical Post-construction Breakwater Conditions, December 2021 (HDR, 2022)



Figure 4.4 Typical Eroding Marsh Shoreline, December 2021 (HDR, 2022)



Figure 4.5 Pre- and Post-construction (Top and Bottom) Photographs



### 4.1.2 Project Funding

Table 4.1 presents the funding breakdown for the project. NFWF contributed federal funds to project construction, and the GLO covered the remaining non-federal costs. Based on the assumption that Texas contributes, proportionally to Texas' share of the national population, about 10% of all federal spending through individual and corporate taxes, this analysis reduces by 90% any project costs funded by national agencies or organizations. This adjustment filters out funds contributed by non-Texas entities to account for costs incurred solely by Texas (Section 2.1). Accordingly, the resulting cost to Texas for Project #1637 amounts to \$575,296; this value equals the sum of the non-federal costs (\$78,115) and 10% state share of federal costs (\$497,181). This analysis treats all costs as though they were incurred at the beginning of 2021, the year of construction, and reflect 2021 prices.

Table 4.1 Funding for Project #1637: Galveston Island State Park Phase 3 (Cycle 10)

Funding Source		Amount
State/Local	GLO, CEPRA	<i>\$78,115</i>
Federal	NFWF (98% of Project Total) <i>Texas Portion (10% of NFWF Funding)</i>	\$4,971,813 <i>(\$497,181)</i>
Total Cost <b>(Texas Only)</b>		\$5,049,928 <b><i>(\$575,296)</i></b>

Notes: Values in bold italics are costs to the State of Texas.  
Values represent present worth, beginning of 2021

### 4.1.3 Benefit Analysis

Benefits for Project #1637 include federal spending and ecosystem services benefits.

#### 4.1.3.1 Federal Spending Benefit

This study considers construction costs funded by non-Texas dollars as an influx of money into the Texas economy and, hence, a financial benefit. The non-Texas portion of the federal contribution (from NFWF) listed above ( $\$4,971,813 * 0.9 = \$4,474,632$ ) represents the total non-Texas funding for the project. Applying a multiplier of 1.4 to the non-Texas funding accounts for the spending and re-spending multiplier, or ripple, effect as the monetary inflow circulates throughout the Texas economy (Section 2.1). Accordingly, the federal spending benefit for Project #1637 equals \$6,264,485 ( $\$4,474,632 * 1.4$ ) in 2021 prices.

#### 4.1.3.2 Ecosystem Services Benefit

Ecosystem services benefits are based on the difference of relevant values between conditions with and without the project. The ecosystem services values for marsh and open water derive from the BlueValue database (see Section 2.3). The following assumptions form the basis of the ecosystem services benefit analysis for Project #1637:

- Ecosystem services benefits will accrue from the breakwaters' prevention of marsh erosion.
- The breakwaters will prevent further erosion of the marsh shoreline.
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor Engineering, 2019).
- Breakwater construction resulted in a loss of open water habitat, measured by the acreage of the breakwaters' footprint.
- Based on the July 2021 construction commencement date, benefits (and losses) began the middle of 2021 and for the rest of the subsequent 20-year project life (i.e., 2022–2041).

Of note, the submerged portion of the breakwaters provides hard substrate habitat that could potentially accrue benefits over time; however, given the shallow water and corresponding minor acreage of the submerged portion, this analysis excludes the potential hard substrate habitat benefit.

Analysis of Google Earth high-resolution satellite images — for years 2006, 2014, 2018, and 2022 — helped determine the historic marsh erosion rate. To facilitate georeferencing the aerial imagery, INTERA-GEC established nine ground control points in Google Earth, saved the points in KML file format, and converted the KML file to a layer file using ArcMap 10.8.1. Then, the authors geometrically rectified the images applying the ground control points and the NAD 1983 State Plane Texas South FIPS 4205 datum with second order polynomial transform algorithms also applied to the images. Identification of the marsh shoreline occurred by computing RGB based vegetation indices (Red-Green-Blue Vegetation Index [RGBVI] and Green Leaf Index [GLI]) to differentiate land from water. The shoreline analysis focused on 13 sections of marsh shoreline (Areas A–M in Figure 4.6) identified in HDR (2022) for post-construction project performance monitoring based on their proximity to the breakwaters and potential for marsh protection benefits. Figure 4.7 provides an example of the extracted shoreline position for Area A.

To calculate the marsh shoreline erosion rate, this analysis applied the Digital Shoreline Analysis System (DSAS version 5.1), an ArcGIS extension tool. DSAS uses a hypothetical baseline created with many baseline-perpendicular transects to evaluate the spatial and temporal change of the shoreline position. Figure 4.8 provides an example of the DSAS baseline and transects and shoreline positions. Appendix A provides similar figures for Areas A–M. Note the analysis subdivided some of the sections where appropriate to allow for a more accurate representation of the shoreline changes.

Table 4.2 provides the marsh shoreline recession rates — including the Linear Regression Rate (LRR) and End Point Rate (EPR) — calculated with DSAS. DSAS calculates the EPR by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline. DSAS calculates the LRR by plotting the distance of the shorelines from the baseline against time and fitting a least-squares regression line to the data; the slope of the regression line provides the shoreline change rate. For each marsh section, multiplying the average recession rate by the shoreline length provides the area of marsh erosion. Summing the erosion of all marsh sections approximates the marsh erosion rate within the project area. As documented in Table 4.2, both the LRR and EPR estimates yielded a marsh erosion rate of approximately 0.6 acres/year.



