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

Texas

June 2015

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

Prepared for

Texas General Land Office

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by

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EXECUTIVE SUMMARY

The Texas Legislature requires the General Land Office (GLO) to report the economic and natural resource benefits derived from Coastal Erosion Planning and Response Act (CEPRA) construction projects every biennium. Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. This study finds the state of Texas receives $3.40 in economic and financial benefits for every dollar of state funding invested in these projects. This result is based on analysis of the following five CEPRA Cycle 6 – 8 projects, which is a representative sampling of the CEPRA program:

- #1382 CR 257 Road Repair and Protective Revetment (Cycle 6)
- #1463 Port Aransas Nature Preserve Shoreline Protection Repair (Cycle 6)
- #1532 Sargent Beach Nourishment (Cycle 7)
- #1565 Nueces Bay Portland Causeway Marsh Restoration (Cycle 7)
- #1584 GIWW Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material (BUDM) Fiscal Year (FY) 2014 event (Cycle 8)

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

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

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

Table E.1 Summary of CEPRA Cycles 6 – 8 Projects, Costs, and Benefits

CEPRA Project Number / Name	County	Year	Beginning of Project Year		Beginning of 2015[2]		Benefit-to-Cost (B/C) Ratio
			Discounted Cost[1]	Discounted Benefits	Discounted Cost[1]	Discounted Benefits	
#1382 / CR 257 Road Repair and Protective Revetment	Brazoria	2012	$7,387,294	$32,447,799	$8,133,580	$35,725,771	4.4
#1453 / Port Aransas Nature Preserve Shoreline Protection Repair	Nueces	2013	$256,146	$2,016,243	$273,119	$2,149,845	7.9
#1532 / Sargent Beach Nourishment	Matagorda	2013	$3,796,450	$428,130	$4,048,013	$456,499	0.1
#1565 / Nueces Bay Portland Causeway Marsh Restoration	San Patricio/ Nueces	2013	$753,957	$6,364,042	$803,916	$6,785,741	8.4
#1584 / GIWW-Rollover Bay Reach Beach Nourishment with BUDM FY 2014 Event	Galveston	2014	$198,360	$29,920	$204,827	$30,895	0.2
Total[3]					$13,463,455	$45,148,750	3.4

Notes: [1]Texas portion only; dollar values reflect present worth equivalents at the beginning of the year of project construction.
[2]Dollar values reflect present worth equivalents at the beginning of 2015 with a 3.26% discount rate; Total Discounted Cost = Texas Cost * $1.0326^{(2015 - y)}$, where y = Project Year.
[3]Total B/C Ratio represents the Total Discounted Benefits divided by the Total Discounted Cost of all five projects combined (i.e., $45,148,750 / $13,463,455 = 3.4).

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the shoreline protection at Port Aransas Nature Preserve reflects contributions from the Federal Emergency Management Agency (FEMA) Public Assistance program, which covered 90% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.15 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits. The Port Aransas Nature Preserve Shoreline Protection Repair Project experienced federal spending benefits ($1,528,789 discounted present worth) from FEMA funding as mentioned above. Similarly, Nueces Bay Portland Causeway Marsh Restoration experienced federal spending benefits ($3,228,683 discounted present worth) from funding by the U.S Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the Coastal Impact Assistance Program (CIAP). The CR 257 Road Revetment Project experienced federal spending benefits ($20,029,527 discounted present worth) from the Federal Highway Administration and CIAP.

As a final note, a discount rate of 3.26% was used in the benefit cost calculations to convert benefits and costs occurring at different points in time to comparable equivalent values ("discounted present worth") for comparison at the beginning of each project's period of analysis. In Table E.1, the discounted present worth of benefits and costs is also converted to equivalent values at a common point in time, 2015. This makes the benefits and costs of the different projects comparable and additive, allowing them to be viewed as a portfolio. The discount rate chosen for this study represents a mid-range average of 20-year AAA corporate bond rates existing at the time of study initiation.

ACKNOWLEDGEMENTS

The authors extend their appreciation to the following individuals and agencies for their efforts. Mr. Thomas Durnin and Mr. Michael Weeks of the GLO offered valuable insight into the projects and provided much data and contacts needed to perform the benefit analysis. Diedre Williams with Texas A&M University provided site-specific survey data. Brazoria County staff provided information regarding temporary road repairs following Hurricane Ike.

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1.0 INTRODUCTION

1.1 Purpose

Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. To address the significant erosive threat to Texas coastal areas, the 76th Texas Legislature passed the Texas Coastal Erosion Planning and Response Act (CEPRA) in 1999. The CEPRA program, in concert with local and other project partners, invests significant state resources to control coastal erosion. Funded biennially in accordance with the state's budget cycles, the CEPRA program has allocated approximately $83 million combined for Cycle 1 – 7 projects, covering state fiscal years 2000 – 2013. The Texas General Land Office (GLO) has created project partnerships between federal, state, and local entities, which have matched the Cycle 1 – 7 CEPRA funds with an additional $37 million from other state and local resources and $141 million in federal funds, resulting in a total investment of approximately $261 million. The GLO applies CEPRA funds for beach nourishment projects, dune restoration projects, shoreline protection projects, habitat restoration/protection, coastal research and studies, and estuary programs. Funding for erosion control projects continued in Cycle 8 (state fiscal year [FY] 2014 – 2015) by allocating about $14.8 million to fund 21 erosion response projects and studies.

The Texas Legislature requires the GLO to report the economic and natural resource benefits derived from CEPRA construction projects every biennium. The GLO contracted Taylor Engineering, Inc. — under GLO Contract No. 13-333-013 and Work Order No. 8827 — to perform the benefit-cost analyses for selected Cycles 6 – 8 construction projects. This study analyzed the following five CEPRA projects:

- #1382 CR 257 Road Repair and Protective Revetment (Cycle 6)
- #1463 Port Aransas Nature Preserve Shoreline Protection Repair (Cycle 6)
- #1532 Sargent Beach Nourishment (Cycle 7)
- #1565 Nueces Bay Portland Causeway Marsh Restoration (Cycle 7)
- #1584 GIWW Rollover Bay Reach Beach Nourishment w/Beneficial Use of Dredged Material (BUDM) FY 2014 event (Cycle 8)

These projects represented $12.4 million out of a collective $37.7 million ($7.4 million for Cycle 6, $15.5 million for Cycle 7, and $14.8 million for Cycle 8) allocated for funding coastal erosion projects and studies during Cycles 6 – 8. Figure 1.1 presents a map of the projects' locations along the Texas coast. These projects include two beach restoration projects, a roadway protection project, and two shoreline protection projects associated with natural resource protection/creation. This report serves to estimate the cost-effectiveness of the five projects listed above via benefit-to-cost ratios.

1.2 Report Scope

This report discusses the methodology and results of the natural resource and economic benefit analyses for select projects constructed during Cycles 6 – 8. 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 the two beach restoration projects and the roadway protection project. Chapter 4 discusses benefits and costs related to the shoreline protection projects associated with natural resource protection/creation. Chapter 5 summarizes and concludes the report.

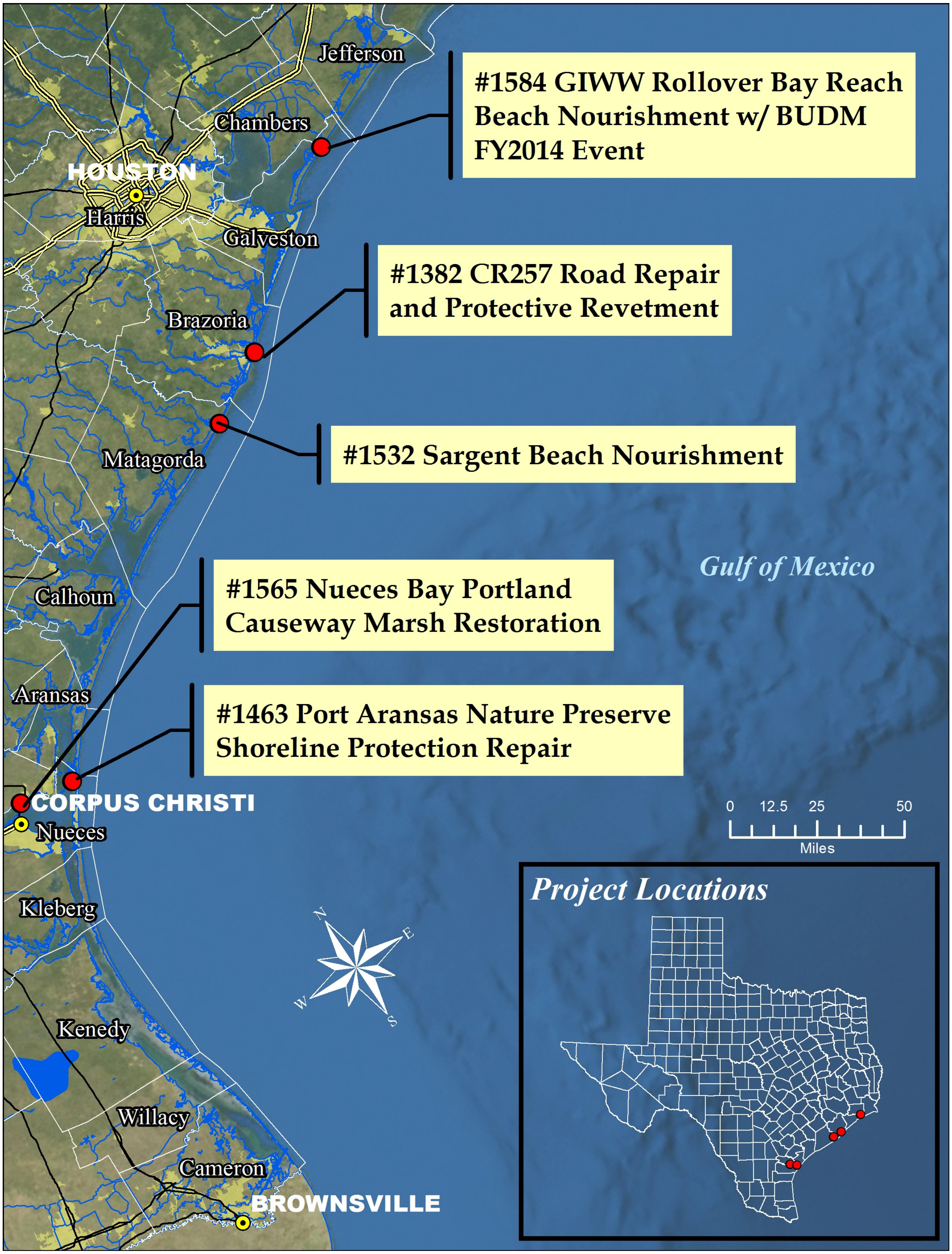

Figure 1.1 Location Map of Cycles 6 – 8 Subject Projects

2.0 ECONOMIC AND NATURAL RESOURCE BENEFITS METHODOLOGY

2.1 General Concepts

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

Overall, benefits and costs represent the estimated difference, over the period of analysis, between conditions with the project and conditions without the project. Adjusting each year's benefits and costs reflects then-current price levels with an assumed annual inflation rate derived from the consumer price index (CPI) (http://www.minneapolisfed.org/community_education/teacher/calc/hist1913.cfm) for historical years and long-term forecasts by the Federal Open Market Committee of the U.S. Federal Reserve and the Congressional Budget Office for years beyond 2014. Table 2.1 summarizes these rates. An annual discount rate of 3.26% (reflecting a mid-range average of 20-year AAA corporate bond rates at the time of this study) converts values occurring at different points in time to comparable equivalent values, adjusting for the time value function. The reference point in time for this discounting, or present worth adjustment calculation, is the beginning of the first year of the project life for each project. This point varied among projects (beginning of 2012, 2013, or 2014). After all benefit cost calculations are complete for the different projects included in this study, further present worth adjustments are made to express benefit cost analysis results at the beginning of 2015 (i.e., as of the same point in time). This enables the portfolio of projects in this report to be additive and comparable.

Table 2.1 Price Level Adjustment Information

Year	Annual Average Consumer Price Index	Annual Inflation from Previous Year (%)
2004	188.9	2.7
2005	195.3	3.4
2006	201.6	3.2
2007	207.3	2.8
2008	215.3	3.9
2009	214.5	-0.4
2010	218.1	1.7
2011	224.9	3.1
2012	229.6	2.1
2013	233.0	1.5
2014	236.7	1.6
2015	--	1.8
2016	--	1.8
Beyond 2016	--	2.0

Present value factors, based on the 3.26% discount rate, convert values at different points in time to comparable values at the same point in time. In these evaluations, the beginning of the period of analysis represents the point in time used for these discounting calculations. The key to this discounting process, or present value conversion, is equivalence. For example, a benefit accruing in year five is equivalent to its discounted value at the beginning of year one. Discounting reflects the concept that values received or spent in the future are worth less than those received or spent now because of interest. Interest reflects a combination of two effects: (1) changes in prices (inflation), and (2) the time value preference function (i.e., even without any inflation an interest rate still exists because a dollar now is preferable to a dollar later). These analyses include inflation in the estimates of benefits accruing over time.

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

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

This study treats costs as single point-in-time values at the beginning of the period of analysis. The analyses exclude a time value adjustment to reflect the actual pattern of project implementation spending that occurred over time because of the relatively short project implementation period (less than a year). The effect of that adjustment would prove insignificant.

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

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

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

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

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

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

One may also estimate a similar effect to account for any federal spending that may occur as part of initial project construction or recurring annual operations (e.g., maintenance and inspection), because a major portion of federal spending taking place within Texas represents a net increase inflow of spending for the state economy. However, one must reduce the amount of initial federal spending to account for contributions to federal tax revenues from individuals and businesses in Texas. Applying the ratio of the state of Texas population to the U.S. population total as a proxy for this effect (approaching 10%), an estimated net multiplier effect to apply to any such spending would equal federal spending times 0.9 times 1.4, or federal spending times 1.26. This federal spending would represent an estimated net economic financial benefit to the Texas economy.

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

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

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

2.2 Beach Restoration and Shoreline Protection Projects

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

“Hard” shoreline protection projects, such as the CR 257 revetment, typically limit the landward extent of erosion. These rock or concrete structures, typically sloped, induce wave breaking and loss of wave energy during the wave runup process and, therefore, limit reflection of wave energy from shore. Rock revetments typically consist of two or more layers of rock with the upper, larger rock providing stability against wave attack. A properly-designed revetment must ensure that the lower, smaller rock does not wash out through the upper layers. Should this occur, the revetment may lose elevation, and therefore its protective capabilities, through settlement.

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

2.2.1 Storm Damage Reduction Benefits

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

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

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

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

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

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

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

Analyses necessitated computing damages due to background erosion and storms for each project year. For years 2012 – 2014, no tropical storms significantly affected the project areas. For 2015 and beyond, this study modeled the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for each future year’s shoreline position.

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

Following similar USACE methods, this analysis distinguishes between slab-on-grade and pile-supported structures. It assumes damage to slab-on-grade structures occurs when the shoreline recedes landward of the seaward edge of the structure and that total damage occurs when the shoreline recedes halfway through the structure. Note that many post-storm observations (e.g., GEC, 2005) revealed that mid- and high-rise residential buildings with robust structural systems and on deep foundations tend to sustain inundation and wave damage only to the lowest floors, with upper floors remaining intact and undamaged by flood. Accordingly, this study assumes damage occurs to pile-supported structures (with two or more stories that likely have deep foundations) when the shoreline recedes landward of the seaward edge of the structure and that total damage (damage to the lowest two stories only) occurs when the shoreline recedes to the landward edge of the structure. Figure 2.1 presents a typical damage function curve for these two structure types. For example, given erosion extends 35% into a slab-on-grade structure's footprint and the structure appraises at $200,000, this structure sustains 70% damage or $140,000 worth of damage with the above assumptions applied.

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

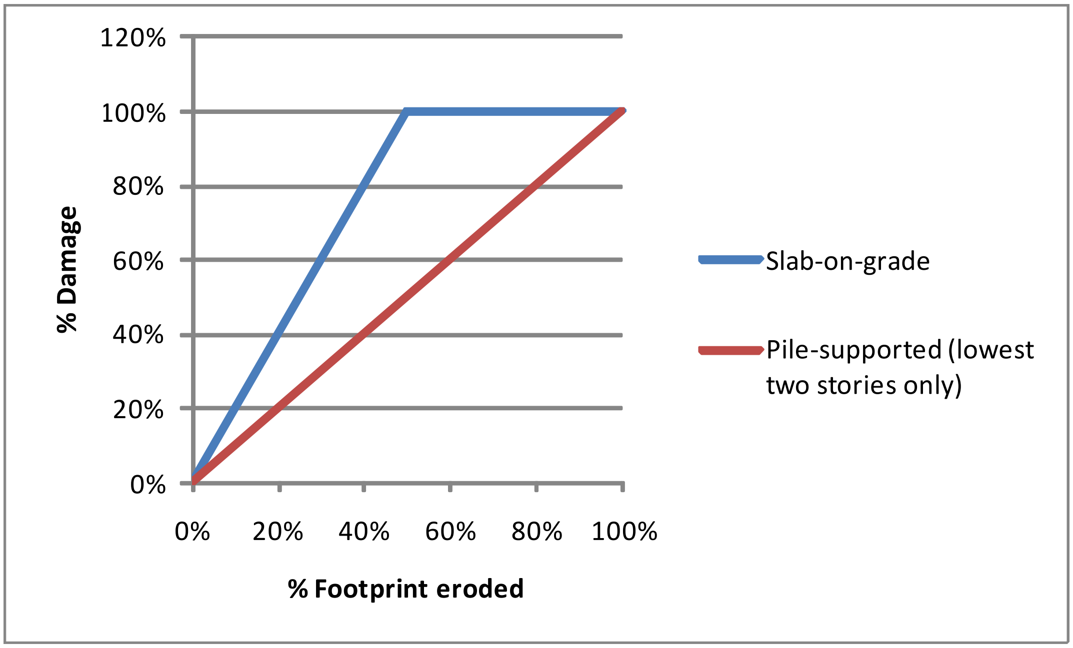

Figure 2.1 Structure Damage Functions

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

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

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

After modeling the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for a particular year's shoreline position, one may develop a damage-cumulative probability curve similar to Figure 2.2. The area under the damage-cumulative probability curve then establishes the expected annual damage for the year. Calculating the area under the curve requires averaging the total damage between adjacent damage points and multiplying by the probability interval between cumulative probabilities corresponding to the damage points (i.e., the trapezoidal integration method). By way of an example, Figure 2.2 shows two labeled points on the damage-cumulative probability curve. The area (valued at $792,000) under the portion of the curve bound by the two points equals the average of $4,900,000 and

$380,000 ($2,640,000) times the difference of 0.8 minus 0.5 (0.3). Following this procedure and summing the individual results produces the total area under the curve (i.e., expected annual damage for that year).

