INTEGRATED
GENERAL REEVALUATION REPORT
AND
ENVIRONMENTAL ASSESSMENT
FOR
COASTAL STORM DAMAGE
REDUCTION PROJECT

FOLLY BEACH, SOUTH CAROLINA

APPENDIX E
ECONOMICS, PARKING AND ACCESS

Executive Summary

The Folly Beach Coastal Storm Risk Management Feasibility Study is authorized by Section 216 of the Flood Control Act of 1970, Public Law 91-611 (33 U.S.C. § 549a). The study is a re-evaluation of a 1991 study to determine continued federal interest in Folly Beach in the presence of escalating costs.

►Alternative Evaluation

Upon conduct of a preliminary screening, followed by an evaluation of a set of an array of preliminary alternatives, and a detailed evaluation of a set of final alternatives, the project delivery team has determined a Recommended Plan for reducing coastal storm and erosion damage to infrastructure and land. Alternatives were evaluated using FY2020 price levels, the FY2020 water resources discount rate of 2.75% and a 50-year period of analysis with a base year of 2024. Structure and content damage, armor construction cost prevented, land loss, and prevention of structure condemnation were included as benefit categories. Incidental recreation benefits are not included. See Table 1 for more detail on the evaluation of the final array of alternatives. Dune values refer to the height of the dune in NAVD88. All dunes are 5' wide at the crest.

Table 1: Final Alternative BCRs & Average Annual Net Benefit (Cost from Beach-*fx*)

Alternative Name	Nourishments (Interval)	Reaches 2-17	Reaches 18-21	Reaches 22-26	BCR	Average Annual Net Benefit
Alternative 1	-	No Action			-	$0
Alternative 2	4 (12 years)	35' Berm, 15' Dune	35' Berm, 15' Dune	50' Berm, 15' Dune	1.29	$1,109,593
Alternative 3	4 (12 years)	35' Berm, 15' Dune	50' Berm, 15' Dune	50' Berm, 15' Dune	1.28	$1,100,438
Alternative 4	5 (10 years)	35' Berm, 15' Dune	35' Berm, 15' Dune	50' Berm, 15' Dune	1.10	$468,619
Alternative 5	5 (10 years)	35' Berm, 15' Dune	50' Berm, 15' Dune	50' Berm, 15' Dune	1.10	$443,523
Alternative 6	6 (8 years)	15' Berm, No Dune			0.93	-$279,870

The plan with the highest net benefits is Alternative 2. However, the PDT decided to recommend Alternative 3 due to its higher resiliency. The physical difference between the two alternatives is that the 50' berm extends to reaches 18-21 under alternative 3.

►The Recommended Plan

Alternative 3 is the Recommended Plan. The Recommended Plan will include initial construction and periodic nourishment of a 15' high NAVD88 dune that is 5' wide at the crest for the full length of the island, excluding the county park in reach 1. The dune will be protected by a 35’ berm in reaches 2-17 and a 50’ berm in reaches 18-26. Dredging from three different sources (1 river, 2 offshore) will be used over the 50-year project lifespan to fill the recommended template.

Table 2 provides a summary of the Recommended Plan with and without incidental recreation benefits added at FY2020 prices and discounted with the FY2020 water resources discount rate of 2.75%. The costs from the Total Project Cost Summary (TPCS) are used in Table 2 resulting in a change to the BCR and net benefits from Table 1.

Table 2: Economic Summary of the Recommended Plan

Economic Category	**Primary Storm Damage Reduction Benefit**	**Primary Storm Damage Reduction + Incidental Recreation Benefit**
Price Level	FY2020	FY2020
FY2020 Water Resources Discount Rate	2.75%	2.75%
Average Annual Structure and Content Damage Benefit	$295,513	$295,513
Average Annual Armor Construction Cost Benefit	$1,047,639	$1,047,639
Average Annual Land Loss Benefit	$2,556,610	$2,556,610
Average Annual Structure Condemnation Benefit	$1,139,099	$1,139,099
Average Annual Incidental Recreation Benefit	-	$19,392,413
Average Annual Total Benefit	$5,038,861	$24,431,274
Average Annual Total Cost (from beach-*fx*)	$3,938,423	$3,938,423
Average Annual Total Cost (from TPCS)	$4,632,337	$4,632,337
Average Annual Net Benefit (using TPCS)	$406,524	$19,798,937
BCR (using TPCS)	1.09	5.27

Table of Contents

List of Figures

List of Tables

1 Introduction

The purpose of this economics appendix is to tell the story of the economics investigation and provide greater detail on the results of the analysis. The sections that follow will cover the following topics:

►**Existing Conditions**
Items discussed include assessment of socio-economic conditions, spatial organization of the study area, and an inventory of the coast infrastructure within the study area.

►**Coastal Storm Risk Management Benefits**
This section will cover the methods used to estimate the future without-project, and future with-project condition using Beach-*fx*, accounting for risk and uncertainty. The future without – project condition will cover the distribution of damages in the following dimensions:

- ►Spatial (Where)
- ►Categorization of structures (What)
- ►Damage diving parameter (How)
- ►Temporal (When)

The future with-project condition discussion will cover the CSRM alternatives analyzed, and the analysis results. In addition, an analysis of alternative performance under low and high sea level change scenarios is provided.

►**NED & Recommended Plan Selection and Performance**
This section addresses the rationale for NED and Recommended Plan selection. A detailed description of the performance of the NED Plan is provided with the same 4 dimensions given in the Coastal Storm Risk Management section. A discussion of the project's incidental recreation benefits is also provided.

►**Beach-*fx* Overview**
Beach-*fx* was developed by the USACE Engineering Research and Development Center in Vicksburg, Mississippi. On April 1, 2009 the Model Certification Headquarters Panel certified the Beach-*fx* hurricane and coastal storm risk management (CSRM) model based on recommendations from the CSRM – Planning Center for Expertise. The model was reviewed by the Planning Center for Expertise for coastal and storm damage and found to be appropriate for use in CSRM studies.

Beach-*fx* fully incorporates risk and uncertainty and is used to simulate lifecycle hurricane and storm damages and to compute accumulated present worth damages and costs. Storm damage is defined as the damage incurred by the temporary loss of a given amount of shoreline as a direct result of wave attack, erosion, and/or inundation caused by a storm of a given magnitude and probability. Beach-*fx* is an event-driven life-cycle model that estimates damages and associated costs over a period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Damages or losses to developed shorelines include buildings, roads, vehicles, seawalls, revetments, bulkheads, replacement of lost backfill, etc. Beach-*fx* also provides the capability to estimate the costs of certain future measures undertaken by state and local organizations to protect coastal assets, such as emergency beach/dune fill projects.

Data on historic storms, beach survey profiles, and private and commercial structures within the project area is used as input to the USACE Beach-*fx* model. The model is then used to estimate future project hurricane and storm damages.

2 Existing Conditions

2.1 Overview of Existing Structures and Data Organization

Economists, real estate specialists, and engineers have collected and compiled detailed structure information for the stretch of shoreline to be modeled in Beach-*fx* as part of the Folly Beach, South Carolina Coastal Storm Risk Management Feasibility Study covering almost 6 miles of shorelines, which includes:

- ►692 Single Family Residences (325 single-story, 367 multi-story)
- ►103 Multi-Family Residences (19 single-story, 84 multi-story)
- ►260 Dunewalks
- ►830 Vehicles
- ►122 Blocks of City Streets

In total, attribute information for 2,207 separate damage elements (DEs) was populated for economic modeling using beach-*fx*. The proximity of the buildings to the beach makes them potentially vulnerable to erosion, wave attack, and inundation.

The study area was disaggregated into 9 representative beach profiles, 26 model (Beach-*fx*) reaches, and 620 lots (of which 100 are currently armored and 223 are armorable in the future) for economic modeling and reporting purposes. Figure 1 shows an aerial view of the Beach-*fx* model features that represents the shoreline in the study area. This hierarchical structure is depicted as follows:

- ►**Beach Profiles**: Coastal beach profile surveys were analyzed by USACE Wilmington District (SAW) Coastal Engineering personnel to develop representative beach profiles that include the dune, berm and submerged portions of the beach. The representative beach profiles are used for shore response modeling in the SBEACH engineering numerical model, and only referred to in this section for informational purposes.
- ►**Beach-*fx* (Model) Reaches**: Quadrilaterals with a seaward boundary that is parallel with the shoreline that contain the Lots and Damage elements, and that are used to incorporate coastal morphology changes for transfer to the lot level. Model reaches are also useful because they allow modelers to divide study reaches into more manageable segments for analysis.

►**Lots**: Quadrilaterals encapsulated within model reaches used to transfer the effect of coastal morphology changes to the damage element. Lots are also repositories for coastal armor costs, specifications, and failure threshold information.
►**Damage Elements**: Represents the smallest unit of the existing condition coastal inventory and a store of economic value subject to losses from wave attack, inundation, and erosion damages. Damage elements are a primary model input and the topic of focus in this discussion. The primary structure categories are coastal armor and coastal structures.

More details on the establishment of the Profiles and Beach-*fx* Model Reaches, which is primarily based on physical shoreline characteristics, can be found in the Appendix A – Coastal Engineering.

Beach-*fx* handles economic considerations at the Lot and Damage Element levels. These considerations include armor construction costs at the Lot level and the extent of damage and rebuilding costs at the Damage Element level. When damages occur in Beach-*fx*, Damage Elements may be partially rebuilt depending on the extent of modeled damage. Beach-*fx* calculates rebuild costs as the difference in the structures depreciated replacement value before and after the damage occurs. Section 2.2 will provide further detail on the Lot and Damage Element attribute data that makes up the structure inventory for this project area.

Figure 1: Typical Beach-*fx* Set Up (ArcGIS World Imagery)

2.2 Data Collection for Structure Inventory

Information on the existing economic conditions along the Folly Beach study area coastline was collected for economic modeling purposes using Beach-*fx*. The information on the coastal assets detailed in this section was collected from mapping resources and site visits.

2.2.1 Lots – Coastal Armor

Beach-*fx* handles coastal armoring parameters and condemnation at the lot level. Lots are designated as being either armored, armorable in the future, or not armorable, based on coastal regulations that dictate armor construction and local history on armor permitting and construction. Since armoring forms one of the major roles of lots in Beach-*fx*, the location and length of potential future armoring dictates the seaward boundary of most lots.

Data on coastal armor within the project area was collected from aerial photography and USACE SAW Coastal Engineering personnel.

The area modeled contains several types of existing coastal armor including seawalls and revetments constructed of various materials. Most of this existing armor has been constructed to protect single family residences from erosion damages. Figure 2 shows the lots color coded by armor status for a typical stretch of shoreline. Lots that are already armored are shown in red.

The project area shoreline that is not currently armored has been categorized as being either armorable in the future or not armorable. This categorization is based on the assumed likelihood that armor would or would not be constructed by local interests should property be threatened in the future by coastal processes.

Lots designated as armorable in the future are shown in yellow in Figure 2. It is assumed that certain structures along the shoreline would be armored by local interests in a similar manner to existing armor as erosion continues to threaten homes and property. In Folly Beach new armor construction must abide by local regulations. These regulations were used for the basis of the specifications dictating how future armor for family homes would perform. It is assumed that the South Carolina Department of Transportation SCDOT would construct armor in order to protect the seaward most roadway (W Ashley St west of Center St, E Artic Ave east of Center St) if erosion threatened it. This road is the first line of defense for which many homeowners access their property. The SCDOT already installed a heavy-duty revetment in an area that has seen all its developable land seaward of the road erode. This area is comprised of beach-*fx* model reaches 20 and 21 and is known locally as "the washout."

SAW personnel developed cost estimates for four unique types of existing or potential future armor in the study area. Table 3 shows the armor costs per linear foot used in the model.

Table 3: Model Armor Cost

Armor Type	CSRM Function	Cost/Linear Foot	Mob/Demob
SCDOT Revetment	Defend Road	$3,000	-
USACE Revetment	Potential Alternative	$6,000	-
Seawall	Defend Commercial Center	$3,000	$30,000
Individual Homeowner	Protect Single Property	$1,000	$1,500

Not armorable lots are shown in green in Figure 2. It is assumed that these lots would not be armored in the future because the DEs contained in the lots would not benefit from armoring. This can be because they are dunewalks that are seaward of expected armor placement, or lots containing vehicles, which are only subject to inundation damages and therefore receive no benefits from armoring.

