ST. LUCIE COUNTY, FLORIDA

COASTAL STORM RISK MANAGEMENT PROJECT

DRAFT INTEGRATED FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT

APPENDIX C
Economics

APRIL 2016

**US Army Corps
of Engineers**
Jacksonville District

1. EXECUTIVE SUMMARY

S t. Lucie County is located on the central-east coast of Florida to the immediate south of Indian River County, and the immediate north of Martin County. Portions of St. Lucie County's 22 mile shoreline are subject to erosion caused by both storms and natural shoreline processes. A study was undertaken to assess the feasibility of providing Federal Coastal Storm Risk Management (CSRM) measures to portions of the county's shoreline. The local sponsor for this project, St. Lucie County, has indicated strong support for feasibility phase studies to address CSRM. They have also declared willingness and the capability to share applicable costs in the current study. In accordance with appropriate federal guidance, an investigation was performed to estimate the economic benefits of alleviating erosion, inundation, and wave-attack damage to coastal infrastructure.

⌗ Alternative Evaluation

Upon initiation of a preliminary screening, followed by a detailed evaluation of a final array of alternatives, the project delivery team has determined a National Economic-Development Plan (NED) (i.e. a plan that maximizes net-benefits), and a Tentatively-Selected Plan (TSP) for reducing coastal storm and erosion damage to infrastructure. These plans were evaluated using FY2015 price levels and the FY2016 federal water resources discount rate of 3.125%. The evaluation covered the span of a 50-year period of analysis with a base year of 2020. Alternatives were measured against the criteria of efficiency, effectiveness, and acceptability. Refer to **Table 1-1** for more detail on the evaluation of the final array of alternatives en route to selecting a NED. Benefit values in this table include those derived from land loss estimations and incidental recreation benefits. It is important to note that this table represents costs and benefits estimated during the alternative evaluation process based on best available information at that time. Once the most promising alternatives were established further refinements to both costs and benefit models were performed. The refinement results in two of the alternatives, ABerm20DuneEx and ABerm30DuneEx, being modeled at a higher level of detail[1] and thus final values of costs and benefits will vary from those listed in Table 1-1.

Table 1-1: Alternative Net Benefits & BCRs (Screening-Level Costs)

Alternative Name	Brief Description	Total Costs (AAEQ)	Net Benefits (AAEQ)	BCR
ABerm20DuneEx	Existing Dune and 20' sacrificial berm	$ 1,327,721	$ 767,852	1.58
ABerm30DuneEx	Existing Dune and 30' sacrificial berm	$ 1,358,477	$ 733,004	1.54
ABerm40DuneEx	Existing Dune and 40' sacrificial berm	$ 1,356,253	$ 735,194	1.54
ABERM10DuneEx	Existing Dune and 10' sacrificial berm	$ 1,691,824	$ 401,904	1.24
Dune10	10' Dune Extension	$ 1,926,323	$ 161,395	1.08

The plan with the highest net benefits (NED) is the project that maintains the current dune and berm template while adding 20' of sacrificial fill (**ABerm20DuneEx**). The NED plan is also the TSP. **Table 1-2**

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[1] Additional high-value structures that had been absent from initial modeling were added during this refinement. The CSRM benefits provided by the various projects to these structures are absent from Table 1-1.

provides a summary of the TSP with and without land-loss and incidental recreation benefits[2]. Values in this table reflect all cost and benefit modeling refinements.

Table 1-2[3]: Economic Summary of the TSP

ECONOMIC SUMMARY	STORM DAMAGE REDUCTION BENEFITS	STORM DAMAGE REDUCTION + LAND-LOSS BENEFITS	STORM DAMAGE REDUCTION + LAND-LOSS + RECREATION
Price Level	FY16	FY16	FY16
FY16 Water Resources Discount Rate	3.125%	3.125%	3.125%
Average Annual Storm Damage Reduction Benefits	$3,179,950	$3,179,950	$3,179,950
Average Annual Land-Loss Benefits	$0	$276,819	$276,819
Average Annual Recreation Benefits	$0	$0	$584,018
Average Annual Total Benefits	$3,179,950	$3,456,769	$4,040,787
Average Annual Cost	$1,925,977	$1,925,977	$1,925,977
Average Annual Net Benefits	$1,253,973	$1,530,792	$2,114,810
Benefit Cost Ratio	**1.65**	**1.80**	**2.10**

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[2] Unlike incidental recreation benefits, land-loss benefits are considered primary benefits in CSRM studies. Both benefit categories are discussed in detail in sections **4.2** and **4.3**.
[3] This table reflects the project after certified costs have been calculated (including the 20% contingency) and with the addition of high-value structures in reach R115 not present during initial modeling.

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1. INTRODUCTION

The purpose of this appendix is to tell the story of the economics investigation and resulting analysis. A detailed explanation of the qualitative rigor and the precise modeling efforts, from inputs to outputs, which gave rise to the tentatively-selected plan (TSP) will be provided. The subsequent sections will cover the following topics:

- **Existing Conditions:** Items discussed include an assessment of socio-economic conditions, spatial organization of the study area, and an inventory of the coastal infrastructure within the study area.
- **Future Without-project Condition (FWOP):** The FWOP is a forecast of the economic conditions and structure values located within the project area that are subject to the risks associated with coastal processes and coastal storms. The FWOP is the basis for alternative comparison in order to obtain the benefits from any potential federal project.
- **Coastal Storm Risk Management (CSRM) Benefits:** This section will cover the methods and assumptions used to estimate the future without-project and future with-project condition using Beach-*fx*, while also accounting for risk and uncertainty. The future without-project condition (FWOP) will cover the distribution of the damages in the following dimensions:
  - Spatial (Where)
  - Categorization of structures (What)
  - Damage driving parameter (How)
  - Temporal (When)

Discussion of the future-with project condition (FWP) will address the management measures and alternative plans evaluated. In addition, a sensitivity analysis of how the alternatives perform under varying sea-level rise scenarios is provided.

- **NED & TSP Plan Selection and Performance:** This section addresses the quantitative analysis executed to determine which alternative maximizes national economic development (NED) and which alternative will be the TSP. A detailed description of the performance of the NED plan, including certified cost estimates, is provided with the same four dimensions described above in the CSRM section. The methodology underpinning the calculation of additional benefits provided by the project (i.e. land-loss benefits, incidental recreation benefits) will be summarized as well.

2. EXISTING CONDITIONS

A key step in the planning process is to establish the existing (i.e. current) condition by developing an inventory and characterizing the critical resources within the project area. The existing condition is also a key component for forecasting the FWOP, which is described in detail below (**Section 3.3**). All structure and content values presented in this section are in FY2015 price levels.

2.1 Socio-Economic Conditions

St. Lucie County is located in the central-east region of Florida and has approximately twenty-two miles of coastline along the Atlantic Ocean. The cities comprising the county are Ft. Pierce, Port St. Lucie and the communities of Hutchinson Island and St. Lucie Village. It is also one of four counties included in the Research Coast Economic Development Coalition[4].

2.1.1 Demographic Characteristics[5]

According to the US Census Bureau, the 2010 population of St. Lucie County was 277,789 with a land area of 571.93 square miles. Over the past several years, the county has seen rapid population growth. Between 2000 and 2010 the county grew by approximately 44%. Since then, the population has grown by 4.8% to reach an estimated 291,028 in July of 2014.
The ethnic makeup of St. Lucie County is relatively homogeneous. Caucasians make up approximately 71.8% of the population. The largest minority group is African American, which make up approximately 19.1%. All other racial groups comprise less than 10% of the total population. The median age for residents is 43.3 and those aged 60 years and over represent 27.4% of the population. Overall, St. Lucie County is largely an adult population with those aged 18 years and older at 77.7%.

2.1.2 Economic Characteristics

With several notable attractions located within its borders tourism is a critical component of the economy. St. Lucie County is a premier recreational fishing destination with a variety of species available for catch. Notably, the International Game Fish Association (IGFA) reports the record-setting spotted sea trout catch occurred within county waters (17 lbs. 7 oz., Ft. Pierce). In addition to the miles of pristine beaches and nature reserves, the county's Tradition Field is also host to the New York Mets Major League Baseball team for the entirety of spring training. As a result of this influx of tourists St. Lucie County has over 6,000 jobs in the service industry[6].

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[4] *Research Coast Representatives Promote Region for Business*. Vero News. December 7, 2015
[5] All figures from this section are from source: United States Census Bureau, American Fact Finder. Unless otherwise specified, data references 2010 Census.
[6] Source: St. Lucie Economic Development Council

Additionally, agriculture, manufacturing and health care are all important drivers of economic activity in St. Lucie. According to the United States Department of Agriculture, the county has more than 75,000 acres of crop land between grapes, citrus, and oranges alone[7]. Manufacturing accounts for 1,870 jobs and health care an additional 2,8906[6].

The income trends within St. Lucie County are very similar to that of the state of Florida overall. The following is a summary of those trends from the most recent year available (2014)[8]:

- Median Household Income: $42,665
- Per Capita Income: $23,422
- Individuals Below Poverty Line: 14.2%
- Unemployment Rate: 7.5%
- Individuals Receiving Social Security Income: 42.2%
- Individuals with Retirement Income: 22.8%

2.2   Study Area

The initial study area ranged from the Florida Department of Environmental Protection (FDEP) range monument (R) R-077 to R001 (Martin County line). Four reaches were established within the 7.3 mile span of coastline: The Power Plant, North Hutchinson Island, Narrows of Hutchinson Island, and South Hutchinson Island. Preliminary modeling indicated that the federal project should focus exclusively on the South Hutchinson Island reach due to its erosive nature and dense development. Though the power plant represented a potential risk for damages, heavy existing fortification suggested further measures would prove redundant. As a result, the project area was refined to begin at R098 and end at R001 as displayed in **Figure 2-1.** All benefit and cost analysis performed and described in this appendix refer specifically to this project area.

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[7] Source: CropScape – USDA National Agricultural Statistics Service
[8] Source: Us Census Fact Finder 2014

Figure 2-1: Map of Project Area
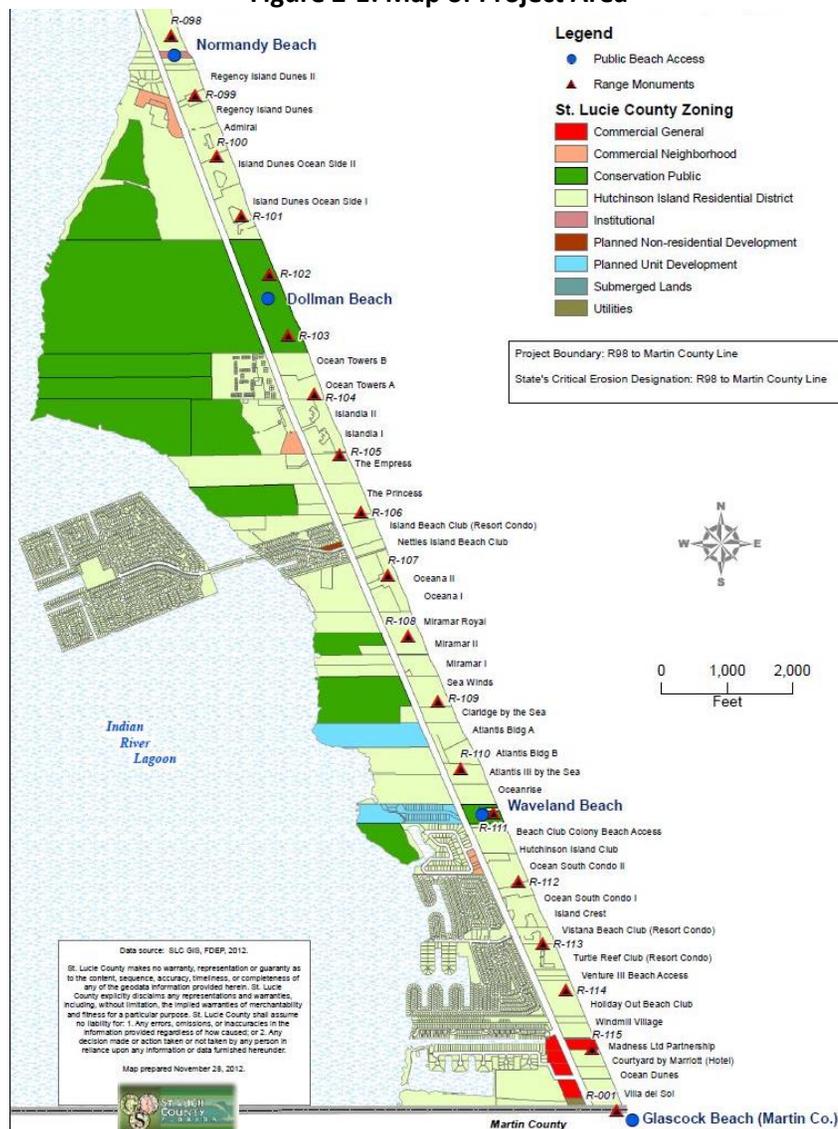
2.3   Data Collection

Economists and real estate specialists have collected and compiled detailed structure information for 3.4 miles[9] of St. Lucie County's coastline. In total, 241 damageable structures were collected for economic modeling using Beach-*fx*. The structure inventory includes all structures that are within 500 feet of the mean-high-water line.

Real estate professionals from the USACE Jacksonville District (SAJ), using geo-spatial parcel data from St. Lucie County, provided detailed data on each structure including: geographic location, structure type, foundation type, construction type, width, length, number of floors, depreciated replacement value, and year built.

The St. Lucie County study area consists of seven profiles, 18 model reaches, and 61 lots for economic modeling and reporting purposes. This hierarchical structure is depicted as follows:

- **Profiles:** Coastal surveys of the shoreline modified by USACE SAJ Coastal Engineering personnel to apply coastal morphology changes to the model reach level. Profiles are strictly used for modeling purposes and only referred to in this section for informational purposes. Specific information regarding the makeup of the profiles can be found in the Engineering Appendix of this report.
- **Beach-*Fx* Model Reaches:** Quadrilaterals parallel with the shoreline used to incorporate coastal morphology changes for transfer to the lot level. In this study the model reaches use Florida Department of Environmental Protection (FDEP) range monuments and are inclusive of reaches R098-R115 and will be referred to simply as "reaches" throughout this appendix. **Figure 2-1** above displays these reaches in the project area.
- **Lots:** Quadrilaterals encapsulated within reaches used to transfer the effect of coastal morphology changes to the damage element. Lots also ensure that the model does not overstate damages by placing value parameters around rebuilding (this is discussed further in section 3.2.2).
- **Damage Elements:**   Represent a unit of coastal inventory in the existing condition 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 the following section.

2.4   Existing Condition Coastal Structure Inventory

Information on the existing economic conditions along the St. Lucie County coastline was collected for economic modeling purposes. The information on the coastal assets detailed in this section was collected from St. Lucie County mapping resources, site visits, and contractors.

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[9] Approximate length from R098-R001

Each parcel along the beach was identified as developed or undeveloped, with streets and parks noted. USACE real estate specialists provided depreciated replacement value of existing structures within the study area.