Note the expected annual damage will not necessarily occur in a particular year. Rather, over a long time period, the average damage will approach this expected value. The damage-cumulative probability relationship changes every year because background erosion moves the shoreline landward every year. Accounting for this erosive beach behavior requires calculating damage-cumulative probability curves for each project year throughout the period of analysis. Furthermore, this analysis, consistent with USACE practice, assumes the repair of the preceding year's structural damage before each subsequent year. For example, say a total expected annual damage equals $2,000,000 including $1,250,000 in structural damage and $750,000 in land loss in 2011. Before 2012, this analysis assumes repair of the $1,250,000 structural damage such that the damage could occur again in 2012. Only the land loss ($750,000) becomes ineligible for future years' damage (or benefit). The total project benefit for a given year represents the difference in the expected value of storm damage between without- and with-project conditions.

Table 2.2 presents an example damage-cumulative probability distribution for a given year's without-project conditions. Calculating the expected average interval damage requires three steps. First, average two adjacent total damage estimates of different return period storms. For example, the total damage for ten- and twenty-year return period storms equals $8,337 and $87,236 based on model simulations. The average of these two values equals $47,786. Next, determine the interval probability (0.05) by subtracting the cumulative probability value for the ten-year (0.90) from the twenty-year (0.95) return period storm. Third, multiply the average interval damage ($47,786) by the interval probability (0.05) to yield the expected value interval damage ($2,389). Repeating these calculations for each expected value interval damage calculation and summing produces the expected average annual damage for a given year and project condition. Performing this procedure for each year in the period of evaluation for conditions with and without the project results in expected value annual damages for each year with and without the project. Table 2.3 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.

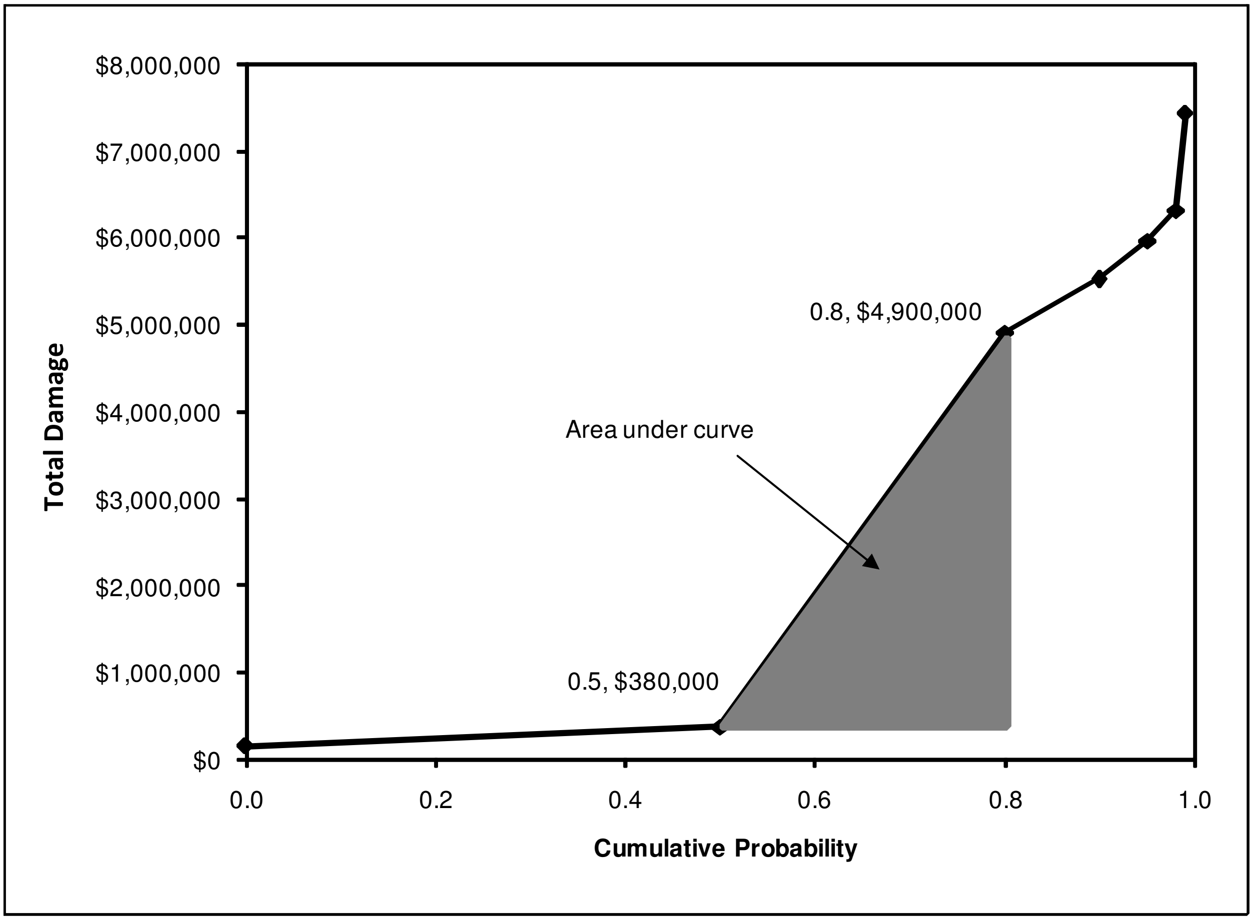

Figure 2.2 Example Damage-Cumulative Probability Curve for a Given Year

Table 2.2 Example of Total Damage-Cumulative Probability (Year 2, without Project)

Tr[1] (yrs)	Probability of Occurrence	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0	$0	--	--	--
2	0.50	0.50	$0	$0	$0	$0	0.50	$0
5	0.20	0.80	$0	$0	$0	$0	0.30	$0
10	0.10	0.90	$8,337	$0	$8,337	$4,168	0.10	$417
20	0.05	0.95	$87,236	$0	$87,236	$47,786	0.05	$2,389
50	0.02	0.98	$193,707	$0	$193,707	$140,472	0.03	$4,214
100	0.01	0.99	$207,832	$0	$207,832	$200,769	0.01	$2,008
>100	<0.01	>0.99	$207,832	$0	$207,832	$207,832	0.01	$2,078
			Expected Average Annual Damage in 2013 Prices:					$11,106

Table 2.3 Example of Storm Damage Reduction Benefit Calculation

Year	Without Project (2013 Prices)	With Project (2013 Prices)	Difference (Benefit)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
2013	$11,040	$6,678	$4,362	$4,362	$4,279	$4,279
2014	$11,106	$6,912	$4,194	$4,269	$4,030	$8,309
2015	$11,375	$7,618	$3,758	$3,894	$3,537	$11,846
2016	$12,953	$7,742	$5,212	$5,509	$4,815	$16,662
2017	$12,921	$7,659	$5,261	$5,673	$4,772	***$21,433***

Notes: [1]Tr = return period; e.g., a 5-yr return period storm has a 20% probability of occurrence in any given year. Inflation rates: 1.6% for 2013 – 2014, 1.8% annually for 2014 – 2016, and 2.0% annually beyond 2016. Present worth values represent equivalent values, beginning of 2013, 3.26% discount rate (mid-year discounting)

2.2.2 Beach Visitation Benefits

For beach visitation benefits, this study evaluated two categories — spending by out-of-state visitors and recreational enjoyment by all visitors. To develop with- and without-project out-of-state visitor spending estimates requires knowing annual out-of-state visitation, out-of-state visitor spending, and how the with- and without-project conditions affect beach width for each year in the period of analysis. Oden and Butler (2006) report out-of-state visitation by percentage of the total beachgoer population, total number of peak day visitors, and spending for various beach sites throughout Texas — including Galveston Island and South Padre Island beaches — based on site-specific beachgoer surveys. Based on these same surveys, Oden and Butler note that people will visit out-of-state beaches instead of Texas beaches if the Texas beaches become increasingly narrower. Note that Oden et al. (2003) report the number of peak visitor days during the year for South Padre Island. Other project analyses assume a number of peak visitor days based on the traditional Memorial Day to Labor Day period, or no peak period. All analyses assume beach visitation increases at the same rate as general population growth, approximately 1.4%/year (reflecting a long-term weighted average of Texas and U.S. forecast growth, based on the observation that visitors from outside the state generally approach 10% of all visitors). This growth forecast reflects downward revised projections following the 2010 Census.

This study assumes that out-of-state visitor spending per person is the same for both with- and without-project conditions. Increasing the beach visitation each year by the general population growth rate (1.4%/year) produced estimates of beach population assuming the beach has the capability to accommodate this beach population growth. Because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches. Calculating the beachgoer population each year (adjusted for beach narrowing) and multiplying by the out-of-state spending times the 1.4 multiplier effect produces the value for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.4, in bold italic) over the period of analysis.

Based on 2004 and 2005 site-specific beachgoer surveys, Oden and Butler estimate beach visitation with respect to beach width "elasticity," which measures the percentage change in annual visitation given a percentage change in beach width, at South Padre Island and Galveston and Surfside area beaches. These surveys revealed that the elasticity coefficient of visitation with respect to beach width equals -0.22 at South Padre Island and -0.28 at Galveston and Surfside area beaches. These elasticity values mean that should the beach become one-half as wide (50% reduction in beach width), people will reduce their annual beach visits by 11% (i.e., 50% * 0.22) at South Padre Island and 14% (i.e., 50% * 0.28) at Galveston and Surfside area beaches. In short, a 0.22% visitor reduction at South Padre Island and a 0.28% visitor reduction at Galveston and Surfside area beaches occurs for every 1% loss of beach width.

The elasticity relationships described above may differ from today's condition. New beachgoer surveys might reveal different visitor preferences. No credible method, however, exists to adjust these relationships to reflect today's visitors and conditions. As such, this study applied established (although possibly dated) relationships.

Regarding reduced visitation as a beach narrows, some minimal low level of visitation would likely still occur even if erosion reduced the beach width to near zero. For example, people may, even with no beach, come to the shore to surf, fish, swim, or view wildlife. Acknowledging this concept requires prescribing a minimal level of visitation at 100% beach width loss. This study adopts 20 – 30% beach visitation (or 70 – 80% reduction in beach visitation) at 100% beach loss. Without this assumption, application of only the Oden and Butler relationship between beach loss and visitation reduction would result in unrealistically and unlikely high beach visitation with complete beach loss. This unrealistically high visitation occurs because Oden and Butler based their evaluation on a survey question as to how beach visitation would change with a 50% loss in beach width; the survey did not focus on complete beach loss. This study elected to use the Oden and Butler relationship for up to 80% beach width loss, then apply an assumed linear relationship between that level of visitation reduction (for 80% loss of beach width) and 70 – 80% reduction in visitation at 100% beach loss. This assumption likely results in a more

Table 2.4 Example of Out-of-State Beach Visitor Benefit Calculation

Year	Total Visitation		Out of State				Difference (2013 Prices)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
			Visitation		Visitor Spending					
	With Project	Without Project	With Project	Without Project	With Project	Without Project				
2013	160,610	149,333	30,355	28,224	$3,471,168	$3,227,448	$243,720	$243,720	$239,079	$239,079
2014	162,859	149,366	30,780	28,230	$3,519,765	$3,228,148	$291,616	$296,865	$280,228	$519,307
2015	165,139	149,370	31,211	28,231	$3,569,041	$3,228,236	$340,805	$353,185	$320,815	$840,122
2016	167,450	149,344	31,648	28,226	$3,619,008	$3,227,693	$391,315	$413,640	$361,556	$1,201,677
2017	169,795	149,289	32,091	28,216	$3,669,674	$3,226,502	$443,172	$477,824	$401,904	***$1,603,581***

Notes: Out-of-state visitation = 18.3% of total visitation
Out-of-state visitor spending = $81.68 per person (2013 prices)
Multiplier effect = 1.4
Inflation rates: 1.6% for 2013 – 2014, 1.8% annually for 2014 – 2016, and 2.0% annually beyond 2016
Present worth beginning of 2013, 3.26% discount rate, mid-year discounting

realistic relationship than would have been the case with a large discontinuity at the assumed 70 – 80% visitation reduction at 100% beach loss.

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

The other category of visitation benefits includes recreation value for all visitors. Estimating this category of benefits requires knowing the total annual beach visitation with and without the project and the unit day value (UDV). The UDV method (USACE, 2014) relies on expert or informed opinion and judgment to approximate the average "willingness to pay" of visitors (per person per visit) to recreational project sites. The UDV method assigns points to general recreation based on five criteria: (1) recreation experience, (2) availability of opportunity, (3) carrying capacity, (4) accessibility, and (5) environmental. One rates an individual site based on a total of 100 points. Table 2.5 presents the guidelines for assigning points. Table 2.6 facilitates converting points to dollar values for general recreation.

Assessing both with- and without-project conditions generates the points for each general recreation category in Table 2.5. Summing these points and interpolating that point value against the values shown in Table 2.6 yields with- and without-project UDVs. Applying the beachgoer population for with- and without-project conditions each year, multiplying by the appropriate UDV, and then taking the difference produces the estimated benefit for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.7, in bold italic) over the period of analysis.

This paragraph presents an example of how to assign points to a typical beach area common to the Texas coast. In this example, a beach can accommodate a variety of activities including swimming, surfing, snorkeling, fishing, picnicking, sunbathing, and other active and passive activities. Further, no high quality value activities, defined as activities not common to the region, exist. Accordingly, one could assign a recreation experience value of 8 points to the beach area. Availability of opportunity assigns points based on travel times to the recreational activity. If visitors have a couple beaches within 45 – 60 minutes travel time to choose from, one could assign a value of 8 points for availability of opportunity. A beach area may possess adequate facilities, such as a relatively wide dry beach, to allow beachgoers to enjoy their recreational experience; these conditions may warrant assigning 6 points for carrying capacity. Accessibility measures the ability of visitors to reach the site. Given people can access the beach via good roads, one may assign 10 points for accessibility. Finally, the environmental category judges the site's aesthetics, such as topography, air and water quality, vegetation, climate, adjacent areas, and pests. In this example, the beach may appear average compared to other area beaches. As such, the beach may warrant 6 points for this category. Summing these assigned points over the five categories yields 38 points. Interpolating between 30 and 40 points in Table 2.6 produces a UDV of about $6.80. In this hypothetical example, the same point assignment process would be done for conditions without the project. If the points were to total 21, interpolating between 20 and 30 points in Table 2.6 results in a UDV of about $5.03.