Figure 2: Lot Armor Status

2.2.2 Damage Elements – Structure and Contents Value

Beach-*fx* handles economic considerations at the DE level. These considerations include extent of damage, cost to rebuild, and time to rebuild. Beach-*fx* uses pre-defined damage functions to calculate the extent of damage. For each damage element, the following information is input into Beach-*fx*:

- ►Geographical reference (northing and easting of center point)
- ►Alongshore length and cross-shore width
- ►Usage (e.g., single family, multi-family, commercial, walkover, pool, gazebo, tennis court, parking lot)
- ►Number of floors
- ►Construction type (e.g., wood frame, concrete, masonry)
- ►Foundation type (e.g., shallow piles, deep piles, slab)
- ►Armor type (e.g., seawall)
- ►Ground and/or first floor elevation
- ►Value of structure (replacement cost less depreciation)
- ►Value of contents

The geospatial location and footprint of the damage elements was verified using aerial photography in ArcMap Pro. The occupancy, construction, and foundation type of each damage element was gathered from the Charleston County property appraiser information and visual observations by SAW staff. First floor elevations of all the damage elements in the study area were obtained via combining Lidar topology data and manual recording of how far above ground elevation the first floor of each structure is. An uncertainty of +/- .197' was assigned to these elevations, the margin of error of the Lidar data.

Real Estate professionals from SAS provided updated depreciated replacement costs for all the damage elements in April 2020. An uncertainty of +/- 13% was assigned to these costs. This is the percent change from one standard deviation for the mean property.

The value for roads was taken to be $97 per foot, the value for Milling and Resurfacing a 2 Lane Rural Road with 5' Paved Shoulders from the Florida Department of Transportation. A value of $134 was used for Center St, and 150' of Ashley Ave where it connects to Center St. This is the value for Milling and Resurfacing 3 Lane Rural Road with 5' Paved Shoulders and Center Turn Lane from the Florida Department of Transportation. Lengths were measured in ArcMap Pro.

For dunewalks, a value of $150/linear foot was used. This is taken from previous USACE CSRM studies. Values for vehicles are taken to be 26.9% of the total value from the National Structure Inventory. The percentage is based on Economic Guidance Memorandum (EGM) 09-04, which states that 26.9% of vehicles get left behind in a tropical storm event. An uncertainty of +/- 10% was assigned the values for roads, dunewalks, and vehicles. Lengths were measured in ArcMap Pro.

The value of contents was assumed to be 50% of the structure value for all habitable structures. Other DEs (roads, dunewalks, and vehicles) had zero content value.

2.3 Structure Inventory Overview

The economic value of the existing structure inventory represents the depreciated replacement costs of damageable structures and their associated contents within the study area along the coastline. The damage element inventory includes 2032 damageable structures with an overall estimated value of $274 million, with structure and content valuations of $189 M and $85 M respectively.

Values aggregated by development type show that most of the value in Folly Beach is in single-family homes and multi-story multi-family buildings. Table 4 provides the distribution of values broken down by damage element type.

Table 4: Distribution of Value by Damage Element Type

Damage Element	Number of Elements	Total Value	Average Value	Percent of Total
Single-Story Commercial	15	$5,088,007	$339,200	1.9%
Multi-Story Commercial	10	$14,509,407	$1,450,941	5.3%
Single-Story Single-Family	325	$52,081,456	$160,251	19.0%
Multi-Story Single-Family	367	$119,865,886	$326,610	43.7%
Single-Story Multi-Family	19	$3,426,742	$180,355	1.2%
Multi-Story Multi-Family	84	$60,696,440	$722,577	22.1%
Road	122	$4,908,077	$40,230	1.8%
Dunewalk	260	$2,970,641	$11,426	1.1%
Vehicle	830	$10,800,081	$13,012	3.9%
Total	2032	$274,346,736	-	100%

3 Coastal Storm Risk Management Benefits

This section of the appendix covers the approach used to estimate the economic benefits of reducing hurricane and storm related damages in Folly Beach, South Carolina using Beach-*fx*. The topics covered include:

- ►Benefit estimation approach using Beach-*fx*
- ►The future without-project condition
- ►The future with-project condition

3.1 Benefit Estimation Approach using Beach-*fx*

Beach-*fx* links the predictive capability of coastal evolution modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the costs and total damages under various CSRM alternatives. This output is then used to determine the benefits of each alternative.

The future structure inventory and values are the same as the existing condition. This conservative approach neglects any increase in value due to future development. Due to the uncertainty involved in projections of future development, using the existing inventory is preferable and considered conservative for Folly Beach where coastal development has historically increased in value.

The future without-project damages will be used as the base condition. Potential alternatives are measured against this base condition. The difference between with and without-project damages will be used to determine project benefits.

Once benefits for each of the alternatives are calculated, they will be compared to the costs of implementing the alternative. Dividing the benefits of an alternative by the costs of the alternative yields a Benefit-to-Cost Ratio (BCR). The federally preferred plan (NED – National Economic Development Plan) is the plan that maximizes net benefits. Net benefits are determined by subtracting the cost of any given alternative from the benefits of that alternative (Benefits – Costs = Net Benefits).

3.2 Model Assumptions

►**Start Year**: The year in which the simulation begins is 2019

►**Base Year**: The year in which the benefits of a constructed federal project would be expected to begin accruing is 2024

►**Period of Analysis**: 50 years (2024 to 2074)

►**Discount Rate**: 2.75% FY2020 Federal Resources Discount Rate

►**Damage Functions**: Damage functions developed by the North Atlantic Coast Comprehensive Study were used for buildings. The dunewalk function was created by SAJ staff. EGM 09-04 was used for vehicles, while the road damage function was obtained from the USACE CSRM Flagler Beach Feasibility Study.

►**Coastal Armor**:

- ►Existing armor set at the lot level will protect the damage elements in that lot from erosion damage until failure is triggered. The structures can still suffer from wave and inundation damage. If the armor fails structures will be subject to erosion damage until the armor is rebuilt.
- ►When erosion reaches the seaward edge of armorable in the future lots, armor will be constructed at this location. Before the armor is built the damage elements are subject to damages. Once construction of the armor is completed, armor will function normally.
- ►Shorefront properties that are not armorable will not be armored in the future because the cost of armor would not likely be warranted to protect the relatively low value structures on these structures (dunewalks and vehicles).
- ►While armor eliminates damage from erosion, it does not stop the background erosion process within beach-*fx*. This makes it difficult to determine the loss of land associated with armored properties. With the tools available in beach-*fx* there are two analytical options; erosion continues unimpeded by armor (although no properties are damaged), or armor stops erosion dead in its tracks. The reality is that erosion will behave somewhere between these extremes. Results for the recommended plan are presented under both

scenarios. SAJ economics staff decided, because erosion rates are significant some areas of Folly, to use the scenario where erosion continues past armor during the plan formulation process.

►**Number of Times Rebuilding Allowed**: The maximum number of structure rebuilds can be specified for damage elements. Based on the assumed likeliness that certain types of damage elements will eventually stop being rebuilt by property owners, the following are the number of times that rebuilding is allowed for certain types of damage events:

- ►Minor Damage Event: A minor damage event is any damage incurred that results in less than 50% of the structure value of the asset being lost from the event. For minor damage events, assets can be rebuilt an unlimited number of times.
- ►Major Damage Event: A major damage event is any damage incurred that results in more than 50% of the structure value of the asset being lost from the event. For major damage events, assets are assumed to lose their entire value and are removed from the inventory. This effectively limits the number of rebuilding times to zero. This is because local law requires any new construction to be built on a pile foundation. The first-floor elevation of these structures would be such that they are no longer in harm's way, thus making them ineligible to receive future damage. Roads and vehicles are an exception to this is and can be rebuilt as many times as necessary.

►**Future Development**: It should be noted that future development has not been assumed to occur on currently vacant lots. The damages and benefits are based only on existing infrastructure. Given uncertainty about what may happen in the future, this is a conservative, but defensible, assumption.

►**Content-to-Structure Value Ratios:** Because site specific surveys about content values are not available, content values were assumed to be 50% of the structure value for all structure types. This is consistent with other Beach-*fx* studies performed by the USACE South Atlantic Division.

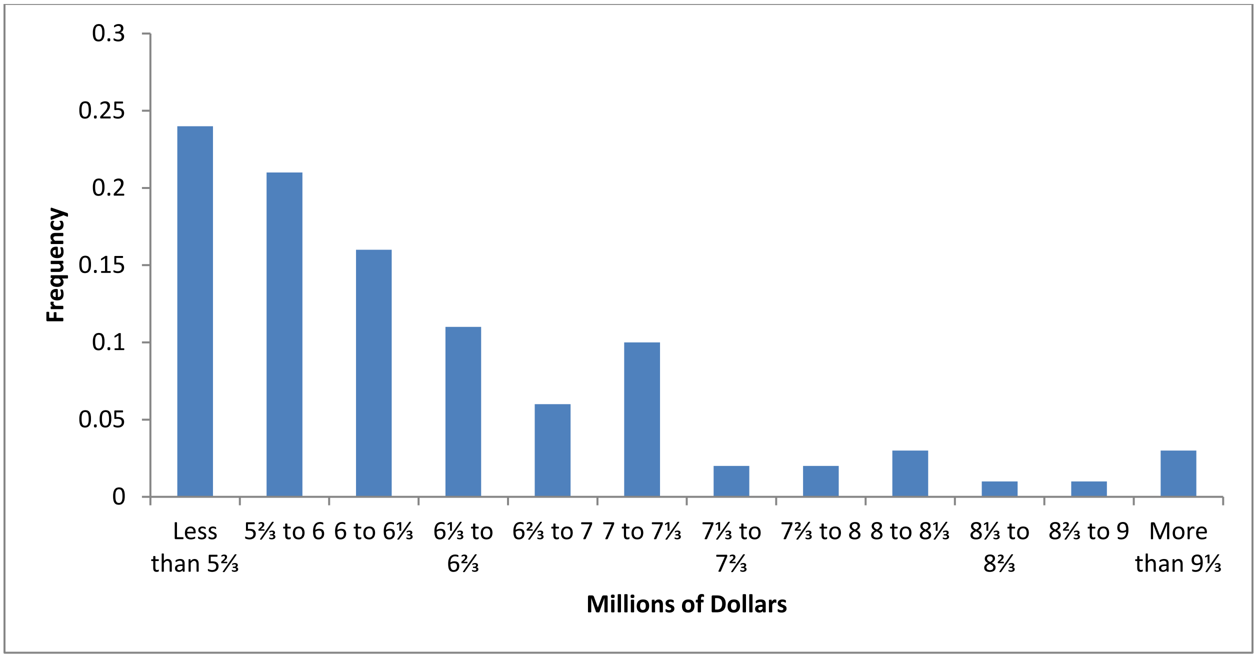
3.3 Future Without-Project Condition

100 iterations of the intermediate sea level rise (SLR) scenario were used as the basis for the future without-project condition (FWOP) damage presented in this section. More information on why the intermediate SLR was used can be found in Appendix A – Coastal Engineering. The FWOP condition damage across the study area range between $5.4 and $15 million average annual present value dollars. 100 iterations were determined to be adequate for the analysis as the moving average of damages and armor costs normalize by 70 iterations. Descriptive statistics on the average annual FWOP model damages are as follows:

- ►Mean: PV: $6,508,048
- ►Median: $6,160,874
- ►Standard deviation: $1,399,210

Provides an illustration of FWOP results as a probability distribution based on the analysis of the model outputs. The distribution is characterized by a relatively high peak and long right tail. This suggests a relatively stable model with only moderate variability between iterations. The reason for the long tail is due to land loss values being included. Land loss is a primary benefit, and is highly dependent on constant background erosion, rather than randomly generated storms. Land loss acts as minimum cap on damages.

Figure 3: Distribution of the Average Annual Future Without-Project Condition Damage



3.3.1 Damage Distribution by Structure Category and Type

Pursuant to estimating future without-project condition damages and associated costs for the Folly Beach study area, Beach-*fx* was used to estimate damages and costs in the following categories:

►**Structure and Content Damage**: Structure damage is economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Content damage is from the material items housed within the structures (usually air conditioned and enclosed) that are potentially subject to damage. Structure and content damage combined make up approximately 6.8% of the total FWOP damages.

►**Coastal Armor Cost**: Beach-*fx* provides the capability to estimate the costs incurred from measures likely to be taken to protect coastal assets and or prevent erosion in the study area. Based on the existence of coastal armor units throughout the study area, Beach-*fx* was used to estimate the costs of erecting such measures throughout the period of analysis. Armor costs account for approximately 19.9% of the total FWOP damages.

►**Land Loss**: Any loss of permanent developable land is counted as a damage category and can be estimated with output from beach-*fx*. Land loss results in 49.7% of the total FWOP damages.