2.4.1   Structure & Contents Value

The economic value of the existing St. Lucie County structure inventory represents the depreciated replacement costs of damageable structures (i.e. damage elements) and their associated contents along the coastline. Real Estate professionals from the USACE SAJ district worked together with economists and planners to provide economic valuations for all of the 241 damageable structures and their contents. These damage elements have an overall estimated value of $670.2M, with structure and content valuations of $579M and $91M respectively. Content values were established as a ratio to overall structure value. The ratios were determined by SAJ economists based on available information from St. Lucie County and best professional judgment. The overall distribution of value by reach is summarized in **Table 2-1**.

Table 2-1: Distribution of Structures & Structure Value by Study Reach

Reach	Structure Value	Content Value	% Total Value	# Damage Elements	% of Damage Elements
R098	$ 868,902.27	$ 91,773.15	0.1%	5	2.1%
R099	$ 70,328,170.49	$ 11,335,908.92	12.2%	18	7.5%
R100	$ 65,393,014.73	$ 8,938,155.87	11.1%	7	2.9%
R101	$ 33,292,909.48	$ 4,583,020.93	5.7%	12	5.0%
R102	$ 510,685.00	$ -	0.1%	2	0.8%
R103	$ 382,169.00	$ -	0.1%	1	0.4%
R104	$ 59,638,936.30	$ 8,233,070.10	10.1%	16	6.6%
R105	$ 50,671,440.86	$ 6,935,733.30	8.6%	12	5.0%
R106	$ 38,827,603.52	$ 5,262,028.06	6.6%	10	4.1%
R107	$ 23,131,258.80	$ 3,342,885.26	3.9%	14	5.8%
R108	$ 67,674,190.47	$ 9,683,230.57	11.5%	16	6.6%
R109	$ 36,383,413.42	$ 5,941,501.65	6.3%	18	7.5%
R110	$ 23,862,725.12	$ 3,165,471.52	4.0%	11	4.6%
R111	$ 26,672,081.83	$ 4,018,669.57	4.6%	20	8.3%
R112	$ 31,434,921.66	$ 4,406,245.96	5.3%	12	5.0%
R113	$ 26,669,669.63	$ 6,969,432.38	5.0%	19	7.9%
R114	$ 1,393,214.69	$ 217,112.45	0.2%	17	7.1%
R115	$ 22,365,139.75	$ 7,626,234.68	4.5%	31	12.9%

Total	$ 579,500,447.02	$ 90,750,474.43	100%	241	100%

Despite the relatively uniform distribution of damage element count, the values aggregated by reach show significant variation, with four of the reaches (R099, R100, R104, R108) accounting for approximately 45% of total value (as demonstrated by the spikes displayed in **Figure 2-2**). The variation is due mainly to differentiation between the types of development within the reach. Specifically, reaches with large commercial structures, such as R113 and R115 with Turtle Reef and Villa Del Sol condominium complexes, tend to contain greater value than neighboring reaches, such as R102-R103 which is a public conservation area. For modeling and reporting purposes the structure inventory was separated into four different structure types. **Table 2-2** provides a summary of these structure types and the associated inventory values[10].

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[10] Some of the high-rise structures and other condominiums in the project area are used for commercial activity and many are residential. For economic modeling purposes the delineation between commercial and residential may differ from that of SAJ real estate appendices. However, the total values of the structures do not vary and thus represent the same inventory. Most condos and high-rises were deemed commercial for damage aggregation.

Figure 2-2: Structure Value & Damage Element Distribution by Reach[11]

Structure Value & Damage Element Distribution by Reach

Legend: % Total Damage Elements — Structure Value — Content Value

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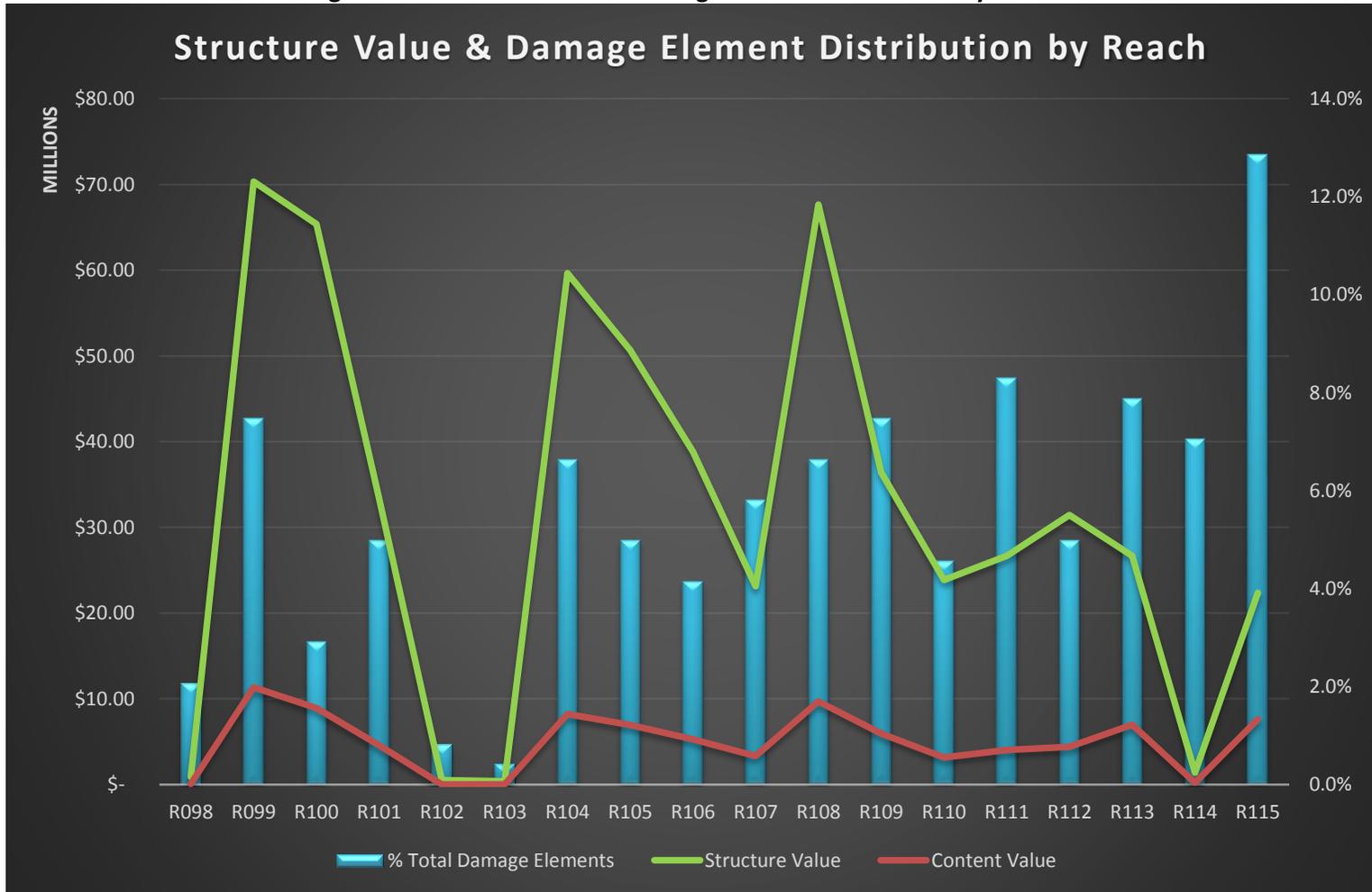
[11] The percent score on the right axis corresponds with the damage element count, not the damage element dollar value.

Table 2-2: Economic Value of Structure Inventory by Structure Type

Structure Type	Structure Value	Contents Value	Total	% of Total Value	Structure Count
Commercial	$ 557,424,139.88	$ 90,315,788.35	$ 647,739,928.23	96.64%	59
Other	$ 11,071,645.80	$ 52,780.96	$ 11,124,426.76	1.66%	118
Public	$ 10,258,756.90	$ 18,109.26	$ 10,276,866.16	1.53%	62
Residential	$ 745,904.44	$ 363,795.86	$ 1,109,700.30	0.17%	2
Grand Total	*$ 579,500,447.02*	*$ 90,750,474.43*	*$ 670,250,921.45*	*100%*	*241*

2.4.2   Evacuation Route

The residents of South Hutchinson Island rely heavily on Florida State Road A1A as a means to evacuate during extreme hurricane events. Additionally, A1A provides residents with access to, and from, critical infrastructure and services located on the mainland such as fire departments, police departments, and hospitals. The project area impacts 3.4 miles of A1A since it parallels the coastline throughout South Hutchinson Island. A1A connects residents to the mainland via Northeast Causeway Boulevard to the south and Seaway Drive to the north. Any obstruction to A1A in the southern reaches that blocks access to Northeast Causeway Boulevard would result in traffic needing to be rerouted approximately 16 miles north to Seaway Drive. All of the nearest hospital services, which are located on the mainland, require clear access to A1A. An analysis of flood concerns impacting A1A and how a project ameliorates these effects will be discussed in subsequent sections.

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 St. Lucie County using Beach-*fx*. The topics covered include:

- Benefit Estimation Approach Using Beach-*fx*
- The Future-Without Project Condition (FWOP)
- The Future-With Project Condition (FWP)

3.1 Benefit Estimation Approach Using Beach-fx

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* CSRM model based on recommendations from the Planning Center of Expertise (PCX). The model was reviewed by the PCX for Coastal and Storm Damage and found to be appropriate for use in CSRM studies. The model 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 shore protection alternatives. The output generated from the model is then used to determine the benefits of each alternative. As an event-based Monte Carlo life-cycle simulation, Beach-*fx* fully incorporates risk and uncertainty. It is used to simulate future hurricane and storm damages at existing and future years and to compute accumulated present-worth damages and costs. Storm damage is defined as the ongoing monetary loss to contents and structures incurred as a direct result of waves, erosion, and inundation caused by a storm of a given magnitude and probability. The model also computes permanent shoreline reductions so that land-loss benefits can be derived exogenously. These damages and associated costs are calculated over a 50-year period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Beach-*fx* also provides the capability to estimate the costs of certain future measures undertaken by state and local organizations to protect coastal assets.

Of course, the abovementioned computations require inputs from USACE personnel in order to function accurately. Data on historic storms, beach survey profiles, and private, commercial and public structures within the project area are used as these inputs. Refer to sections **2.2** and **2.4** for detailed information on key input data specific to St. Lucie County.

The future structure inventory and values are the same as the existing condition. This conservative approach neglects any increase in value accrued from future development. Though Florida has historically experienced increases in density and value in real-dollar terms, using the existing inventory is considered preferable due to the uncertainty involved in projections of future development.

The FWOP damages are used as the base condition and potential project alternatives are measured against this base. The difference between FWOP and FWP damages will be used to determine primary CSRM benefits.

Once benefits for each of the project alternatives are calculated, they will be compared to the costs of implementing the alternative. Dividing the total benefits by the total costs of the alternative yields a benefit-to-cost ratio (BCR). This ratio must be greater than 1.0 (i.e. the benefits must be greater than the costs) in order for the alternative to be justified and implementable. The federally preferred plan, or National Economic Development Plan (NED) is the plan that maximizes net benefits. Net benefits are determined by simply subtracting the cost of any given alternative from the benefits of that alternative ($Benefits - Costs = Net\ Benefits$).

3.2 Assumptions

Beach-*fx* accuracy is not only dependent upon inputs but also requires a meticulous level of thought be given to the parameters (i.e. assumptions) under which the model is bound. This section describes some key assumptions specific to the St. Lucie County CSRM study and the resulting consequences.

3.2.1 Timeframe and Discount Rate

- **Start Year:** The year in which the simulation occurs is 2008. In order to ensure that emergency nourishment efforts effected by St. Lucie County (completed in May 2013) in response to the 2004 and 2005 hurricane season did not influence the outcome of the ongoing feasibility study, it was agreed that the representative FWOP shoreline for the study would be established using survey data collected in the summer of 2006. However, subsequent analysis of the data showed that the 2006 survey did not provide adequate foreshore and offshore coverage of the project area to complete the Beach-*fx* analysis. A comparison of the available portions of the 2006 survey and a comprehensive shoreline survey taken in August 2008 showed insignificant difference in shoreline dimensions between the two. Therefore, the 2008 shoreline was determined to be a good representation of the FWOP condition.
- **Base Year:** The year in which the benefits of a constructed federal project would be expected to begin accruing is 2020.
- **Period of Analysis:** 50 years
- **Discount Rate:** 3.125% FY2016 Federal Water Resources Discount Rate
- **Iterations:** Beach-*fx* was run using 100 iterations. The moving average of FWOP damages reached equilibrium by this point and was thus determined an adequate number of iterations. **Figure 3-1** demonstrates the model achieving equilibrium as the moving average does not vary by more than two percent after the 65 iteration.

Figure 3-1: Model Stabilization
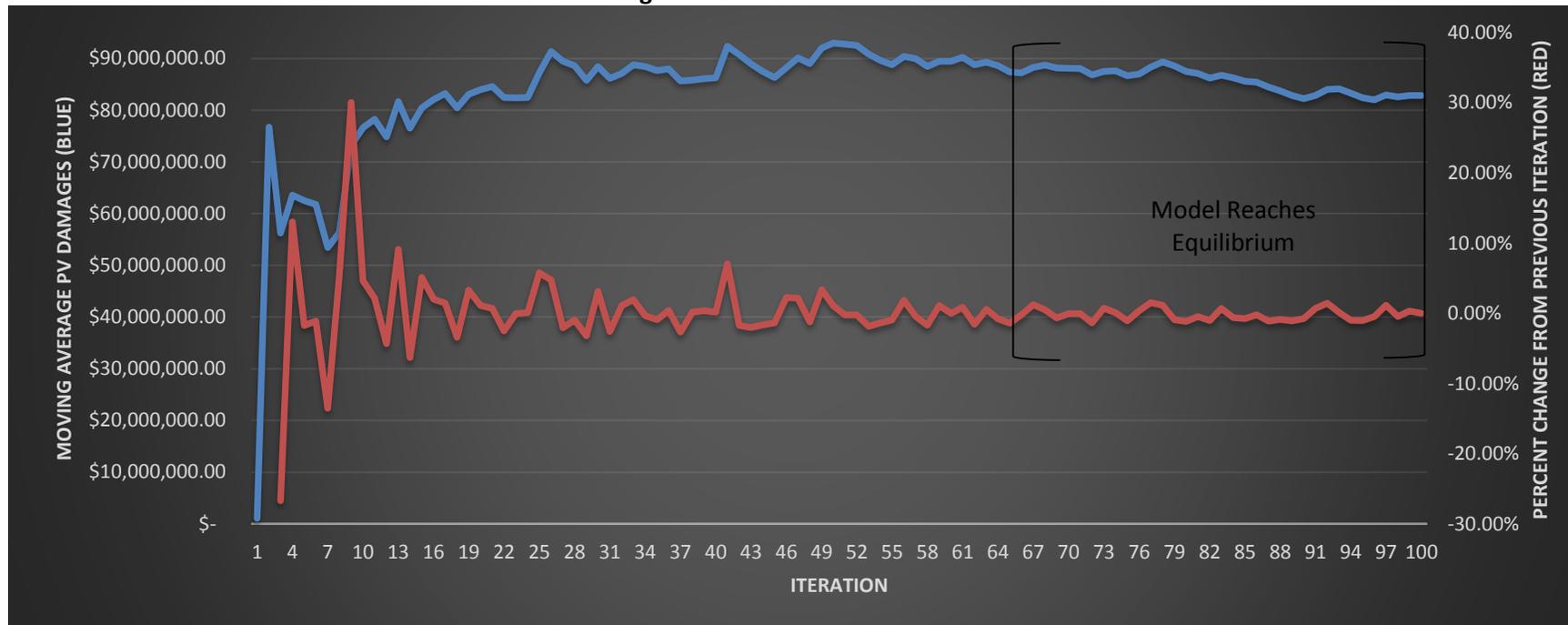
3.2.2 Rebuilding

The rebuilding parameter within Beach-*fx* allows the economic modelers to restrict the amount of monetary investment allocated to structural repair for any specific building type in order to most accurately reflect real-world behavior. Rebuilding does not refer to a total rebuild event (i.e. 100% of structure value), but rather a repair event (i.e. some non-zero percent of value intended to restore the structure). Allowing for an unlimited amount of rebuilding in the period of analysis may be unrealistic for a CSRM study and can potentially overstate damages in the FWOP. However, issuing emergency permits for rebuilding on lots meeting a minimal setback restriction is generally the rule, not the exception

in Florida. Common practice and historical evidence also show that rebuilding lost structures, provided setback restrictions are met, occurs frequently[12]. As a result, the number of rebuilds within the model has been limited to reflect this behavior as follows:

⌗ **Number of Times Rebuilding Allowed Assumptions**
   ⌗ Public Access Structures[13]: 124X
   ⌗ Commercial Recreation Facilities[14]: 62X
   ⌗ Remaining: 31X

Additionally, after long-term erosion has claimed more distance on the oceanfront lot than the building requires, the model ceases to reinstate the same property. The model also considers a lot "condemned" once 50%[15] of the total value of that lot is damaged. These assumptions will continue to prevent overestimation of the FWOP damages while allowing for realistic rebuilding to occur.