Figure 4.6 Location of Measured Marsh Edge Location (HDR, 2022)

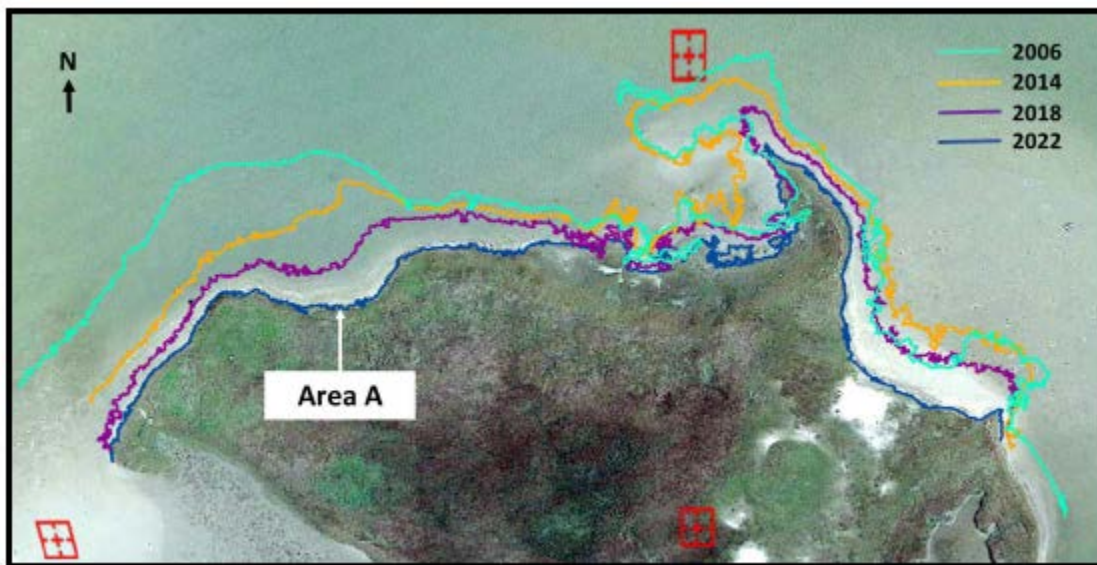


Figure 4.7 Example of Extracted Shoreline Positions

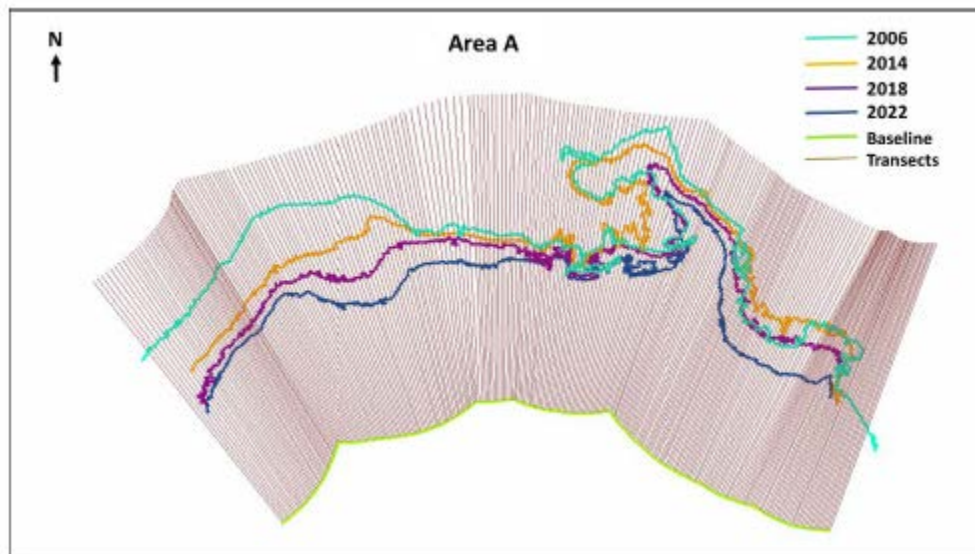


Figure 4.8 Example of DSAS Shoreline Positions, Baseline, and Transects

Table 4.2 Project #1637 Marsh Erosion Estimates

Marsh Section	Shoreline Length (ft)	Average Shoreline Recession Rate (ft/yr)		Marsh Erosion Rate (acres/yr)	
		Liner Regression Method	End Point Method	Liner Regression Method	End Point Method
Area A	2,514.7	4.7	4.7	0.27	0.27
Area B	520.7	1.7	1.8	0.02	0.02
Area C	535.4	0.9	0.9	0.01	0.01
Area D	472.8	2.2	1.9	0.02	0.02
Area E	1,478.0	1.5	1.7	0.05	0.06
Area F	147.6	2.2	1.5	0.01	0.00
Area G	159.5	2.5	2.4	0.01	0.01
Area H	178.0	1.6	1.5	0.01	0.01
Area I	2,107.5	1.9	1.9	0.09	0.09
Area J	496.5	1.0	1.1	0.01	0.01
Area K	2,742.9	0.7	0.7	0.05	0.05
Area L	464.7	0.7	0.8	0.01	0.01
Area M	790.8	1.0	1.1	0.02	0.02
Combined Marsh Erosion Rate (acres/yr)				0.6	0.6

In accordance with the above results, this analysis assumes the constructed breakwaters prevent loss of 0.6 acres of marsh habitat each year. However, breakwater construction resulted in the loss of 5.2 acres of open water estuarine habitat, measured as the acreage of the breakwaters' footprint. Given the July 2021 (i.e., approximately mid-year) construction commencement date, the benefit analysis assumed the with-project scenario provided protection for half the year and prevented 0.3 acres of erosion (i.e., 0.6



acres/yr \* 0.5 yrs). Similarly, the analysis assumed the open water habitat existed during the first half of 2021 and was completely lost during the second half of 2021, yielding an effective loss of 2.6 acres for 2021 (i.e., 5.2 acres \* 0.5).