►**Property Condemnation**: Damageable elements in beach-*fx* are placed in lots. If enough of the land inside the lot erodes, the lot is considered condemned. This damage category captures the value of anything within a lot when it is condemned. Adjustments are made so that double-counting does not occur. Property condemnation accounts for 23.6% of total FWOP damages.

Table 5 provides greater detail on the composition of the average FWOP damages by category and damage element type.

Table 5: Average Annual FWOP Damage by Category and Type

DE Type	Structure and Content Damage	Armor Costs	Land Loss	Property Condemnation	Total Damage	% of Total
Single-Story Commercial	$473	$0	-	$7,035	$7,508	0.1%
Multi-Story Commercial	$5,754	$6,634	-	$45,244	$57,633	0.9%
Single-Story Single-Family	$94,254	$164,202	-	$315,123	$573,579	8.8%
Multi-Story Single-Family	$178,080	$215,301	-	$1,020,189	$1,413,571	21.7%
Single-Story Multi-Family	$6,844	$4,081	-	$8,110	$19,035	0.3%
Multi-Story Multi-Family	$79,781	$44,921	-	$110,037	$234,739	3.6%
Road	$2,821	$859,802	-	$0	$862,623	13.3%
Dunewalk	$44,084	$0	-	$30,431	$74,514	1.1%
Vehicle	$29,031	$0	-	$0	$29,031	0.4%
Land	-	-	$3,235,816	-	$3,235,816	49.7%
Total	$441,121	$1,294,942	$3,235,816	$1,536,170	$6,508,048	100.0%

3.3.1.1 Commercial Buildings

Commercial buildings consist of two groups, single-story and multi-story, of varying construction type and value. This category is mostly located in the commercial hub on Center St. This hub is slightly inland and has a healthy berm and dune in the existing condition. The result is that a low 1.0% of the total FWOP damages are associated with damage to commercial buildings.

3.3.1.2 Single Family Residences

Single family residences consist of two groups, single-story and multi-story, of varying construction type and value. This category accounts for a large amount of the non-land loss damages. 30.5% of the total FWOP damages are associated with damage to these damage elements.

3.3.1.3 Multi Family Residences

Multiple family residences consist of two groups, single-story and multi-story, of varying construction type and value. This is another large category of value and damages in the FWOP. 3.9% of the total FWOP damages are associated with damage to these damage elements.

3.3.1.4 Roads

Roads make up a large percentage of FWOP damages relative to their value. This is due to the modeling assumption that states the SCDOT would build a heavy-duty revetment to protect the seaward roadway when erosion reaches the road. Roads account for 13.3% of the damages in the FWOP.

3.3.1.5 Dunewalks

Dunewalks are rarely protected by coastal armor, are built for outdoor use, tend to be closer to the shoreline, and tend to be less costly to rebuild. As a result, these damage elements are hit by the damage driving parameters more often and rebuilt with a greater frequency.

3.3.1.6 Vehicles

Vehicles makes up an almost negligible amount of the total damages in the FWOP due to most vehicles being taken with the owners during storm events.

3.3.1.7 Land

Land loss makes up a large part of the total damages in the FWOP due to the high land values and erosion rates on Folly Beach. Second row land values per square foot were used for these estimates. Land loss is responsible for almost half of the damage in FWOP.

3.3.2 Spatial Distribution of Without-Project Damage

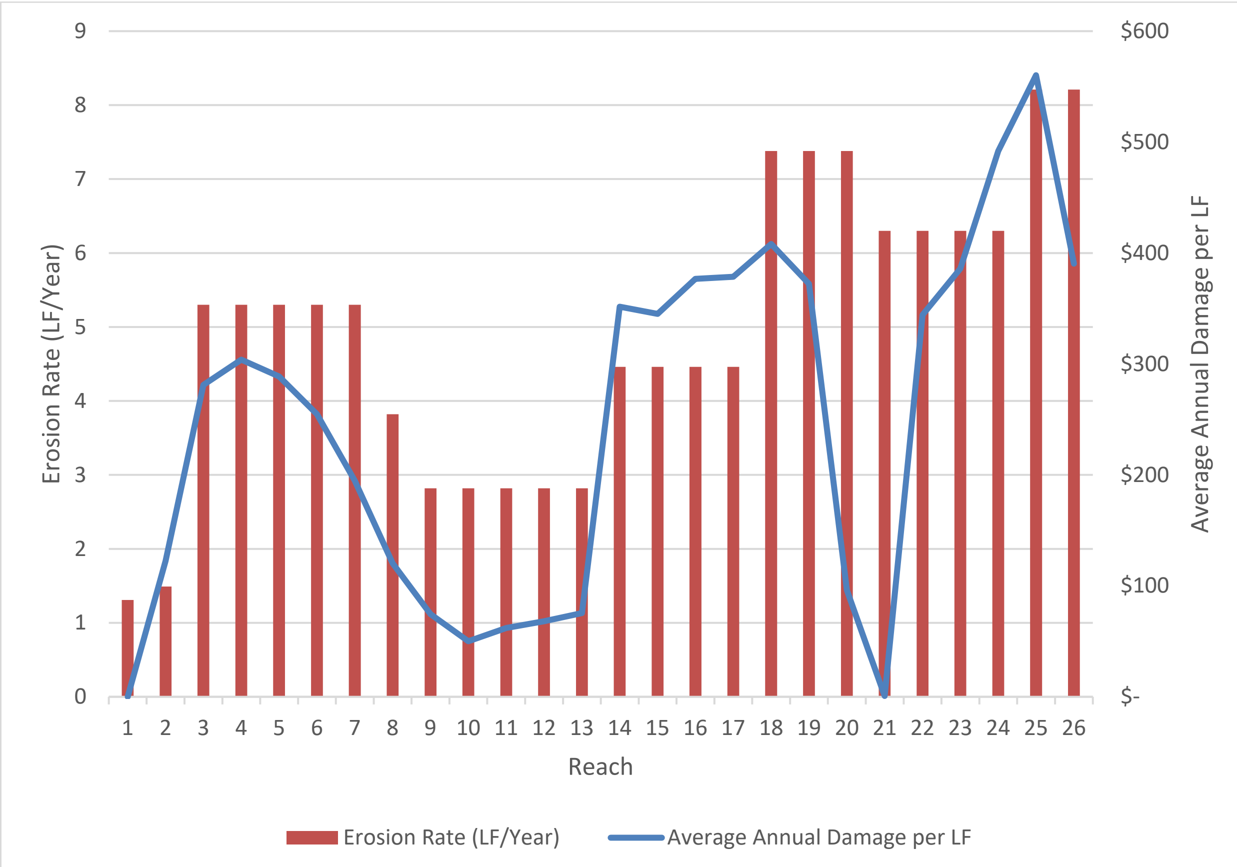
There are several reaches within the area modeled where the FWOP damages and armor costs are the greatest. The segment that includes model reaches 2-17 accounts for about 51.3% of the overall FWOP damages, and the segment that includes model reaches 18-26 accounts for about 48.7% of the overall FWOP damages. These results are summarized in Table 6. The primary driver of differences in spatial damages are erosion rates.

Figure 4 illustrates relationship between erosion rate and FWOP damages per linear foot by reach.

Table 6: Average Annual FWOP Damage by Category and Beach-*fx* Reach

Beach-*fx* Reach	Annual Erosion (ft/yr)	Structure and Content Damage	Armor Cost	Land Loss	Property Condemnation	Total Damage	% of Total
1	1.31	$121	$0	$89	$1	$211	0.0%
2	1.49	$12,456	$28,320	$137,924	$38,974	$217,674	3.3%
3	5.30	$27,466	$110,074	$206,995	$81,128	$425,663	6.5%
4	5.30	$11,799	$53,604	$109,099	$56,489	$230,992	3.5%
5	5.30	$9,222	$48,988	$105,245	$57,511	$220,966	3.4%
6	5.30	$6,159	$51,366	$96,991	$35,686	$190,201	2.9%
7	5.30	$12,968	$61,733	$106,175	$43,184	$224,061	3.4%
8	3.82	$1,638	$804	$94,116	$88,031	$184,588	2.8%
9	2.82	$15,805	$17,421	$31,916	$19,162	$84,304	1.3%
10	2.82	$10,309	$12,418	$11,821	$3,875	$38,423	0.6%
11	2.82	$10,940	$13,569	$17,586	$5,060	$47,155	0.7%
12	2.82	$10,097	$17,372	$14,670	$8,621	$50,761	0.8%
13	2.82	$7,589	$22,357	$20,816	$7,741	$58,504	0.9%
14	4.46	$30,447	$106,674	$195,838	$64,904	$397,864	6.1%
15	4.46	$31,197	$88,506	$207,501	$65,087	$392,290	6.0%
16	4.46	$14,711	$56,650	$150,117	$72,046	$293,524	4.5%
17	4.46	$22,188	$52,848	$139,865	$69,668	$284,569	4.4%
18	7.38	$14,303	$38,300	$167,598	$89,589	$309,789	4.8%
19	7.38	$16,688	$66,438	$161,587	$43,535	$288,247	4.4%
20	7.38	$11,829	$34,822	$57,279	$52,866	$156,797	2.4%
21	6.30	$552	$0	$0	$67	$619	0.0%
22	6.30	$41,469	$70,745	$128,926	$58,134	$299,274	4.6%
23	6.30	$39,720	$117,997	$362,806	$140,782	$661,305	10.2%
24	6.30	$36,071	$74,053	$218,961	$129,638	$458,723	7.0%
25	8.21	$14,669	$47,665	$159,338	$159,737	$381,409	5.9%
26	8.21	$30,709	$102,216	$332,555	$144,653	$610,134	9.4%
Total	-	$441,121	$1,294,942	$3,235,816	$1,536,170	$6,508,048	100.0%

Figure 4: Spatial Distribution of Damage and Erosion Rates by Reach



3.3.3 Damage Distribution by Damage Driving Parameter

Just about all the FWOP damages and costs are attributed to erosion. This is because the armor cost, land loss, and property condemnation can be indirectly attributed to erosion. Below is the distribution of total damage by driving parameter:

- ►Erosion: 94.6%
- ►Inundation: 2.3%
- ►Wave Attack: 3.1%

3.3.4 Temporal Distribution of Damages

Table 7 illustrates the non-present value damages by study reach and over time, in 10-year intervals. There is a great deal of variability in the amount of damages amongst the Beach-*fx* Reaches. This is explained by the large number of variables, all of which the Beach-*fx* model considers. Examples of variation between the reaches result from the following:

- ►Density and amount of development
- ►Typical size and value of structures
- ►Typical distance between structures and mean-high water
- ►Size, shape and location of the dunes and coastal morphology
- ►Rate of erosion for each reach

►Amount and type of coastal armoring present
►Timing that property owners construct coastal armoring in the future.

Table 7: Non-Present Value FWOP Damage over Space and Time (No Land Loss)

Beach-*fx* Reach	Before Construction (2019-2023)	First 10 Years (2024-2033)	Second 10 Years (2034-2043)	Third 10 Years (2044-2053)	Fourth 10 Years (2054-2063)	Final 10 Years (2064-2073)
1	$730	$520	$660	$1,155	$1,396	$1,571
2	$294,694	$178,228	$204,903	$548,447	$729,258	$999,007
3	$212,001	$178,566	$260,527	$3,245,025	$1,690,530	$555,684
4	$116,650	$108,598	$103,826	$1,884,958	$1,578,278	$88,759
5	$98,740	$102,339	$172,760	$2,086,687	$1,161,085	$59,825
6	$81,859	$41,036	$139,915	$564,728	$1,421,443	$221,808
7	$168,424	$13,831	$74,902	$409,929	$2,564,881	$324,389
8	$337,964	$4,652	$111,073	$141,256	$1,299,494	$5,068,790
9	$198,601	$6,066	$171,083	$278,106	$562,799	$1,026,436
10	$118,676	$3,977	$52,797	$109,523	$219,471	$340,237
11	$123,697	$5,279	$66,165	$115,046	$241,153	$409,606
12	$128,920	$6,003	$92,298	$133,992	$280,204	$531,575
13	$93,968	$4,404	$71,612	$120,781	$297,867	$398,736
14	$1,196,730	$358,780	$625,439	$2,400,771	$993,406	$202,207
15	$622,276	$360,907	$817,154	$2,357,567	$501,698	$331,678
16	$360,828	$537,505	$1,963,166	$398,889	$119,999	$144,841
17	$277,305	$513,346	$2,013,901	$705,422	$126,710	$163,440
18	$134,351	$370,903	$2,808,898	$890,043	$74,699	$117,971
19	$99,872	$291,894	$1,477,500	$546,966	$57,017	$126,653
20	$340,892	$1,284,317	$30,208	$79,823	$160,136	$455,027
21	$4,043	$6,963	$1,186	$1,926	$5,883	$8,530
22	$509,095	$2,129,544	$163,776	$129,030	$278,743	$185,807
23	$704,087	$3,036,044	$1,920,919	$124,599	$184,860	$240,367
24	$648,636	$2,390,010	$2,124,649	$475,947	$174,438	$309,461
25	$544,324	$3,853,141	$1,029,442	$45,603	$66,806	$327,924
26	$407,466	$2,344,867	$2,583,186	$464,830	$159,347	$636,005
Total	$7,824,830	$18,131,721	$19,081,946	$18,261,049	$14,951,600	$13,276,336

3.3.5 FWOP Damages in Alternative Sea Level Rise Scenarios

The FWOP condition was modeled for three SLR scenarios. Engineer Regulation (ER) 1110-2-8162 provides both a methodology and a procedure for determining a range of sea level rise estimates based on the local historic sea level rise rate, the construction (base) year of the project, and the design life of the project. The Beach-*fx* results presented above refer to the intermediate scenario. The results associated with the other two SLR scenarios are presented here. The three level rise scenarios are graphically shown in Figure 3.3 of the Main Report.