3.2.3   Damage Functions

Damage functions are used within the model to determine the extent of storm-induced damages attributable to any specific combination of damage element type, foundation type, and construction type. There are a total of six types of damage function which include erosion damages, inundation damages, and wave damages for both contents and structure. The functions are completely user-definable within the model and transfer damages to the individual damage elements. Damage is determined as a percentage of overall structure or content value using a triangular distribution (minimum, most likely, maximum). The range of percentage points used for the damage is determined by parameters dependent upon which function is being triggered. For erosion it is dependent upon the extent to which the structure's footprint has been compromised and inundation and wave-attack are dependent upon storm-surge heights in excess of first-floor elevation. An example diagram of how these damage functions operate is provided by **Figure 3-2**.

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[12] Reference Florida Office of General Counsel order 12-1453 and 12-1264 as examples.
[13] Examples of public access structures include dune walks, shelters, guard shacks and roads.
[14] Examples of commercial recreation facilities include pools, parking areas, and tennis courts.
[15] This amount, the lot condemnation ratio, can be manipulated within the model as needed but is set to 50% for this study

Figure 3-2: Example Damage Function
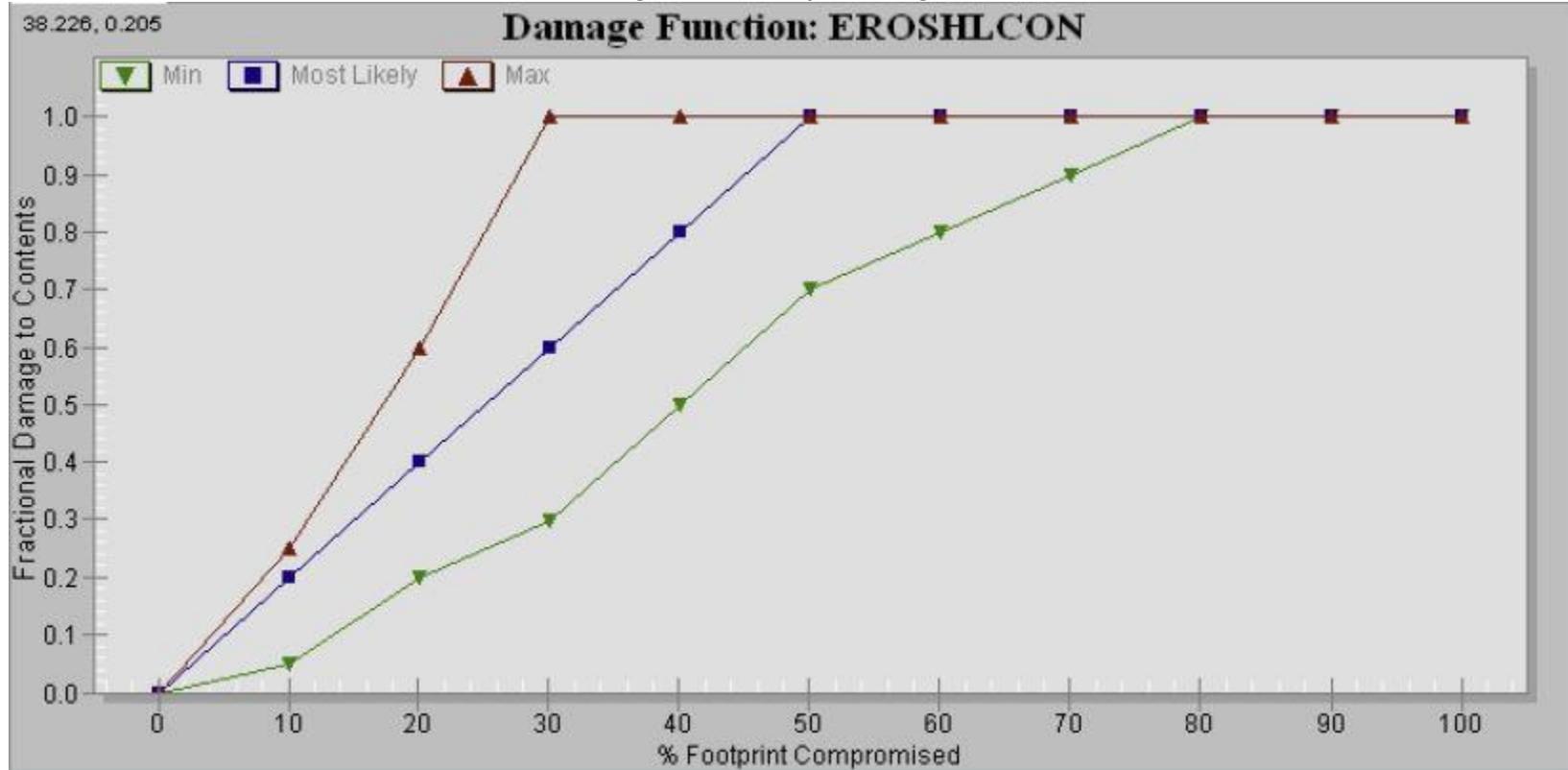
For the vast majority of aforementioned combinations within this study the damage functions used were those developed by the Institute for Water Resources (IWR), within the Coastal Storm Damage Workshop (CSDW), Coastal Storm Damage Relationships Based on Expert Opinion Elicitation in 2002. However, the various high-rise buildings located within the project area proved to be the exception since the IWR wave-damage function did not adequately address these structures. Using empirical evidence on the performance of high-rise structures during major

hurricanes[16] it was conservatively assumed that wave-attack damages would likely only affect the lower floors. As a result, the high-rise structures were separated into three categories:

- HIGHRISE1: Maximum of 6-10 floors
- HIGHRISE2: Maximum of 11-14 floors
- HIGHRISE3: Maximum of 16-20 floors

Once separated, a relationship between the structure value and maximum number of floors was established to create the triangular distribution of values for the model to accurately calculate wave-attack damages.

3.3   Future without Project Condition (FWOP)

Descriptive statistics on the damages per the FWOP model results are as follows:

- Mean: PV $82,844,425 (AAEQ~ $3,296,624)
- Standard deviation: $65,241,923 (AAEQ~ $2,596,167)
- Coefficient of Variance: .79
- Median: $81,015,316 (AAEQ~ $3,223,834)

The nearness in value between the mean and standard deviation indicates some volatility of the FWOP damage incurred in the project area throughout the 100 iterations. This volatility is due to the fact that damages are primarily driven by storm occurrence and severity rather than annual erosion rates. In short, St. Lucie County's shoreline structures are highly susceptible to storm damage in the FWOP.
Pursuant to estimating FWOP damages and associated costs for the study area in St. Lucie County, Beach-*fx* was used to estimate damages and costs in the following categories:

- Damages:
    - Structure Damage: Economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Structure damages account for 71% of the damages for the FWOP.
    - Contents Damage: The material items housed within the structures (usually air-conditioned and enclosed) that are potentially subject to damage. Content damages are 29% of the total damages.

[16] Sources: FEMA Mitigation Assessment Team Report for Hurricane Katrina (July 2006) and Hurricane Sandy (November 2013)

3.3.1 Damage Distribution by Structure Category and Type

This section addresses what is being damaged in the FWOP by structure category and type. The coastal inventory was categorized as 'Commercial', 'Public Access & Recreation', and 'Residential'. **Table 3-1** provides greater detail on the type of structures within each category as well as the composition of the FWOP damages within those categories. The distribution of the damages by category is as follows:

- Commercial: 87.34%
- Public Access & Recreation Structures: 12.57%
- Residential: .09%

Table 3-1: Distribution of Damages by Damage Category

Category	Type	Structure	Contents	Total	% of Total
Commercial	BUILDING-1	$ 45,678,775.25	$ 23,331,162.27	$ 69,009,937.53	83.30%
	COMM-1	$ 20,144.20	$ 8,382.24	$ 28,526.45	0.03%
	HIGHRISE-1	$ 778,118.18	$ 113,309.67	$ 891,427.85	1.08%
	HIGHRISE-2	$ 988,656.23	$ 137,557.45	$ 1,126,213.67	1.36%
	HIGHRISE-3	$ 1,153,621.63	$ 149,471.28	$ 1,303,092.91	1.57%
Commercial Subtotal		$ 48,619,315.50	$ 23,739,882.91	$ 72,359,198.41	87.34%
Public Access & Recreation Structures	DECK	$ 397,772.57	$ 0.00	$ 397,772.57	0.48%
	DUNEWALK	$ 6,266,873.05	$ -	$ 6,266,873.05	7.56%
	GARAGE	$ 36,932.06	$ 27,635.02	$ 64,567.09	0.08%
	GARAGE-U	$ 216,293.46	$ 108,146.73	$ 324,440.19	0.39%
	GUARDSHACK	$ 10,475.47	$ 1,467.47	$ 11,942.94	0.01%
	PARKING	$ 799,913.17	$ -	$ 799,913.17	0.97%
	PATIO	$ 931.85	$ -	$ 931.85	0.00%
	POOL	$ 2,042,506.32	$ -	$ 2,042,506.32	2.47%
	POOLHEATER	$ 511.98	$ -	$ 511.98	0.00%
	PUBLIC-1	$ 2,005.33	$ 281.73	$ 2,287.06	0.00%
	SHELTER	$ 495,528.63	$ -	$ 495,528.63	0.60%
	STORAGE	$ 1,912.19	$ 1,185.56	$ 3,097.75	0.00%
	ROAD-1	$ 104.94	$ -	$ 104.94	0.00%
	TENNIS	$ 455.24	$ -	$ 455.24	0.00%
PA & Rec Subtotal		$ 10,272,216.27	$ 138,716.52	$ 10,410,932.79	12.57%
Residential	MFR-3	$ 15,407.32	$ 4,329.99	$ 19,737.32	0.02%
	SFR-3	$ 32,676.90	$ 21,879.63	$ 54,556.52	0.07%
Residential Subtotal		$ 48,084.22	$ 26,209.62	$ 74,293.84	0.09%
GRAND TOTAL		**$ 58,939,615.99**	**$ 23,904,809.05**	**$ 82,844,425.04**	**100%**

3.3.1.1 *Commercial*

The St. Lucie shoreline is dotted with various commercial real estate subject to damage. The structures are primarily condominium complexes or large hotels and represent nearly three-quarters of all the damages in the FWOP. Again, some of these condominiums may be used primarily as permanent residences and thus deemed residential in real estate appendices. However, for purposes of economic damage aggregation the delineation between condominiums was not made and they are deemed commercial.

3.3.1.2 *Residential*

The only two varieties of residential structures in the project area are three-story multi-family residences (MFR-3 in **Table 3-1**) and three-story single-family residences (SFR-3 in **Table 3-1**). The damage incurred to these structures is paltry and makes up less than one percent of overall damages.

3.3.1.3 *Public Access and Recreation Structures*

A public access structure refers to those that provide the general public with safe access to beaches and shorelines throughout St. Lucie County which include, but are not limited to, roads, dune walks, public shower and bathroom facilities, and life-guard stations. A recreation structure refers to items such as pools, patios and tennis courts.

3.3.2 Spatial Distribution of Without Project Damages

FWOP damages really spike in the southern portion of St. Lucie's shoreline. Reaches R113-R115 make up around 84% of the damages, while the remainder are relatively evenly distributed; R098 and R100-R103 are the only reaches that account for less than one-percent of damages each. R115 accounts for the lion's share of total damage at 60% due in large part to several groups of valuable condominium complexes situated very near the dune that are on slab foundations instead of deep-pile. Structures on slab foundation are far more susceptible to damages from erosion than those with a deep-pile foundation and their location in the nearshore further compounds the damage risk. The spatial damage results are summarized in **Figure 3-3**.