2.2.3 Period of Analysis

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

Table 2.5 Guidelines for Assigning Points to General Recreation Projects (USACE, 2014)

Criteria	Judgment Factors				
Recreation Experience Total Points: 30 Point Value:	Two general activities 0 – 4	Several general activities 5 – 10	Several general activities; one high quality value activity 11 – 16	Several general activities; more than one high quality value activity 17 – 23	Numerous high quality value activities; some general activities 24 – 30
Availability of Opportunity Total Points: 18 Point Value:	Several within 1 hr travel time; a few within 30 min travel time 0 – 3	Several within 1 hr travel time; none within 30 min travel time 4 – 6	One or two within 1 hr travel time; none within 45 min travel time 7 – 10	None within 1 hr travel time 11 – 14	None within 2 hr travel time 15 – 18
Carrying Capacity Total Points: 14 Point Value:	Minimum facility for development for public health and safety 0 – 2	Basic facility to conduct activities 3 – 5	Adequate facilities to conduct without deterioration of the resource or activity experience 6 – 8	Optimum facilities to conduct activity at site potential 9 – 11	Ultimate facilities to achieve intent of selected alternative 12 – 14
Accessibility Total Points: 18 Point Value:	Limited access by any means to site or within site 0 – 3	Fair access, poor quality roads to site; limited access within site 4 – 6	Fair access, fair road to site; fair access, good roads within site 7 – 10	Good access, good road to site; fair access, good roads within site 11 – 14	Good access, high standard road to site; good access within site 15 – 18
Environmental Total Points: 20 Point Value:	Low aesthetic factors that significantly lower quality 0 – 2	Average aesthetic quality; factors exist that lower quality to minor degree 3 – 6	Above average aesthetic quality; any limiting factors can be reasonably rectified 7 – 10	High aesthetic quality; no factors exist that lower quality 11 – 15	Outstanding aesthetic quality; no factors exist that lower quality 16 – 20

Table 2.6 Conversion of Points to Dollar Values for Fiscal Year 2015 (USACE, 2014)

Point Values	General Recreation Values UDV (per person per visit)
0	$3.91
10	$4.64
20	$5.13
30	$5.86
40	$7.32
50	$8.30
60	$9.03
70	$9.52
80	$10.50
90	$11.23
100	$11.72

Table 2.7 Example of Recreation Benefit for All Beach Visitors

Year	Number of Visitors		Recreation Value		Difference (Benefit)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2013	28,323	28,323	$192,455	$142,479	$49,976	$49,976	$49,181	$49,181
2014	28,720	28,720	$195,150	$144,474	$50,676	$51,486	$49,068	$98,248
2015	29,122	29,122	$197,882	$146,497	$51,385	$53,147	$49,051	$147,299
2016	29,529	29,529	$200,652	$148,548	$52,104	$54,861	$49,034	$196,334

Notes: UDV (with project) = $6.80 (2013 price level)
UDV (without project) = $5.03 (2013 price level)
Inflation rates: 1.6% for 2013 – 2014, 1.8% annually for 2014 – 2016
Present worth equivalent values at beginning of 2013, mid-year discounting, 3.26% discount rate [mid-year discount factor = (1/1.0326)n+0.5, where n = year – 2013]

2.3 Natural Resource Restoration Projects

Natural resource restoration projects generally create or enhance an area's natural resources. Examples of previous GLO natural resource restoration projects include those that created beach and wetland habitat, protected estuarine habitats, and other projects that directly or indirectly created, enhanced, or provided protection for the development and sustainability of natural habitats and the plant and animal communities themselves.

This study assesses the economic benefits of shoreline revetments to protect a marsh restoration project in Nueces Bay (Portland Causeway) and natural resources in Port Aransas Nature Preserve. These projects protect the valuable new marsh and existing habitats that benefit the ecosystem by increasing area for the life cycle activities of a wide variety of species with commercial and recreational value as well as the many other species that create a self-sustaining community. The marshes also function to capture, filter, and improve the quality of rainfall runoff from adjacent residential areas and, as part of the larger ecosystem, restore some of the carbon-sequestering capacity of the original marsh extent.

Similar to the prior economic benefits studies, this study quantified natural resource benefits. 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 (e.g., Louisiana). In addition to those over-arching concepts presented in Section 2.1, the economic benefit estimates developed in this study for the natural resource projects rest on the assumptions that the project sites provide economic benefits in a manner similar to those described in the literature. This assumption served as a surrogate for the extensive on-site interviews and natural resource evaluations described in the literature pertinent to this study. Calculations assumed benefits accrue over the entire project benefit period of analysis for natural resource functions.

The GecoServ database (http://www.gecoserv.org/), developed by the Harte Research Institute, Texas A&M University, Corpus Christi, provides a large ecosystem services valuation database with ecosystem economic services unit area dollar values. With the exception of aesthetic valuations (for which there were no Gulf state values reported), this analysis excluded those services values developed from ecosystems in states not bordering on the Gulf of Mexico or not present in Nueces Bay or Port Aransas Nature Preserve. Additionally, this analysis excluded a few early value estimates that recent research has found were less robust than originally assumed.

The services selected for benefit calculations included (in the database terms) *habitat, recreation, disturbance regulation, gas regulation, waste regulation,* and *aesthetics.* Table 2.8 provides the GecoServ definitions of those terms. Based on the literature for the *habitat* service, this analysis assumed this category provided the basic benefit for commercial and recreational fishing; as a result, the analysis did not use specific commercial and recreational fisheries value estimates. Further, *recreation* included recreational fishing; the database provides 2012 values that this analysis inflated to 2013 dollars using a 1.5% inflation rate as listed in Table 2.1. This study applied median values for use in benefit calculations.

Table 2.8 Ecosystem Service Values

Ecosystem Service	Definition	Per Acre Value, (2013 Price Level)
Habitat	The physical place where organisms reside; refugium for resident and migratory species; spawning and nursery grounds	$52.78
Recreation	Opportunities for rest, refreshment, and recreation Ecotourism; bird-watching; outdoor sports	$85.64
Disturbance Regulation	Dampening of environmental fluctuations and disturbance Storm surge protection; flood protection	$792.74
Gas Regulation	Regulation of the chemical composition of the atmosphere and oceans. Biotic sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds	$548.35
Waste Regulation	Removal or breakdown of non-nutrient compounds and materials Pollution detoxification; abatement of noise pollution	$2,028.69
Aesthetics	Sensory equipment of functioning ecological systems Proximity of houses to scenery; open space	$53.81
Total Ecosystem Services Per Acre Value		$3,562.01

Note: Values provided in 2012 price levels at http://www.gecoserv.org; values converted to 2013 price levels using a 1.5% inflation rate (2013 value = 2012 value * 1.015)

Project benefits to real estate (residential lots and residences immediately adjacent to ecosystem restoration projects) often occur as a one-time increase in the property value. Average property values for the local area around a wetland or natural habitat enhancement project, and in particular those properties immediately adjacent to such a project, will often increase due to the perceived increase in aesthetic value. Fausold and Lilieholm (1999) and Kroger and Manalo (2006) provide examples of estimating such benefits. The increased value would benefit the present owners. Any subsequent value reassessment or sale would pass along the property amenity; the presence of the Nueces Bay project would not result in a further project-related increase in value. The Port Aransas Nature Preserve project, which repaired a revetment initially constructed in 2007, also does not result in increased property values, because the original project provided a one-time real estate benefit (Stites, et al., 2008).

Table 2.10 Example of Benefit Calculation for Erosion of Newly Created Acreage

	Relevant Acres		Acres With	Benefit Value	With	Discounted Present	Cumulative Discounted Present
Year	With Project	Without Project	vs. Without	(2010 Prices)	Inflation	Worth	Worth
2011	20	0	20	$20,000	$20,220	$19,827	$19,827
2012	18	0	18	$18,000	$18,416	$17,364	$37,192
2013	16	0	16	$16,000	$16,567	$15,019	$52,211
2014	14	0	14	$14,000	$14,670	$12,788	$64,999
2015	12	0	12	$12,000	$12,800	$10,729	$75,728
2016	10	0	10	$10,000	$10,859	$8,752	$84,480
2017	8	0	8	$8,000	$8,844	$6,853	$91,334
2018	6	0	6	$6,000	$6,752	$5,031	$96,365
2019	4	0	4	$4,000	$4,582	$3,283	$99,648
2020	2	0	2	$2,000	$2,332	$1,607	***$101,255***

3.0 BEACH RESTORATION AND SHORELINE PROTECTION BENEFIT ANALYSIS

3.1 Brazoria County — #1382 CR 257 Road Repair and Protective Revetment

Project Description and Background Information

Bluewater Highway (CR 257) extends approximately 12 miles between Surfside and Treasure Island (Figure 3.1). CR 257, Brazoria County's only access route to Follet's Island and Treasure Island, is the only emergency evacuation for Follet's Island and one of only two evacuation routes for Galveston Island. Elevated water levels and waves from Hurricane Ike, which made landfall in Galveston County on September 13, 2008, destroyed 2.3 miles of road and partially damaged 3.5 miles of road. Additionally, storm-induced erosion lowered beach berm elevations by 3 – 4 ft and dune elevations by 4 – 6 ft, resulting in 3.25 miles of coastline fronting CR 257 eroded to sea level or below. These severely eroded post-storm beach conditions offered little storm protection to the remaining roadway and the island's 2,600 acres of wetland habitat.

Following temporary roadway repairs constructed by Brazoria County within the first eight months after the storm, CEPRA Project #1382 implemented permanent roadway repairs (5 miles of road repair and 10.3 miles of asphalt overlay) and construction of a rock revetment and overwash scour protection to guard against future storms. Construction occurred during 2012. Figures 3.2 – 3.3 present pre-construction (post-storm) conditions, and Figures 3.4 – 3.5 show the project under construction.

Project Funding

Table 3.1 presents the funding breakdown for the project. Cost shares that originate from national agencies or organizations decrease by 90% (see Section 2.1) to account for the fact that some entity other than the state of Texas incurs those costs. Federal dollars fund the Federal Highway Administration (FHA) and U.S. Fish and Wildlife Service (FWS) and Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of the federal dollars through individual and corporate taxes. Given 90% of FHA's $15,572,252 and FWS' $324,197 originates from non-Texas sources, the cost incurred by Texas represents just 10% ($1,589,645) of these federal cost shares. Texas incurs 100% of the CEPRA and Texas Division of Emergency Management cost shares. Therefore, the project cost to Texas revises downward for this benefit-cost analysis from $21,694,099 (i.e., the total actual project cost) to $7,387,294 (i.e., $1,589,645 + $5,797,649).

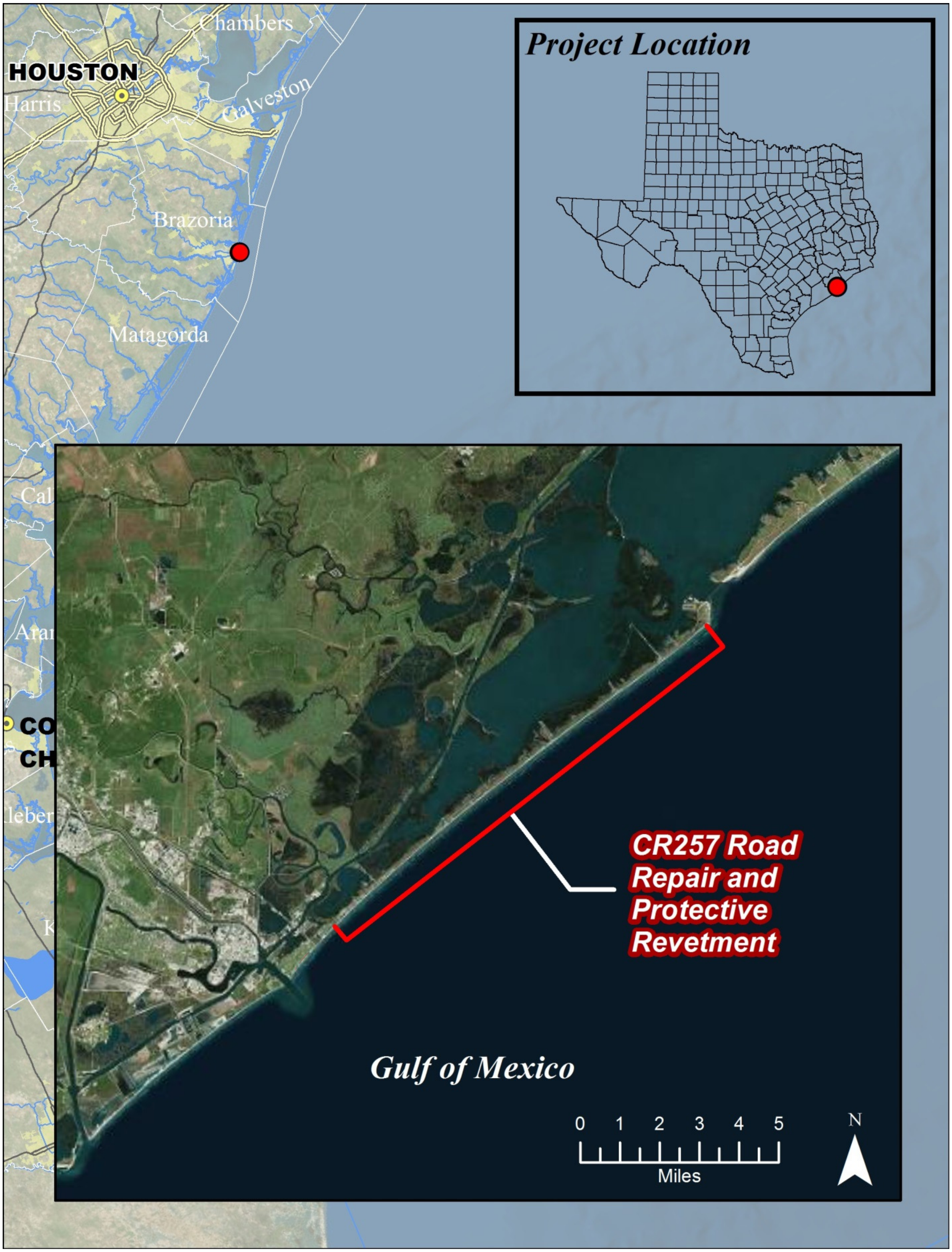

Figure 3.1 CR 257 Road Repair and Protective Revetment Project Location Map

Figure 3.2 CR 257 Post-Hurricane Ike (September 24, 2008; photo provided by GLO)

Figure 3.3 CR 257 Post-Hurricane Ike (November 4, 2008; photo provided by GLO)

Figure 3.4 CR 257 Rock Revetment during Construction (June 29, 2012; photo provided by GLO)

Figure 3.5 CR 257Road Repairs during Construction (July 2, 2012; photo provided by GLO)

Table 3.1 Funding for the CR 257 Road Revetment Project

Funding Source		**Amount**[1]
Federal	Federal Highway Administration (71.78% total actual project cost) *(Texas Portion)*	$15,572,252 *($1,557,225)*
	2007 CIAP (U.S. Fish and Wildlife Service; 1.49% total actual project cost) —WO 3465 (Damage Assessment & Alternatives Analysis) *(Texas Portion)*	$324,197 *($32,420)*
	Total Federal (73.275% of total actual project cost) *(Texas Portion)*	$15,896,450 *(1,589,645)*
State	CEPRA (Texas GLO; 1.36% total actual project cost) — WO 3511 (Emergency Road Assessment & Design)	*$293,925*
	Texas Division of Emergency Management (25.37% total actual project cost)	*$5,503,724*
	Total State (26.725% of total actual project cost)	*$5,797,649*
Total Project Cost ***(Texas Total)***		**$21,694,099** ***($7,387,294)***

Note: Values in italics are costs to the State of Texas
[1]2013 price levels

Analysis

The economic benefits defined in this analysis include storm damage reduction and traffic delay savings benefits that result from the protection provided by the constructed revetment. This analysis assumes the revetment will completely protect and maintain the functionality of the roadway in the event of future storms. Hence, storm damage reduction benefits include prevention of costs associated with temporary and permanent post-storm roadway repairs. Traffic delay savings benefits represent the prevention of costs associated with the additional time and mileage required to use alternative routes when closure of CR 257 becomes necessary due to storm damage. The following sections discuss these two benefit categories. The benefit analyses assume a 25-year project lifespan.

Storm Damage Reduction Benefits

Following Hurricane Ike, roadway repair efforts included immediate temporary repair measures implemented by Brazoria County followed by the permanent repairs constructed as part of this project. Both of these efforts represent costs that will occur in the without-project condition following storms of sufficient magnitude to cause damage to the roadway. The difference between these without-project damages and with-project conditions (i.e., no road damage and, hence, no repair costs) represents project benefits.

Brazoria County staff (personal communication on April 27, 2015) indicated the temporary roadway repairs completed in 2009 totaled approximately $4,783,000 ($5,119,705 inflated to 2012 dollars). These costs were eligible for 90% reimbursement from FEMA, a federal agency funded roughly 10% (in proportion to Texas' share of the national population) by Texas federal taxpayers. Thus, the Texas portion of the temporary road repair costs comprises the 10% non-reimbursable portion ($511,970.50) plus 10% of the FEMA portion ($5,119,705*0.9*0.1 = $460,773.50), which totals $972,744 (i.e., $511,970.50+$460,773.50).

Project cost information provided by the GLO indicated that, excluding mobilization costs, revetment construction costs (including itemized costs for excavation and fill, geotextile fabric, bedding stone, armor stone, and temporary shoring) totaled approximately $11,020,600 (52.6% of total project costs excluding mobilization), and roadway repair costs totaled approximately $9,917,500 (47.4% of total project costs excluding mobilization). Mobilization costs for revetment construction and roadway repairs totaled $756,000. Assuming the mobilization costs applied to the revetment and roadway according to the above cost percentages, the total revetment construction cost equaled $11,418,300 (i.e., $11,020,600 + $756,000*0.526) and roadway repairs equaled $10,275,800 (i.e., $9,917,500 + $756,000*0.474). Combined, these two project components compose the total project cost listed in Table 3.1. Adjusting the road repair costs to account for federal and state cost sharing according to the percentages (approximately 73.27% and 26.73%) listed in Table 3.1 and Texas' contributions to federal dollars, the Texas portion of the permanent road repair costs equals about $3,499,200 (i.e., $10,275,800*0.26725 + $10,275,800*0.73275*0.1 = $2,746,200 + $753,000 = $3,499,200).

Combining the temporary and permanent road repairs, the total road repair costs following Hurricane Ike equaled $4,471,944 (i.e., $972,744 for temporary repairs + $3,499,200 for permanent repairs). Compared to the local statistical distribution of storms, Hurricane Ike had a 30-year return period (Coast and Harbor Engineering [CHE], 2008).