Table 8 provides an overall summary of FWOP average present value damage and armor costs in each SLR scenario. The total damage increases by 9.5% from the low to intermediate scenarios, and 36.9% from the intermediate to high scenarios. Erosion is the primary damage driver, accounting for about 95.2% and 92.5% of the FWOP damage in the low and high SLR scenarios, respectively.

Figure 5 shows the distribution of average present value FWOP damages by model reach and Figure 6 shows the distribution of average non-present value FWOP damages over time respectively for the three SLR scenarios. The SLR results suggest that damages increase as the erosion rate increases. With greater erosion, more structures become subject to damage sooner.

Table 8: Average Annual FWOP Damage by SLR Scenario

SLR Scenario	Structure and Content Damage	Armor Cost	Land Loss	Property Condemnation	Total Damage
Low	$366,892	$1,170,755	$2,990,537	$1,417,095	$5,945,281
Intermediate	$441,121	$1,294,942	$3,235,816	$1,536,170	$6,508,048
High	$815,959	$1,714,117	$4,127,040	$2,254,513	$8,911,629

Figure 5: Average Annual FWOP Damage by Model Reach and SLR Scenario

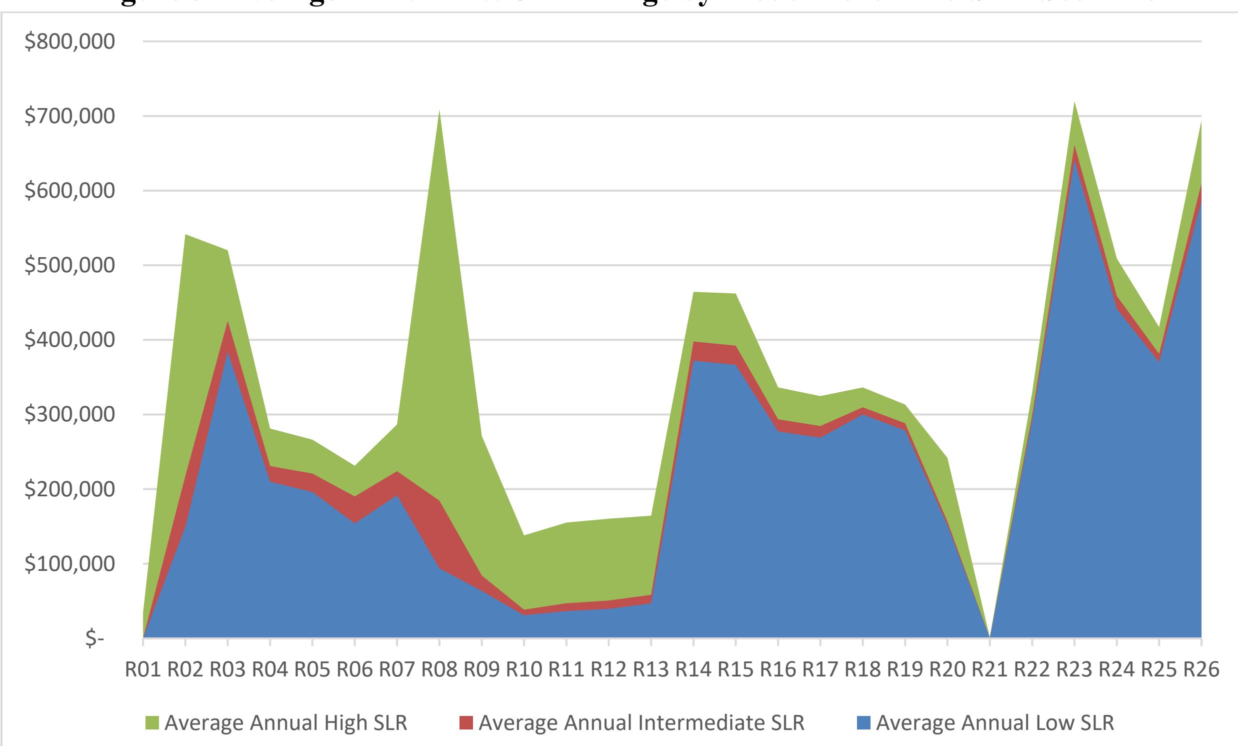
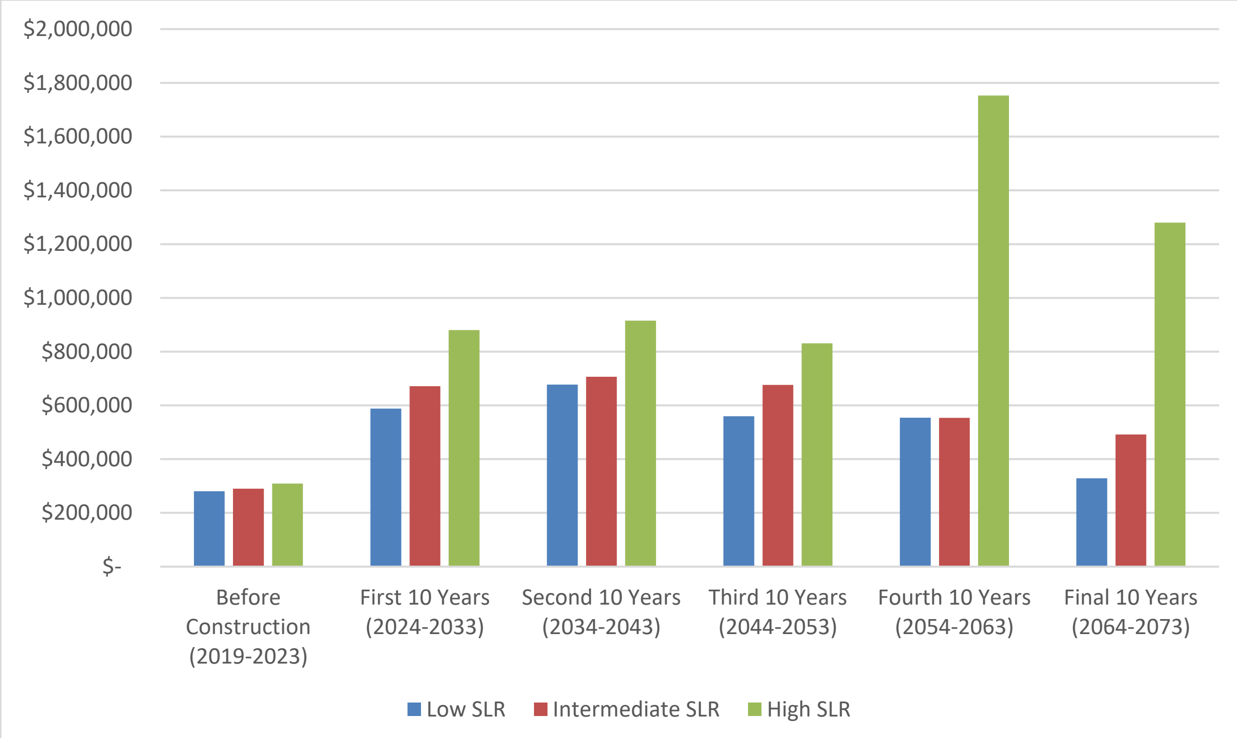


Figure 6: Non-PV FWOP Damage over Time by SLR Scenario (No Land Loss)



3.3.6 FWOP Condition Conclusion

►Most of the FWOP damages are associated with family residences located along the shoreline.
►The overwhelming majority of the damage and armoring is indirectly caused by erosion.
►Damages in the future without project condition increase in the accelerated sea level rise scenarios.

3.4 Future With Project (FWP) Conditions

This section of the appendix tells the story behind the evaluation and comparison of Folly Beach CSRM study alternatives. A description of the alternatives and their performance in terms of benefits and costs are provided in the sub-sections that follow.

3.4.1 Management Measures

Management measures were selected to accomplish at least one of the planning objectives for the Folly Beach study. Both nonstructural measures and structural measures were identified. The following is a summary of the management measures considered for the study area.

►**Structural Measures**:

- ►Breakwaters
- ►Seawalls
- ►Groins
- ►Revetments
- ►Berm Enhancement
- ►Dunes and Vegetation

►**Non-Structural Measures**:

- ►No Action
- ►Relocation of Structures
- ►Retreat
- ►Floodplain and regulatory restrictions
- ►Community Education
- ►Updating Evacuation Plans
- ►Floodplain and Building Code Updating

During the plan formulation process, management measures were screened against thirteen criteria. Benefits and costs were not calculated at this early stage of formulation, though a qualitative assessment of potential benefits was conducted. Ultimately, most of these measures were screened out. No non-structural measure carried forward to the modeling stage. Three structural measures were carried forward to the modeling stage: Dunes and Vegetation, Beach Nourishment, and Revetments. More information about each measure is provided below.

►**Dunes and Vegetation**: This measure would include placement of beach compatible material, from either upland, inlet, or offshore sources, in a dune feature. The front slope of the dune would be a function of the material grain size and construction equipment. Vegetation would be planted after initial placement of the dune material where needed. Engineering design work on the most feasible implementation plan for dunes and vegetation can be found in the Appendix A – Coastal Engineering.

►**Beach Nourishment**: This measure includes initial construction of a beach fill and future re-nourishments at regular intervals. Re-nourishment of the beach would be undertaken periodically to maintain the erosion control features within design dimensions. Engineering design work on the most feasible implementation plan for beach nourishment can be found in the Appendix A – Coastal Engineering.

►**Revetment**: This measure would involve building a heavy-duty revetment seaward of the existing property lots. There would be no dune or berm associated with the construction. The revetment option was not fully developed by engineering because of environmental concerns.

3.4.2 Alternative Development

An alternative plan is a set of one or more management measures functioning to address one or more objectives. Each project alternative is a combination of a selected measure and the reaches where it would be applied. Fully developed alternatives consisting of dune, beach nourishment, and revetment measures were carried forward in all Beach-*fx* reaches.

3.4.2.1 Initial Screening in Beach-*fx*

Modeling alternatives in Beach-*fx* is a time-consuming process; a single 100 iteration simulation can take most of a day. Therefore, it was not practical to fully model many alternatives for screening purposes. Therefore, the first stage of preliminary Beach-*fx* alternatives were run for 20 iterations rather than 100.

The dune and beach nourishment alternatives were set up to be modeled in any of the Beach-*fx* reaches for any combination of no dune, 14', or 15' NAVD88 high x 5' wide (at crest) dune along with 25', 50', and 75' berm extensions. Screened dune heights stopped at 15', because damage causing wave and flood heights were no greater than 15' in the FWOP analysis. Wider dunes were considered, but the net benefits favored widening the berm, rather than the dune. More information on the development of the shoreline response database and alternative templates can be found in the Appendix A – Coastal Engineering. The 'Planned Nourishment' inputs were entered into Beach-*fx* for the nourishment alternatives. The model was run for these FWP alternatives for the entire length of the study area. For the initial set of screenings, the model was set to nourish the beach approximately every 10 years. This assumption is relaxed later. More information on the nourishment triggers and minimum volume thresholds used can be found in the Appendix A – Coastal Engineering.

The revetment plan was modeled in beach-*fx* by replacing the individual property owner's armor, with a heavier duty construction. In the beach-*fx*, this is assumed to prevent any erosion past the armor line and be impervious to failure.