Table 4.3 details the annual ecosystem services benefits from marsh protection.

Table 4.4 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 (\$929,570) less the value of open water habitat lost (\$470) — resulting from Project #1637 equals \$929,100 (present worth, beginning of 2021).

Table 4.3 Project #1637 Ecosystem Services Value – Marsh Preserved

Year	Marsh Lost (acres)				Net Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Cumulative Discounted Present Worth, Beginning of 2021
	With Project		Without Project			Values (2021 Prices) <sup>1</sup>	With Inflation <sup>2</sup>	Discounted Present Worth, Beginning of 2021 <sup>3</sup>	
	Annual	Cumulative	Annual	Cumulative					
2021	0.3	0.3	0.6	0.6	0.3	\$2,810	\$2,810	\$2,746	\$2,746
2022	0	0.3	0.6	1.2	0.9	\$8,430	\$9,155	\$8,540	\$11,286
2023	0	0.3	0.6	1.8	1.5	\$14,051	\$15,595	\$13,887	\$25,172
2024	0	0.3	0.6	2.4	2.1	\$19,671	\$22,313	\$18,968	\$44,140
2025	0	0.3	0.6	3.0	2.7	\$25,291	\$29,319	\$23,794	\$67,934
2026	0	0.3	0.6	3.6	3.3	\$30,912	\$36,623	\$28,373	\$96,307
2027	0	0.3	0.6	4.2	3.9	\$36,532	\$44,234	\$32,716	\$129,023
2028	0	0.3	0.6	4.8	4.5	\$42,152	\$52,162	\$36,830	\$165,852
2029	0	0.3	0.6	5.4	5.1	\$47,773	\$60,418	\$40,724	\$206,577
2030	0	0.3	0.6	6.0	5.7	\$53,393	\$69,011	\$44,408	\$250,984
2031	0	0.3	0.6	6.6	6.3	\$59,013	\$77,954	\$47,887	\$298,871
2032	0	0.3	0.6	7.2	6.9	\$64,633	\$87,256	\$51,171	\$350,043
2033	0	0.3	0.6	7.8	7.5	\$70,254	\$96,930	\$54,267	\$404,309
2034	0	0.3	0.6	8.4	8.1	\$75,874	\$106,988	\$57,181	\$461,491
2035	0	0.3	0.6	9.0	8.7	\$81,494	\$117,441	\$59,922	\$521,412
2036	0	0.3	0.6	9.6	9.3	\$87,115	\$128,302	\$62,495	\$583,907
2037	0	0.3	0.6	10.2	9.9	\$92,735	\$139,584	\$64,907	\$648,815
2038	0	0.3	0.6	10.8	10.5	\$98,355	\$151,301	\$67,165	\$715,980
2039	0	0.3	0.6	11.4	11.1	\$103,975	\$163,465	\$69,275	\$785,255
2040	0	0.3	0.6	12.0	11.7	\$109,596	\$176,092	\$71,242	\$856,497
2041	0	0.3	0.6	12.6	12.3	\$115,216	\$189,195	\$73,072	\$929,570

<sup>1</sup>The marsh ecosystem service value is \$9,367.16/acre (2021 prices)

<sup>2</sup>Inflation adjustments equal 8.6% from 2021 to 2022 and 2.2% annually thereafter

<sup>3</sup>Present worth, beginning of 2021, based on mid-year discounting; mid-year discount factor =  $(1/1.0475)^{n+0.5}$ , where n = year - 2021; discount rate = 4.75%

Table 4.4 Project #1637 Ecosystem Services Value – Open Water Loss

Year	Open Water Area Lost (acres)	Annual Value Lost			Cumulative Discounted Present Worth
		Value (2021 Prices) <sup>1</sup>	With Inflation <sup>2</sup>	Discounted Present Worth <sup>3</sup>	
2021	2.6	\$14	\$14	\$14	\$14
2022	5.2	\$28	\$31	\$29	\$42
2023	5.2	\$28	\$31	\$28	\$70
2024	5.2	\$28	\$32	\$27	\$97
2025	5.2	\$28	\$33	\$27	\$124
2026	5.2	\$28	\$33	\$26	\$150
2027	5.2	\$28	\$34	\$25	\$175
2028	5.2	\$28	\$35	\$25	\$200
2029	5.2	\$28	\$36	\$24	\$224
2030	5.2	\$28	\$36	\$23	\$247
2031	5.2	\$28	\$37	\$23	\$270
2032	5.2	\$28	\$38	\$22	\$292
2033	5.2	\$28	\$39	\$22	\$314
2034	5.2	\$28	\$40	\$21	\$335
2035	5.2	\$28	\$41	\$21	\$356
2036	5.2	\$28	\$42	\$20	\$376
2037	5.2	\$28	\$42	\$20	\$396
2038	5.2	\$28	\$43	\$19	\$415
2039	5.2	\$28	\$44	\$19	\$434
2040	5.2	\$28	\$45	\$18	\$452
2041	5.2	\$28	\$46	\$18	\$470