Figure 3-3: FWOP Present Value Damages by Reach ($ and %)
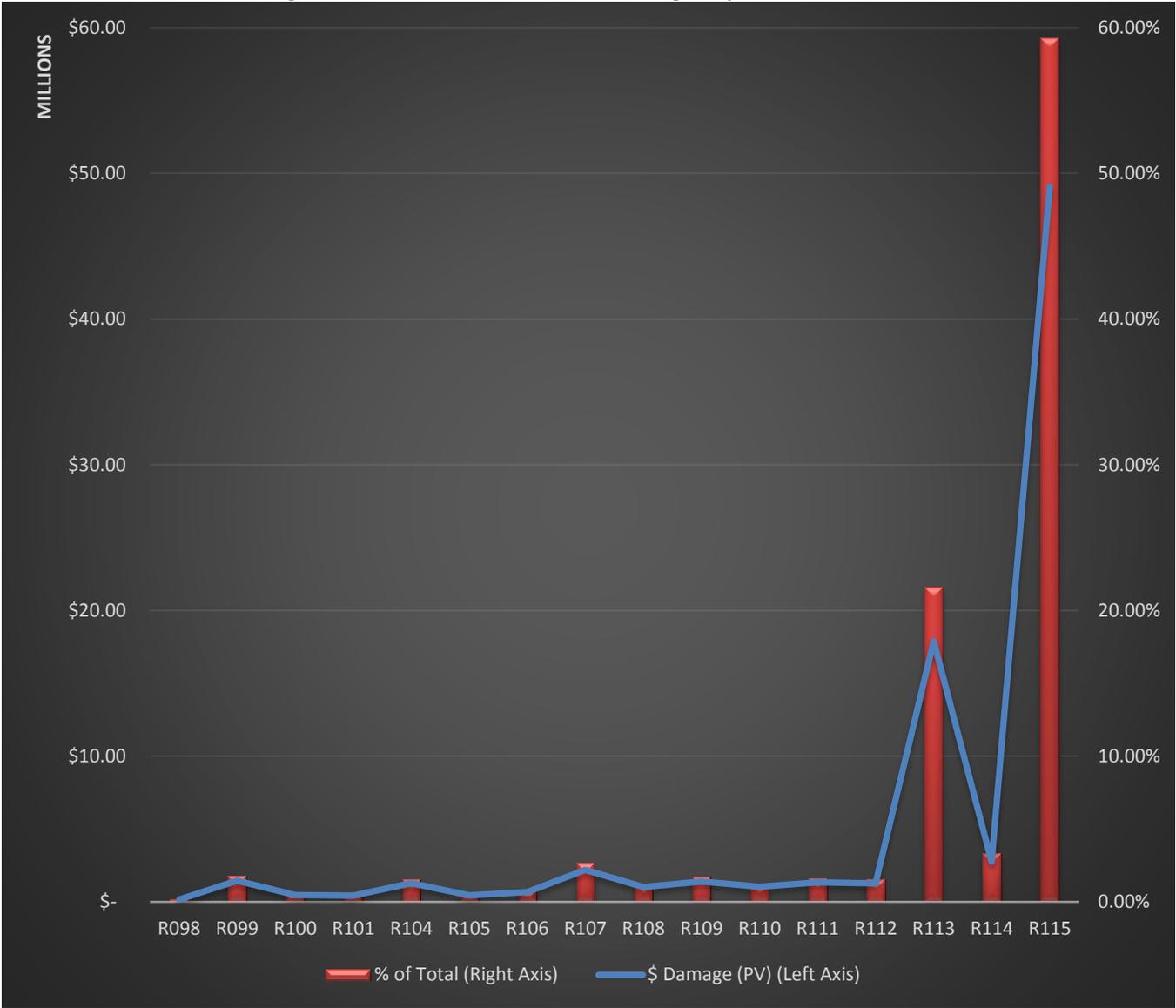
Figure 3-4 illustrates the spatial distribution of damages and erosion rates[17] by reach. Similar to **Figure 3-3** above, **Figure 3-4** displays minor damages until R107 and then the spikes at R113 and R115. The spatial distribution of erosion and damage shows the following pattern:

- **R098-R101**: This stretch has the highest erosion rates averaging .89 ft./year but relatively low damages at around 3% of the total. R099 is the main driver of damages in this range due to the presence of condominium complexes in the nearshore environment.
- **R102-R103**: There are no damages occurring in these two reaches. This is primarily due to the fact that there are only two damageable elements in these reaches and they are set back far enough from the shoreline to avoid all damages. Also, erosion rates are minimal and R103 sees annual accretion versus erosion.
- **R104**: Despite having the highest level of accretion in the project area this reach still incurs a fair amount of damage. The average annual accretion is offset by the value and high density of structures susceptible to storm-based damages within the reach (roughly seven-percent of total damage elements, refer to previous **Figure 2-2)**.
- **R105-R112**: Erosion rates begin to rise throughout these southern reaches and culminate in a secondary peak of .66 ft./year at R112. Despite the increasing erosion rates, the damages are fairly smooth in this area and hover around the average for all reaches excluding outliers (R113 and R115).
- **R113-R115**: In these final reaches the erosion rate is stable and very near the mean. Again, the spike in damages is driven almost entirely by the many structures on slab foundations in the nearshore.

[17] Negative erosion rates indicate areas of annual accretion

Figure 3-4: Spatial Distribution of Damages and Erosion Rates by Model Reach
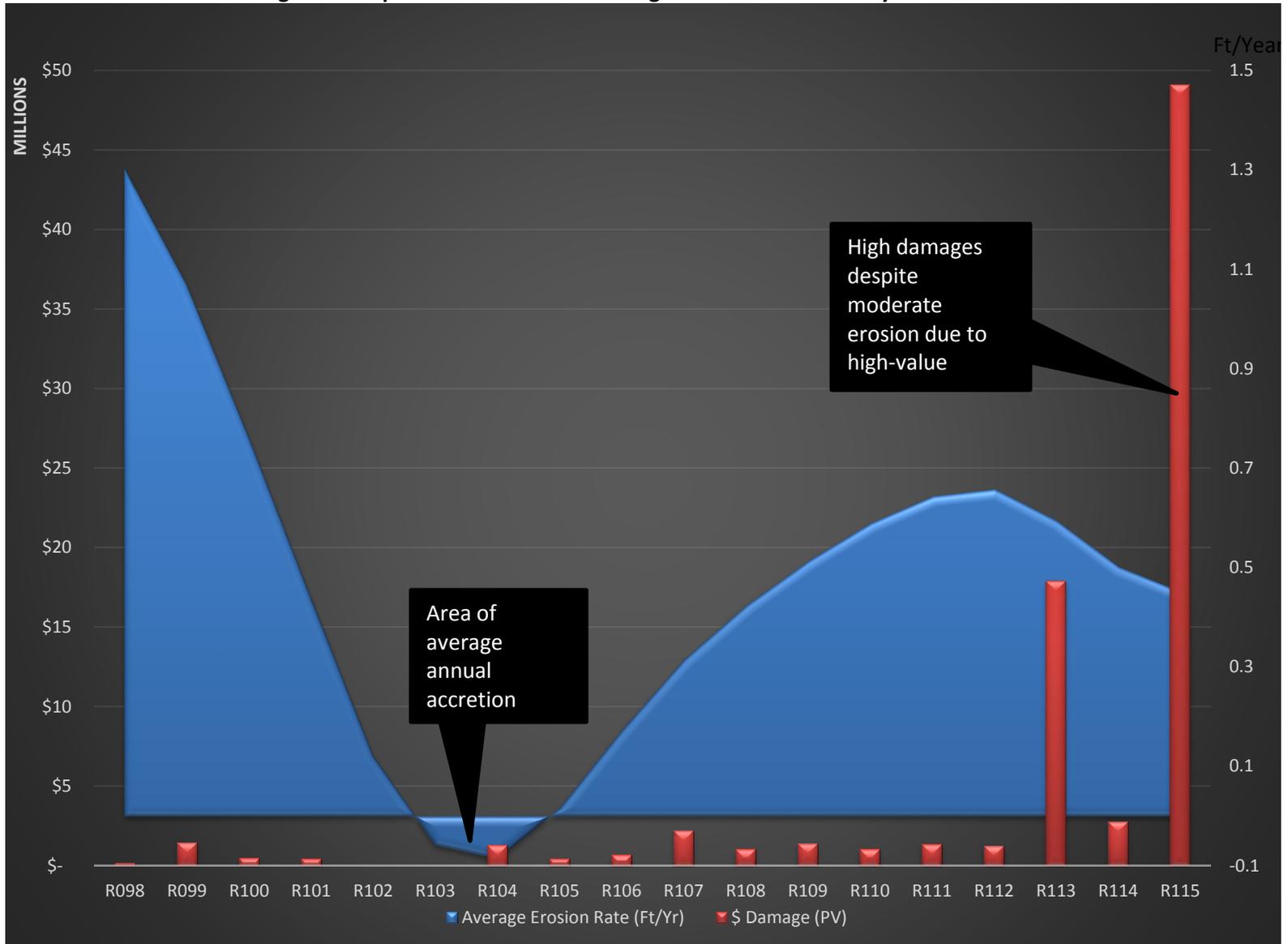
3.3.3   Damage Distribution by Damage Driving Parameter

It is very typical for Florida CSRM studies to find that most damages are due to erosion. St. Lucie is no exception as virtually all of the FWOP damages are attributable to erosion. The distribution of damages is as follows:

- Erosion: 95.06%
- Inundation: 4.28%
- Wave Attack: .67%

3.3.4   Temporal Distribution of Damages

Damages remain relatively constant on a yearly basis throughout the 50 year period of analysis in non-present value.

Figure 3-5 illustrates the damages over time by condensed reaches[18] in non-present value. In years 2037-2043 there are a series of small spikes in damages and that pattern continues throughout the remaining years culminating in a final peak in 2069. The pattern brings to light the frequent vulnerability of the St. Lucie shoreline to the powerful effects of storms and hurricanes. **Figure 3-6** displays similar information but converts the damages into present value (PV). As would be expected due to the effects of discounting, the damages peak in the relative near-term (2024). However, it is important to note that despite this discounting, damages remain relatively high in the final half of the project lifecycle as the cumulative effects of storms and erosion take their toll on shoreline structures.

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[18] For graphical display purposes the reaches were grouped as R098-R107, R108-114, and R115. R102 and R103 were not displayed as damages remain at zero throughout the project life.

**Figure 3-5: Damages Over Time by Combined Reaches (Non-PV$)**

Damages by Year by Reach (Non PV)

Legend:
- $- - $500,000.00
- $500,000.00 - $1,000,000.00
- $1,000,000.00 - $1,500,000.00
- $1,500,000.00 - $2,000,000.00
- $2,000,000.00 - $2,500,000.00
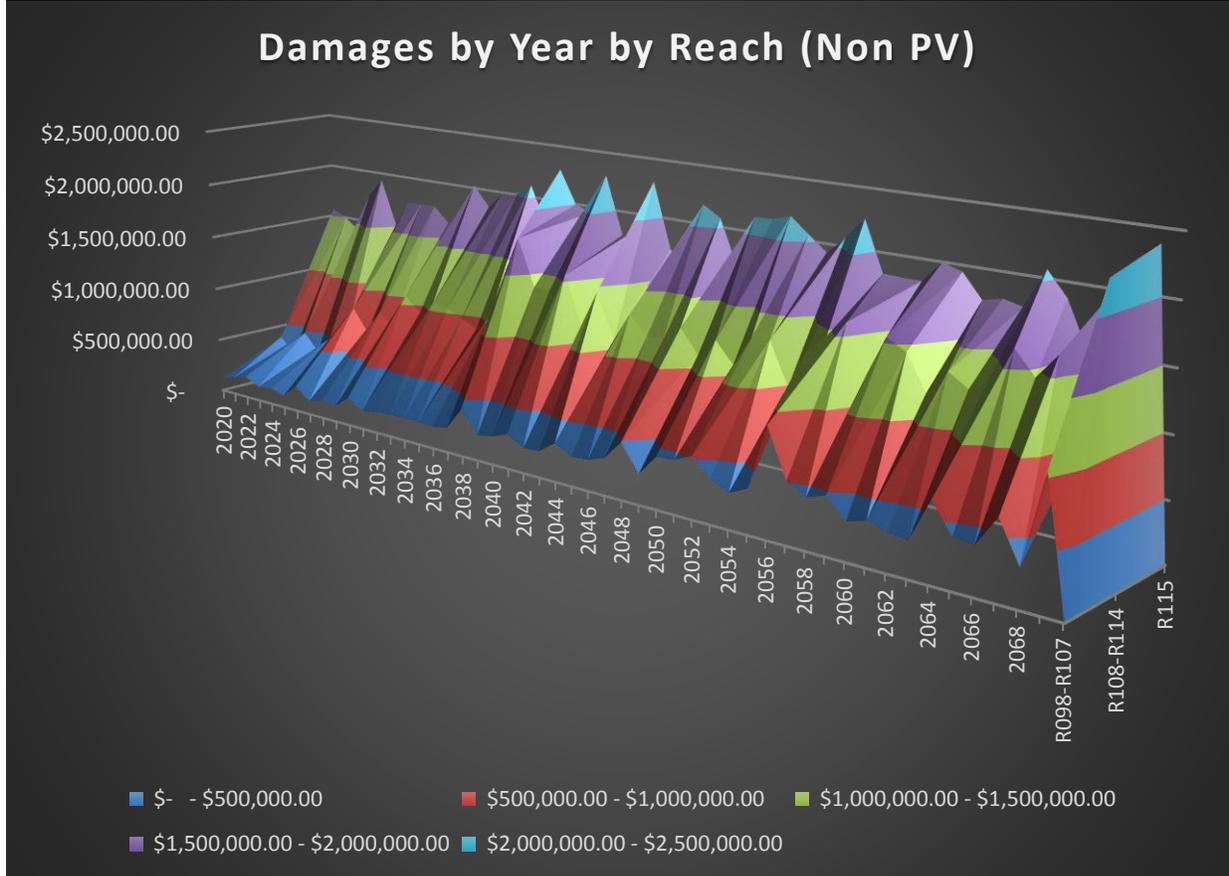
Figure 3-6: Damages Over Time by Reach (PV$)
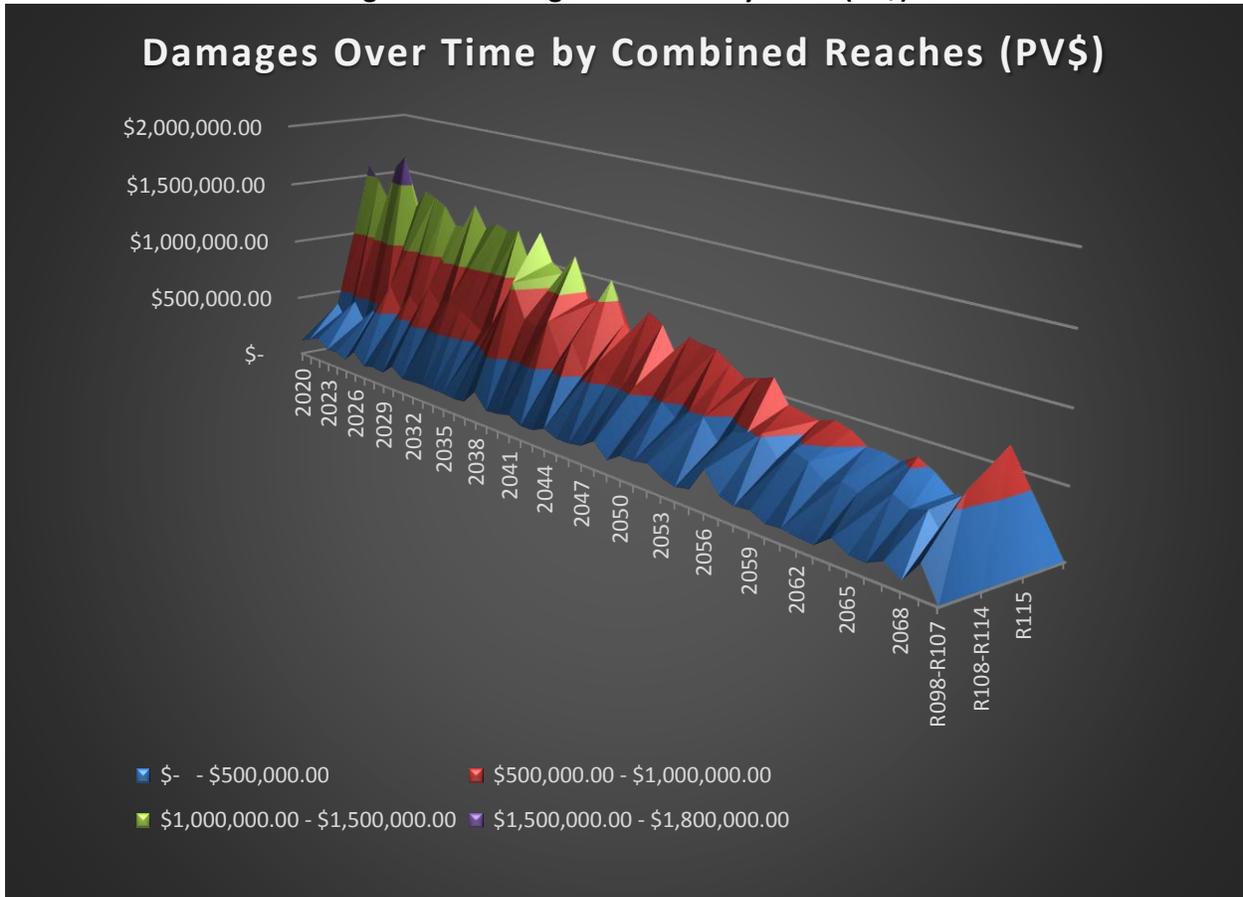
3.3.5 Evacuation Route Flooding

As described in section **2.4.2** Florida State Route A1A is South Hutchinson Island's hurricane evacuation route and provides vital access to critical infrastructure and services. Of additional importance, the Centers for Disease Control report that each year more deaths occur due to flooding than from any other thunderstorm related hazard and half of those fatalities occur when a vehicle is driven into hazardous flood water. The National Weather Service (NWS) reports that just 12 inches of rushing water can carry away a small car and two feet can sweep away most vehicles.