Initial beach-*fx* model runs showed that a wide variety of dune and beach nourishment alternatives were economically justified. Similarly, the revetment option is the superior plan for the northeastern segment of the island, past the washout. To ensure that the full range of options were contained in the screenings, a 100' berm extension and no dune was added to the set of screening options. The initial runs showed the 25' berm extension and 15' high dune had the highest net benefits. Engineering was concerned with the practical ability to upkeep such a small berm. As such, a 35' berm and 15' high dune option was added to the analysis. Table 9 summarized the results from the initial beach-*fx* screening exercise for the most promising dune and beach nourishment combinations.

Based on the initial screening results, three potential plans were identified and summarized in Table 10. Reach 1 was screened out due to the only asset being a county park, which is not in the federal interest. Reaches 9-13, while having negative benefits, were carried forward at this part of the process due to how close they were to being economically justified. Reaches 20 and 21, otherwise known as "the washout", were included in the plan to maintain a consistent project across the barrier island. The Revetment Plan was not selected for further consideration, despite having the largest net benefits in reaches 18-26 due to environmental concerns. More information on this can be found in the Main Report.

Table 9: Average Annual Net Benefit for Initial Beach-*fx* FWP Modeling by Reach

Beach-*fx* Reach	15' Dune 25' Berm	15' Dune 35' Berm	15' Dune 50' Berm	No Dune 75' Berm	Revetment
1	-$29,920	-$39,378	-$58,658	-$56,223	-$654,498
2	$60,100	$48,567	$37,299	$27,073	-$164,472
3	$203,557	$206,659	$218,273	$208,723	$77,656
4	$118,973	$123,293	$126,965	$121,522	$59,614
5	$114,171	$121,453	$118,513	$113,660	$51,423
6	$92,278	$94,214	$91,243	$85,855	$25,557
7	$84,468	$78,914	$72,176	$66,714	-$36,677
8	$106,535	$103,584	$97,814	$85,912	-$111,233
9	$4,744	-$474	-$6,107	-$16,964	-$169,262
10	-$8,455	-$10,684	-$17,849	-$22,780	-$136,379
11	-$4,550	-$6,923	-$12,324	-$18,515	-$125,134
12	$411	-$3,190	-$7,035	-$13,910	-$117,706
13	-$2,777	$2,008	-$1,960	-$8,249	-$112,951
14	$109,486	$127,982	$140,311	$119,864	$124,393
15	$119,199	$140,249	$147,934	$128,211	$112,403
16	$98,967	$111,641	$118,743	$102,029	$106,259
17	$101,302	$112,298	$118,332	$104,927	$95,466
18	$80,197	$88,683	$71,895	$65,554	$125,598
19	$112,486	$103,830	$89,444	$92,969	$110,782
20	-$190,156	-$191,388	-$223,612	-$253,428	-$218,684
21	-$140,751	-$152,916	-$165,012	-$172,584	-$190,284
22	$33,162	$25,146	$37,647	$35,345	$88,193
23	$201,461	$178,544	$205,555	$218,875	$254,173
24	$172,563	$167,331	$190,471	$199,703	$228,588
25	$137,318	$151,256	$131,323	$155,791	$220,040
26	$222,626	$222,909	$172,378	$198,521	$325,066
Reaches 2- 17	$1,198,409	$1,249,591	$1,242,329	$1,084,072	-$321,043
Reaches 18-21	-$138,225	-$151,791	-$227,284	-$267,490	-$172,588
Reaches 22-26	$767,129	$745,187	$737,373	$808,235	$1,116,061
Mob	$707,089	$769,032	$805,221	$805,258	-
Reaches 2-26 w/ Mob	$1,120,224	$1,073,955	$947,198	$819,559	$622,429

Table 10: Potential Alternatives from Screening Results

Plan Prefix	Description
Previously Authorized Project	A recreation of the previously authorized project. This is a 15’ berm and no dune for reaches 2-26. The re-nourishment interval for this plan would be 8 years.
BeachAA	The top performing dune/berm plan. This is a 35’ berm and 15’ high x 5’ wide (at crest) dune for reaches 2-21, and a 75’ berm with no dune for reaches 22-26.
BeachBB	Slightly larger berm and dune system than the BeachAA plan. This is a 50’ berm and 15’ high x 5’ wide (at crest) dune for reaches 2-26.

3.4.2.2 Beach Alternative Optimization in Beach-*fx*

The initial screening exercised assumed that the beach would be nourished approximately every 10 years. This optimization exercise relaxes that assumption to find the optimal nourishment interval. This was done in beach-*fx* by varying the mobilization threshold. The mobilization threshold states how much sand is necessary to place on the beach, before the model triggers a nourishment.

Including the initial construction, as few as three total nourishment were considered (an average gap of 16-17 years) up to a maximum of seven total nourishments (an average gap of about 8 years).

The beach-*fx* iteration count was increased to 100 for this stage of alternative identification. The BeachAA plan was run for 3, 4, 5, 6, and 7 total nourishments. The BeachBB plan, being a larger template, was only run for 3, 4, and 5 total nourishments. The results of the optimization exercise were that the option with four total nourishments had the highest net benefits. However, BeachAA_4 performed the best in reaches 2-19 and BeachBB_4 performed the best in reaches 22-26. A combined plan BeachAB_4 was created specifically to test if this combination would yield higher net benefits than the sum of its parts. BeachAB_4 is a 35’ berm for reaches 2-21 and a 50’ berm for reaches 22-26. All reaches (except reach 1) have a 15’ high NAVD88 x 5’ wide (at crest) dune. BeachAB_4 comprised of 4 total nourishments (including initial construction) over the project lifespan. A complete breakdown of the optimization results can be found in Table 11.

Table 11: Beach-*fx* FWP Modeling Optimization Results

Plan Name	Total Nourishments	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
BeachAA_7	7	$5,458,182	$4,429,442	1.23	$1,028,739
BeachAA_6	6	$5,323,985	$4,262,522	1.25	$1,061,464
BeachAA_5	5	$5,080,221	$3,995,184	1.27	$1,085,037
BeachBB_5	5	$5,181,984	$4,181,820	1.24	$1,000,165
BeachAA_4	4	$4,773,387	$3,654,993	1.31	$1,118,394
BeachBB_4	4	$4,921,176	$3,857,429	1.28	$1,063,747
BeachAB_4	4	$4,762,530	$3,616,044	1.32	$1,146,486
BeachAA_3	3	$4,112,789	$3,477,086	1.18	$635,703
BeachAB_3	3	$4,559,016	$3,630,794	1.26	$928,222

3.4.3 Alternative Comparison

The BeachAB_4 plan was carried forward as the basis for the beach nourishment alternative. In addition to a no action plan, three other alternatives were built around the BeachAB_4 plan as well as a plan meant to mimic the previously authorized project. The final alternative capture potential sources of benefits that might arise from including planform rates into the analysis, as previous model runs did not include planform rates. These options include, 1) extending the 50' berm to reaches 18-21, due to the high erosion rates, or 2) adding a nourishment to account for additional sand leaving the system via the planform rates. Alternative 6 is meant to mimic the 1992 authorized plan. The final alternatives are summarized in Table 12.

Table 12: Description of Final Alternatives

Alternative Name	Nourishments (Interval)	Reaches 2-17	Reaches 18-21	Reaches 22-26
Alternative 1	-	No Action		
Alternative 2	4 (12 years)	35' Berm, 15'x5' Dune	35' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune
Alternative 3	4 (12 years)	35' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune
Alternative 4	5 (10 years)	35' Berm, 15'x5' Dune	35' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune
Alternative 5	5 (10 years)	35' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune	50' Berm, 15'x5' Dune
Alternative 6	6 (8 years)	15' Berm, No Dune		

The six final alternatives were run in Beach-*fx* using 100 iteration simulations. The results of these simulations were used to determine the National Economic Development (NED) Plan and the Recommended Plan. Note, that while Alternative 2 is the same as BeachAB_4 from the previous step, the net benefits and BCR are slightly different. This is the result of the project delivery team making adjustments during the time between optimizing the beach option, and the final production runs presented in Table 13. The changes were the inclusion of planform rates, a slight modification of the sea level change rate and a risk informed decision to alter the borrow source sequencing due to concerns with the river's ability to recharge fast enough between nourishments.

Table 13: Economic Overview of Final Alternatives

Alternative Name	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
Alternative 1	$0	$0	-	$0
Alternative 2	$5,000,960	$3,891,367	1.29	$1,109,593
Alternative 3	$5,038,861	$3,938,423	1.28	$1,100,438
Alternative 4	$4,944,939	$4,476,321	1.10	$468,619
Alternative 5	$4,971,371	$4,527,847	1.10	$443,523
Alternative 6	$3,893,047	$4,172,917	0.93	-$279,870

The plan with the highest net benefits is the NED plan, this is Alternative 2. However, the net benefits of Alternative 3 are very close (within 1%) to Alternative 2. The PDT decided to recommend Alternative 3 based primarily on the confidence in performance based on coastal engineering judgment. Alternative 3 costs just under $50,000 more than Alternative 2 annually. More information on why the PDT is recommending Alternative 3 can be found in Appendix A – Coastal Engineering. The screening of alternatives was based on reduced structure, content, armor damages, land loss, and structure condemnation resulting from land loss.

4 The Recommended Plan

Alternative 3 is the Recommended Plan.

4.1 Beach-*fx* Modeling and Project Cost

The Beach-*fx* model results describing the physical performance of the Recommended Plan will not change from the simulation run for the final array of alternatives. The physical performance results most relevant to the economic analysis are the nourishment volumes and the timing of nourishment events.

Beach-*fx* is a life cycle simulation model. One iteration represents one 50-year life cycle. All iterations within the model simulation are unique. The values presented in Table 14 are essentially probabilistic nourishment events.

The average initial construction volume over 100 iterations is 1,833,012 cubic yards (cy). The average volume of all re-nourishments over 100 iterations is 8,156,581 cubic yards. The average time interval between nourishment events over 100 iterations is 12 years. Table 14 provides a summary on the volume of material per construction event over the 100 iterations modeled.

In most projects, the initial construction consists of the highest volume. This is not the case for this project, because there is an existing federal project at Folly Beach. As a result, the initial construction behaves similarly to a renourishment from a volume perspective.

The volume for the second renourishment, from Stono Ebb Shoal, has a lower volume than the other events. This is because the material from the Stono Ebb Shoal is significantly higher quality. The overfill ratio is lower than the other sources. A lower overfill ratio requires less material to sustain the same sized template. More information on the borrow sources and overfill ratios can be found in Appendix C – Geotechnical Engineering.

Table 14: Beach-*fx* Volume and Source per Construction Event (cy)

Event	Source	Year	Average	Min	Max
Initial Construction	Lighthouse Inlet	2024	1,833,012	1,786,259	2,351,651
1st Re-nourishment	Folly River	2036	1,962,447	1,790,053	2,501,028
2nd Re-nourishment	Stono Ebb Shoal	2048	1,854,280	1,722,810	2,195,618
3rd Re-nourishment	Folly River	2060	2,506,842	1,725,498	3,045,464

The final run of alternatives used a 12-year fixed nourishment interval rather than a dynamic approach. Extra volume was included as part of the final renourishment to extend over the final two years. A description of the Recommended Plan is as follows:

►**Name (Description)**: Alternative 3 (Construction of 35' foot equilibrated berm extension for reaches 2-17 and a 50' berm extension for reaches 18-26. The project template will include a dune feature that is at a height of 15' NAVD88 and is 5' wide at the crest. A dredge will be used to fill the template with sand from multiple sources over the lifetime of the project.)
►**Average Number of Nourishment Events**: 1 Initial Construction. 3 Re-nourishments.
►**Number of Nourished Reaches**: 25
►**Range of Nourished Reaches**: Beach-*fx* Reach 2 – Beach-*fx* Reach 26
►**Average Volume of Initial Construction**: 1,833,012 cy
►**Average Volume of Each Periodic Nourishment**: 2,107,857 cy
►**Average Periodic Nourishment Interval**: 12 years
►**Initial Construction Duration**: 6 months
►**Interest During Construction**: $39,846 (at 2.25% annual interest rate)

The cost estimate for the Recommended Plan was developed by SAW Cost Engineering. Table 15 provides details on the distribution of cost by nourishment event. This estimate assumed that initial construction would occur in 2024 and re-nourishment events would occur at the average 12-year interval. The cost estimate for the final periodic nourishment assumes an additional 2/12 of the beach-*fx* reported volumes to bring the project to the end of the 50-year period of Federal participation. These costs are at FY20 price levels and include a contingency. Additional details on the project costs can be found in Appendix D - Cost Engineering.