Taylor Engineering conducted SBEACH modeling, aiming to assess potential storm erosion damage to CR 257 throughout the 25-year project lifespan. However, utilizing representative beach profiles derived from 2014 upland survey data and 2009 LiDAR data, the SBEACH results indicated that CR 257 would not incur significant erosion near the roadway unless the 50- to 100-year return-period storms or greater were to occur. This result conflicted with the known damage resulting from Hurricane Ike, a 30-year storm event. However, SBEACH is not capable of predicting localized effects such as return-flow scour, wave and current focusing, and resultant erosional hotspots — the culmination of which resulted in the majority of damage to CR 257 during Hurricane Ike. Additional considerations include large variability in beach profile characteristics (dune height, beach width, etc.) along the 12-mile project area and the varying level of connectivity to the inland waters during events with significantly elevated water levels, both of which could contribute to localized wave erosion and return-flow scour hotspots.

In lieu of the SBEACH storm-erosion projections, this study assumes that the majority of road damage under the without-project condition will occur from wave forces and return-flow when storm water levels rise above the elevation of CR 257 and the adjacent low-lying dune. Given the known damages from Hurricane Ike, the benefit calculations assume that a future 30-year event, as well as storms of greater magnitude, will require the same level of repair costs that resulted from Hurricane Ike. Additionally, analysis of estimated water levels for various return period storms (CHE, 2008) indicate that partial inundation of CR 257, with road elevations of approximately 6 – 8 ft-NAVD according to the project construction drawings, would begin to occur during a 2-year event. Table 3.2 contains the average values reported in CHE(2008); the storm surge (wind setup) values are based on measurements at the USCG tide gauge at Freeport, TX (protected from wave effects), and the total water levels include effects of wave setup that would increase water levels along the open coast. Based on comparison of the total water levels to those reported for Hurricane Ike, this analysis assumes that a 5-year event will require 10% of the road repair costs caused by Hurricane Ike, and a 10-year and 20-year event will require 30% and 70% of such repair costs. The benefit calculations assume that storms less severe than a 5-year event may cause partial inundation but will cause no damage to the road. Of note, Hurricane Ike caused significant erosion of the beach and dune, making CR 257 more susceptible to damage from future storms; thus, a future storm of the magnitude of Hurricane Ike could cause more road damage than occurred in 2008. This benefits analysis does not attempt to project the potential increased road repair costs that could result from the reduced storm protection provided by the eroded beach conditions.

Based on the above cost estimates and assumptions, Table 3.3 presents the expected annual damage cumulative probability distribution. From the table, the expected annual total damage averages $413,655 (2012 prices). Table 3.4 shows the cumulative present worth of the storm damage reduction benefits for all years in the period of analysis. No storms occurred in 2012 – 2014, thus no benefits accrued for these years. Over the 25-year project life, the extra vehicle operating cost equals $7,514,994.

Table 3.2 Return Period Water Levels (CHE, 2008)

Return Period	Storm Surge Elevation (Wind Setup) (ft NAVD88)	Total Water Level (Wind and Wave Setup) (ft NAVD88)
1-yr	2.9	5.4
2-yr	4.2	7.1
5-yr	5.4	8.9
10-yr	6.1	10.1
20-yr	7.0	11.6
50-yr	7.7	12.6
Hurricane Ike	10.9	11.7

Table 3.3 Total Damage-Cumulative Probability (2012, with Project)

Return Period (yrs)	Probability	Cumulative Probability	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	-	-	-
2	0.50	0.50	$0	-	0.50	-
5	0.20	0.80	$447,194	-	0.30	-
10	0.10	0.90	$1,341,583	$894,389	0.10	$89,439
20	0.05	0.95	$3,130,361	$2,235,972	0.05	$111,799
30	0.033	0.97	$4,471,944	$3,801,152	0.02	$63,353
>100	<0.01	>0.99	$4,471,944	$4,471,944	0.03	$149,065
Expected Average Annual Damage in 2012 Prices						$413,655

Table 3.4 Storm Damage Reduction Benefit

Year	Damages (2012 Prices)			Inflation from Previous Year	Benefit With Inflation	Discounted Benefit	Cumulative Discounted Benefit
	Without Project	With Project	Difference (Benefit)				
2012	$ -	$ -	$ -	0.00%	$ -	$ -	$ -
2013	$ -	$ -	$ -	1.50%	$ -	$ -	$ -
2014	$ -	$ -	$ -	1.60%	$ -	$ -	$ -
2015	$ 413,655	$ -	$ 413,655	1.80%	$ 434,256	$ 388,135	$ 388,135
2016	$ 413,655	$ -	$ 413,655	1.80%	$ 442,072	$ 382,647	$ 770,783
2017	$ 413,655	$ -	$ 413,655	2.00%	$ 450,914	$ 377,978	$ 1,148,761
2018	$ 413,655	$ -	$ 413,655	2.00%	$ 459,932	$ 373,366	$ 1,522,127
2019	$ 413,655	$ -	$ 413,655	2.00%	$ 469,131	$ 368,810	$ 1,890,938
2020	$ 413,655	$ -	$ 413,655	2.00%	$ 478,513	$ 364,310	$ 2,255,248
2021	$ 413,655	$ -	$ 413,655	2.00%	$ 488,084	$ 359,865	$ 2,615,112
2022	$ 413,655	$ -	$ 413,655	2.00%	$ 497,845	$ 355,473	$ 2,970,586
2023	$ 413,655	$ -	$ 413,655	2.00%	$ 507,802	$ 351,136	$ 3,321,721
2024	$ 413,655	$ -	$ 413,655	2.00%	$ 517,958	$ 346,851	$ 3,668,573
2025	$ 413,655	$ -	$ 413,655	2.00%	$ 528,317	$ 342,619	$ 4,011,192
2026	$ 413,655	$ -	$ 413,655	2.00%	$ 538,884	$ 338,438	$ 4,349,630
2027	$ 413,655	$ -	$ 413,655	2.00%	$ 549,661	$ 334,308	$ 4,683,938
2028	$ 413,655	$ -	$ 413,655	2.00%	$ 560,655	$ 330,229	$ 5,014,167
2029	$ 413,655	$ -	$ 413,655	2.00%	$ 571,868	$ 326,200	$ 5,340,367
2030	$ 413,655	$ -	$ 413,655	2.00%	$ 583,305	$ 322,219	$ 5,662,586
2031	$ 413,655	$ -	$ 413,655	2.00%	$ 594,971	$ 318,288	$ 5,980,874
2032	$ 413,655	$ -	$ 413,655	2.00%	$ 606,871	$ 314,404	$ 6,295,278
2033	$ 413,655	$ -	$ 413,655	2.00%	$ 619,008	$ 310,567	$ 6,605,845
2034	$ 413,655	$ -	$ 413,655	2.00%	$ 631,388	$ 306,778	$ 6,912,623
2035	$ 413,655	$ -	$ 413,655	2.00%	$ 644,016	$ 303,034	$ 7,215,657
2036	$ 413,655	$ -	$ 413,655	2.00%	$ 656,896	$ 299,337	$ 7,514,994

Notes: Present worth, beginning of 2012; mid-year discounting, 3.26% discount rate [mid-year discount factor = (1/1.0326)n+0.5, where n = year – 2012]

Traffic Delay Savings Benefits

Following Hurricane Ike, CR 257 was closed for approximately eight months (September 13, 2008 – April 24, 2009) while Brazoria County procured funding and made temporary repairs to the roadway. During the road closure, motorists that would normally travel between Surfside Beach and Galveston Island were forced to take a lengthier alternate route. Traffic delay savings benefits represent the value of time saved and vehicle operating costs saved (i.e., the difference between with- and without-project conditions) by the revetment protecting CR 257 and preventing damage that would result in road closure.

The daily traffic volume that would be affected by road closure amounts to 1,444 vehicles (Google Earth Pro traffic counts in 2012 approximately 3.5 miles east of the CR 332/CR 257 intersection in Surfside Beach) travelling the route between Surfside Beach and Galveston Island. The additional travel time and mileage resulting from road closure would vary widely on a case-by-case basis. For example, residents from the east end of CR 257 wishing to travel to Lake Jackson would experience a much longer alternate route than CR 257 (approximately 73 miles vs 25 miles, a 48-mile difference) than motorists traveling from Surfside to Galveston (approximately 57 miles vs 39 miles, an 18-mile difference). Given the lack of data regarding the origination and destination of the 1,444 vehicles, this analysis applies the alternate route from Surfside to Galveston to represent the traffic delay savings for all vehicles.

The estimated traffic delay savings benefits are based on the assumption that storm events similar to Hurricane Ike (i.e., a 30-year return period event) or greater will result in a similar amount of road closure time that occurred as a result of that event. Thus, a 30-yr storm or greater will result in eight months (240 days) of road closure. Similar to the storm damage benefits analysis, this benefits analysis assumes that storms less severe than a 5-year event would cause no damage to the road. Additionally, 5-yr, 10-yr, and 20-yr return period storms will result in 10%, 30%, and 70% of the effect of Hurricane Ike (i.e., 17 days, 72 days, and 168 days of road closure time). The following sections discuss the two categories of traffic delay benefits.

Vehicle Operating Cost Savings Benefit

The daily extra operating cost during road closure equals the product of the traffic volume (1,444 vehicles), average operating cost per mile per vehicle, and extra travel distance (18) miles. The vehicle operating cost (Table 3.5) is based on 2012 average operating costs (average per mile cost for gas, maintenance, and tires) as reported in American Automobile Association (2012). Assuming an even distribution of vehicle type, the average operating cost per mile ($0.21) translates into extra vehicle operating costs, for a 30-year return period and greater storm, of about $5,458/day (i.e., 1,444 vehicles/day * $.21/mile * 18 miles/day = $5,458.32/day).

Table 3.5 Vehicle Operating Costs

Vehicle Type	Operating Cost Per Mile
Small Sedan	$0.163
Medium Sedan	$0.201
Large Sedan	$0.226
Sport Utility Vehicle	$0.248
Minivan	$0.2134
Average	$0.21

Table 3.6 presents the vehicle operating cost cumulative probability distribution for 2012 without-project conditions. Assuming a 30-yr storm event results in a 240-day road closure period during which motorists use the alternative route, the extra vehicle operating cost for such a storm equals $1,309,920 (i.e., $5,458/day x 240 days). Similar calculations provide the results for the 5-yr, 10-yr, and 20-yr return period storms. Applying the probability of occurrence of these events and calculating the expected average interval damage indicates an expected average annual cost of $107,113. Table 3.7 shows the cumulative present worth of the storm damage reduction benefit for all years in the period of analysis. No storms occurred in 2012 – 2014, thus no benefits accrued for these years. Over the 25-year project life, the extra vehicle operating cost equals $1,945,959.

Table 3.6 Total Vehicle Operating Cost Cumulative Probability (2012, Without Project)

Return Period (yrs)	Probability	Cumulative Probability	Total Cost	Average Interval Cost	Interval Probability	Expected Value Interval Cost
1	1.00	0.00	-	-	-	-
2	0.50	0.50	-	-	0.50	-
5	0.20	0.80	$92,786	-	0.30	-
10	0.10	0.90	$392,976	$121,441	0.10	$12,144
20	0.05	0.95	$916,944	$654,960	0.05	$32,748
30	0.033	0.967	$1,309,920	$1,113,432	0.02	$18,557
>100	<0.01	>0.99	$1,309,920	$1,309,920	0.03	$43,664
Total Annual Damage						$107,113

Table 3.7 Vehicle Operating Cost Savings Benefit Calculations

Year	Benefit (2012 Prices)	Inflation from Previous Year	Inflation Factor	Benefit with Inflation	Discount Factor	Discounted Benefit	Cumulative Discounted Benefit
2012	$107,113	*na*	1.00000	$107,113	0.98409	$105,409	$0
2013	$107,113	1.5%	1.01500	$108,720	0.95302	$103,612	$0
2014	$107,113	1.6%	1.03124	$110,459	0.92293	$101,947	$0
2015	$107,113	1.8%	1.04980	$112,448	0.89379	$100,505	$100,505
2016	$107,113	1.8%	1.06870	$114,472	0.86558	$99,084	$199,589
2017	$107,113	2.0%	1.09007	$116,761	0.83825	$97,875	$297,464
2018	$107,113	2.0%	1.11187	$119,096	0.81179	$96,681	$394,145
2019	$107,113	2.0%	1.13411	$121,478	0.78616	$95,501	$489,646
2020	$107,113	2.0%	1.15679	$123,908	0.76134	$94,336	$583,982
2021	$107,113	2.0%	1.17993	$126,386	0.73730	$93,185	$677,166
2022	$107,113	2.0%	1.20353	$128,914	0.71402	$92,048	$769,214
2023	$107,113	2.0%	1.22760	$131,492	0.69148	$90,924	$860,138
2024	$107,113	2.0%	1.25215	$134,122	0.66965	$89,815	$949,953
2025	$107,113	2.0%	1.27719	$136,804	0.64851	$88,719	$1,038,672
2026	$107,113	2.0%	1.30274	$139,540	0.62804	$87,636	$1,126,309
2027	$107,113	2.0%	1.32879	$142,331	0.60821	$86,567	$1,212,876
2028	$107,113	2.0%	1.35537	$145,178	0.58901	$85,511	$1,298,386
2029	$107,113	2.0%	1.38248	$148,081	0.57041	$84,467	$1,382,854
2030	$107,113	2.0%	1.41013	$151,043	0.55240	$83,437	$1,466,290
2031	$107,113	2.0%	1.43833	$154,064	0.53496	$82,419	$1,548,709
2032	$107,113	2.0%	1.46709	$157,145	0.51807	$81,413	$1,630,122
2033	$107,113	2.0%	1.49644	$160,288	0.50172	$80,419	$1,710,541
2034	$107,113	2.0%	1.52636	$163,494	0.48588	$79,438	$1,789,979
2035	$107,113	2.0%	1.55689	$166,764	0.47054	$78,469	$1,868,448
2036	$107,113	2.0%	1.58803	$170,099	0.45568	$77,511	$1,945,959

Value of Time Savings Benefit

This evaluation is based on U.S. Army Corps of Engineers guidance (ER 1105-2-100, Appendix D, Economic and Social Considerations, paragraph D-4.f., Opportunity Cost of Time [OCOT]). This guidance is based on the more thorough discussion of this subject and the recommendations contained in Value of Time Saved for use in Corps Planning Studies, A Review of the Literature and Recommendations, IWR Report 91-R-12, October 1991. Following this guidance, time savings benefits are based on the amount of time saved per trip, the hourly family income of the driver, and the number of occupants per vehicle for work trips. For non-work trip purposes, the value of time saved is on a per vehicle basis and does not depend on the number of vehicle occupants.

For the Surfside Beach to Galveston route, this analysis assumes an average speed of 40 mph for the CR 257 route and 45 mph for the alternate route. The extra time per trip is then calculated as follows: (57-mile detour route)/(45 mph) – (39-mile CR 257 route)/(40 mph) = 66 min – 56 min = 17.5 min. The Texas median family income equaled $51,477/year in 2012 (http://www.deptofnumbers.com/income/texas/); based on 52 weeks/year and 40 hours/week, the Texas median family income per hour equals $24.75/hour (i.e., $51,477/2,080 hours). The estimated daily traffic count affected by the project is 1,444. Because details on trip type are not available, this analysis assumes a distribution of 50% work trips and 50% non-work trips.

The above-referenced guidance considers time saved per trip exceeding 15 minutes "high time savings." For work trips, the recommended value of time saved for such trips is 53.8% of the product of hourly family income, average number of vehicle occupants, and time saved. Data on the number of occupants per vehicle for work trips is not available. This analysis assumes half the work trips have two occupants per vehicle and half have one occupant, resulting in an average of 1.5 occupants per work trip vehicle. Assuming half of the 1,444 daily trips are work trips, the daily value of time saved for work trips is $4,206/day (i.e., 1,444/2 work trips per day * 0.538 * $24.75/hour * 1.5 * 17.5/60 hours/trip).

For non-work trips, the recommended value of time saved is 60% of the hourly family income per vehicle for social/recreation trips, and 64.5% of the hourly family income per vehicle for trips classified as "other." This analysis assumes that the non-work trips are evenly divided between these two categories and therefore uses the average of these two percentage values, 62.25%. For non-work trips, the recommended value of time saved is unaffected by the number of occupants per vehicle. The resulting daily value of time saved for non-work trips is $3,244 (i.e., 1,444/2 work trips per day * 0.6225 * $24.75/hour x 17.5/60 hours/trip).

The combined value of extra travel time caused by closure of CR 257 equals $7,450/day ($4,206/day for work trips + $3,244/day for non-work trips) in 2012 prices. Table 3.8 presents the time savings cumulative probability distribution for 2012 with-project conditions. Assuming a 30-yr storm event results in a 240-day road closure period during which motorists use the alternative route, the time saved by preventing closure of CR 257 equals $1,788,000 (i.e., $7,450/day * 240 days). Similar calculations provide the results for the 5-yr, 10-yr, and 20-yr return period storms. Applying the probability of occurrence to these events indicates an expected average annual savings of $162,783. Table 3.9 contains the cumulative present worth of the storm damage reduction benefit for all years in the period of analysis. No storms occurred in 2012 – 2014, thus no benefits accrued for these years. Over the 25-year project life, the extra vehicle operating cost equals $2,957,319.