<sup>1</sup>The open water ecosystem service value equals \$5.42/acre (2021 prices)

<sup>2</sup>Inflation adjustments equal 8.6% from 2021 to 2022 and 2.2% annually thereafter

<sup>3</sup>Present worth, beginning of 2021, based on mid-year discounting; mid-year discount factor =  $(1/1.0475)^{n+0.5}$ , where n = year - 2021; discount rate = 4.75%

#### 4.1.4 Benefit Cost Summary

The federal spending and ecosystem services benefits combine for a total benefit of \$7,193,585, accrued throughout the 20-year period of analysis. Dividing the total project benefits value by the total Texas project cost (\$575,296) results in a benefit-cost ratio of 12.5 (Table 4.5).



Table 4.5 Benefit-Cost Summary — #1637 Galveston Island State Park Phase 3 (Cycle 10)

Benefits and Costs	Discounted Present Worth (beginning of 2021) <sup>2</sup>
Total Benefit	\$7,193,585
Federal Spending	\$6,264,485
Ecosystem Services Benefit	\$929,100
Total Cost <sup>1</sup>	\$575,296
B/C Ratio	12.5

Notes: <sup>1</sup>Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)

<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2021 with a 4.75% discount rate

## 4.2 Nueces County — #1685: Causeway Rookery Island Phase 2 (Cycle 11)

### 4.2.1 Project Description and Background Information

Causeway Rookery Island Shoreline Protection Phase 2 (CEPRA Project #1685), completed in February 2022, constructed a segmented rock breakwater surrounding Causeway Rookery Island to protect valuable roosting and nesting habitat for colonial waterbirds (e.g., Great Blue Herons, Great Egrets, Snowy Egrets, Roseate Spoonbills, Reddish Egrets, Caspian Terns, and Black Skimmers). The project comprises nine breakwater segments of various lengths — totaling 3,415 ft — with crest elevations of approximately three feet above the bay bottom. The constructed breakwaters protect the island’s existing seven acres of habitat and allow expansion of the island to 17.8 acres via natural accretion and beneficial placement of dredge material. Listed as a Tier 1 project in the GLO’s 2019 Texas Coastal Resiliency Master Plan, the project exemplifies Texas’ ecological resiliency initiatives.

Erosion of the island’s habitat has been ongoing for decades. The Coastal Bend Bays & Estuaries Program (CBBEP) installed geotextile tube breakwaters on the island’s north side in 2003 to address erosion and made efforts to restore eroded habitat through placement of dredge material on the Island in 2007, 2012, and 2017. In 2016, CBBEP received funding from the Texas Coastal Management Program (CMP) and CEPRA to identify a more resilient solution to address erosion and contain the placed dredge material, resulting in CEPRA Project #1685.

Figure 4.9 provides a location map. Figure 4.10 shows pre- and post-construction aerial imagery. Figure 4.11 shows the condition of a constructed breakwater from its crest and Figure 4.12 shows a subaerial view of the constructed breakwaters. Construction began in late December 2021 and ended in February 2022.