Table 15: Non-PV Recommended Plan Project Cost from TPCS

Cost Description	Initial Construction (2024)	1st Re-Nourishment (2036)	2nd Re-Nourishment (2048)	3rd Re-Nourishment (2060)
Construction	$39,824,000	$40,890,000	$49,580,000	$49,747,000
Lands & Damages	$4,000	$31,000	$32,000	$31,000
PED	$3,072,000	$625,000	$640,000	$625,000
Construction Management	$3,072,000	$625,000	$640,000	$625,000
Total Cost	$45,972,000	$42,172,000	$50,892,000	$51,028,000

These estimated project costs were calculated outside the Beach-*fx* user interface. The beach nourishment cost information that can be input to Beach-*fx* is limited to a single unit construction cost ($/cy) and a single mobilization cost. The Beach-*fx* model applies these two costs in the same way for each nourishment event regardless of the borrow source. Unique about this study, there was five distinct borrow sources identified by the Geotechnical engineers. All five of these borrow areas have different unit costs and three of them were ultimately included in the Recommended Plan. The only way to consider all borrow areas was to use beach-*fx* to provide nourishment volumes, and calculate the costs in Excel, outside the model.

The cost analysis showed that the Folly River borrow source was the cheapest option for each nourishment. However, there was concern whether the river would have enough volume of material to nourish the beach for the whole 50-year lifespan. For initial construction, it was unclear if the river could provide the required volume. The difference cost of the using the Lighthouse Inlet instead of Folly River for the initial construction was minimal. Using the Lighthouse Inlet instead of Folly River would have been significantly more expensive for the first re-nourishment. Even if the river had enough material for initial construct, including it in Recommended Plan would have included the risk of depleting the river and having to use the Lighthouse Inlet 12 years later, when it was relatively more expensive.

Similarly, the decision to use Stono Ebb Shoal for the second re-nourishment was made to give Folly River ample time to replenish between uses. Table 16 gives an overview of the costs to mobilize and dredge from each borrow source. These are not the costs used in the TPCS because they do not include all the factors, only the mobilization and dredging costs that are output from Beach-*fx*. The reason the gap between Folly River and the other two sources increases after the initial construction is because during initial construction, more sand is required at the Northeast segment of the island. This segment is the furthest from where the dredged material in Folly River would originate, increasing cost. The opposite holds true to the Lighthouse Inlet. Due to this effect, if the Lighthouse Inlet were to be used, the most cost-effective time to do so would be during initial construction. The Stono Ebb Shoal is recommended for the second re-nourishment, because the Lighthouse Inlet only has enough material for one use.

Table 16: Non-PV Cost of Nourishments from Different Sources

Event	Lighthouse Inlet	Stono Ebb Shoal	Folly River
Initial Construction	$37,752,499	$42,822,027	$37,346,329
1st Re-nourishment	$41,075,260	$46,042,752	$39,680,460
2nd Re-nourishment	$43,233,368	$48,382,034	$41,646,250
3rd Re-nourishment	$51,021,786	$56,830,515	$48,683,006

Even though Beach-*fx* models cost variability by tabulating costs when nourishment events occur for each unique iteration, the final net benefits and BCR presented in the conclusion of this appendix will reflect re-nourishment costs occurring at the average 12-year interval. In that way the costs used to calculate the project economics will match the costs presented in the TPCS found in Appendix D – Cost Engineering. Cost for the remainder of this section reflect results from beach-*fx*.

Interest during construction (IDC) for the initial nourishment was also calculated for the Recommended Plan. As stated in ER 1105-2-100 Para. D-3.e. (11), IDC "represents the opportunity cost of capital incurred during the construction period." Using the estimated initial construction period of approximately 6 months, the total initial construction costs is estimated in the TPCS at $45,972,000 in FY2020 dollars. Total IDC for initial construction of the Recommended Plan is $39,846 at an annual interest rate of 2.25%, the FY2020 interest rate for Non-Federal repayments according to EGM 20-01 Encl 2 page 4. Middle of the month uniform payments were assumed. This economic cost is factored into the final net benefits and BCR presented for the Recommended Plan. Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) cost of $101,000 annually is also factored into the final net benefit and BCR calculations to account for future escarpment removal, vegetation maintenance, long term monitoring, and sand rebalancing.

4.2 Benefits of the Recommended Plan

The economic benefits of the plan are generated by reductions in coastal storm damages. The benefits described in this section do not include recreation benefits, which are discussed later in this appendix. As described in

Table 17, the model results suggest that the alternative is effective at reducing coastal storm damages in the study area, caused primarily by erosion. In the with-project condition, 77% of damages are prevented within the entire study area.

Table 17: Average Annual Recommended Plan Damage by Reach

Beach-*fx* Reach	**Average Annual FWOP Damage**	**Average Annual FWP Damage**	**Average Annual Benefit**	**% of Damage Prevented**
1	$211	$211	$0	0%
2	$217,674	$82,722	$134,952	62%
3	$425,663	$27,447	$398,216	94%
4	$230,992	$14,734	$216,257	94%
5	$220,966	$13,400	$207,566	94%
6	$190,201	$11,631	$178,570	94%
7	$224,061	$17,377	$206,684	92%
8	$184,588	$34,784	$149,805	81%
9	$84,304	$36,051	$48,253	57%
10	$38,423	$16,874	$21,550	56%
11	$47,155	$21,169	$25,986	55%
12	$50,761	$30,372	$20,389	40%
13	$58,504	$45,249	$13,255	23%
14	$397,864	$120,679	$277,184	70%
15	$392,290	$103,353	$288,937	74%
16	$293,524	$75,631	$217,893	74%
17	$284,569	$71,773	$212,796	75%
18	$309,789	$78,473	$231,316	75%
19	$288,247	$41,969	$246,279	85%
20	$156,797	$57,500	$99,297	63%
21	$619	$368	$251	41%
22	$299,274	$105,823	$193,451	65%
23	$661,305	$174,991	$486,313	74%
24	$458,723	$126,727	$331,997	72%
25	$381,409	$83,252	$298,157	78%
26	$610,134	76,625	533,509	87%
Total	$6,508,048	1,469,187	5,038,861	77%

Most of the benefits are associated with reductions in damage to land loss and reductions structure condemnation in oceanfront buildings.

Table 18 provides a summary at what types of damage is being prevented from the Recommended Plan.

Table 18: Damage and Benefit by Damage Source, Recommended Plan

Damage Source	Average Annual FWOP Damage	Average Annual FWP Damage	Average Annual Benefit	% of Damage Prevented
Erosion	$88,780	$4,116	$84,664	95%
Inundation	$151,498	$60,295	$91,203	60%
Wave Attack	$200,843	$81,197	$119,646	60%
Armor Cost	$1,294,942	$247,302	$1,047,639	81%
Land Loss	$3,235,816	$679,206	$2,556,610	79%
Structure Condemnation	$1,536,170	$397,071	$1,139,099	74%
Total	$6,508,048	$1,469,187	$5,038,861	77%

4.3 Sea Level Rise Considerations

An important question about the Recommended Plan is its performance under different SLR scenarios. Each of the SLR scenarios described in the main report are considered equally likely to occur. Therefore, if the project does not perform, then it cannot be considered a completely effective plan. However, the optimization was done under the intermediate plan. The benefits presented in this section do not include recreation benefits. Table 19 shows the average BCRs and net benefits of the plan in the different SLR scenarios.

Table 19: Recommended Plan Benefit and Cost for Different SLR Scenarios

SLR Scenario	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
Low	$4,587,988	$3,679,033	1.25	$908,955
Intermediate	$5,038,861	$3,938,423	1.28	$1,100,438
High	$7,002,252	$4,804,546	1.46	$2,197,706

As shown in Table 19, though the average benefits of the project increase significantly in the SLR scenarios, the average costs also increase. The costs increase because re-nourishment is triggered more frequently. Thus, the project performance (in terms of the benefit-cost ratio) is "relatively constant" throughout the SLR scenarios. The average re-nourishment intervals and damages are summarized in Table 20.

Table 20: Average Nourishment Intervals and Damage for Different SLR Scenarios

SLR Scenario	Average Periodic Nourishment Interval	Average Annual FWOP Damage	Average Annual FWP Damage
Low	12 Years	$5,945,281	$1,357,292
Intermediate	12 Years	$6,508,048	$1,469,187
High	12 Years	$8,911,629	$1,909,377

Because both costs and benefits are increasing, the net benefits increase with increasing rates of sea level rise. Overall, these SLR results suggest that the Recommended Plan is effective in all three simulated SLR scenarios. Note that the recommended nourishment interval is fixed at the request of the coastal engineers. It is possible that greater benefits could be achieved for the low and high SLR scenario by varying the nourishment interval in those scenarios.

4.4 Uncertainty and Reliability of the Recommended Plan

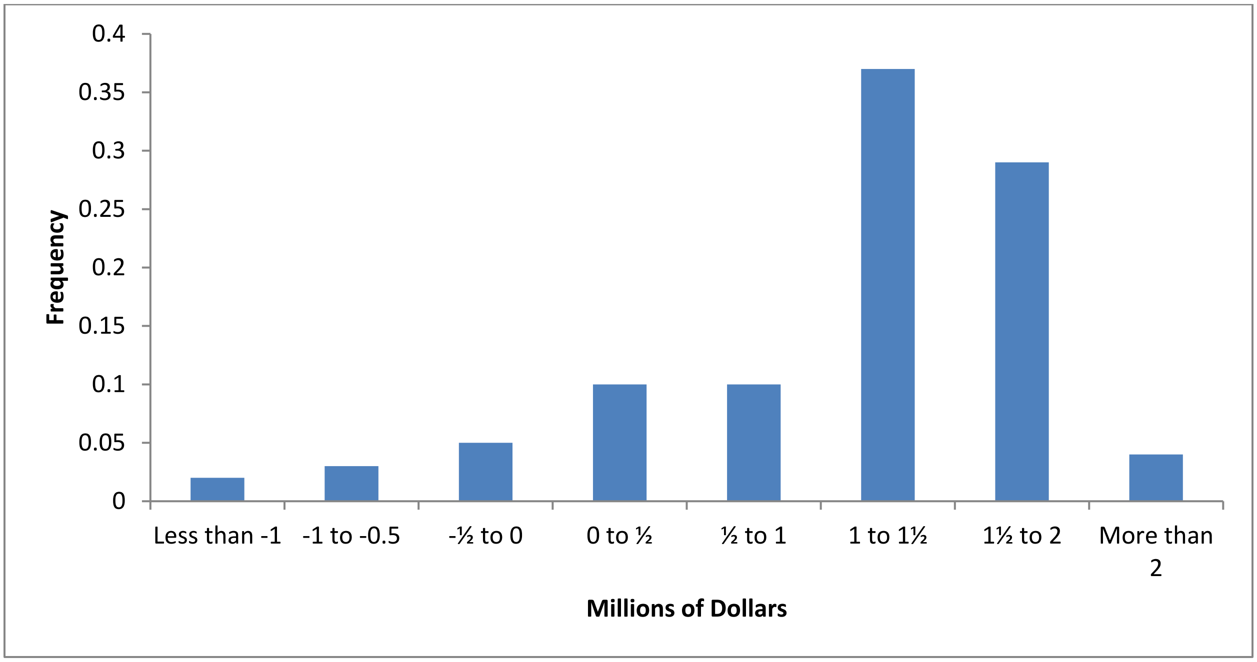
Beach-*fx* is a life-cycle model that outputs a range of possible results from implementing the Recommended Plan. This range of outputs can be used to quantify the uncertainty associated with the performance of the Recommended Plan. Quantifying this uncertainty allows for a more complete understanding of how the Recommended Plan should be expected to perform, compared to only considering the average results. This section will present the uncertainty associated with the Recommended Plan and show how reliable the Recommended Plan is expected to be. The benefits presented in this section do not include recreation benefits and are presented in the intermediate SLR scenario.

Table 21 shows the range of possible costs and benefits over the 100 life cycles (iterations) modeled in Beach-*fx*. Figure 7 shows the frequency distribution of net benefits provided by the Recommended Plan over the 100 life cycles modeled.