Table 3.8 Total Time Savings Value Cumulative Probability (2012, With Project)

Return Period (yrs)	Probability	Cumulative Probability	Total Cost	Average Interval Cost	Interval Probability	Expected Value Interval Cost
1	1.00	0.00	$0	-	-	-
2	0.50	0.50	$0	-	0.50	-
5	0.20	0.80	$126,650	-	0.30	-
10	0.10	0.90	$536,400	$331,525	0.10	$33,153
20	0.05	0.95	$1,251,600	$894,000	0.05	$44,700
30	0.03	0.97	$1,788,000	$1,519,800	0.02	$25,330
>100	<0.01	>0.99	$1,788,000	$1,788,000	0.03	$59,600
Total Annual Damage						$162,783

Traffic Delay Savings Benefit Summary

In 2012 prices, the estimated annual value of traffic delay savings benefits equals the vehicle operating cost savings plus the value of time savings, or $107,113 + $162,783 = $269,896. The cumulative discounted present worth of traffic delay savings benefits over the 25-year period of analysis = $4,903,279 (i.e., $1,945,959 + $2,957,319).

Federal Spending Benefit

Federal spending that occurs as part of the initial construction represents a net increase inflow of spending for the state economy. Reducing the initial federal funding contribution by 10% (i.e., the estimated amount of federal funds originating from Texas) and applying the multiplier effect (Section 2.1), the estimated federal spending benefit for this project is $20,029,527 (i.e., $15,896,450* 0.9 * 1.4) in 2012 prices.

Table 3.9 Value of Time Savings Benefit Calculations

Year	Benefit (2012 Prices)	Inflation from Previous Year	Inflation Factor	Benefit with Inflation	Discount Factor	Discounted Benefit	Cumulative Discounted Benefit
2012	$162,783	*na*	1.00000	$162,783	0.98409	$160,192	$0
2013	$162,783	1.5%	1.01500	$165,224	0.95302	$157,462	$0
2014	$162,783	1.6%	1.03124	$167,868	0.92293	$154,931	$0
2015	$162,783	1.8%	1.04980	$170,889	0.89379	$152,740	$152,740
2016	$162,783	1.8%	1.06870	$173,965	0.86558	$150,580	$303,320
2017	$162,783	2.0%	1.09007	$177,445	0.83825	$148,743	$452,063
2018	$162,783	2.0%	1.11187	$180,994	0.81179	$146,928	$598,991
2019	$162,783	2.0%	1.13411	$184,614	0.78616	$145,135	$744,127
2020	$162,783	2.0%	1.15679	$188,306	0.76134	$143,364	$887,491
2021	$162,783	2.0%	1.17993	$192,072	0.73730	$141,615	$1,029,106
2022	$162,783	2.0%	1.20353	$195,913	0.71402	$139,887	$1,168,992
2023	$162,783	2.0%	1.22760	$199,832	0.69148	$138,180	$1,307,172
2024	$162,783	2.0%	1.25215	$203,828	0.66965	$136,494	$1,443,666
2025	$162,783	2.0%	1.27719	$207,905	0.64851	$134,828	$1,578,494
2026	$162,783	2.0%	1.30274	$212,063	0.62804	$133,183	$1,711,677
2027	$162,783	2.0%	1.32879	$216,304	0.60821	$131,558	$1,843,235
2028	$162,783	2.0%	1.35537	$220,630	0.58901	$129,953	$1,973,188
2029	$162,783	2.0%	1.38248	$225,043	0.57041	$128,367	$2,101,555
2030	$162,783	2.0%	1.41013	$229,544	0.55240	$126,801	$2,228,355
2031	$162,783	2.0%	1.43833	$234,135	0.53496	$125,253	$2,353,609
2032	$162,783	2.0%	1.46709	$238,817	0.51807	$123,725	$2,477,334
2033	$162,783	2.0%	1.49644	$243,594	0.50172	$122,215	$2,599,549
2034	$162,783	2.0%	1.52636	$248,466	0.48588	$120,724	$2,720,273
2035	$162,783	2.0%	1.55689	$253,435	0.47054	$119,251	$2,839,524
2036	$162,783	2.0%	1.58803	$258,504	0.45568	$117,796	$2,957,319

Benefit Cost Summary

Summing the above estimates for storm damage reduction, traffic delay savings, and federal spending benefits yields a total project benefit of $32,447,799. Dividing the total benefits by the Texas project cost ($7,387,294) results in a B/C ratio of 4.4. (Table 3.10)

Table 3.10 Benefit-Cost Summary for CR 257 Road Repair and Protective Revetment

Benefits and Costs	**Discounted Present Worth (beginning of 2012)[2]**
Storm Damage Reduction	$7,514,994
Traffic Delay Savings	$4,903,279
Federal Spending	$20,029,527
Total	$32,447,799
Total Cost[1]	$7,387,294
B/C Ratio	4.4

[1]Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)
[2]Dollar values represent present worth equivalents at the beginning of 2012 with a 3.26% discount rate

3.2 Matagorda County — #1532 Sargent Beach Nourishment

Project Description and Background Information

CEPRA Project #1532 nourished approximately 3,600 ft of shoreline in Sargent Beach, Matagorda County to protect the existing dune and restore recreational access. The project area (Figure 3.6) lies within the deltaic headland region between the Colorado River and Brazos River, an area impacted by one of the Texas' highest coastal erosion rates. Past studies (Stauble et. al 1994 and UTBEG, 2000) estimate a historic shoreline erosion rate of roughly 26 ft per year on average.

During the 1990s, to guard against the severe erosion and protect the Gulf Intracoastal Waterway from an imminent breach of the fronting beach, USACE constructed an 8-mile long granite revetment landward of the dune. The low-crested revetment remains primarily buried with the top intermittently exposed. The revetment also provides vital storm protection to Sargent Beach's roadways and structures, which include single-family homes and a public beach access with restroom facilities and several pavilions.

As originally designed, the Sargent Beach Nourishment Project entailed placement of 133,000 cy along 2,065 ft of shoreline extending eastward from FM 457. Project design revisions intended to improve project performance and reduce losses during construction increased the project length (via a westward extension from FM 457) to 3,600 ft, decreased the target beach fill width from 300 ft to 120 ft, and decreased the design volume to 78,470 cy. Construction occurred from January – March 2013 with the placement of roughly 82,870 cy of beach fill. Figures 3.7 – 3.10 present representative pre-construction conditions, construction photographs, and existing conditions during a March 4, 2015 site visit approximately two years following construction. Figures 3.11 and 3.12 present available aerial photographs of pre-construction (10/28/12) and approximately one-year post-construction (5/15/14) conditions.

Project Funding

Funding for the Sargent Beach Nourishment Project originated solely from Texas agencies; federal funding was not involved. Table 3.11 presents the funding breakdown for the project.

Table 3.11 Funding for the Sargent Beach Nourishment Project #1532 (2013 Prices)

Funding Source	Amount
Texas General Land Office, CEPRA (39.5% of total project cost	*$1,499,597.74*
Matagorda County (60.5% of total project cost)	*$2,296,852.26*
Total Project Cost	*$3,796,450.00*

Note: Values in italics are costs to the State of Texas

Figure 3.6 Sargent Beach Location Map

Figure 3.7 Sargent Beach Pre-Construction Conditions at Low Tide (1/31/13; Photo provided by Texas GLO)

Figure 3.8 Sargent Beach during Construction (2/8/13; Photo provided by Texas GLO)

Figure 3.9 Eastward View of Sargent Beach from FM 457 Two Years Post-Construction (3/4/15)

Figure 3.10 Westward View of Sargent Beach from FM 457 Two Years Post-Construction (3/4/15)

Figure 3.11 Pre-construction Aerial 10/28/12 (source: Google Earth)

Figure 3.12 Pre-construction Aerial 5/15/14 (source: Google Earth)

Analysis

Economic benefits from the 2013 project result from preventing exposure of the revetment and recreational enjoyment. A site visit conducted March 4, 2015 documented approximately 50 ft of the beach fill remaining within the project area. Given the 26 ft/year background erosion rate, the remaining fill will likely disappear within 2 years. Accordingly, this analysis assumes a 4-year project life, from 2013 – 2016. As discussed below, no overcrowding of the beach occurs with or without the project; thus, the visitation estimates are the same for both cases, and no out-of-state visitor spending benefits accrue as a result of this project (i.e., out-of-state visitor spending is the same with or without the project).

Replacement of Riprap Benefit

Given the lack of as-built detailed design information of the revetment, this study applied several general assumptions in measuring the difference between conditions with and without the project. The analysis assumed the existing revetment, designed by USACE, would stabilize the shoreline in the event of a severe storm during the 4-year period of analysis; thus, a storm-damage protection benefit to the upland properties is not applicable to the beach nourishment project. Nevertheless, the project offset the extreme background erosion during this period and prevented exposure of the revetment. Without the nourishment project, the high background erosion rates would likely have resulted in some level of exposure of the revetment. Once this occurs, the erosion rates of the beaches adjacent to the exposed revetment would accelerate, given the diminished sand supply. Additionally, exposure of the revetment would also open the door for expensive maintenance and repair costs of the revetment, which would represent the sole line of defense against storms.

One could argue that the without-project condition would entail no effort to maintain the revetment. However, abandonment of the revetment would eventually lead to its failure and subsequent impacts to the Intracoastal Waterway (ICW) and its associated commercial and recreational traffic. This situation is unlikely to occur given the enormous economic benefit of the ICW. Rather, revetment maintenance would occur, with repair costs dependent on the design and condition of the revetment as well as the frequency and intensity of future storms. For example, once exposed, if the revetment does not have sufficient toe protection from wave-induced scour, potential undermining and failure of the revetment would prompt expensive redesign and repair costs.

In the absence of sufficient revetment design details, this analysis assumes, for the without-project case, that rip rap armor exists as toe protection for the revetment, and roughly 20% of the armor along the 3,600-ft long project segment needs replacing at a cost of $242,390 (2013 dollars). This replacement cost is based on a similar estimate made for the 12,650-ft long Galveston Seawall Emergency Beach Nourishment (CEPRA Project #1447) in 2010. This analysis inflated the 2010 estimate ($797,263) to 2013 price levels ($851,730) according to the inflation data in Table 2.1 ($797,263 * 233/218.1 = $851,730) and reduced the result by the ratio of project lengths ($851,730/12,650*3650 = $242,390) to develop a planning level estimate for Sargent Beach.

Given the narrow beach width existing prior to the project, this analysis assumes exposure of the revetment, which lies less than 50 ft from the current dune vegetation line, would have occurred within two years without the nourishment project, and replacement of riprap would have occurred during the fourth year (2016) of the analysis period. Adjusting the riprap cost for inflation ($242,390*1.6%*1.8%*1.8% = $255,213 in 2016 prices) and discounting, the replacement of riprap benefit equals $231,796 (discounted present worth beginning of 2013; $255,213/1.0326^3 = $231,796). Of note, the project benefit likely extends beyond the project limits as longshore fill dispersion feeds sand to the adjacent beach and, hence, extends protection to the adjacent revetment; the slightly wider beach west of the project area evident by comparing Figures 3.11 and 3.12 demonstrates this effect. Because this analysis has only estimated benefits to the immediate project area and has not attempted to include effects on adjacent beach areas, the benefit estimates are likely conservative in that they probably understate the full beneficial effects of the project.

Recreation Benefits

Site-specific visitation estimates are unavailable for Sargent Beach. According to the community's website (http://sargentbeachtexas.com/history.html), approximately 500 permanent residents live in the Sargent area, while on holiday weekends the population may reach 5,000. Oden and Butler (2006) report visitation estimates for nearby (approximately 24 miles eastward) Surfside Beach, which has a similar population. However, with the majority of houses situated along canals providing water access, Sargent Beach appears to be more of a boating community as opposed to the beachside community of Surfside Beach; thus, the above-mentioned visitation estimates likely do not directly represent the beach-going population of Sargent Beach. Given the lack of data, this study assumes that Sargent Beach experiences 20 percent of the Surfside Beach visitation estimates reported in Oden and Butler (2006).

Oden and Butler (2006) report about 400 peak day visitors to Surfside Beach based on an afternoon survey in 2004. Assuming an average daily turnover rate of 2, the daily visitation estimate would be 800. According to Oden et al. (2003), 104 peak visitor days occur in the Surfside Beach area. One-fifth (assumed) of the peak day visitors (80) visit the beach during off peak days and 261 (i.e., 365 – 104) off peak days occur during a 365-day year. Given the above visitor information, approximately 124,960 visits (83,200 [800 * 104] + 41,760 [160 * 261]) occurred in 2004 in the project area. Increasing this number to a 2013 (i.e., the project base year) value by the rate of general population growth (1.4%) yields 141,616 (i.e., 62,480 * 1.014^9). Based on our above-mentioned assumption, this visitation estimate reduces to 28,323 (i.e., 141,616 * 0.20) for Sargent Beach.

Based on beachgoer surveys, Oden and Butler report that out-of-state visitors account for 10.1% of Galveston area visitors; absent site-specific survey data, this study adopted this out-of-state visitor percentage for Sargent Beach, resulting in an estimated 2,861 out-of-state visitors in 2013. However, because of the assumed modest levels of beach use, no overcrowding occurs with or without the project, and the visitation estimates are the same for both scenarios; therefore, no out-of-state visitor spending benefit is expected to result from the project.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV-developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.12 presents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about $6.80 and $5.03 per person per visit (2013 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project for each year, adjusted for general annual population growth (i.e., 1.4%), yields the benefit for each year. Table 3.13 presents the recreation value benefit for this project ($196,334 present value, beginning of 2013).

Benefit Cost Summary

Because of the limited visitation and storm protection provided by the existing revetment, the total project benefits are relatively low (Table 3.14). The estimated benefits occur throughout the year. Combining the riprap prevention benefit and total recreational benefit, the total project benefit is $428,130. With project costs totaling $3,796,450, this project has a 0.11 benefit/cost ratio.

Table 3.12 UDV Points Assigned — #1532 Sargent Beach Nourishment Project

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	8	2	30
Availability of Opportunity	8	8	18
Carrying Capacity	6	2	14
Accessibility	10	7	18
Environmental	6	2	20
Total	38	21	100

Table 3.13 Recreational Benefit for All Users — #1532 Sargent Beach Nourishment Project

Year	Total Visitation		Recreation Value		Difference (Benefit in 2013 Prices)	Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2013	28,323	28,323	$192,455	$142,479	$49,976	$49,976	$49,181	$49,181
2014	28,720	28,720	$195,150	$144,474	$50,676	$51,486	$49,068	$98,248
2015	29,122	29,122	$197,882	$146,497	$51,385	$53,147	$49,051	$147,299
2016	29,529	29,529	$200,652	$148,548	$52,104	$54,861	$49,034	$196,334

Notes: UDV (with project) = $7.03 (2015 price levels), $6.80 (2013 price levels)
UDV (without project) = $5.20 (2015 price levels), $5.03 (2013 price levels)
Inflation rate 2013 to 2014 = 1.6%; 2014 price level x 1/1.016 = 2013 price level
Inflation rate 2014 to 2015 = 1.8%; 2015 price level x 1/1.018 = 2014 price level
Present worth, beginning of 2013, mid-year discounting, 3.26% discount rate [mid-year discount factor = (1/1.0326)n+0.5, where n = year – 2013]

Table 3.14 Benefit-Cost Summary for Sargent Beach Nourishment Project

Benefits and Costs	Discounted Present Worth (beginning of 2013)[2]
Replacement of Riprap	$231,796
Recreation Value	$196,334
Total Benefit	$428,130
Total Cost[1]	$3,796,450
B/C Ratio	0.11

[1]Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)
[2]Dollar values represent present worth equivalents at the beginning of 2013 with a 3.26% discount rate

3.3 Galveston County — #1584 GIWW Rollover Bay Reach Beach Nourishment (BN) with Beneficial Use of Dredged Materials (BUDM) (FY 2014 Event)

Project Description and Background Information

Rollover Pass, a man-made inlet at the eastern end of the Bolivar Peninsula in Galveston County, links the Gulf of Mexico with Rollover Bay and East Bay. Chronic long-term erosion, storm-related episodic erosion, and low-density upland development characterize the beaches near the Pass. During January – February 2014, the GLO, in cooperation with USACE and Galveston County, nourished Caplen Beach, west of the Pass, with beach quality material dredged from the Gulf Intracoastal Waterway Rollover Bay segment. This project is part of a long-term effort involving other CEPRA projects to manage the severe erosion problems affecting the Bolivar Peninsula, particularly the erosion caused by Rollover Pass.

The 2014 project placed 173,000 cy of sand along approximately 2,700 ft of shoreline (Figure 3.13), beginning about 1,600 ft west of the Pass, widening the dry beach by roughly 40 ft on average (per comparison of pre- and post-construction surveys). Figure 3.14 represents post-construction conditions. Based on information obtained from UTBEG, the study area's shoreline erodes about 5.7 ft/year. Upland development in the project area, generally comprised of elevated single-family homes, lies a fair distance from the shoreline. Based on the maximum predicted erosive shoreline condition, this analysis includes the first row of Gulf front properties and lots. Of note, Hurricane Ike devastated the study area in September 2008, destroying a very large percentage of structures on the peninsula and dramatically affecting the shoreline.

Table 3.15 presents the funding breakdown for the project. The USACE cost represents the federal cost to dredge the Gulf Intracoastal Waterway (GIWW) and place the material in a dredge material placement area (DMPA). The state and county costs represent the total incremental cost of placing the dredged material on the beach as opposed to a DMPA. This analysis uses the summation of the CEPRA and Galveston County costs, $198,360, as the total project cost; it excludes the federal cost, because USACE's maintenance dredging of the GIWW would still occur without CEPRA's support for the nourishment project.