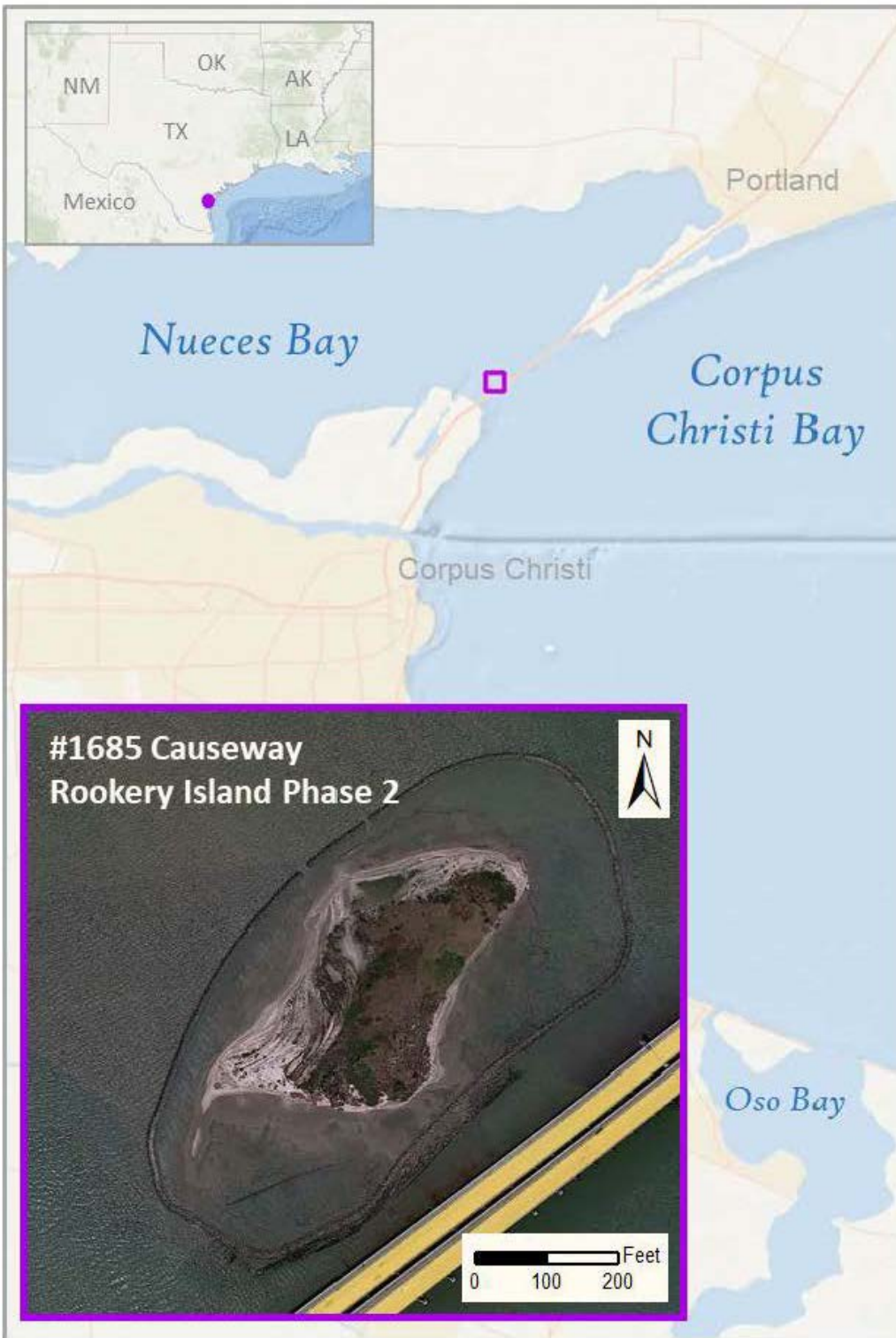




Figure 4.9 Location Map — Project #1685 Causeway Rookery Island Shoreline Protection Phase 2



Figure 4.10 Causeway Rookery Island Pre- and Post-construction (source: GLO)

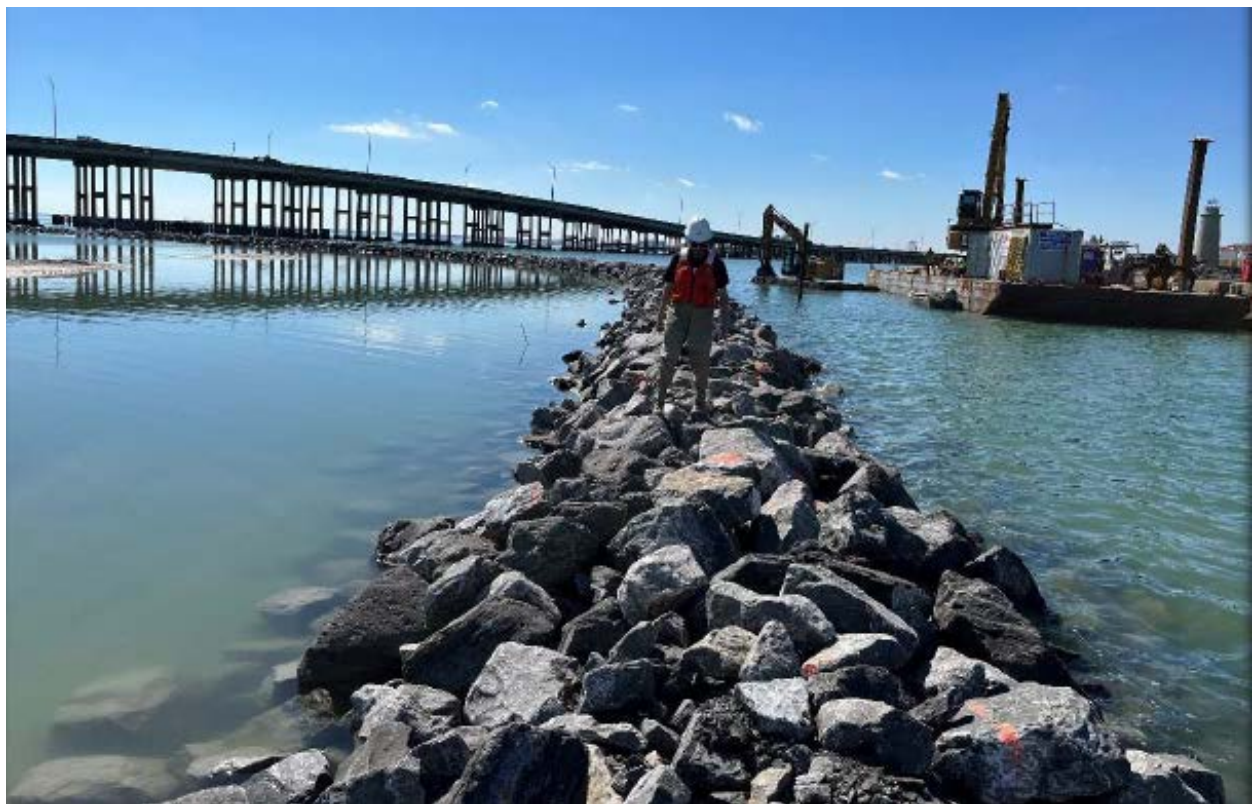


Figure 4.11 Typical Constructed Breakwater Conditions in 2022 (source: GLO)



Figure 4.12 Northeastward View of Completed Project in 2022 (source: GLO)

## 4.2.2 Project Funding

Table 4.6 presents the funding breakdown for the project. The GLO contributed CEPRA and GOMESA funds and the Coastal Bend Bays & Estuaries Program (CBBEP) provided matching funds. Federal funding did not occur. Of note, GOMESA funds derive from revenues generated by certain federal offshore leases; the U.S. Department of the Interior Office of Natural Resources Revenue disperses the funds to Texas, Louisiana, Mississippi, and Alabama in accordance with cost-sharing provisions specified in the act. However, Texas’ receipt of GOMESA funds does not depend on construction of any project (i.e., Texas would have received the funds with or without construction of Project #1685). Thus, this analysis treats GOMESA funding as a state source. Accordingly, the resulting cost to Texas for Project #1685 amounts to \$1,550,394. This analysis treats all costs as though they were incurred at the beginning of 2022, the year of construction, and reflect 2022 prices.