Table 21: Range of Recommended Plan Cost and Benefit

Statistic	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
Average	$5,038,861	$3,938,423	1.28	$1,100,438
Minimum	$1,858,357	$3,709,773	0.43	-$2,453,980
Maximum	$6,108,517	$4,312,337	1.55	$2,173,555
Std	$774,670	$78,905	0.21	$828,946

Figure 7: Frequency Distribution of Recommended Plan Average Annual Net Benefits



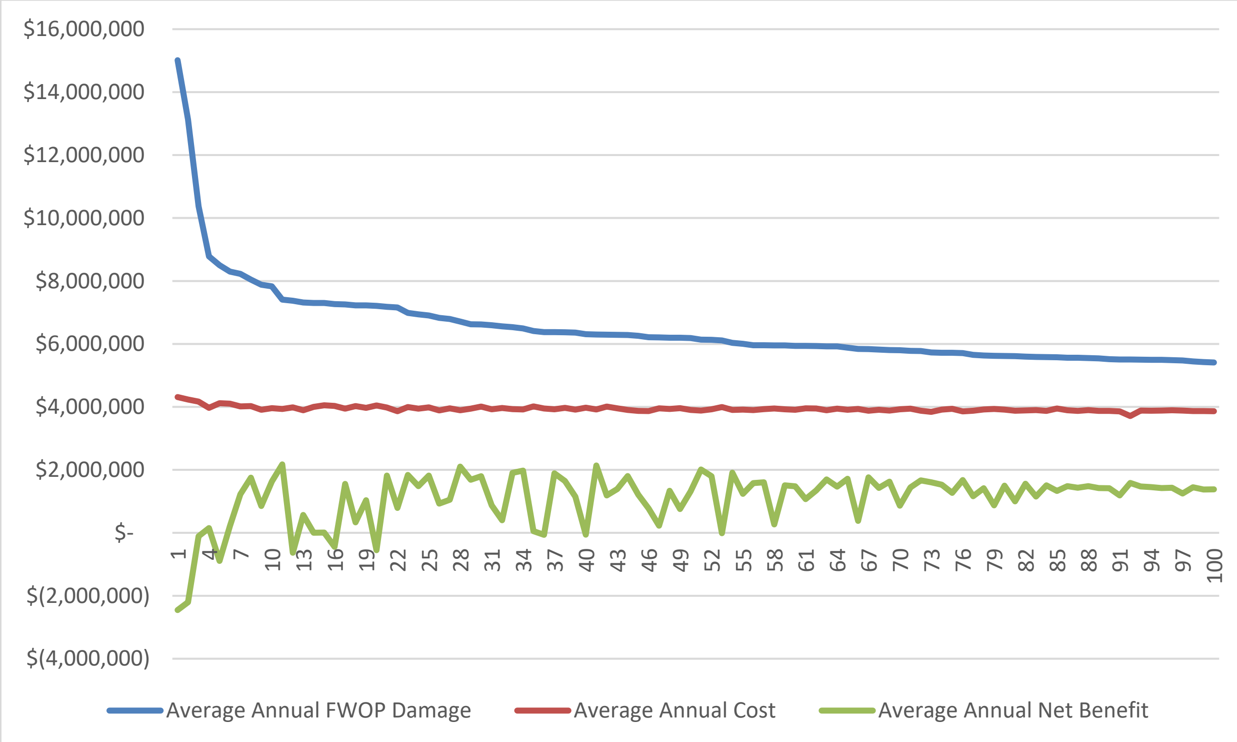
The results show that in 87 out of the 100 life cycles modeled, the Recommended Plan will produce positive net benefits. Table 22 shows how the reliability of the Recommended Plan varies for the three SLR scenarios.

Table 22: Recommended Plan Reliability for SLR (Averages from Intermediate SLR)

With Respect to Having…	Low SLR Recommended Plan Reliability	Intermediate SLR Recommended Plan Reliability	High SLR Recommended Plan Reliability
> Average Net Benefit	61%	67%	86%
> 0 Net Benefit	88%	90%	95%
> Average BCR	65%	67%	81%
> Average Cost	2%	41%	100%
> Average +20% Cost	0%	0%	85%

Figure 8 shows the costs and net benefits for each iteration sorted in order of the model iteration having the greatest FWOP damages. The results show that the model iterations having the greatest FWOP damages generally have the lowest net benefits, while costs are relatively constant. This means that the Recommended Plan is would be subject to poor performance if the future holds a bad sequence of storms.

Figure 8: Recommended Plan Average Annual Cost and Benefit Sorted by FWOP Damage



4.5 Land Loss Benefit

In outlining the process and procedures to be used in the evaluation of coastal storm risk management projects, ER 1105-2-100 mentions the inclusion of land loss due to erosion, stating that such damages should be computed as the market value of the average annual area expected to be lost. Prevention of land loss is a component of primary benefits but is not computed within the Beach-*fx* model. Thus, calculation of land loss benefits must be completed outside of the model and added to the structure and contents damage and armor costs benefits as computed by Beach-*fx* to obtain the total benefits of the project.

Following the guidance provided, two key pieces of information are needed to calculate land loss benefits of a CSRM project: (1) the square footage of the land lost each year and (2) the market value of land in the project footprint.

In the case of Folly Beach, only land that was part of a city parcel was considered for land loss. ER 1165-2-130 does not allow land loss benefits to be claimed for beach areas subject to temporary shoreline recessions.

Land loss was calculated on per iteration basis. If, during an iteration, the land loss encroached on a city parcel that land would be no longer be considered developable. If this happened in the FWOP, and not in the FWP, then it was claimed as a benefit in that iteration.

Armor in Beach-*fx* prevents erosion damage but does not stop the background erosion process. Given the high erosion rates in Folly, it was assumed that land loss would continue past armoring put up by individual property owners, but not past SCDOT or USACE revetments. The model results are sensitive to this assumption, and the effects on the Recommended Plan of changing the assumption are discussed in a later sub-section of this appendix.

As the second component of the land loss benefits calculation, ER 1105-2-100 instructs that nearshore land values be used to estimate the value of land lost. The SAS Real Estate Department estimated a nearshore land value of $50.70 per square foot for the Folly Beach study area.

Land loss calculations were made using the technique described, on an iteration-by-iteration and reach-by-reach basis. Values for land loss were included in alternative development, as they varied with alternatives, and presented in every part of the economic appendix.

4.6 Structure Condemnation Benefit

This benefit category is unique to this project. In Beach-*fx* a lot is considered condemned if erosion reaches the centroid of the lot. If a lot is condemned, the damage elements on the lot are not damaged solely because the lot status has changed. It was the conclusion of SAJ Economists that if half of the footprint of a building were to be eroded away, that the building would be uninhabitable and thus economic damage would have occurred.

To account for this in the benefit pool, lots for ocean-front properties were drawn such that the centroid of the lot was roughly equal to the center of the property's foundation, as viewed in ArcGIS Pro.

The above procedure allowed post-processing of structure condemnation benefits. If Beach-*fx* marked a lot in front of the SCDOT road revetment (first row) as condemned, then every damage element on that lot would immediately be added to the pool of damages (at the current present value.) This was done in both the FWOP and FWP conditions, meaning structure condemnation would only result in a benefit if it occurred in the FWOP and not in the FWP. Additionally, any future damage done to a condemned property was removed from the damage pool, to avoid double counting.

Post-processing for structure condemnation was done on an iteration-by-iteration and lot-by-lot basis. Values for structure condemnation were included in alternative development, as they varied with alternatives, and presented in every part of the economic appendix.

4.7 Incidental Recreation Benefit

According to ER-1105-2-100, incidental recreation benefits can be calculated in CSRM studies. While recreation benefits cannot make up more than 50% of the total benefits needed for project justification, the guidance states that "if the criterion for participation is met, then all recreation benefits are included in the benefit to cost analysis."

4.7.1 Unit Day Value

ER-1105-2-100 specifies that benefits arising from recreation opportunities created by a project be measured in terms of willingness to pay. Three acceptable calculation methods are outlined: (a) the travel cost method, (b) the contingent valuation method, and (c) the unit day value method (UDV).

The unit day value method estimates a user's willingness to pay for a given recreational opportunity by assigning ratings to five criteria designed to measure the quality of the overall recreation experience provided in the project area. According to ER-1105-2-100 Appendix E, UDV is appropriate in several scenarios, including cases where plan formulation or selection is not materially influenced by recreation benefits and where annual visitation to the project area does not exceed 750,000.

In the case of Folly Beach, the first scenario is met. Plan formulation is not materially influenced by recreation benefits as the Recommended Plan was chosen prior to the calculation of recreation benefits. However, the second guideline, relating to annual visitation does not apply. Due to visitation expected to exceed 750,000 annual visits, the Folly Beach project, in conjunction with Collier County, Pinellas County, Miami-Dade County and Puerto Rico Coastal Feasibility Studies have funded a regional contingent valuation study.

The result of the CVM is not yet available, but they are expected to be included in the Chief's Report. As a proxy for this methodology, an unconstrained UDV method is used in this report. This approach is undertaken with the understanding that if the CVM results are not available before the final report, the recreation benefits would have to be recalculated with a UDV constrained to 750,000 annual visitations.

As mentioned above, the UDV method uses five criteria to gauge the overall quality of the experience, availability, carrying capacity, accessibility, and environment in the project area. Each criterion can be assigned to one of five possible scoring ranges rated from low to high. Within each range a specific point value is also chosen. These point values are summed together and applied a dollar day value based on the current UDV guidance. The current unit day values, provided by USACE Economics Guidance Memorandum #20-03, Unit Day Values for Recreation for Fiscal Year 2020, are presented in

Table 23. Linear interpolation was used to estimate the dollar value of point scores not published. For example, a point score of 16 corresponds to a dollar value of $5.318.

Table 23: Current Unit Day Values for Recreation

Point Values	General Recreation Values (FY2020)
0	$4.21
10	$5.00
20	$5.53
30	$6.32
40	$7.90
50	$8.95
60	$9.74
70	$10.27
80	$11.32
90	$12.11
100	$12.64

The point assignments are based on qualitative criteria and depend on best professional judgment (also referred to as "judgment criteria") and knowledge of the project area. In order to learn more about recreation in Folly Beach, SAJ and SAC economists consulted with the non-federal sponsor. The non-federal sponsor sent out a survey to local experts to elicit their opinions. The survey asked local experts to rate the beach on the same scale and criteria that the Corps uses in the UDV analysis. This collaboration helped in the assignment of the following judgment criteria applied to the project footprint.

Results of the survey were analyzed in 4 different fashions. First, using the raw data from the City's survey. Second, the data was refined to omit individuals that did not seem to comprehend the survey or did not respond in good faith. This was done by removing respondents that scored the with-project as worse than the without-project in more than one category or gave a score of zero to the without-project in more than one category. Despite the adjustment made by omitting responses, significant bias still existed in the responses. The goal of the third method was to remove the bias. Bias is evidenced in the point values for the "Availability of Opportunity" question. The presence of a federal project would not change the distance of other recreation activities, as such, the point values in the with and without project should be the same. Option 3 used the survey responses to the "Availability of Opportunity" question to identify the bias in the response. This bias was used to correct the point values assigned to each category. The final method is a combination of the second and third option. The fourth and final method "Bias Corrected Refined Data" are the point values used in the UDV analysis. Point values are summarized in Table 24.

Table 24: Total Unit Day Points Scored Applied to Folly Beach

UDV Category	Raw Data		Refined Data		Bias Corrected Raw Data		Bias Corrected Refined Data	
	FWOP	FWP	FWOP	FWP	FWOP	FWP	FWOP	FWP
Recreation Experience	7.86	26.62	8.63	27.31	10.83	23.65	10.37	25.56
Availability of Opportunity	6.98	10.54	7.97	10.06	8.76	8.76	9.02	9.02
Carrying Capacity	2.98	11.51	3.26	12.24	4.36	10.13	4.07	11.43
Accessibility	6.80	13.52	8.18	14.37	8.58	11.74	9.23	13.32
Environmental Quality	4.42	15.23	4.80	16.31	6.40	13.25	5.96	15.14
Total Points	29.05	77.42	32.83	80.30	38.94	67.54	38.65	74.48
UDV	$6.24	$11.05	$6.77	$11.34	$7.73	$10.14	$7.76	$10.51
FWP vs FWOP Difference	$4.80		$4.58		$2.41		$2.75	

After assigning point scores and dollar values, these values must be applied to expected recreation visits over the life of the project. Because Folly Beach does not conduct beach counts in the project area, estimated beach visitation was calculated using data from a April 2015 report entitled "The Economic and Fiscal Impacts of Folly Beach on the Charleston Area and the State of South Carolina", which was conducted by the Office of Tourism Analysis.

Several key pieces of information are taken from the 2015 report. First, the reports provide the estimated number of annual individual day trips (500,000) and annual individual overnight stays (1,000,000). Upon talking with the non-federal sponsor, they estimate that of the overnight stays, 150,000 are 2-night weekend trips, and the remaining 850,000 are week-long stays. For weeklong stays we used a conservative estimate of 4 nights per stay. These numbers total to 4,200,000 estimated annual daily visitations to the beaches on Folly, well above the standard UDV cap of 750,000. Demand was assumed not to increase over the timespan of the study, another conservative estimate.

In order to verify the reasonableness of the recreation benefits, total projected visitation must be compared to total recreation capacity. In the case of the Folly Beach Recommended Plan, total recreation capacity has three key components, (1) parking capacity, (2) residential/hotel capacity within walking distance of the beach, and (3) available space on the beach.