In order to gauge the potential impact of flooding on Florida State Route A1A Beach-*fx* was adjusted to model two different scenarios with the statistics from the NWS used as a framework. In the first scenario, all damage element types were assigned a null damage function except inundation damages to A1A. In order to gauge the depth of flooding all damages were set to zero until inundation reached one foot. In this model scenario, 53% of iterations experienced one foot or more of flooding at some point in the 50 year period of analysis. One of the southern reaches, R112, is flooded in 48% of the iterations. The importance of the southern reaches is as mentioned above in section **2.4.2**; an impassable A1A to the south could result in traffic needing to be rerouted approximately 16 miles during evacuations.

The second scenario followed the exact same methodology but damages were set to zero until inundation on A1A reached two feet. In this scenario 36% of iterations experienced two or more feet of flooding. Again, R112 was consistently inundated, having two or more feet in 32% of iterations.

This flooding represents a potential hazard to all residents of Hutchinson Island both within and outside of the project area boundaries. There are no alternative roads that run north to south and attempting to navigate flood waters in depths of one foot or more can prove to be fatal.

3.3.6   FWOP Damages in Alternative Sea-Level-Rise Scenarios

Evaluating sea-level rise (SLR) is a vital component in the planning process to ensure alternatives are selected based on risk-informed analysis. To incorporate risk into the analysis the FWOP must be run assuming three distinct future rates of SLR. EC 1165-2-211 provides both a methodology and a procedure for determining a range of SLR estimates based on the local historic rate, the construction (base) year of the project, and the design life of the project. In St. Lucie County the average baseline (SLR1), intermediate (SLR2) and high (SLR3) rates were found to be 0.0077 feet/year, 0.0163 feet/year, and 0.0439 feet/year, respectively. The Beach-*fx* results that were presented above refer strictly to SLR1, which is based on the historic rate. The results comparing the SLR scenarios are presented here. **Figure 3-7** provides an overall summary of damages in each SLR scenario and includes a trend line; **Table 3-2** shows how those damages are distributed amongst the different structure types.

Figure 3-7: Total Damages by SLR Scenario
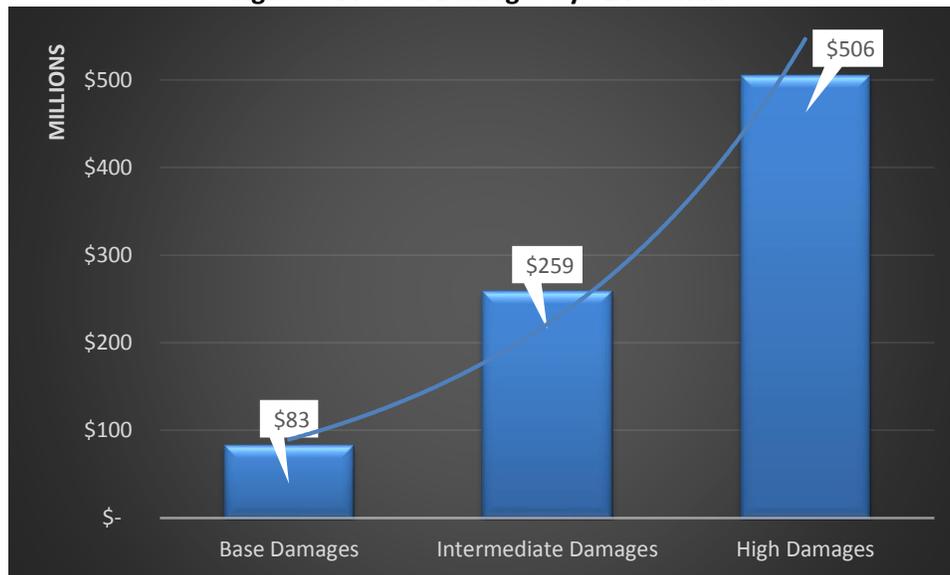
Table 3-2: Distribution of Damages by Category in the SLR scenarios

Category	Type	SLR1	SLR2	SLR3
Commercial	BUILDING-1	$ 69,009,937.53	$ 166,358,715.68	$ 200,645,580.17
	COMM-1	$ 28,526.45	$ 7,821,856.78	$ 16,414,768.69
	HIGHRISE-1	$ 891,427.85	$ 19,470,428.79	$ 27,098,889.72
	HIGHRISE-2	$ 1,126,213.67	$ 12,475,838.55	$ 65,796,836.01
	HIGHRISE-3	$ 1,303,092.91	$ 19,962,504.08	$ 144,157,930.84
Commercial Subtotal		$ 72,359,198.41	$ 226,089,343.88	$ 454,114,005.42
Public Access & Recreation Structures	DECK	$ 397,772.57	$ 893,619.02	$ 732,285.90

	DUNEWALK	$ 6,266,873.05	$ 10,193,506.27	$ 6,826,516.32
	GARAGE	$ 64,567.09	$ 1,181,339.52	$ 6,191,787.65
	GARAGE-U	$ 324,440.19	$ 2,477,054.75	$ 4,263,194.90
	GUARDSHACK	$ 11,942.94	$ 56,403.06	$ 95,976.84
	PARKING	$ 799,913.17	$ 3,414,166.33	$ 9,847,325.43
	PATIO	$ 931.85	$ 214,891.88	$ 1,044,060.20
	PAVED	$ -	$ 7,965.17	$ 35,053.97
	POOL	$ 2,042,506.32	$ 11,662,156.01	$ 18,503,718.23
	POOLHEATER	$ 511.98	$ 45,903.90	$ 96,284.91
	PUBLIC-1	$ 2,287.06	$ 120,708.98	$ 169,874.17
	SHELTER	$ 495,528.63	$ 1,082,077.97	$ 1,265,867.67
	STORAGE	$ 3,097.75	$ 60,277.05	$ 101,741.83
	ROAD-1	$ 104.94	$ 3,099.01	$ 8,024.79
	ROAD-2	$ -	$ 2,893.50	$ 124,222.17
	ROAD-3	$ -		$ 314,501.78
	TENNIS	$ 455.24	$ 65,332.72	$ 230,355.22
PA & Rec Subtotal		$ 10,410,932.79	$ 31,481,395.13	$ 49,850,791.99
Residential	MFR-3	$ 19,737.32	$ 138,012.93	$ 269,313.60
	SFR-3	$ 54,556.52	$ 1,017,657.63	$ 1,267,168.30
Residential Subtotal		$ 74,293.84	$ 1,155,670.56	$ 1,536,481.90
GRAND TOTAL		**$ 82,844,425.04**	**$ 258,726,409.57**	**$ 505,501,279.31**

The SLR results are intuitive in the sense that one would expect damages to be positively correlated with water levels (i.e. as water levels increase throughout the project life so do damages). What is important to note, however, is the magnitude of the effect. From SLR1 to SLR2 the difference was a mere .0086 ft./year in average SLR and resulted in an increase of roughly 212%, or $175.9 million, worth of damages. From SLR2 to SLR3 there was a .0276 ft./year average rise with a corresponding increase of 95%, or $246.8 million, in damages. From SLR1 to SLR3 damages increase over 510%.

There is also an interesting shift in what drives the damages in each scenario. As mentioned in **section 3.3.3** above, it is very common for erosion to be the main cause of damages in Florida CSRM studies. However, as sea levels rise, inundation begins to take on more of the share of damages. By SLR3, damages caused by erosion have fallen from 95% to 51% with inundation accounting for most of the difference; coastal overstep is reducing the propensity for erosion. **Figure 3-8** displays the changing trend in how damages are occurring.

Figure 3-8: Percent of Total Damages by Driver in the SLR Scenarios
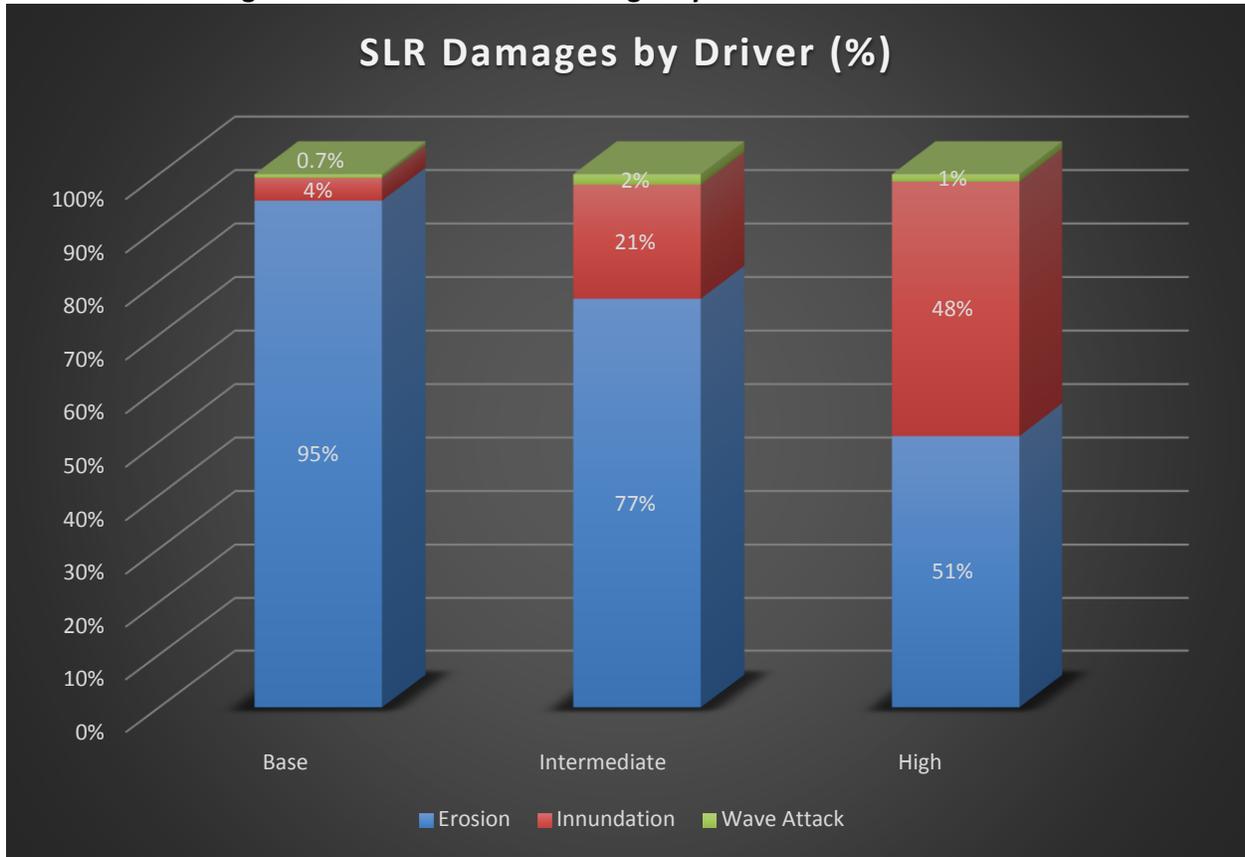
Coastal overstep is also causing an increasing number of lots to be determined condemned within the model and is shifting damage hot spots into areas that are more susceptible to flooding. Reaches 104-108 begin to see a larger increase in damages as high-value structures are increasingly inundated (**Figure 3-9**). In SLR1 there are very few condemned lots during any period of the project lifecycle. However, in SLR2 19% of lots are determined condemned at some point in the lifecycle and 48% in SLR3 (see **Figure 3-10**). Not only does this maintain the assertion that St. Lucie County is highly susceptible to storm damage but also demonstrates how critical a project would be in mitigating damages in the event sea levels continue to rise above and beyond baseline projections.

**Figure 3-9: SLR Damages by Model Reach**
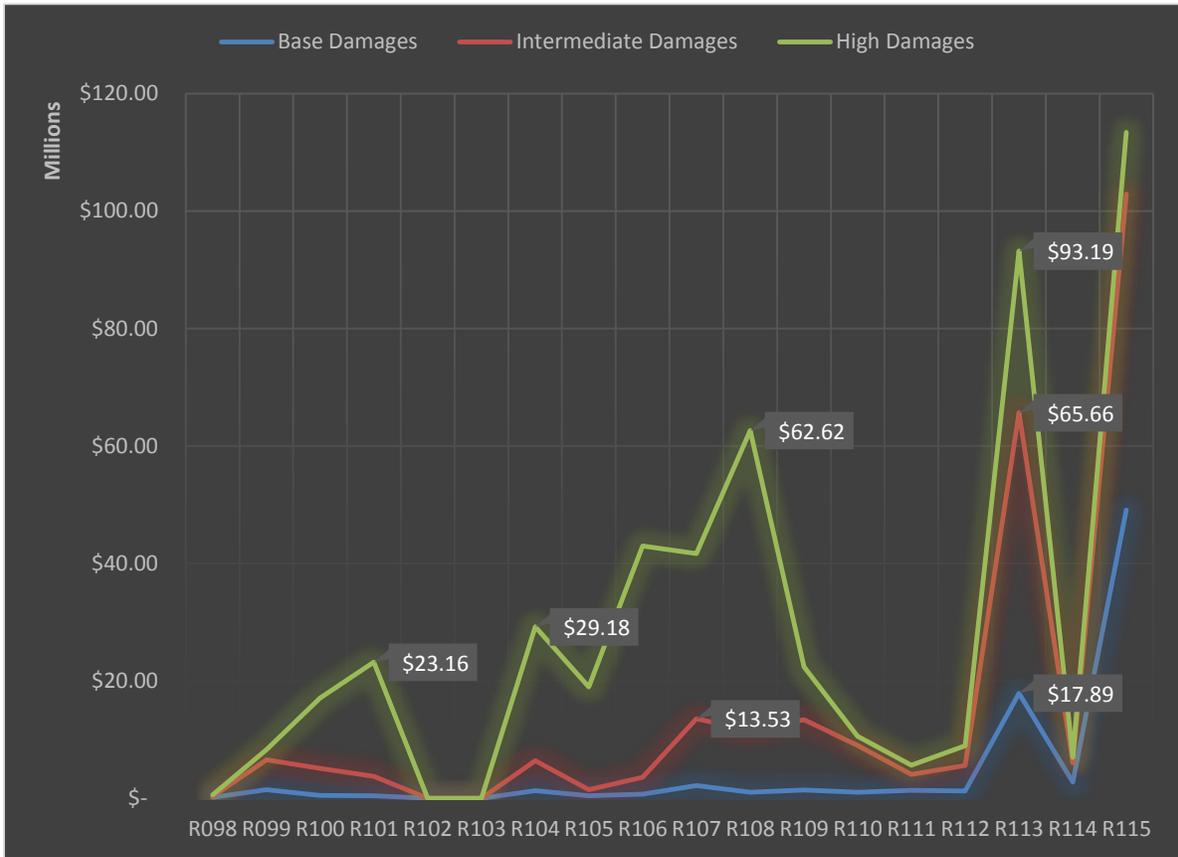
Figure 3-10: Percent of Lots Condemned in SLR Scenarios[19]