Table 4.6 Funding for Project #1685: Causeway Rookery Island Phase 2 (Cycle 11)

Funding Source		Amount
State/Local	GLO, CEPRA	\$42,000
	CBBEP	\$37,155
	GLO, GOMESA	\$1,471,239
Federal	N/A	N/A
Total Cost <i>(Texas Only)</i>		\$1,550,394 <i>(\$1,550,394)</i>

Notes: Value in bold italics represents cost to the State of Texas.

Values represent present worth, beginning of 2022

## 4.2.3 Benefit Analysis

Benefits for Project #1685 include ecosystem services.

### 4.2.3.1 Ecosystem Services Benefits

The constructed breakwaters provide ecosystem services benefits by preventing habitat erosion and allowing for future habitat accumulation by preventing erosion of periodically placed dredge materials. The following assumptions form the basis of the ecosystem services benefit analysis for Project #1685:



- The breakwaters will prevent erosion of the island, leading to accrual of ecosystem services benefits.
- The breakwaters will allow future placed dredged material to remain and increase the acreage of habitat, leading to additional accrual of ecosystem services benefits.
- Future dredge material placements will occur every five years, with or without the project, consistent with the average frequency of past events.
- Breakwater construction resulted in a loss of 2.4 acres of open water estuary.
- Consistent with prior evaluations of similar projects (Taylor Engineering, 2019), the project has a 20-yr life.
- With nearly all construction occurring in January 2022, full benefits start at the beginning of 2022 and the 20-yr life runs from 2022-2041.

Notably, the submerged portion of the breakwaters provides hard substrate habitat that could potentially accrue benefits over time; however, given the shallow water and corresponding minor acreage of the submerged portion, this analysis excludes the potential hard substrate habitat benefit.

Analysis of Google Earth high-resolution satellite images — for years 2022, 2020, 2019, 2017, 2016, 2014, 2011, 2008, and 2006 — helped determine the historic habitat boundary and annualized net gain or loss of habitat acreage. Table 4.7 lists the acquisition date of the images and sources. To facilitate georeferencing the aerial imagery, INTERA-GEC established nine ground control points in Google Earth, saved the points in KML file format, and converted the KML file to a layer file using ArcMap 10.8.1. Then, the authors geometrically rectified the images applying the ground control points and the NAD 1983 State Plane Texas South FIPS 4205 datum with second order polynomial transform algorithms also applied to the images. Identification of the island boundary occurred by computing RGB based vegetation indices (RGBVI and GLI) to differentiate land from water. Table 4.8 lists the island acreage associated with each aerial image and the rates of acreage change.

Table 4.7 Aerial Image Metadata

Acquisition Date	Image Source
07/08/2022	2022 Maxar Technologies
01/31/2020	Landsat/Corpernicus
01/18/2019	2022 Maxar Technologies
08/29/2017	Landsat/Corpernicus
12/16/2016	Landsat/Corpernicus
11/22/2014	Landsat/Corpernicus
11/22/2011	Landsat/Corpernicus
04/27/2008	Texas Orthoimagery Program
03/31/2006	U.S. Geological Survey

Table 4.8 Area Change Analysis Results

Analysis Year	Causeway Rookery Island Area (acres)	Net Area Change from Prior Analysis Year (acres)	Annualized Rate of Change from Prior Analysis Year (acres/yr) <sup>3</sup>
2022	5.84	-0.46	-0.19
2020	6.30	-0.32	-0.31
2019	6.62	-0.36	-0.26
2017 <sup>1</sup>	6.98	1.68	2.40
2016	5.30	-1.92	-0.93
2014 <sup>1</sup>	7.22	0.63	0.21
2011	6.59	-1.28	-0.36
2008 <sup>1</sup>	7.87	4.88	2.35
2006	2.99	-	-
Average Erosion (excluding dredge material placements) <sup>2</sup>			-0.4

<sup>1</sup>Accretion reflects the effect of dredge material placement in 2007, 2012, and 2017

<sup>2</sup>Excludes 2016-2017, 2011-2014, and 2006-2008 values

<sup>3</sup>Annualized rates of change calculated with actual dates of aerial imagery

Prior dredge material placement events occurred in 2007, 2012, and 2017. In Table 4.8, the acreage increases for 2016-2017, 2011-2014, and 2006-2008 reflect the temporary habitat accumulation from these events. The accumulation values (net positive changes) associated with these events range widely from approximately one to five acres. Excluding the above accumulation values and averaging the annualized erosion rates occurring between placement events yields an erosion rate of 0.4 acres/yr. Based on the prior five-year frequency of placement events and the goal of accumulating approximately 10 acres over the project life (Section 4.2.1), this analysis assumed future dredge material placements will occur every five years and create 2.5 acres per event beginning in 2024 for both with and without the project. The above assumption results in 10 acres created during the 20-year project life for the with-project condition; for the without-project condition, the created acreage erodes at 0.4 acres/yr, resulting in continued cycles of accretion and erosion with minimal long-term net change.