Figure 3.13 Location Map for #1584 GIWW Rollover Bay Reach BN with BUDM (FY 2014 event)

Figure 3.14 Caplen Beach after the 2014 Nourishment (January 27, 2014)

Table 3.15 Funding for Project #1584 GIWW Rollover Bay Reach BN with BUDM (2014 Prices)

Funding Source		Amount
Federal Cost Share	U.S. Army Corps of Engineers (In-kind dredging contribution, 96.21% of total project costs)	$5,040,100
State/Local Cost Shares	Texas General Land Office, CEPRA (85% of incremental cost, 3.21% of total project cost)	*$168,360*
	Galveston County (15% of incremental cost, 0.57% of total project cost)	*$30,000*
Total Project Cost (*Texas Portion*)		$5,238,460 *($198,360)*

Note: Values in italics are costs to the State of Texas

Analysis

Taylor Engineering visited the site on March 5, 2015, just over one-year post-construction. This site visit, however, occurred just after the 2015 beach nourishment with BUDM event and, thus, did not allow for observations of the 2014 project performance. Based on performance of the prior projects

(Taylor Engineering, 2013), this study assumes that no significant amount of beach fill remained on the dry beach prior to the 2015 project and, thus, adopts a one-year project life for the 2014 project. With the short project length, such rapid erosion of the beach fill is expected. Fill material may remain offshore, but lack of data prohibits verification of this.

Economic benefits from the 2014 project include land value protection and recreational enjoyment. Storm-damage protection did not occur, because no major storms impacted the project area during 2014 (i.e., the one-year project life). Nevertheless, the project did offset the background erosion during this period and thus preserved land values. Given the 2014 Galveston Central Appraisal District information, these property values equal $1,065,420. Dividing the total property value by the average lot depth (approximately 300 ft) and multiplying by the background erosion (5.7 ft) yields a benefit of $20,243.

Based on July 2004 observations, Oden and Butler report about 90 peak day visitors to Rollover Pass. Assuming an average daily turnover rate of 2, the daily visitation estimate increases to 180. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (36) visit the beach during off peak days and 285 (i.e., 365 – 80) off peak days exist during a 365-day year. Given the above visitor information, the estimated number of beach visits occurring in 2004 was approximately 24,660 visits (14,400 [180 * 80] + 10,260 [36 * 285] = 24,660). Increasing this number to a 2014 (i.e., the project base year) value by the rate of general population growth (1.4%), as discussed in Section 2.1, yields 28,338 (i.e., 24,660 * 1.014^{10}). Based on beachgoer surveys, Oden and Butler report that out-of-state visitors account for 10.1% of Galveston area visitors; absent site-specific survey data, this study adopted this out-of-state visitor percentage, resulting in an estimated 2,862 out-of-state visitors in 2014.

Oden and Butler found out-of-state visitors spent $78.80 (2004 dollars) per day per visit to the Galveston and Surfside area beaches; data are unavailable for Bolivar Peninsula. Inflating this value to 2014 price levels, based on the inflation data in Table 2.1, yields $98.74 (i.e., $78.8 * 236.7 / 188.9). Greater development, amenities, and transportation access to Galveston area beaches suggests visitors spend more per day on Galveston Island than on Bolivar Peninsula. Accordingly, this study assumes Bolivar Peninsula out-of-state visitors spend 25% less per day per visit than Galveston Island visitors, or $74.05 (i.e., $98.74 * 0.75) per day per visit for Bolivar Peninsula analyses. This translates into total annual spending of $211,945 by out-of-state visitors. Because of the modest levels of beach use, no overcrowding occurs with or without the project, and therefore no out-of-state visitor spending benefits accrue as a result of this project (i.e., out-of-state visitor spending is the same with or without the project).

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV-developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.16 presents a summary of the points assigned for with- and without-project conditions in the project area. This assignment of points reflects the incremental improvement afforded by the wider re-nourished beach. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about $5.68 and $5.33 per person per visit (2014 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. Table 3.17 presents the recreation value benefit for this project ($10,160 present value, mid-year 2014).

Table 3.16 UDV Points Assigned — #1584 GIWW Rollover Bay Reach BN with BUDM

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	8	6	30
Availability of Opportunity	3	3	18
Carrying Capacity	5	3	14
Accessibility	7	6	18
Environmental	6	6	20
Total	29	24	100

Table 3.17 Recreational Benefit for All Users — #1584 GIWW Rollover Bay Reach BN with BUDM

Year	Total Visitation		Recreation Value (2014 Prices)		Present Worth (Difference; 2014 Prices)	Discounted Present Worth
	With Project	Without Project	With Project	Without Project		
2014	28,338	28,338	$161,092	$150,932	$10,160	$9,999

Notes: UDV (with project) = $5.79 (2015 price levels) = $5.68 (2014 price levels)
UDV (without project) = $5.42 (2015 price levels) = $5.33 (2014 price levels)
Inflation rate 2014 to 2015 = 1.8%; 2015 price level x 1/1.018 = 2014 price level
Present worth, beginning of 2014, mid-year discounting, 3.26% discount rate
Discounted present worth = Difference / $1.03265^{(0.5)}$

Summary

Because of the limited visitation and inexpensive land values in the project area, the total project benefits are relatively low (Table 3.18). The estimated benefits occur throughout the year. Using mid-year discounting, the present worth of the $20,243 land value benefit equates to $19,921 (i.e., $20,243 x $1/1.0326^{0.5}$ = $19,921). Combined with the recreational benefit, $9,999, the total project benefit is $29,920. With project costs totaling $198,360, this project has a 0.15 benefit/cost ratio. Although the benefit/cost ratio is low, the project represents a very low cost alternative (with a unit cost of $1.15 per cubic yard of beach fill) for mitigating Rollover Pass' erosive effects on Caplen Beach.

Table 3.18 Benefit-Cost Summary — #1584 GIWW Rollover Bay Reach BN with BUDM

Benefits and Costs	**Discounted Present Worth (beginning of 2014)[2]**
Land Value	$19,921
Recreation Value	$9,999
Total Benefit	$29,920
Total Cost[1]	$198,360
B/C Ratio	0.15

[1]Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)
[2]Dollar values represent present worth equivalents at the beginning of 2014 with a 3.26% discount rate

4.0 NATURAL RESOURCE RESTORATION BENEFIT ANALYSIS

4.1 Nueces County — #1463 Port Aransas Nature Preserve Shoreline Protection Repair

Project Description and Background Information

Port Aransas Nature Preserve lies on the northeast tip of Mustang Island, in Port Aransas, Nueces County, Texas (Figure 4.1). Port Aransas Nature Preserve locates with the Corpus Christi Ship Channel (CCSC) to the north and Piper Channel to the west. The CCSC provides a heavily used, high velocity, shipping channel that links Port Aransas and the Gulf of Mexico. Piper Channel provides the sole connection between a local waterfront/dockside residential community of several hundred homes and the CCSC.

In response to significant long-term CCSC shoreline erosion (17 ft, or about 2.16 acres, per year) along the preserve, the Texas GLO constructed an approximately 6,000-ft long limestone rock revetment in 2007 (CEPRA project #1239) to eliminate the loss of habitat and preserve the remaining ecosystem. Prior to this shoreline stabilization project, the erosion had resulted from unstable substrate along the shoreline, ship-generated wake, natural subsidence, and human induced subsidence. The revetment design included two stretches of revetment with a low crest elevation to allow periodic wash over during storms, which historically sustains the natural estuarine wetland communities. The revetment protects over 2,000 acres of diverse habitat within the preserve, including freshwater and brackish marshes, estuarine areas, wind tidal flats, essential fish habitat and associated uplands. These habitats support numerous species of finfish, shellfish, shorebirds, wading birds, waterfowl, and sea turtles.

Increased water levels and wave activity from Hurricane Ike in September 2008 displaced many of the revetment’s limestone boulders, resulting in a renewed potential for rapid shoreline erosion within the length of greatest boulder displacement. In response, CEPRA Project #1463 repaired and enhanced a 2,059 linear-foot section of the revetment to restore the revetment’s ability to stabilize the shoreline and protect the nature preserve’s habitat and ecological function. Figures 4.2 – 4.4 present pre-construction, post-construction, and six-month post-construction photographs.

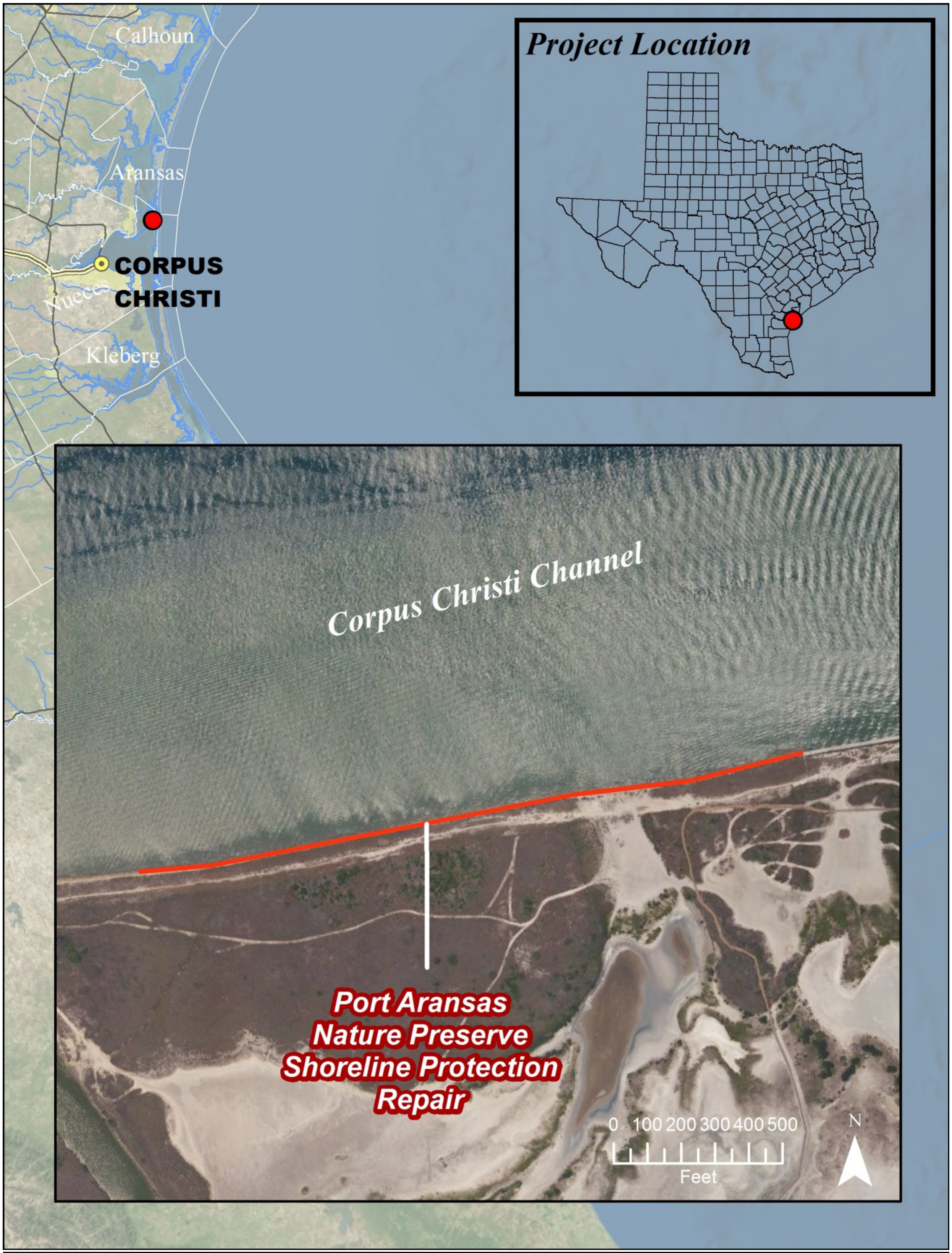

Figure 4.1 Port Aransas Nature Preserve Shoreline Protection Repair Project Location Map

Figure 4.2 Revetment Repair Project Pre-construction Conditions (6/28/12; photo provided by GLO)

Figure 4.3 Revetment Reconstruction (October 28, 2013)

Figure 4.4 Post-construction Conditions (12/16/13; photo provided by GLO)

Project Funding

Funds for project execution included direct and in-kind support from federal and Texas sources (Table 4.1). The FEMA Public Assistance program funded the majority of the repair work, with a hazard mitigation component added to provide enhanced resiliency to the revetment structure. CEPRA Cycle 6 funds provided by the Texas GLO and local funds contributed by the City of Port Aransas composed the non-federal cost share. Construction of the repair and hazard mitigation enhancement project occurred from October 6 – December 6, 2013.

Because this evaluation considers costs and benefits from a Texas point of view, any costs that originate from national agencies or organizations outside of Texas are decreased by 90% (see Section 2.1) because some entity other than the state of Texas incurs those costs. Federal dollars fund FEMA and Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of the federal dollars through individual and corporate taxes. Given 90% of FEMA's $1,213,325 contribution originates from non-Texas sources, the cost incurred by Texas represents just 10% of the federal cost share. Thus, Texas' portion of the federal cost shares equals $121,333 (i.e., 0.1 * $1,213,325). Texas incurs 100% of the CEPRA and Port Aransas cost shares. Therefore, the project cost to Texas revises downward for this benefit-cost analysis from $1,348,138 (i.e., the actual total project cost) to $256,146.

Table 4.1 Funding for the Port Aransas Nature Preserve Shoreline Protection Repair

Funding Source		Amount[1]
Federal Cost Share (90% of project cost)	FEMA Federal Cash Commitment-Public Assistance (GLO PW: SAS055) (*Texas Portion*)	$1,213,325 (*$121,333*)
State/Local Cost Shares (10% of project cost)	Texas GLO (CEPRA) - 6% actual project cost (60% of the non-federal cost share)	*$80,888*
	Port Aransas (QPP) 4% actual project cost (40% of the non-federal cost share)	*$53,925*
Total Project Cost (*Texas Portion*)		$1,348,138 (*$256,146*)

Note: Values in italics are costs to the State of Texas
[1]2013 price levels

Analysis

Ecosystem Services Benefit

This benefits analysis assumes the revetment repair stabilizes the shoreline and, hence, protects the resources directly behind the repaired portion of the revetment. A site assessment previously conducted by Taylor Engineering (Stites, et al., 2008) identified and mapped coastal scrub, Brazilian Pepper, tidal flats, slough water, and saltwater marsh in the project vicinity. These resources provide ecosystem services consistent with those described in Section 2.3, with the exception of aesthetics due to the project area's distance from the closest residential areas. Thus, summing values for the other benefits listed in Table 2.9 yields an ecosystem services benefit of $3,508.20 per acre. The value of the ecosystem service acreage protected, or the acreage of erosion prevented, by the repaired revetment over the project lifespan — assumed 20 years for this analysis — represents the project benefit. Given project construction occurred at the end of 2013, the analysis period spans from 2014 – 2033.

Applying the long-term average rate of shoreline erosion (17 ft/year) over the 2,059-ft length of the revetment repairs yields an erosion area of 0.8 acres/year, or a total of 16 acres over the 20-year analysis period (2014 – 2033). Therefore, the project preserves 16 acres of ecosystem services. Without the project, the ecosystem would lose 0.8 acres per year of ecosystem services beginning in 2014. Table 4.2 presents the service functions' benefits, estimated as the difference between with- and without-project conditions.

Table 4.2 Natural Resources Benefits Calculations, 2014-2033

Year	Ecosystem Service Acres			Annual Per Acre Benefit		Ecosystem Service Benefit (2013 Prices)	Ecosystem Service Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	Difference (Benefit)	Inflation Rate (%)	With Inflation				
2014	16.0	15.2	0.8	1.6%	$3,564	$2,807	$2,851	$2,718	$2,718
2015	16.0	14.4	1.6	1.8%	$3,628	$5,613	$5,806	$5,358	$8,076
2016	16.0	13.6	2.4	1.8%	$3,694	$8,420	$8,865	$7,924	$15,999
2017	16.0	12.8	3.2	2.0%	$3,768	$11,226	$12,057	$10,436	$26,435
2018	16.0	12.0	4.0	2.0%	$3,843	$14,033	$15,372	$12,886	$39,321
2019	16.0	11.2	4.8	2.0%	$3,920	$16,839	$18,815	$15,274	$54,595
2020	16.0	10.4	5.6	2.0%	$3,998	$19,646	$22,390	$17,602	$72,197
2021	16.0	9.6	6.4	2.0%	$4,078	$22,452	$26,101	$19,872	$92,069
2022	16.0	8.8	7.2	2.0%	$4,160	$25,259	$29,951	$22,083	$114,152
2023	16.0	8.0	8.0	2.0%	$4,243	$28,066	$33,944	$24,237	$138,389
2024	16.0	7.2	8.8	2.0%	$4,328	$30,872	$38,085	$26,335	$164,724
2025	16.0	6.4	9.6	2.0%	$4,414	$33,679	$42,379	$28,379	$193,103
2026	16.0	5.6	10.4	2.0%	$4,503	$36,485	$46,828	$30,369	$223,471
2027	16.0	4.8	11.20	2.0%	$4,593	$39,292	$51,439	$32,306	$255,777
2028	16.0	4.0	12.00	2.0%	$4,685	$42,098	$56,216	$34,191	$289,968
2029	16.0	3.2	12.80	2.0%	$4,778	$44,905	$61,163	$36,025	$325,993
2030	16.0	2.4	13.60	2.0%	$4,874	$47,712	$66,285	$37,810	$363,803
2031	16.0	1.6	14.40	2.0%	$4,971	$50,518	$71,588	$39,545	$403,348
2032	16.0	0.8	15.20	2.0%	$5,071	$53,325	$77,076	$41,233	$444,581
2033	16.0	0.0	16.00	2.0%	$5,172	$56,131	$82,755	$42,873	$487,454

Notes: Per acre benefit in 2013 prices = $3,508.20; Present worth, beginning of 2013; mid-year discounting, 3.26% discount rate [mid-year discount factor = $(1/1.0326)^{n+0.5}$, where n = year – 2013]

Federal Spending Benefit

Federal spending that occurs as part of the initial construction represents a net increase inflow of spending for the state economy. Reducing the initial federal funding contribution by 10% (i.e., the estimated amount of federal funds originating from federal taxpayers in Texas) and applying the multiplier effect (Section 2.1), the estimated federal spending benefit for this project is $1,528,789 (i.e., $1,213,324.61* 0.9 * 1.4) in 2013 prices.