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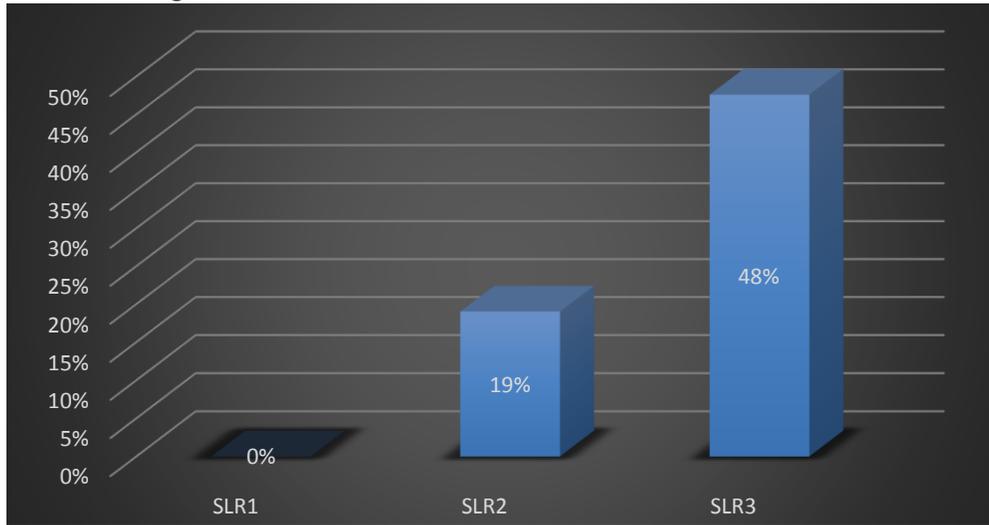
[19] A "lot" was included in the total if it was marked condemned at any point in the project lifecycle in at least 50% of the model iterations

3.4   **FWOP Condition Conclusion**

⌗ Damages are largely driven by storm events instead of gradual erosion.
⌗ The overwhelming majority of the damage is structural in nature. Commercial structures account for well three-quarters of all damages.
⌗ Proximity to the shoreline, vulnerability of structure type (i.e. slab foundation) and exposure to recurring damages are the most important factors for determining structure damage.
⌗ Damages in the FWOP increase dramatically in the SLR scenarios.

3.5   **Future with Project Condition**

This section of the appendix tells the story behind the evaluation and comparison of the St. Lucie County CSRM study alternatives. A description of the alternatives, their performance in terms of benefits and costs, and the methods used for screening are provided in the sub-sections that follow.

3.5.1   Management Measures

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

⌗ **Structural Measures:**
  ⌗ Beach Nourishment
  ⌗ Groins
  ⌗ Submerged Artificial Reefs
  ⌗ Dunes and Vegetation
⌗ **Non-structural Measures:**
  ⌗ No Action
  ⌗ Condemnation and Land Acquisition

During the plan formulation process, management measures were screened against seven 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. Two structural measures were carried forward to the modeling stage: Dunes and Vegetation and Beach Nourishment. More information about each measure is provided below. More information about the management measure screening process is provided in the main report.

Dunes and Vegetation: This measure would include placement of beach compatible material, from either upland or offshore sources, into an extension of the existing dune feature. Vegetation would be planted after initial placement of the dune material. Preliminary engineering design work concluded that the most feasible plan for dunes and vegetation would be extending the existing dune by either 10 or 20 feet. These alternatives were named "Dune10" and "Dune20" respectively. Periodic nourishment triggers would occur once the extended dunes were fully eroded and construction would be completed using a hydraulic dredge to transport material from an off-shore borrow source.

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. There were several combinations of project dimensions initially considered for beach nourishment. Five different "design berm" templates were considered which included maintaining a zero-foot berm (A), 20-foot berm (B), 40-foot berm (C),

60-foot berm (D), and 80-foot berm (E). Using these design berm templates, a "sacrificial fill" amount was then considered in 20-foot increments. For example, one project option would be to maintain a 20-foot design berm with an additional 40-feet of sacrificial fill. Much like the dunes and vegetation measure, periodic nourishment triggers would occur once sacrificial berm lengths have been fully eroded. Using truck transportation of fill was considered as a possible option for beach nourishment but was found to be too cost prohibitive. Thus, hydraulic dredging would be used for this measure as well.

3.5.2   Alternative Development

An alternative plan is a set of one or more management measures functioning in tandem to address project-area objectives. Though the team only carried forward two management measures there were a total of 42 alternatives for initial modeling. The two dune extension options (10' and 20') were modeled individually and also in combination with the beach nourishment berm extensions. The alternative names were descriptive and followed a convention of design template (A-C as described above), berm width (20-100'), and the width of the dune extension (0-20'). So for example, a project that maintains a 0-foot design template, 40-foot berm extension, and maintains the existing dune would be labeled: ABerm40DuneEx. For a more detailed explanation of re-nourishment triggers and the various alternative specifications please refer to the Engineering Appendix (Appendix A) of this report.

After initial modeling it was apparent that the only economically justifiable design template was maintaining a 0-foot berm extension (A), and only sacrificial fill extensions up to 40-feet. The various alternatives provided nearly the same level of total benefits but the costs increased greatly with the size of the project. Dune extensions in combination with beach nourishments were also unjustifiable but a stand-alone project of Dune10 was carried forward to the final array. Upon realizing larger projects had no justification, the decision was made to add alternatives and model sacrificial-fill amounts in 10-foot increments. The alternatives carried into the final array for Beach-*fx* modeling (100 iterations) were as follows:

- ⌗ ABerm10DuneEx[20]
- ⌗ ABerm20DuneEx
- ⌗ ABerm30DuneEx
- ⌗ ABerm40DuneEx
- ⌗ Dune10[20]

3.5.3   Alternative Comparison

All of the alternatives described above were modeled in Beach-*fx* using full (100 iteration) life-cycle simulations in order to calculate benefits and costs. Additionally, land-loss benefits of $176,245[21] (AAEQ) were added to the total project benefits for each of the alternatives. For a full discussion on how land-loss benefits were calculated please refer below to section **4.2**. The results of these simulations, which were used to discover the NED plan, are presented in **Table 3-3**, **Table 3-4**, and shown graphically in

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[20] These alternatives were determined too small for dredging so trucking costs were used in Beach-*fx* modeling
[21] Land-loss benefits were further refined after the point of alternative comparison and included real estate appraisal updates. The updated amount and methodology is discussed in detail in section **4.2.**

Figure 3-11. Again, it is important to note that these values represent cost and benefits obtained during the alternative evaluation process based on best available information at that time and were further refined after selecting the TSP. The alternative with the highest BCR and net-benefits is ABerm20DuneEx making it the NED Plan and the TSP.

Table 3-3: AAEQ Damages for Final Array of Alternatives

Alternative Name	FWOP Damages AAEQ	FWP Damages AAEQ	Total Project Benefits AAEQ
ABerm20DuneEx	$ 1,593,522.30	$ 82,294.39	$ 1,511,228
ABerm30DuneEx	$ 1,593,522.30	$ 86,386.16	$ 1,507,136
ABerm40DuneEx	$ 1,593,522.30	$ 86,419.27	$ 1,507,103
ABERM10DuneEx	$ 1,593,522.30	$ 84,139.24	$ 1,509,383
Dune10	$ 1,593,522.30	$ 90,149.22	$ 1,503,373

Table 3-4: AAEQ Benefits and Costs for Final Array of Alternatives

Alternative Name	Total Benefits AAEQ	Total Costs AAEQ	Net Benefits AAEQ	BCR
ABerm20DuneEx	$ 1,511,228	$ 1,327,721	$ 183,507	1.14
ABerm30DuneEx	$ 1,507,136	$ 1,358,477	$ 148,659	1.11
ABerm40DuneEx	$ 1,507,103	$ 1,356,253	$ 150,850	1.11
ABERM10DuneEx	$ 1,509,383	$ 1,691,824	$ (182,441)	0.89
Dune10	$ 1,503,373	$ 1,926,323	$ (422,950)	0.78

Figure 3-11: Alternative Comparisons (AAEQ)
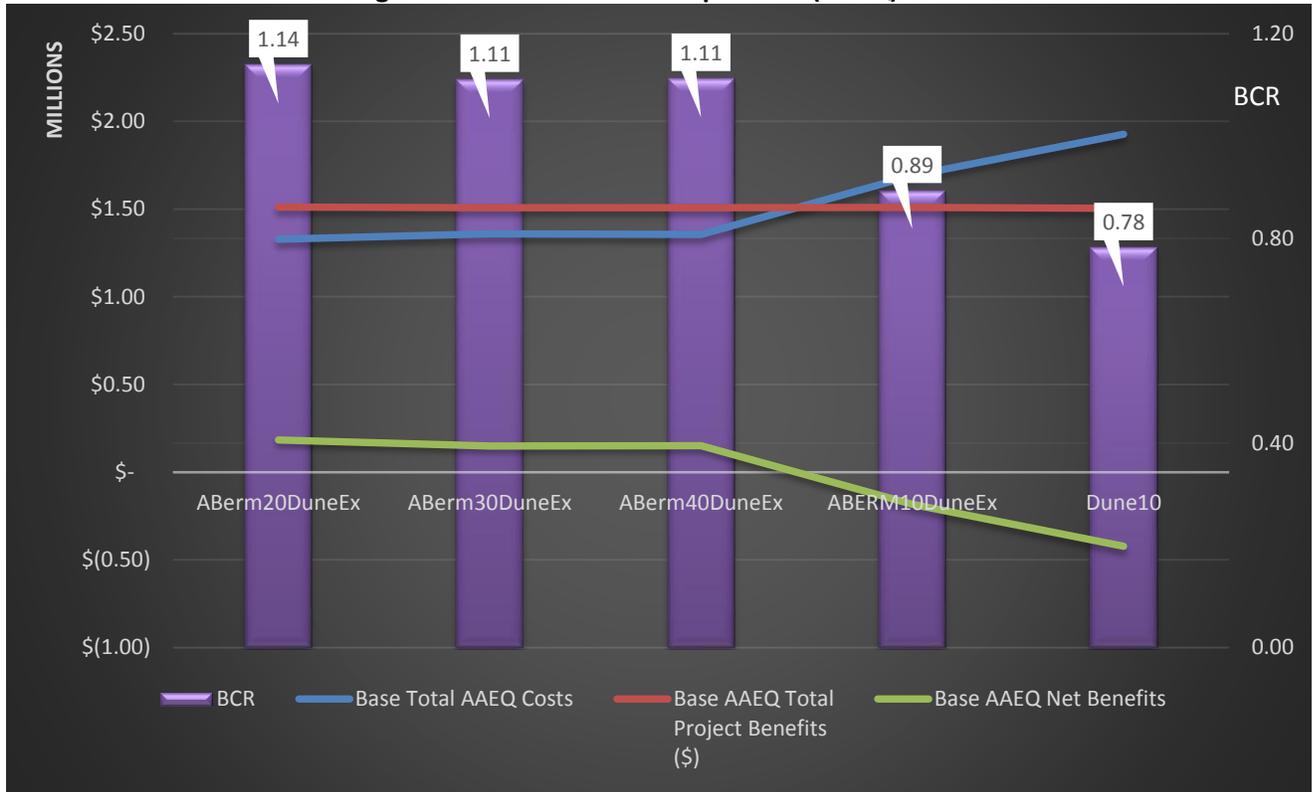
3.5.4   Performance of NED/TSP in the SLR scenarios[22]

An important question when evaluating a final array of alternatives is performance under different SLR scenarios. Intuitively, given the protection a plan provides, total benefits will increase as sea-levels begin to rise and damages in the FWOP increase. While this is true, costs also begin to increase since nourishment events are triggered more frequently. Also, a project must provide sufficient protection to establish enough benefits in each scenario. Each of the SLR scenarios are considered equally likely to occur so a project must perform satisfactorily across all three in order to be considered effective and robust.

The TSP performs satisfactorily in each SLR scenario and establishes itself as a robust option in the face of risk and uncertainty. Benefits increase at a much greater magnitude than costs and the BCR grows by 50% from SLR1 to SLR2. From SLR2 to SLR3 the magnitude of the increase is less but there is still a significant increase in BCR. The main reason for the diminishing returns is explained by the nourishment interval column in **Table 3-5**. The interval indicates that under the SLR3 scenario the TSP will have a number of nourishments such that the increase in costs grows faster than the increase in benefits

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[22] Costs calculated for the SLR scenarios include certified costs for SLR1 and model-projected costs for SLR2 and SLR3 with a 20% contingency added. Benefits include all refinements done to the model but do not include land loss or recreation.

compared to SLR2. That said, the TSP remains an efficient and effective plan for any of the three possible SLR scenarios. **Figure 3-12** demonstrates this completeness with a side-by-side comparison of the BCRs.

Table 3-5: AAEQ Benefits and Costs for TSP in different SLR Scenarios

	Nourishment Interval (Years)	Total Cost	Total Benefits	Net Benefits	BCR
SLR1	17	$1,925,977	$3,179,950	$1,253,973	1.65
SLR2	7	$4,020,469	$9,990,903	$5,970,434	2.49
SLR3	4	$6,674,833	$19,075,671	$12,400,838	2.86

Figure 3-12: TSP BCR Comparison in the SLR Scenarios
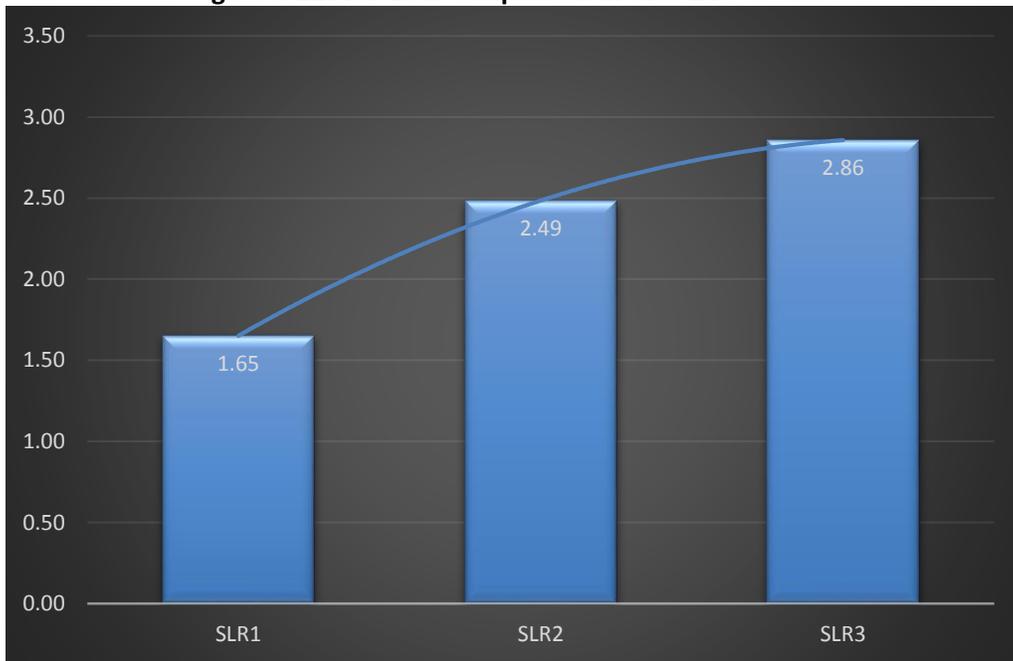
4. THE NED PLAN

Once all of the alternatives have been compared, a NED has been determined, and a TSP has been identified the costs that have been used in modeling require certification under ER 1110-1-1300. Costs

are refined to a higher level of accuracy and include a contingency during this process. In the sections to follow, the NED will be reevaluated using these refined costs.