Table 4.9 details the annual ecosystem services benefits from habitat protection, and Table 4.2.5 details the value of lost open water ecosystem services. Adjusting coastal wetlands ecosystem services values to 2022 price levels provided a value of \$10,175.98/acre for this project evaluation. Converted to 2022 prices, open water ecosystem services are valued at \$5.89/acre. Section 2.3 describes the value per acre for both coastal wetlands and open water. The net value of ecosystem services—the discounted value of habitat erosion prevented (\$615,651) less the value of open water habitat lost (\$221) — resulting from Project #1685 equals \$615,430 (present worth, beginning of 2022).



Table 4.9 Project #1685 Ecosystem Services Value – Habitat Preserved

Year	Change in Habitat (acres)				Net Habitat Preserved with Project (acres)	Annual Value of Habitat Preserved <sup>1</sup>			Cumulative Discounted Present Worth, Beginning of 2022
	With Project		Without Project			Values (2022 Prices) <sup>1</sup>	With Inflation <sup>2</sup>	Discounted Present Worth, Beginning of 2022 <sup>3</sup>	
	Annual	Cumulative	Annual	Cumulative					
2022	0	0	-0.4	-0.4	0.4	\$4,070	\$4,070	\$3,977	\$3,977
2023	0	0	-0.4	-0.8	0.8	\$8,141	\$8,320	\$7,760	\$11,737
2024	2.5	2.5	2.1	1.3	1.2	\$12,211	\$12,754	\$11,357	\$23,095
2025	0	2.5	-0.4	0.9	1.6	\$16,282	\$17,380	\$14,774	\$37,869
2026	0	2.5	-0.4	0.5	2.0	\$20,352	\$22,203	\$18,018	\$55,888
2027	0	2.5	-0.4	0.1	2.4	\$24,422	\$27,230	\$21,096	\$76,983
2028	0	2.5	-0.4	-0.3	2.8	\$28,493	\$32,467	\$24,013	\$100,996
2029	2.5	5.0	2.1	1.8	3.2	\$32,563	\$37,921	\$26,775	\$127,771
2030	0	5.0	-0.4	1.4	3.6	\$36,634	\$43,600	\$29,388	\$157,159
2031	0	5.0	-0.4	1.0	4.0	\$40,704	\$49,510	\$31,859	\$189,018
2032	0	5.0	-0.4	0.6	4.4	\$44,774	\$55,659	\$34,192	\$223,210
2033	0	5.0	-0.4	0.2	4.8	\$48,845	\$62,055	\$36,392	\$259,602
2034	2.5	7.5	2.1	2.3	5.2	\$52,915	\$68,705	\$38,465	\$298,067
2035	0	7.5	-0.4	1.9	5.6	\$56,986	\$75,618	\$40,415	\$338,482
2036	0	7.5	-0.4	1.5	6.0	\$61,056	\$82,802	\$42,248	\$380,730
2037	0	7.5	-0.4	1.1	6.4	\$65,126	\$90,265	\$43,968	\$424,698
2038	0	7.5	-0.4	0.7	6.8	\$69,197	\$98,017	\$45,578	\$470,276
2039	2.5	10	2.1	2.8	7.2	\$73,267	\$106,065	\$47,085	\$517,361
2040	0	10	-0.4	2.4	7.6	\$77,337	\$114,421	\$48,490	\$565,851
2041	0	10	-0.4	2.0	8.0	\$81,408	\$123,093	\$49,800	\$615,651

<sup>1</sup>The coastal wetlands ecosystem service value = \$10,175.98/acre (2022 prices)

<sup>2</sup>Inflation adjustments equal 2.2% annually

<sup>3</sup>Present worth, beginning of 2022, based on mid-year discounting; mid-year discount factor =  $(1/1.0475)^{n+0.5}$ , where n = year – 2022; discount rate = 4.75%

Table 4.10 Project #1685 Ecosystem Services Value – Open Water Loss

Year	Open Water Area Lost (acres)	Annual Value Lost			Cumulative Discounted Present Worth, Beginning of 2022
		Value (2022 Prices) <sup>1</sup>	With Inflation <sup>2</sup>	Discounted Present Worth, Beginning of 2022 <sup>3</sup>	
2022	2.4	\$14	\$14	\$14	\$14
2023	2.4	\$14	\$14	\$13	\$27
2024	2.4	\$14	\$15	\$13	\$40
2025	2.4	\$14	\$15	\$13	\$53
2026	2.4	\$14	\$15	\$13	\$66
2027	2.4	\$14	\$16	\$12	\$78
2028	2.4	\$14	\$16	\$12	\$90
2029	2.4	\$14	\$16	\$12	\$102
2030	2.4	\$14	\$17	\$11	\$113
2031	2.4	\$14	\$17	\$11	\$124
2032	2.4	\$14	\$18	\$11	\$135
2033	2.4	\$14	\$18	\$11	\$145
2034	2.4	\$14	\$18	\$10	\$156
2035	2.4	\$14	\$19	\$10	\$166
2036	2.4	\$14	\$19	\$10	\$175
2037	2.4	\$14	\$20	\$10	\$185
2038	2.4	\$14	\$20	\$9	\$194
2039	2.4	\$14	\$20	\$9	\$203
2040	2.4	\$14	\$21	\$9	\$212
2041	2.4	\$14	\$21	\$9	\$221

<sup>1</sup>The open water value equals \$5.89/acre (2022 prices)

<sup>2</sup>Inflation adjustments equal 2.2%

<sup>3</sup>Present worth, beginning of 2022, based on mid-year discounting; mid-year discount factor =  $(1/1.0475)^{n+0.5}$ , where n = year – 2022; discount rate = 4.75%

#### 4.2.4 Benefit Cost Summary

The sole benefit category, ecosystem services, provides a total benefit of \$615,430, accrued throughout the twenty-year project life. Dividing the total project benefits value by the total Texas project cost (\$1,550,394) results in a benefit-cost ratio of 0.4 (Table 4.11).