Folly Beach takes great pride in their commitment to offering parking and access. Almost every street that dead ends into the beach has a public access and parking turnoff. In addition, it is legal to park on the side of the road on almost any street in town. The combination of these two access methods fulfills the parking capacity component.

No comprehensive analysis was done on the residential/hotel capacity in Folly. 3,700,000 person-nights is about 10,000 people per day and more during peak demand months. The city has one major hotel on the beach, and multitudes of smaller bed and breakfasts/vacation rentals all within walking distance of the beach. Given the economic report referenced referred to approximately 3,700,000 annual person-night visits to the city it was assumed that they would only be making those trips if they had a place to stay.

Visitation space on the beach itself was estimated by calculating the square footage of beach and comparing that to daily visitation, if the average visitor needs 100 square feet of space to recreate and turnover happens once per day. Daily visitation numbers were obtained from the original federal authorization in 1991 and extrapolated proportionally to meet the annual visitation from the 2015 report. For example, it was estimated that 2.9% of the annual visitation in 1990 occurred on the 4th of July. Using that same 2.8% and extrapolating to 2015 implies 117,600 beach users on the 4th of July.

Using the daily visitation method, the Recommended Plan was only constrained due to space on the 4th of July and a few prime demand summer weekend days. The FWOP is constrained significantly as time goes on and the size of the beach shrinks.

Using these methods and applying the visitation cap results in an estimated total present value of recreation benefits of $19,392,413 in average annual terms (at a discount rate of 2.75%). This is significantly higher than $2,148,844 if the visitation was capped at 750,000 users. Recreation benefits are summarized in Table 25.

Table 25: Incidental Recreation Benefit

Visitation Scenario	Average Annual Benefit
UDV Cap of 750,000	$2,148,844
4,200,000 Visits	$19,392,413
Difference	$17,243,259

4.7.2 Parking and Access

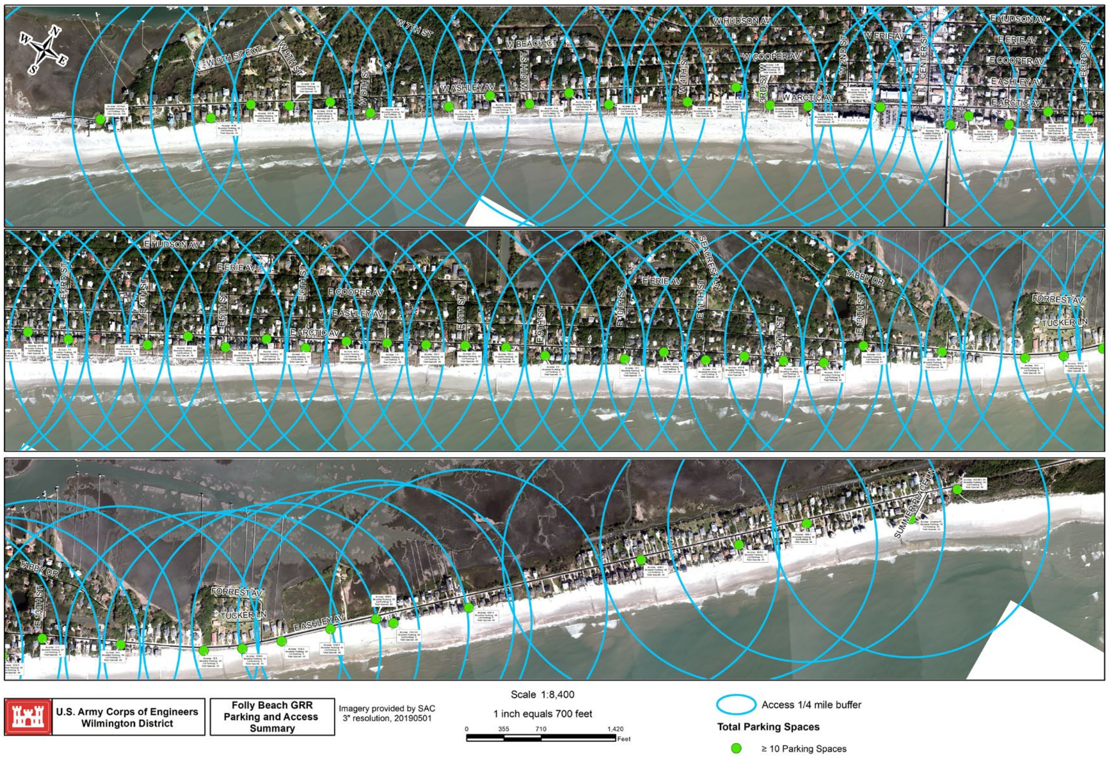
The Army Corps of Engineers has several requirements that must be met in order to fully cost share in a shore protection project (see ER 1105-2-100 and ER 1165-2-130). One of these requirements is that the beaches must be available for public use. As described in ER 1165-2-130 (Federal Participation in Shore Protection, paragraph 6.h.) public use implies reasonable access and parking. The Corps' Wilmington District, additionally, has developed more specific minimum parking requirements for participation in shore protection projects within the District's boundaries.

ER 1165-2-130 stipulates that in order to qualify for Federal cost sharing of Hurricane and Storm Risk Management projects, the local community must, at a minimum, provide public access and parking within a one quarter mile radius of any point of the project. Parking must satisfy the lesser of beach capacity or peak hour demand for that beach community. The peak demand hour had been previously identified as noon on the 4th of July holiday by USACE. The Wilmington District has further established a ten-space minimum for parking lots within one-quarter mile of each required public access point. Total beach visitation and the associated recreation benefit depend on day trip visitors having adequate available public parking. In areas where adequate parking is not provided, the recreation benefits for that portion of the project cannot be counted towards the justification of the project.

Folly Beach has 53 public beach access points within the project limit. The access points generally consist of small parking areas and wooden walkways to the beach often supplemented with shoulder parking. The county park in reach 1 and the commercial district in reach 8 have larger parking access points. All areas of the project are within .25 miles of a public access area, much of the beach having multiple access points within the .25-mile threshold. See Figure 9 for an aerial overview of the public access locations.

The City of Folly Beach has demonstrated that they have provided enough public access locations across the project area to satisfy the .25-mile requirement. Additionally, the number of spots must meet the lesser of beach capacity or peak hour demand for that beach community beach. There is a total of 1,694 parking spots available among the 53 public access points. Beach capacity peaks directly after a nourishment at 39,563. It is possible that peak demand hour on the 4^{th} will be less, but that cannot be established until after the full regional model has been completed. However, it is unlikely that the 1,694 spots would be adequate to fill the maximum capacity of the beach. If there does not exist adequate parking availability, then the recreation benefit could be limited. In that circumstance, all segments of the beach would still be able to claim some amount of recreation benefit, because the city has previously been shown to comply regarding the number of access points.

Figure 9: Overview of Public Access Locations



4.8 Risk and Uncertainty of the Recommended Plan

This sub-section outlines the two significant outlying contributors to risk and uncertainty in the economic modeling.

4.8.1 Inconsistency in Hard Structure Modeling

FWOP modeling assumed that individual property owners would continue to construct and repair armoring to their property consistent with the Folly Beach Code of Ordinances § 151.23, provided by the City of Folly Beach. Furthermore, it was assumed that if erosion was so severe as to reach the main roadway, the SCDOT would construct a revetment to protect the roadway, as they have done previously in reaches 20 and 21.

Based on the ubiquitous nature of armor and revetments on Folly's shoreline, a revetment option was initially included as part of the initial screenings. In the highly erosional areas (reaches 22-26) the revetment option had over 50% greater net benefit than the eventual recommendation ($1,116,061 to $737,373 average annual.) The revetment option was not carried forward past this point.

The decision to not consider a revetment alternative leaves the economic modeling inconsistent with the plan formulation. There is a substantial risk that the Recommended Plan does not maximize NED benefits due to the uncertainty around revetments.

4.8.2 Sensitivity to Armoring Assumption

Previously in this appendix, it was identified that the economic results were extremely sensitive to a modeling assumption. This assumption is whether erosion continues past armor installed by individual property owners. In the analysis prior to this sub-section, it was assumed that individual property owner's armor did not stop erosion. This sub-section will present results if the armor completely stops erosion.

Reality is likely a mix of the two extremes, however, given the limitations of Beach-*fx* it was required one be selected over the other. Given the high erosion rates in Folly, the decision was made to focus on the situation where erosion continued.

Table 26: Damage and Benefit by Damage Source, Recommended Plan, Armor Sensitivity

Damage Source	Average Annual FWOP Damage	Average Annual FWP Damage	Average Annual Benefit	% of Damage Prevented
Erosion	$88,780	$4,116	$84,664	95%
Inundation	$151,498	$60,295	$91,203	60%
Wave Attack	$200,843	$81,197	$119,646	60%
Armor Cost	$722,139	$225,487	$496,652	69%
Land Loss	-	-	-	-
Structure Condemnation	-$28,851	$3,414	-$32,265	-
Total	$1,134,409	$374,508	$759,900	67%

Note, structure condemnation in the FWOP is negative because under this analysis, fully condemning structures when they are damage beyond 50% of their value removes the potential for repetitive damage, thus lowering damage. As seen in Table 26, the FWOP Damages are significantly less due to the changed assumption. Lower FWOP damages result in a lower potential benefit pool for project justification. The result is that the average annual benefit is significantly lower. The percent of damage prevented is also lower due to the unpredictable nature of inundation and wave attacks (67% vs 77%). Table 27 illustrates how this assumption impacts the net benefits and BCR. Recreation benefits are not included in the table but remain the same.

Table 27: Comparison of Armor Sensitivity on Recommended Plan (without Recreation)

Armor Assumption	Context	Average Annual Benefit	Average Annual Cost (from TPCS)	BCR	Average Annual Net Benefit
Erosion Continues past Individual Property Armor	Primary Analysis	$5,038,861	$4,632,337	1.09	$406,524
Erosion Stops at Individual Property Armor	Sensitivity Analysis	$759,900	$4,632,337	0.16	-$3,872,437

The Recommended Plan was optimized with respect to continued erosion and yields a BCR close to unity of 1.09. Under the sensitivity exercise, the BCR of the Recommended Plan drops to 0.16. Realistically, the truth is somewhere between the two. The wide range of the BCR represents significant risk that the Recommended Plan is failing to deliver the stated benefit.

5 Conclusion

Table 28 provides a summary of the Recommended Plan with recreation benefits added expressed in average annual equivalent terms. The costs from the Total Project Cost Summary are used in Table 28 resulting in a change to the BCR and net benefits from previous sections in this appendix.

Table 28: Economic Summary

Economic Category	Primary Storm Damage Reduction Benefit	Primary Storm Damage Reduction + Incidental Recreation Benefit
Price Level	FY2020	FY2020
FY2020 Water Resources Discount Rate	2.75%	2.75%
Average Annual Structure and Content Damage Benefit	$295,513	$295,513
Average Annual Armor Construction Cost Benefit	$1,047,639	$1,047,639
Average Annual Land Loss Benefit	$2,556,610	$2,556,610
Average Annual Structure Condemnation Benefit	$1,139,099	$1,139,099
Average Annual Incidental Recreation Benefit	-	$19,392,413
Average Annual Total Benefit	$5,038,861	$24,431,274
Average Annual Total Cost (from beach-*fx*)	$3,938,423	$3,938,423
Average Annual Total Cost (from TPCS)	$4,632,337	$4,632,337
Average Annual Net Benefit (using TPCS)	$406,524	$19,798,937
BCR (using TPCS)	1.09	5.27

Portions of Folly Beach's shoreline are vulnerable to coastal erosion and storm damage. Beach-*fx* modeling has demonstrated that significant economic damage from coastal forces can be expected to occur over the next 50 years in the future without project condition. In the high sea level rise scenario, damages increase substantially, and are marginally lower in the low sea level rise scenario.

To reduce future damages, many management measures were considered. After a detailed investigation and extensive modeling effort, a plan was selected that minimizes risk while reasonably maximizing expected future net benefits. This plan, Alternative 3, involves initial and periodic nourishment of a 35-foot equilibrated berm extension for the southwest and center of the barrier island, and a 50-foot equilibrated berm extension for the area in the northeast. The project template will include a dune feature at 15' NAVD88 high by 5' wide (at the crest). A dredge will be used to fill the template with sand from Folly River, the Lighthouse Inlet, and the Stono Ebb Shoal. The average annual net benefits of the Recommended Plan are $19,798,937 if incidental recreation benefits are included, and $406,524 without recreation.