4.1   **Project Cost Refinements**

The refined costs provide a breakdown of initial construction, plans and specifications, re-nourishment events, and continuous monitoring and are summarized in **Table 4-1.** These costs include a 20% contingency.

Table 4-1: NED Project Cost Refinements (AAEQ)

	Initial Construction[23]	1st Re-Nourishment	2nd Re-Nourishment	Plans & Specs	Monitoring	TOTAL
Quantity (CY)	530,400	380,000	380,000	N/A	N/A	1,290,400
Cost	$ 1,092,245	$ 435,282	$ 250,161	$ 20,500	$ 127,789	$ 1,925,977

There is a difference in costs from that which was determined during Beach-*fx* modeling in the alternative screening phases discussed above. As a result, the BCR will be impacted and will be described in more detail below.

4.2   **Land-Loss Benefits**

In outlining the process and procedures to be used in the evaluation of CSRM projects, ER-1105-2-100 details 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 and is computed based on output data from Beach-*fx*. Land-loss benefits must be added to the structure and content benefits as computed by Beach-*fx* to obtain the total CSRM 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 St. Lucie County, annual reduction in dune width and upland width across all Beach-*fx* study reaches was obtained from the Beach-*fx LandLoss.csv* FWOP and FWP output files based on modeled changes to the shoreline. ER 1165-2-130 does not allow land loss benefits be claimed for beach areas subject to temporary shoreline recessions. Thus, changes in dune and upland width, rather than changes in berm width, are used as the appropriate measure of land loss. Beach-*fx* measures dune width from the seaward toe of the dune to the landward toe of the dune.

For Beach-*fx* reaches located within the project area (reaches R098-R115), the basis of the annual changes in dune and upland width calculation is the width in each reach in the model start year (2008), which is the template assumed to be maintained throughout the project life in the FWP. The difference between the constant with-project width and the without-project width in a given year results in the *cumulative* loss of dune and upland width given the profile of that specific reach. However, for the

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[23] Amount includes plans and specifications leading up to initial construction

purpose of calculating land-loss benefits, the *annual* loss of width is needed. This is obtained by taking the cumulative change in width in a given year and subtracting from it from the cumulative change in width from the previous year. This calculation results in the yearly incremental change in dune and upland width for a given reach.

Using the annual decrease in width for a specific reach and the corresponding length of shoreline eligible for land-loss benefits, the total annual square-footage of land lost is obtained on a reach-by-reach basis and then summed across all study reaches for a given project year. **Figure 4-1** graphically displays the square-feet lost in St. Lucie County each year.

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. In the *St. Lucie County Beach Restoration Estimated Depreciated Replacement Costs of Damage Elements* report, the SAJ Real Estate Department estimated a nearshore land value of $14.00 per square foot for the St. Lucie study area.

Using the analysis technique described, the total present value of land-loss benefits over the 50 year project life is estimated at $6,956,475, or $276,819 in average annual equivalent (AAEQ) terms.

Figure 4-1: Average Land Lost Each Year
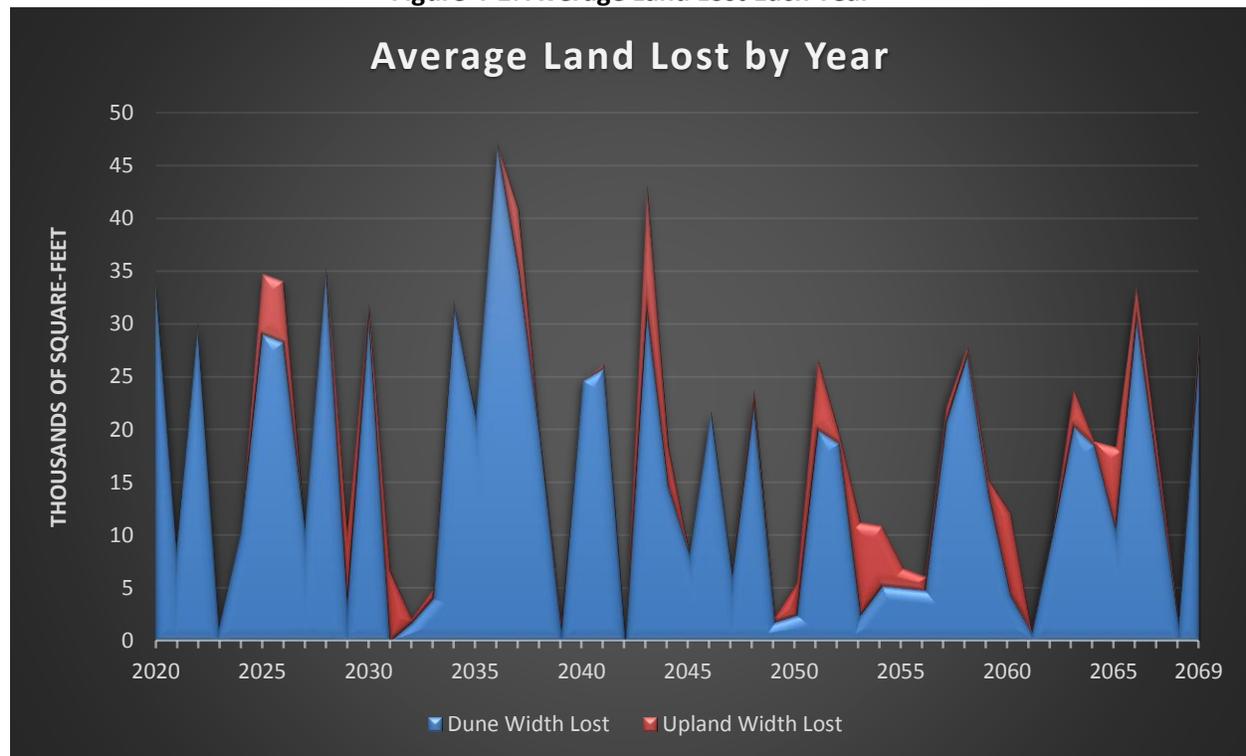
4.3 Incidental Recreation Benefits

According to ER-1105-2-200, incidental recreation benefits that result from the construction of a project can be calculated and added to overall project benefits in CSRM studies. Recreation benefits are not to be used in plan formulation, but they can constitute up to 50% of total benefits for project justification.

Typically in coastal studies, recreation benefits are calculated using the travel cost method (TCM). The basis for this method is that by increasing the carrying capacity of a particular recreation resource, a

project may reduce the travel time and costs associated with recreation visits. In this case, preliminary investigations concluded that there is no excess demand for recreation in St. Lucie County. Therefore, TCM is not applicable.

However, even though a project in St. Lucie County would not increase the *availability* or *quantity* of recreation in the project area, there may be some benefits associated with increasing the *quality* of recreation that is already occurring. Thus, in the St. Lucie County Feasibility study, recreation benefits were calculated using the Unit Day Value method, as described in EGM 09-03 and in Appendix E of ER 1105-2-100. The Unit Day Value (UDV) method estimates a user's willingness to pay for a given recreational opportunity (i.e. a dollar amount the recreational experience would be worth to them were they required to pay). This value is estimated via a series of criteria applied to the various recreation facilities and opportunities provided by the project; criteria gauging the overall quality of the experience, availability, carrying capacity, accessibility, and environmental factors. Each criterion can be assigned a score selected from one-of-five possible ranges which represents rating from low to high. These point values are summed together and applied a dollar value based on the current UDV guidance. The current unit-day values, provided by USACE Economic Guidance Memo #16-03, *Unit Day Values for Recreation*, FY 2016, are presented in **Table 4-2.** Linear interpolation was used to estimate the dollar value of point scores between ranges. So, for example, a point score of 2 in General Recreation corresponds with a dollar value of $4.05.

Table 4-2: Current Unit Day Values for Recreation

Point Values	General Recreation Values (1)	General Fishing and Hunting Values (1)	Specialized Fishing and Hunting Values (2)	Specialized Recreation Values other than Fishing and Hunting (2)
0	$3.90	$5.61	$27.33	$15.86
10	$4.64	$6.35	$28.07	$16.84
20	$5.12	$6.83	$28.55	$18.06
30	$5.86	$7.57	$29.29	$19.52
40	$7.32	$8.30	$30.02	$20.74
50	$8.30	$9.03	$32.95	$23.43
60	$9.03	$10.01	$35.87	$25.87
70	$9.52	$10.49	$38.07	$31.24
80	$10.49	$11.23	$41.00	$36.36
90	$11.23	$11.47	$43.93	$41.49
100	$11.71	$11.71	$46.37	$46.37

The recreation point values assigned to St. Lucie vary by year. They are summarized in

Table 4-3**.**

Table 4-3: Total Unit Day Point Scores applied to St. Lucie County

Year	Without Project	With Project
2020	45	53
2030	43	53
2040	41	53
2050	39	53
2060	38	53
2069	38	53

The point assignments are based on qualitative criteria; they depend on best professional judgment (i.e. "judgment criteria"). The differences in the assigned point scores vary for each category depending on the relevant recreation facilities. The following list briefly explains the logic behind the judgment criteria applied to St. Lucie County and **Table 4-4** summarizes the point comparison halfway through the project life (2045).

- **Recreation Experience:** St. Lucie County beaches were assigned a point score of 19 in the FWOP, which corresponds to "several general recreation activities; more than one high quality activity". The beaches offer visitors the opportunity to experience several general activities, including swimming, surfing, fishing and hiking. As for high quality activities, the beaches of St. Lucie County are a premier destination for wildlife viewing (specifically turtle nesting) and regional triathlon competitions. The value in the FWP is assigned a 23 since the project will not create any additional recreation experiences but will improve upon the quality of those experiences. The value for the FWOP declines throughout the project life as further degradation of quality is anticipated.
- **Availability of Opportunity:** The county beaches were assigned a point score of 1, which corresponds to "several opportunities within one hour of travel time and a few within 30 minutes". All of the project area beaches are within easy driving distance of several other popular beaches, including Glascock and Pepper Park. This point score does not change between the FWOP and FWP because the proposed project would have no effect on the availability of other recreation opportunities.
- **Carrying Capacity:** In both the FWOP and FWP the carrying capacity was assigned a point score of 5, indicating basic facilities to conduct activities. This score remains throughout the lifecycle as the project is not anticipated to improve the basic facilities nor are damages anticipated to degrade the facilities such that they'd be determined as "minimum development".
- **Accessibility:** Again, the FWOP and FWP do not change in this category. A point score of 14 for "good access, good roads to site; fair access, good roads within site" was assigned to both scenarios. Damages to roads in the FWOP are not enough to qualify a reduction in score throughout the project life and the project is not expected to improve on the access quality.
- **Environmental Quality:** In the base year the FWOP was assigned a score of 6 as there exist some factors which lower quality to a minor degree (see **Figure 4-2** as an example). Over time, the aesthetic quality of the project area beaches are expected to deteriorate a significant degree as damages are inflicted on the dune and the dune walks. By 2069, the score assigned to St. Lucie County was reduced to 3. In the FWP, the point score was held constant at 10 as the project is expected to prevent most of the damage in the project area.

Table 4-4: Criteria Score Comparison in Year 2045

Judgment Criteria	FWOP Score (Year 2045)	FWP Score
Recreation Experience	17	23
Availability of Opportunity	1	1
Carrying Capacity	5	5
Accessibility	14	14
Environmental Quality	4	10

Figure 4-2: Indications of Lower Aesthetic Quality and Damaged Access in the Existing Condition

After assigning point scores and dollar values, these values must be assigned to expected recreation visits over the life of the project. In 2009, a study was published by Dr. William Stronge[1] on behalf of the county to gauge beach visitation estimates. The study was conducted across the entire county. For the purposes of this recreation analysis only the beaches that fall within the project area were extracted from Dr. Stronge's study and are summarized in detail in **Table 4-5**. The total number of visitors in that year was estimated at 200,356.

Table 4-5: Beach Visitations

Beach Name	Visits	Percent of Total
Normandy Public	14,088	7%
S. of Normandy-to Island Dunes	17,509	9%
Dollman Public	27,163	14%
Ocean Towers-Nettles Island	31,423	16%
Oceana-North of Waveland	19,297	10%
Waveland Public	46,822	23%
Island Crest S to County Line	44,054	22%
Total	200,356	100%

[1]Visitation estimates based on 2009 study- *South St. Lucie County Beaches Recreational Use and Economic Impact 2007-08*

In order to project visitation over the life of the project we used a growth rate that was in step with that of overall visitation trends to the state of Florida. According to Visit Florida, visitation grew at an average of 2.99% from 2002-2014[24]. Therefore, in an unconstrained environment visitation to all of the project-area beaches was expected to reach 1,170,954 by 2069.

However, it is reasonable to assume that there will be capacity constraints pertaining to each stretch of beach and visitation estimates should not exceed that ceiling. In order to estimate those constraints SAJ Economists used parking availability for the public beaches displayed in **Figure 4-3** (i.e. Waveland, Dollman, Normandy) and for the remaining stretches the number of rental or privately-owned units located on the beach were used. For parking we assumed a maximum of four people per car with each available spot receiving up to two cars per day for the entire year. In the case of rental or privately-owned units, a conservative double-occupancy per unit for the entire year was assumed. The maximum visitation resulting from these constraints is summarized in **Table 4-6**. The only beach to reach maximum visitation in the project lifecycle was Normandy Public, capping out at the 46,720 visitors by the year 2050. As a result, total constrained visitation in the year 2069 was estimated at 1,135,339.

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[24] In 2009, Visit Florida adjusted their visitation estimate methodology. As a result, only years using the same methodology were compared to establish the average growth rate.