Table 4.11 Benefit-Cost Summary — #1685 Causeway Rookery Island Shoreline Protection Phase 2

Benefits and Costs	Discounted Present Worth (beginning of 2022) <sup>2</sup>
Total Benefit	\$615,430
Ecosystem Services Benefit	\$615,430
Total Cost <sup>1</sup>	\$1,550,394
B/C Ratio	0.4

Notes: <sup>1</sup>Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)

<sup>2</sup>Dollar values represent present worth equivalents at the beginning of 2022 with a 4.75% discount rate

## 5.0 Conclusions

This study finds the state of Texas receives \$3.0 in economic and financial benefits for every Texas dollar invested in these projects. Table 5.1 presents a summary of the assessed CEPRA Cycles 10–11 projects, which is a representative sampling of the CEPRA program.

The leveraging of federal participation plays a substantial role in the economic benefit calculations for several projects. For example, the low Texas cost of #1637: Galveston Island State Park Phase 3 reflects a substantial contribution from NFWF, which covered 98.4% of the total project costs. As another example, the low Texas cost of the #1702: Isla Blanca Park Beach Nourishment with BUDM reflects the substantial cost savings from partnership with USACE for the beneficial use of dredged material from maintenance dredging of the shipping channel. This project placed beach fill at an effective unit cost of \$5.93/cy of beach fill, far below typical industry costs. Even without including federal spending as a benefit — federal spending would be the same with or without the project as the federal dredging project would occur with or without the beach nourishment — the project achieved a benefit-to-cost ratio of 7.5.

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. Two of the six evaluated projects realized these benefits as follows. Galveston Island State Park Phase 3 experienced federal spending benefits (\$6,264,485 discounted present worth) from NFWF as mentioned above. Similarly, Funding provided by FEMA led to significant federal spending benefits for #1665: Corpus North Beach Harvey Repair (\$842,788; present worth, beginning of 2023).

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

As stated in the text, this study attempted to restrict costs and benefits to those affecting only Texas. Nevertheless, some of the information necessarily has spillover effects to the rest of the nation and to the rest of the world. This occurrence is especially true of ecosystem service values. Evaluation work intentionally applied "low estimates" for ecosystem service values to avoid overstating the monetized economic effects. Though the applied values possibly underestimate the ultimate magnitude of these effects, prudence dictates adopting a conservative approach considering the uncertainty involved in quantifying ecosystem service values. Overall, cost and benefit information and potentially some of the engineering calculations applied in this study are subject to variation. Values can vary widely, resulting in different outcomes and overall conclusions. The methodology and assumptions documented in this report strive to achieve the best estimates representing the CEPRA program.



Table 5.1 Summary of CEPRA Cycle 11 Construction Project Costs and Benefits

CEPRA Project	County	Project Year <sup>1</sup>	Discounted Present Worth, Beginning of Project Year		Discounted Present Worth, Beginning of 2022 <sup>3</sup>		Benefit-to-Cost (B/C) Ratio	
			Cost <sup>2</sup>	Benefits	Cost	Benefits		
#1637: Galveston Island State Park Phase 3 (Cycle 10)	Galveston	2021	\$575,296	\$7,193,585	\$602,623	\$7,535,280	12.5	
#1653: South Padre Island Beach Nourishment with BUDM (Cycle 11)	Cameron	2021	\$1,530,000	\$6,889,481	\$1,602,675	\$7,216,731	4.5	
#1665: Corpus North Beach Harvey Repair (Cycle 10)	Nueces	2023	\$141,208	\$1,647,085	\$141,208	\$1,647,085	11.7	
#1685: Causeway Rookery Island Phase 2 (Cycle 11)	Nueces	2022	\$1,550,394	\$615,430	\$1,550,394	\$615,430	0.4	
#1693: Babe’s Beach BUDM (2021 BUDM Cycle) (Cycle 11)	Galveston	2021	\$12,000,000	\$28,361,072	\$12,570,000	\$29,708,223	2.4	
#1702: Isla Blanca Park Beach Nourishment with BUDM (Cycle 11)	Cameron	2021	\$510,000	\$3,814,534	\$534,225	\$3,995,724	7.5	
<b>Total<sup>4</sup></b>						\$17,001,125	\$50,718,474	3.0
Notes: <sup>1</sup> Project Year represents the year benefits begin to accrue and may not represent the actual construction year. <sup>2</sup> Texas portion only; dollar values reflect present worth equivalents at the beginning of Project Year. <sup>3</sup> Dollar values reflect present worth equivalents at the beginning of 2022 with a 4.75% discount rate. <sup>4</sup> Total B/C Ratio represents the total discounted benefits divided by the total discounted cost of all six projects combined (\$50,718,474 / \$17,001,125 = 3.0).								

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