Benefit Cost Summary

Summing the above estimates for ecosystem service, tourism (out of state visitor spending), and federal spending benefits yields a total project benefit of $2,113,353. Dividing the total benefits by the Texas project cost ($256,104) results in a B/C ratio of 8.3. (Table 4.3)

Table 4.3 Summary of Benefits for Port Aransas Nature Preserve Shoreline Protection Repair

Benefit/Cost Category	Discounted Present Worth (Beginning of 2013)[2]
Ecosystem Services	$487,454
Federal Spending	$1,528,789
Total Benefits	$2,016,243
Total Costs[1]	$256,146
B/C Ratio	7.9

[1]Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)
[2]Dollar values represent present worth equivalents at the beginning of 2013 with a 3.26% discount rate

4.2 San Patricio/Nueces County — #1565 Nueces Bay Portland Causeway Marsh Restoration

Project Description and Background Information

CEPRA Project #1565 is a component of the second phase of the Nueces Bay Portland Causeway Marsh Restoration Project (Figure 4.5), the first phase of which occurred in 2011. Completed in 2013, the CEPRA project constructed a rock revetment designed to stabilize the outer shoreline of a berm that protects the restored marsh habitat. Revetment construction included placement of graded riprap and quarry stone along the 4,140-ft long earthen berm and construction of two revetment terminal sections to protect the ends of the berm. Partial excavation of the berm was necessary to accommodate proper placement of the graded riprap revetment.

Portland Causeway is that section of U.S. Highway 181 crossing the mouth of Nueces Bay between Corpus Christi and Portland. Historically, this area included significant amounts of high quality marsh habitat. Approximately 180 acres of marsh habitat was lost to dredging and construction of the causeway in the late 1940s, and approximately 160 acres of marsh has been lost to subsequent erosion. Prior impacts to the site included those associated with construction of the roadway and railroad that existed prior to the 1940s. The remaining marsh supports a variety of fisheries (including important nursery habitat) and provides foraging and loafing opportunities for migratory colonial waterbirds and shorebirds. The marsh complex and adjacent uplands also protect the causeway from wave-induced erosion (Belaire Environmental, Inc. 2013).

The first phase of the Nueces Bay Portland Causeway Marsh Restoration Project included the following, as reported in Cravy (2011):

- Restoration of 76 acres of marsh complex, consisting of approximately 25% elevated planting area and 75% open water
- Construction of a protective outer-berm, providing another 12 acres of elevated planting area
- Planting of 31,000 Spartina plants throughout the newly created marsh
- Creation of an 80-acre confined cell between the terraces and outer-berm, allowing for the future placement of dredged material to create additional marsh habitat
- Short-term protection, provided by the restored marsh habitat, of 4,800 ft of shoreline adjacent to critical infrastructure (U.S. Highway 181)

Figure 4.6 compares conditions in 1950 to those in 2011, upon completion of the marsh terraces and protective outer-berm (the long berm shown on the left side in the 2011 aerial photograph).

The second phase of the marsh restoration project, completed in 2013, included additional marsh restoration within the 80-acre confined cell (Figure 4.7) —, the large triangular shaped area bounded by the outer-berm and the planting terraces created in 2011 — and construction of the above-mentioned rock revetment along the Nueces Bay side of the outer berm (Figure 4.8). The marsh restoration component created about 80 acres of marsh habitat via construction and planting of three large marsh cells immediately behind the outer berm. Fill material for the restoration project derived from adjacent excavation areas, and planting units of *Spartina alterniflora* (smooth cordgrass) originated from the designated harvest area along the adjacent shoreline of the outer berm. Final fill elevations provided suitable conditions for establishment of smooth cordgrass and allowance for migration of the marsh in response to anticipated sea level rise (Belaire Environmental, Inc. 2013).

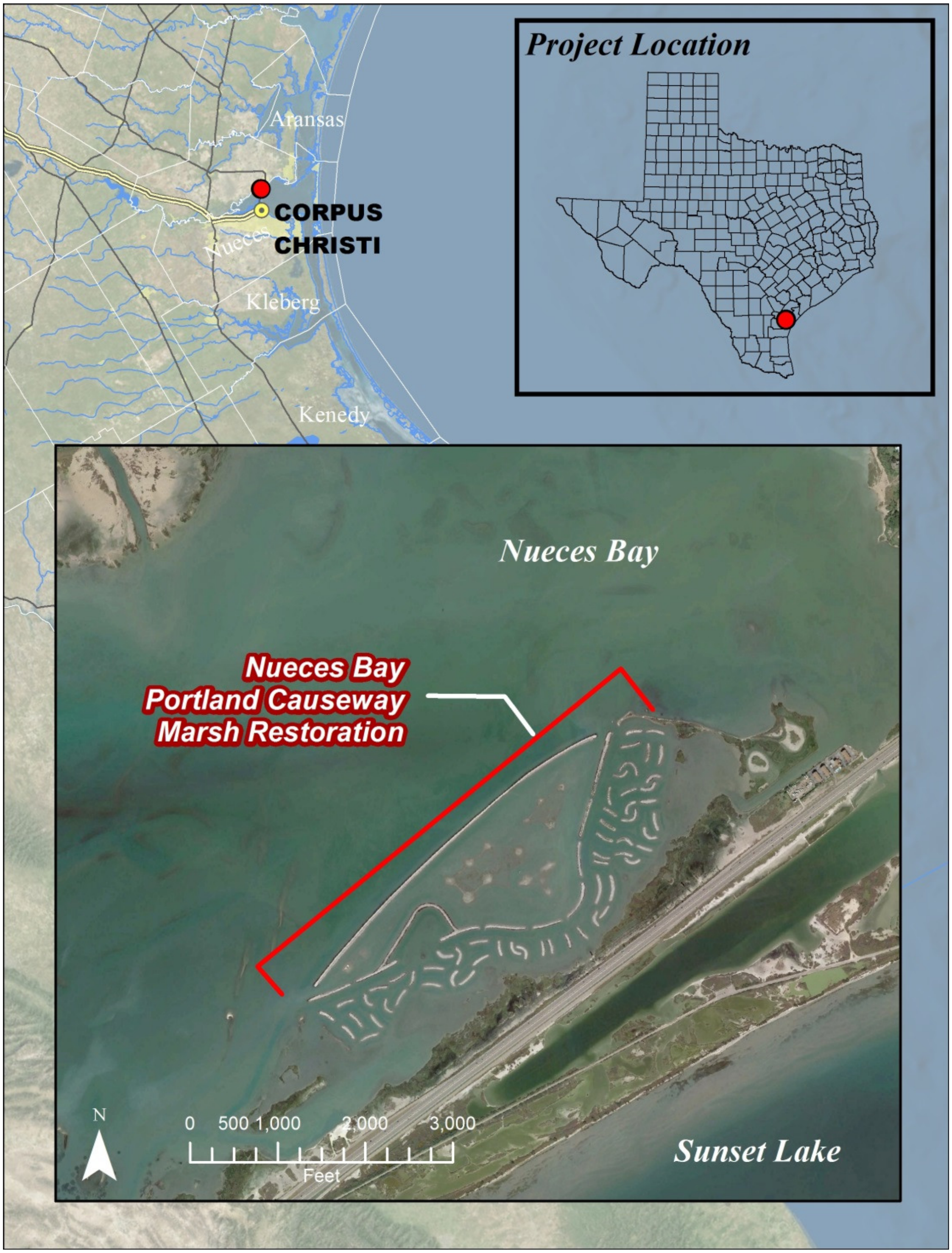

Figure 4.5 Nueces Bay Portland Causeway Marsh Restoration Project Location Map

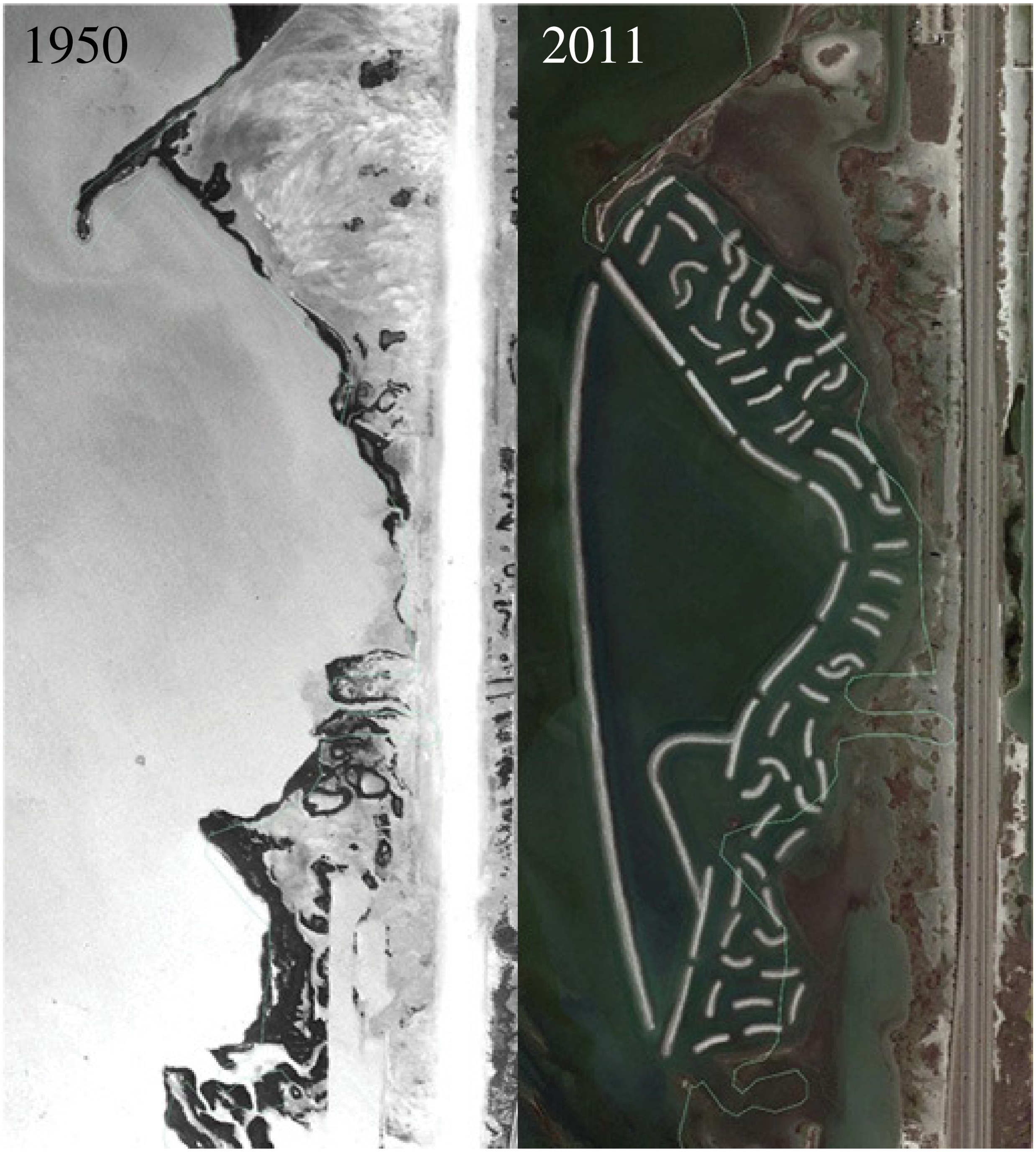

Figure 4.6 1950 Shoreline and 2011 Shoreline with Phase 1 Terraces and Protective Berms Completed (Aerial Source: Google Earth)

Figure 4.7 Nueces Bay Portland Causeway Marsh Restoration Phase II Post-Construction (Photo provided by the GLO; photo dated March 30, 2014)

Figure 4.8 Detail of Rock Revetment at Southwest End of Outer Berm (Aerial Source: Google Earth)

Project Costs

Funds for project execution included direct and in-kind support from federal and Texas sources including NOAA via the Texas Coastal Management Program (CMP), USFWS via the Texas Coastal Impact Assistance Program as well as direct contributions, Texas Commission on Environmental Quality (TCEQ), CEPRA, and local agencies (Table 4.4). As described in Section 2.1, the Texas accounting perspective reduces Texas' share of the federal cost to $324,275.22. As a result, Texas' project cost for this benefit-cost analysis is $753,957.32 (i.e., $324,275.22 + $429,682.10).

Table 4.4 Funding for the Nueces Bay Portland Causeway Marsh Restoration

Funding Source		Amount[1]
Federal Cost Shares	State CIAP (2008; funded by USFWS) (*Texas Portion*)	$2,320,675 *($232,068)*
	CMP (Cycle 16; funded by NOAA) (*Texas Portion*)	$238,031 (*$23,803*)
	USFWS (*Texas Portion*)	$3,740 (*$374*)
State/Local Cost Shares	TCEQ	*$57,563*
	Local	*$10,468*
	Texas GLO (CEPRA Cycle 7)	$*429,682*
Total Project Cost *(Texas Portion)*		$3,060,159 *($753,957)*

Note: Values in italics are estimated costs to the State of Texas
[1]2013 price levels

Analysis

Project Ecosystem Services Benefits

The ecosystem services (ES) benefit estimates developed in this chapter rest on several assumptions:

- The GLO project sites provide economic benefits in a manner similar to those described in the literature for Gulf of Mexico estuarine marshes in this region. This assumption substituted for the extensive on-site interviews and natural resource evaluations described in the literature pertinent to this project.
- This study applied a 20-year project life, because similar marsh restoration projects in Texas have maintained or expanded their original footprints. In addition, analysis of potential effects

of sea level rise on marshes in the project area (Feagin et al., 2010) have suggested that (at least for existing rates of sea level rise) the marshes will most likely migrate and remain viable.

- Based on the construction dates and examination of aerial and ground photographs of the site, the marsh benefits are currently partial (the site is undergoing expected surface sediment redistribution creating marsh habitat and opportunity for estuarine community development) and per acre ecosystem services benefits will increase to full value over a 15-year period following completion of initial construction completion.
- The period of analysis covers 21 years. The first year, 2013, is the year during which construction took place. Because construction occurred at the end of 2013, marsh development and resulting ecosystem service value benefits accrual begins in 2014 for this analysis. Benefit estimates represent the difference between conditions with and without this project through 2033. Ecosystem services benefits accrue in two areas: (1) the newly created 80-acre marsh area inside the outer berm; and (2) the older marsh area created in the 2011 Phase I project (the 2013 project affects erosion rates for the marsh ecosystem created by the 2011 project).
- Ecosystem services benefits equal $3,562.01 per acre as described in Section 2.3; the benefit categories include Habitat, Recreation, Disturbance Regulation, Gas Regulation, Waste Regulation, and Aesthetics as described in Table 2.9.

Ecosystem annual service value calculations for the with- and without-project conditions are based on the level of ecosystem function and, thus, ES provided by the ecosystem of interest. Given the above assumptions, estimating the ES benefits requires the rate of marsh habitat and services development, the effect of wave-induced erosion on the marsh habitat and services, and the value of these services. The following sections discuss these topics.

Marsh Development

For this project, the terraces and berms were constructed to settle over time to create additional marsh physical habitat for vegetation development. Based on analysis of available aerial photographs (provided for 2011 and 2014 in Google Earth), settlement of the irregular terraces and berms (constructed in 2011) to optimum wetland elevation is still ongoing. This analysis used the aerial photographs to measure the berm and terrace top width changes over the three-year period as a means to estimate the settlement rate. Measurements yielded an average berm top width loss rate of 2.47 ft per year; this equates to 8.3% annual settlement rate given the 30-ft design top widths and assuming the berms were constructed as designed. The irregular terraces, with a design top width of 25 ft, eroded at 2.3 ft per year, or 9.2%

annually. Combining these rates yields an average of 8.8% settlement for the entire 2011 marsh complex. This analysis also assumed the marsh complex substrate constructed in 2013 will settle at the same rate as the substrate constructed in 2011. In effect, the above settlement rate indicates the 2011 and 2013 restoration projects will achieve the target restoration acreage (i.e., 88 acres for the 2011 project and 80 acres for the 2013 project) during the 12th year after construction. Given the construction completion dates discussed above (i.e., beginning of 2011 and end of 2013), the 2011 and 2013 projects will achieve the target acreage in 2023 and 2026. The resulting estimated marsh ecosystem acreage in each year, reflecting the assumptions discussed above, is shown in the 2nd two columns of Table 4.5, "Ecosystem Acres With Project," for the marsh areas constructed in 2011 and 2013, respectively.