**Figure 4-3: Public Beach Access in Project Footprint**
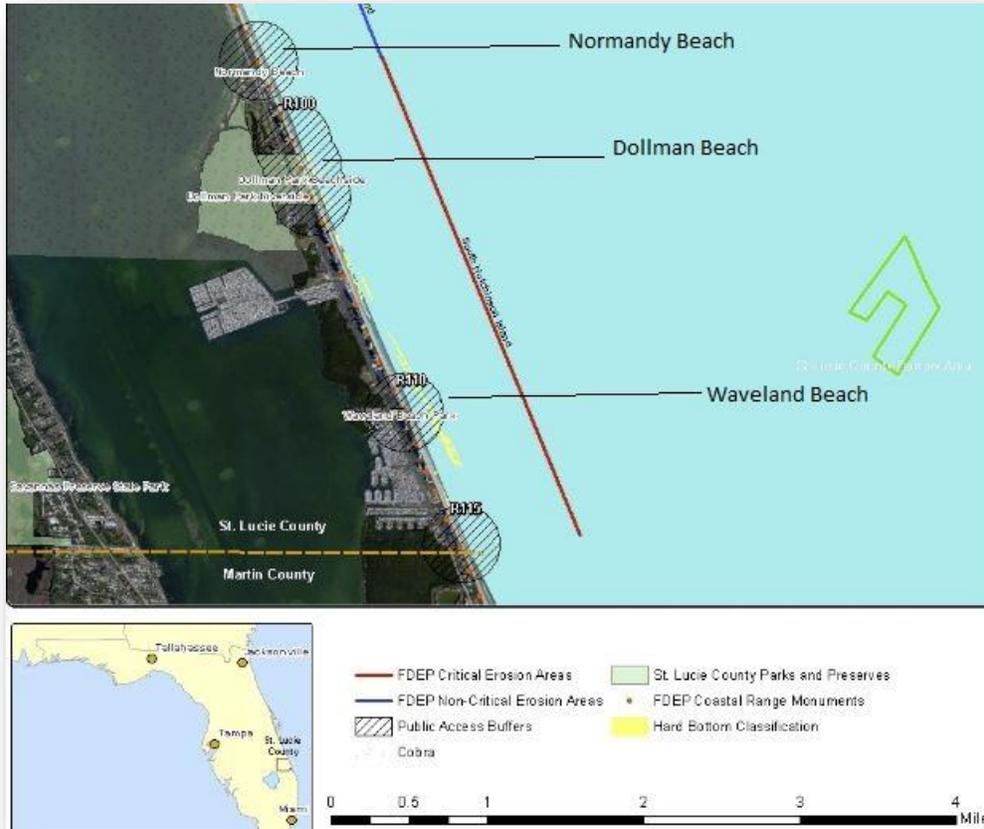
Table 4-6: Visitation Constraints

Beach Name	Parking	Rental Units	Max Visitation
Normandy Public	16	N/A	46,720
S. of Normandy-to Island Dunes	N/A	274	200,020
Dollman Public	102	N/A	297,840
Ocean Towers-Nettles Island	N/A	540	394,200
Oceana-North of Waveland	N/A	757	552,610
Waveland Public	100	N/A	292,000
Island Crest S to County Line	N/A	950	693,500
Total	**218**	**2521**	**2,476,890**

The total annual visitation numbers combined with the relevant UDV in each year resulted in total recreation benefits for St. Lucie County to be calculated at **$14,676,408 (PV)**, or **$584,018** in AAEQ.

4.4 Benefits of the NED Plan

The CSRM primary economic benefits of the plan are generated by reductions in erosion, wave, and inundation damages. As described in **Table 4-7**, the model results suggest that the NED is highly effective at reducing nearly all damages. The FWP condition under the NED protects St. Lucie County from 94% of all damages in the project life. In R113 and R115, where damages in the FWOP were the most dramatic due to high-value structures on slab foundation, 99% and 95% of damages are avoided.

Table 4-7: Benefits (PV) and % Damage Avoided by Reach

| Reach	Reach Benefits	% Damages Avoided
R098	$148,523.93	97%
R099	$1,441,844.84	99%
R100	$456,467.79	98%
R101	$415,921.32	98%
R102	$0.00	N/A
R103	$0.00	N/A
R104	$1,265,579.29	99%
R105	$422,479.73	97%
R106	$655,720.82	97%
R107	$2,102,268.46	96%
R108	$992,997.21	97%
R109	$1,356,532.05	97%
R110	$1,008,654.80	98%
R111	$1,254,577.98	94%
R112	$1,245,396.14	99%
R113	$17,681,378.15	99%
R114	$2,595,466.55	95%
R115	$46,868,569.00	95%
TOTAL	**$79,912,378.08**	**96%**

Additionally, the project is reducing the number of structure types that are receiving damage. In the FWOP, 21 different structure types were being damaged (**Table 3-1**) whereas under the NED only six different structure types receive damage (**Table 4-8**). Important to note is the complete absence of residential property (MFR-3 and SFR-3), roads, and all high-rise structure damage.

Table 4-8: NED Damages by Category (PV)

Type	Structure	Contents	Total	% of Total
BUILDING-1	$1,681,885.99	$864,054.79	$2,545,940.78	87%
DECK	$8,794.37	$-	$8,794.37	0%
DUNEWALK	$292,632.49	$-	$292,632.49	10%
PARKING	$25,602.26	$-	$25,602.26	1%
POOL	$14,943.17	$-	$14,943.17	1%
SHELTER	$44,133.89	$-	$44,133.89	2%
Grand Total	**$2,067,992.17**	**$864,054.79**	**$2,932,046.96**	**100%**

The NED is also effective over time and requires only two re-nourishment events throughout the 50 year life of the project. Benefits begin to accrue immediately after initial construction and peak in 2026 when the project provides $2.38M (PV) in benefits. After 2026 benefits begin to gradually decline until reaching a relative low in 2036, triggering a projected nourishment event. Again, the benefits are immediately realized by the nourishment and provide $2.4M (PV) worth in 2038 alone, the project's overall largest year for benefits. Despite the impact of discounting, the NED provides substantial benefits in later years leading up to a second projected re-nourishment event around 2055. **Figure 4-4** summarizes these annual results.

Figure 4-4: NED Benefits by Year (PV)
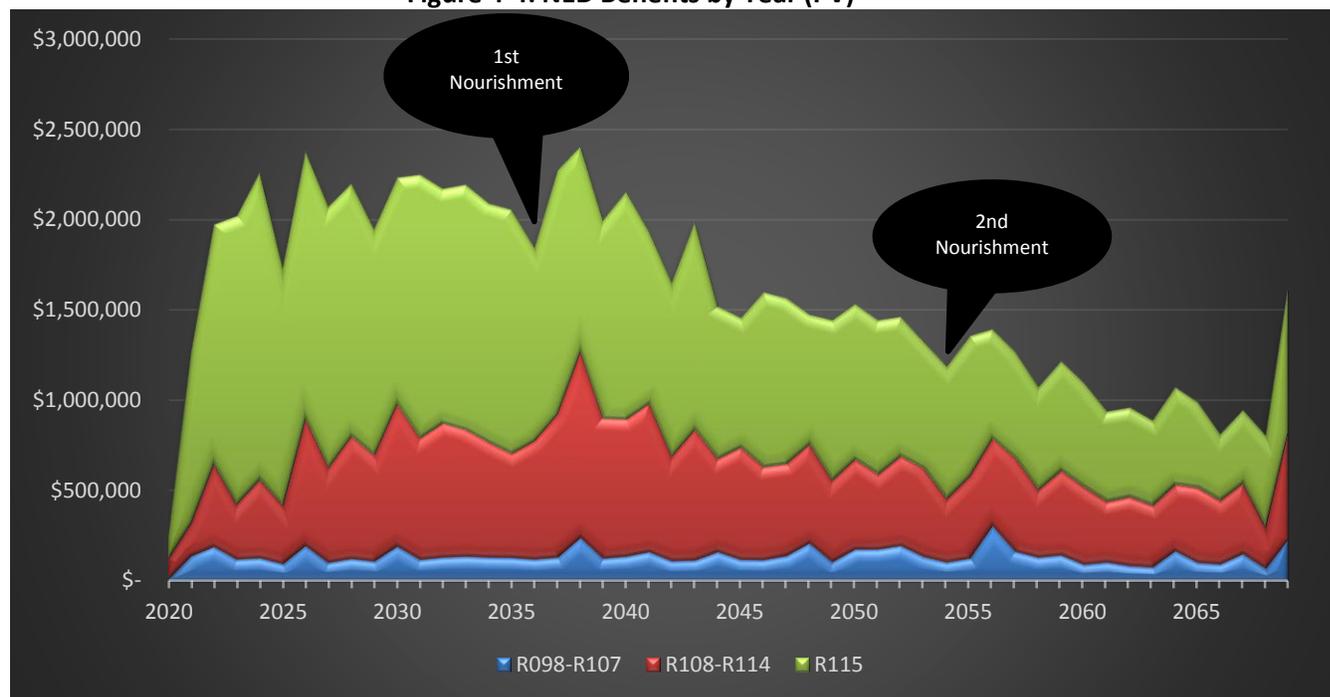
Total CSRM benefits for the NED plan amount to $79,912,378 (PV), or $3,179,950 in AAEQ. Adding land-loss benefits of $276,819 AAEQ (**Section 4.2)** and recreation benefits of $584,018 AAEQ (**Section 4.3**) brings the total project benefits to $4,040,786 AAEQ. Section **4.4.2** will summarize how these benefits compare to the refined costs to determine the final BCR.

4.4.1   Benefits of the NED on Evacuation Route Inundation

Following the same methodology used in section **3.3.5,** the NED was modeled to obtain how effective it would be at preventing flooding of both one foot or more and two feet or more to Florida State Route A1A. The NED was incredibly effective in achieving both of these goals since 0% of the iterations experienced flooding of either one or two feet. Thus, the NED performs satisfactorily in keeping A1A accessible as an evacuation route.

4.4.2 NED Benefit-Cost Ratio

As mentioned above, the BCR has been affected by the refined cost update. Comparing the $4,040,786 AAEQ in benefits with the $1,925,977 AAEQ in costs yields a BCR of 2.10. **Figure 4-5** summarizes the BCRs with a delineation between primary benefits and incidental benefits.

Figure 4-5: BCRs with Refined Costs
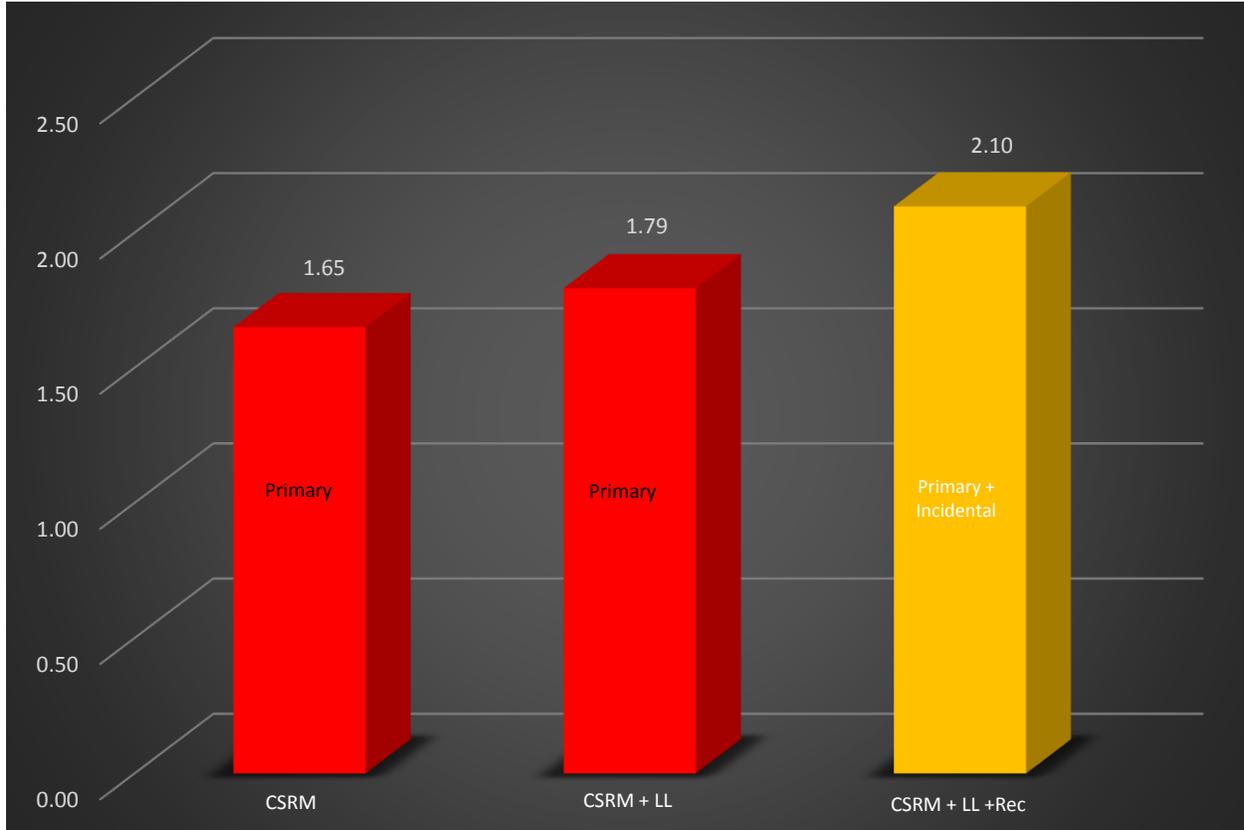
4.5 Conclusion

St. Lucie County is highly susceptible to hurricane and storm damage. This is particularly true for the large and high-value commercial structures and more pronounced in the southern section of the project area. Beach-*fx* modeling has demonstrated that, in the absence of a federal project, significant economic damage from coastal forces can be expected to occur over the next 50 years. When factoring in the potential for sea levels to rise in excess of baseline projections those economic damages could average almost half of a billion dollars in present-value terms.

In an effort to reduce as much damage as possible this CSRM project team considered a multitude of management measures. Years of technical expertise, best professional judgment and rigorous modeling efforts were all leveraged to determine a plan that maximizes net-benefits and contributes to national economic development. This plan, ABerm20DuneEx, prevents 96% of economic damages across 50

years with only two re-nourishments and nets $2,114,809 AAEQ worth of benefits. The project yields $2.10 in benefits for every $1.00 spent (i.e. BCR is 2.10). **Table 4-9** provides a summary of the NED CSRM benefits with land-loss and recreation added.

Table 4-9: Economic Summary of TSP (AAEQ)

ECONOMIC SUMMARY	STORM DAMAGE REDUCTION BENEFITS	STORM DAMAGE REDUCTION + LAND-LOSS BENEFITS	STORM DAMAGE REDUCTION + LAND-LOSS + RECREATION
Price Level	FY16	FY16	FY16
FY16 Water Resources Discount Rate	3.125%	3.125%	3.125%
Average Annual Storm Damage Reduction Benefits	$3,179,950	$3,179,950	$3,179,950
Average Annual Land-Loss Benefits	$0	$276,819	$276,819
Average Annual Recreation Benefits	$0	$0	$584,018
Average Annual Total Benefits	$3,179,950	$3,456,769	$4,040,787
Average Annual Cost	$1,925,977	$1,925,977	$1,925,977
Average Annual Net Benefits	$1,253,973	$1,530,792	$2,114,810
Benefit Cost Ratio	**1.65**	**1.80**	**2.10**

The plan is efficient, acceptable and complete. It is also robust and increasingly efficient in the face of rising sea levels. Though the recommended plan is relatively small in scope and scale, it represents the most prudent investment of Federal and sponsor dollars.