Marsh restoration projects also require time to fully develop their ecosystem benefits. Unfortunately, few long-term studies of saltmarsh ecosystem component development exist. Based on the Benthic Habitat Atlas of Coastal Texas (Finkbeiner et al., 2009) and other descriptions of Nueces Bay resources, colonization by seagrass, oysters, and the wide variety of other species present is assumed ongoing for some years until the full ecosystem components and their related functions have completed development. For a North Carolina *Spartina alterniflora* marsh, Craft et al. (2013, 2014) identified a 5-year period of vegetative colonization and an additional 10 or more years for full benthic community and soil column development. Based on these results, this analysis assumed a 15-year trajectory for development of full ecosystem services, with 10% of the full ecosystem services value per acre accruing in the first year following construction and a linear annual increase in value from 10% to 100% over the ensuing 14 years. This rate of development represents an increase in services value of 6.429% (i.e., [100% - 10%]/14 years) of full ecosystem services value in each of those 14 years. . For the marsh area created in 2011, this translates into 10% in 2011 (because construction was completed at the beginning of 2011), 16.4% in 2012, and 22.9% in 2013 when construction of Phase II occurred, and so forth until full services are reached in 2015. For the marsh area created in 2013, the ecosystem services value is 10% of full value in 2014 (because construction was completed at the end of 2013) and increases by about 6.429% per year until full services are reached in 2028. These percentages are shown in the two columns of Table 4.5, "Percent Service Provided" for the marsh areas constructed in 2011 and 2013.

<u>With- and Without-Project Future Marsh Area Calculations</u>

Given the erosion experienced along the protective outer berm from 2011 – 2013, prior to construction of the revetment, this analysis assumes the marsh restoration implemented in 2013 was contingent on construction of the revetment. The with-project scenario assumes the revetment prevents degradation of the marsh ecosystem implemented in 2011 (88 acres) and 2013 (80 acres). In the with-project scenario, the 2013 marsh restoration grows to the targeted 80 acres of marsh ecosystem by 2026 (i.e. after 12 full years), and the 2011 marsh restoration grows to its full 88 acres by 2023. For both the with-project and without-project (discussed below) scenarios, full development of the ecosystem services provided by each restoration event occurred over a 15-year period from initial construction as discussed above. Additionally, once fully developed, the marsh area and its services are expected to remain intact for the remainder of the 20-year project life. As mentioned earlier, the with-project estimated marsh area acreages are shown in the 2nd two columns of Table 4.5, "Ecosystem Acres With Project," for the marsh areas constructed in 2011 and 2013.

To estimate the effect of erosion on the marsh ecosystem for the without-project scenario, this analysis examined other similar marsh restoration projects completed several years earlier in West Galveston Bay. Aerial photographs indicated projects that did not construct an outer berm to protect the restored marsh are eroding along the marsh edges directly exposed to the wave energy of the bay. Apart from this erosion, the overall development of those marshes appears (from aerial photographs) to correspond roughly to project descriptions. Accordingly, to estimate the acreage loss of marsh ecosystem in Nueces Bay without the protective revetment, this analysis assumed the marsh would develop normally but would erode along the edge exposed to the bay at a rate of 7.98 ft/yr (i.e, the estimated 1950 – 2009 erosion rate as calculated in Appendix 1). Applied uniformly across the 4,140-ft long exterior edge of the marsh, this erosion rate translates to a loss of about 0.76 acres/year.

Benefits Calculations

This benefits analysis incorporates the following concepts:

- Natural resource function benefits are estimated to accrue over a 20-year project life 2014 – 2033; 2014 is selected as the first year of benefit accrual, because the project was completed at the end of 2013.
- The benefit value in each year is expressed in that year's price levels (Table 2.1) and is the calculated difference between the ecosystem services value with the project and without the project.
- The period of analysis is 2013 through 2033. Costs were incurred in 2013, the year of project construction, and benefits in each year are converted to present worth as of the beginning of 2013, using a discount rate of 3.26% (Section 2.1).

Table 4.5 Ecosystem Services Benefits, Nueces Bay Portland Causeway Marsh Restoration

Year	Ecosystem Acres				Percent Service Provided		Net Service Acres			Annual Per Acre Benefit		Ecosystem Service Benefit (2013 Prices)	Ecosystem Service Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project			W/o Project	2011 Constr.	2013 Constr.	With Project	W/o Project	Difference (Benefit)	Inflation Rate (%)	With Inflation				
	2011 Constr.	2013 Constr.	Total	2011 Constr.											
2013	26.2		26.2	26.2	22.9	-	-	-	-	-	$3,562	-	-	-	-
2014	32.8	13.0	45.8	32.0	29.3	10.0	10.9	9.4	1.5	1.6	$3,619	$5,423	$5,510	$5,251	$5,251
2015	39.4	18.9	58.3	37.9	35.7	16.4	17.2	13.5	3.6	1.8	$3,684	$12,991	$13,437	$12,401	$17,653
2016	46.0	24.8	70.8	43.7	42.1	22.9	25.1	18.4	6.6	1.8	$3,750	$23,608	$24,857	$22,217	$39,869
2017	52.6	30.7	83.3	49.6	48.6	29.3	34.5	24.1	10.5	2.0	$3,825	$37,272	$40,029	$34,648	$74,517
2018	59.2	36.6	95.8	55.4	55.0	35.7	45.6	30.5	15.2	2.0	$3,902	$53,985	$59,137	$49,572	$124,089
2019	65.8	42.5	108.3	61.2	61.4	42.1	58.3	37.6	20.7	2.0	$3,980	$73,746	$82,400	$66,891	$190,980
2020	72.4	48.4	120.8	67.1	67.9	48.6	72.6	45.5	27.1	2.0	$4,060	$96,555	$110,044	$86,512	$277,492
2021	79.0	54.3	133.3	72.9	74.3	55.0	88.5	54.2	34.4	2.0	$4,141	$122,413	$142,304	$108,341	$385,833
2022	85.6	60.2	145.8	78.8	80.7	61.4	106.1	63.6	42.5	2.0	$4,224	$151,318	$179,425	$132,290	$518,123
2023	88.0	66.1	154.1	80.4	87.1	67.9	121.5	70.1	51.5	2.0	$4,308	$183,273	$221,660	$158,271	$676,394
2024	88.0	72.0	160.0	79.6	93.6	74.3	135.8	74.5	61.3	2.0	$4,394	$218,275	$269,274	$186,198	$862,592
2025	88.0	77.9	165.9	78.9	100	80.7	150.8	78.9	72.0	2.0	$4,482	$256,325	$322,539	$215,989	$1,078,580
2026	88.0	80.0	168.0	78.1	100	87.1	157.7	78.1	79.6	2.0	$4,572	$283,516	$363,888	$235,985	$1,314,565
2027	88.0	80.0	168.0	77.4	100	93.6	162.9	77.4	85.5	2.0	$4,663	$304,542	$398,692	$250,393	$1,564,958
2028	88.0	80.0	168.0	76.6	100	100	168.0	76.6	91.4	2.0	$4,756	$325,568	$434,743	$264,414	$1,829,372
2029	88.0	80.0	168.0	75.8	100	100	168.0	75.8	92.2	2.0	$4,852	$328,275	$447,125	$263,360	$2,092,732
2030	88.0	80.0	168.0	75.1	100	100	168.0	75.1	92.9	2.0	$4,949	$330,982	$459,829	$262,291	$2,355,023
2031	88.0	80.0	168.0	74.3	100	100	168.0	74.3	93.7	2.0	$5,048	$333,689	$472,861	$261,210	$2,616,233
2032	88.0	80.0	168.0	73.6	100	100	168.0	73.6	94.4	2.0	$5,149	$336,396	$486,232	$260,116	$2,876,349
2033	88.0	80.0	168.0	72.8	100	100	168.0	72.8	95.2	2.0	$5,252	$339,103	$499,947	$259,010	$3,135,359

Notes:
Marsh area constructed in 2013 is associated with the with-project case only.
Net Service Area = Ecosystem Acres * Percent Service Provided (example: 2014 without-project net service area = 32.0 * 0.293 = 9.4 acres; 2014 with-project net service area = 32.8 * 0.293 + 13.0 * 0.10 = 10.9 acres).
Present worth, beginning of 2013, mid-year discounting, 3.26% discount rate [mid-year discount factor = (1/1.0326)n+0.5, where n = year – 2013].

- Benefits for fully developed marsh have an estimated value of $3,562.01 per acre per year (2013 prices) for the acreage in service each year. Table 4.5 (column heading "Percent Service Provided") shows the growth in percent ecosystem service/acre for marsh acreage in each marsh area. For example, in Table 4.5, the acreage in the 2011 marsh area will have matured by the year 2015 such that 35.7% of $3,562.01 is the estimated service value produced per acre in that year; other cells in these two columns are to be similarly interpreted).
- Benefits total $3,562.01 per acre per year (2013 prices) for the acreage in service each year.
- Benefit values are neither aggressively high nor conservatively low; this evaluation has used median dollar values for the natural resource functions provided by the marsh ecosystem (marsh, benthic and open water communities).

Natural resource function benefits equal the estimated difference between conditions with and without the project. Because the restoration expected settling of the initial construction to create the final expected acreage and planting covered only a minor fraction of the constructed area, this analysis phased in the benefits based on the initial construction date (2011 and 2013) as discussed above. Table 4.5 summarizes the natural resource benefit calculations.

Federal Spending Benefit

Federal spending that occurs as part of the initial construction represents a net increase inflow of spending for the state economy. Reducing the initial federal funding contribution by 10% (i.e., the estimated amount of federal funds originating from federal taxpayers in Texas) and applying the multiplier effect (Section 2.1), the estimated federal spending benefit for this project is $3,228,682.97 (i.e., $2,562,446.80 * 0.9*1.4) in 2013 prices.

Benefit Cost Summary

Summing the above estimates for ecosystem service and federal spending benefits yields a total project benefit of $3,228,683. Dividing the total benefits by the Texas project cost ($753,957) results in a B/C ratio of 8.3. (Table 4.6)

Table 4.6 Benefit Cost Summary for Nueces Bay Portland Causeway Marsh Restoration

Benefit/Cost Category	**Discounted Present Worth (Beginning of 2013)[2]**
Ecosystem Services	$3,135,350
Federal Spending	$3,228,683
Total Benefits	$6,364,042
Total Costs[1]	$753,957
B/C Ratio	8.44

[1]Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)
[2]Dollar values reflect present worth equivalents at the beginning of 2013 with a 3.26% discount rate

5.0 CONCLUSIONS

This study finds the state of Texas receives $3.50 in economic and financial benefits for every Texas dollar invested in these projects. Table 5.1 presents a summary of the assessed CEPRA Cycles 6 – 8 projects, which is a representative sampling of the CEPRA program.

Table 5.1 Summary of CEPRA Cycles 6 – 8 Projects, Costs, and Benefits

CEPRA Project Number / Name	County	Year	Beginning of Project Year		Beginning of 2015[2]		Benefit-to-Cost (B/C) Ratio
			Discounted Cost[1]	Discounted Benefits	Discounted Cost[1]	Discounted Benefits	
#1382 / CR 257 Road Repair and Protective Revetment	Brazoria	2012	$7,387,294	$32,447,799	$8,133,580	$35,725,771	4.4
#1453 / Port Aransas Nature Preserve Shoreline Protection Repair	Nueces	2013	$256,146	$2,016,243	$273,119	$2,149,845	7.9
#1532 / Sargent Beach Nourishment	Matagorda	2013	$3,796,450	$428,130	$4,048,013	$456,499	0.1
#1565 / Nueces Bay Portland Causeway Marsh Restoration	San Patricio/ Nueces	2013	$753,957	$6,364,042	$803,916	$6,785,741	8.4
#1584 / GIWW-Rollover Bay Reach Beach Nourishment with BUDM FY 2014 Event	Galveston	2014	$198,360	$29,920	$204,827	$30,895	0.2
Total[3]					$13,463,455	$45,148,750	3.4

Notes: [1]Texas portion only; dollar values reflect present worth equivalents at the beginning of the year of project construction.
[2]Dollar values reflect present worth equivalents at the beginning of 2015 with a 3.26% discount rate
[3]Total B/C Ratio represents the Total Discounted Benefits divided by the Total Discounted Cost of all five projects combined (i.e., $45,148,750 / $13,463,455 = 3.4).

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the shoreline protection at Port Aransas Nature Preserve reflects contributions from the Federal Emergency Management Agency (FEMA) Public Assistance program, which covered 90% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.15 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits. The Port Aransas Nature Preserve Shoreline Protection Repair Project experienced federal spending benefits ($1,528,789 discounted present worth) from FEMA funding as mentioned above. Similarly, Nueces Bay Portland Causeway Marsh Restoration experienced federal spending benefits ($3,228,683 discounted present worth) from funding by USFWS, NOAA, and CIAP. The CR 257 Road Revetment Project experienced federal spending benefits ($20,029,527 discounted present worth) from the FHWA and CIAP.

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

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APPENDIX A

Erosion Rates — Project #1565 Nueces Bay Portland Causeway Marsh Restoration

TAYLOR ENGINEERING INC.
10151 DEERWOOD PARK BLVD.
BLDG. 300 SUITE 300
JACKSONVILLE, FL 32256
CERTIFICATE OF AUTHORIZATION # 4815

FIGURE A1.1
1950-2009 SHORELINE EROSION DATA POINTS
NUECES COUNTY, TEXAS

Notes:
1. 1950-2009 Shoreline Location Map
2. Basemap Source: 2009 Aerial Texas NRIS
3. Horizontal Datum: NAD 1983

PROJECT	C2014-088
DRAWN BY	NA
SHEET	
DATE	MAR 2014

S:\Technical\ArcMapTemplates\Landscape 8_5x11 JAX.mxd

Table A1.1 1950 – 2009 Shoreline Erosion Data Points

1950-2009 Shoreline Erosion - Data Points		
Data Points	**1950-2009 Erosion (linear feet)**	**1950-2009 Erosion (ft/yr)**
1950(1) 2009(1)	872	14.78
1950(2)-2009(2)	770	13.05
1950(3)-2009(3)	787	13.34
1950(4)-2009(4)	488	8.27
1950(5)-2009(5)	117	1.98
1950(6)-2009(6)	126	2.14
1950(7)-2009(7)	178	3.02
1950(8)-2009(8)	158	2.68
1950(9)-2009(9)	191	3.24
1950(10)-2009(10)	599	10.15
1950(11)-2009(11)	891	15.10
	Average Distance	**7.98**
	Median	**8.3**
	Maximum	**15.1**
	Minimum	**2.0**
	1st Quartile	**2.8**
	3rd Quartile	**14.8**
	Sample Standard Deviation	**5.2**

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FIGURE A1.2
SETTLING RATE COLLECTION POINTS
NUECES COUNTY, TEXAS

Notes:
1. Basemap Source: 2012 Texas NRIS
2. Horizontal Datum: NAD 1983

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SHEET	
DATE	MAR 2015

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Table A1.2 Confined Cell Outer Berm Settling Rate 2011 – 2014 (3 Years)

Confined Cell Outer Berm Top Width Settling Erosion Rate			
Collection ID	Berm Top Width (ft)		Width Change (ft)
	2011	2014	
T1P1	34.81	18	16.81
T2P1	27.68	16.84	10.84
T3P1	26.91	12.17	14.74
T4P1	30.21	14.75	15.46
T5P1	25.58	11.86	13.72
T6P1	13.9	5.93	7.97
T7P1	22.71	0	22.71
T8P1	15.038	6.24	8.80
T9P1	27.79	12.09	15.70
T10P1	31.06	7.52	23.54
Average Distance	25.5688	10.54	15.03

Table A1.3 Confined Cell Inner Berm Settling Rate 2011 – 2014 (3 Years)

Confined Cell Inner Berm Top Width Settling Erosion Rate			
Collection ID	Berm Top Width (ft)		Width Change (ft)
	2011	2014	
T1P2	26.62	19.78	6.84
T2P2	22.43	15.41	7.02
T3P2	26.24	19.22	7.02
T4P2	26.8	19.16	7.64
T5P2	27.24	14.98	12.26
T6P2	21.67	10.19	11.48
T7P2	30.04	26.26	3.78
T8P2	23.83	7.77	16.06
T9P2	28.9	26.87	2.03
T10P2	34	33.96	0.04
Average Distance	26.777	19.36	7.42

Table A1.4 Marsh Complex Settling Rate 2011 – 2014 (3 Years)

Marsh Terraces Top Width Settling Erosion Rate			
Collection ID	**Berm Top Width (ft)**		**Width Change (ft.)**
	2011	**2014**	
Ex1	21.88	13.21	8.67
Ex2	22.64	14.6	8.04
Ex3	23.2	13.81	9.39
Ex4	31.87	27.04	4.83
Ex5	21.11	15.32	5.79
Ex1V	25.28	21.71	3.57
Ex2V	23.75	14.2	9.55
Ex3V	25.22	17.36	7.86
Ex4V	25.58	22.81	2.77
Ex5V	30.11	23.03	7.08
Average Distance	25.064	18.309	6.76