PUERTO RICO COASTAL STUDY

DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX C
Economics

November 2020

US Army Corps of Engineers
Jacksonville District

1. EXECUTIVE SUMMARY

The Puerto Rico Coastal Storm Risk Management (PR CSRM or PRCS) feasibility study is an in-depth analysis of the coastline along the San Juan Metro area in the north of the island and the municipality of Rincon in the west[1]. Much of this shoreline is subject to erosion, flooding, and wave forcing caused by both storms and natural shoreline processes. A study was undertaken to assess the feasibility of providing Federal Coastal Storm Risk Management measures to portions of the island's shoreline. The local sponsor for this project, the Puerto Rico Department of Natural and Environmental Resources (DNER), has indicated strong support for feasibility phase studies to address CSRM. 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. The study area was segmented into two distinct focus areas, San Juan and Rincon, and was further delineated based on modeled areas and separable elements (i.e. planning reaches). The planning reaches are discussed more fully in **Section 4** and are displayed in **Figure 1-1.**

Various measures and combinations of measures, discussed in **Section 7,** were considered for the PRCS. At this time, not all alternatives have been fully quantified and as a result the team has not yet identified the plan which maximizes National Economic Development (NED). This appendix will follow the Main Report in describing the full array of alternatives being considered for recommendation, as well as the current Tentatively Selected Plan (TSP) and the risks and uncertainties surrounding the potential recommendation of each of those possible alternatives. This appendix will focus mainly on the risks and uncertainties as they relate to economic justification (i.e. selection risk versus outcome risk).

[1] The initial scope of the PR CSRM included 11 municipalities, many of which were screened out, see the Main Report for more details since this appendix will focus on only those areas that were modeled.

Figure 1-1: PRCS CSRM Study Delineation

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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 recommended plan 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. 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 & Recommended Plan Selection and Performance:** This section is not yet complete as modeling is still underway. Upon finalization of modeling efforts this section will addresses the quantitative analysis executed to determine which alternative maximizes NED and which alternative will be the recommended plan. A detailed description of the performance of the NED plan, including certified cost estimates, will be 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 in **Section 5**.

2.1 Socio-Economic Conditions

The parameters used to describe the demographic and socioeconomic environments include population, employment, and income distribution. The municipality of Rincon and San Juan will be characterized separately.

2.1.1 San Juan Metro Area

In order to get a better understanding of the specific demographics in the study area, data from the 5-year 2018 American Community Survey was collected at the census tract level within San Juan. The modeled areas of Condado, Ocean Park, and Isla Verde are not perfectly delineated by tract, but the separation is such that each focus area can be individually analyzed. Condado falls entirely within census tract 10 and contains a little overlap with Ocean Park. The rest of the Ocean Park focus area falls within census tract 11, and Isla Verde within Census tract 12.

There are approximately 8,000 people living within each of the three abovementioned census tracts directly impacted by the proposed alternatives. The average unemployment rate is 8% and average income is $69,576. On average, 17% of the residents live below poverty level. A specific breakdown by census tract is displayed in **Table 2-1.** A map of the census tracts can be referenced in **Figure 2-1.**

Category	San Juan Study Area - Census Tracts 10, 11, 12		
	Tract 10	Tract 11	Tract 12
Population	4,919	1,550	1,345
% Below Poverty	15%	26%	10%
Unemployment %	9%	4%	10%
Median Income (2018 Inflation-Adjusted Dollars)	$ 42,277	$ 43,472	$ 36,827
Mean Income (2018 Inflation-Adjusted Dollars)	$ 77,724	$ 73,494	$ 57,510

Table 2-1: San Juan Area Socioeconomic Information – 2018 5-Year American Community Survey

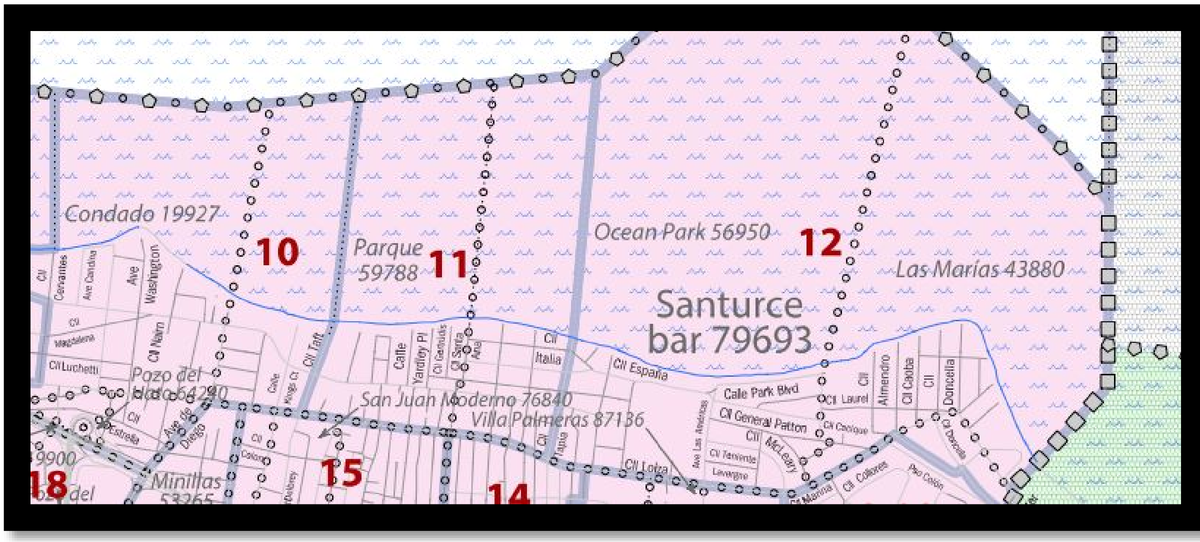


Figure 2-1: San Juan Focus Area Census Tract Map

2.1.2 Rincon

The socioeconomic characteristics of the Rincon Municipality are listed separately as they are greatly different from those found in San Juan. The focus area of Rincon in this feasibility study impacts primarily census tract 9596. Though the unemployment of eight-percent is similar to the census tracts in San Juan, the level of poverty and median wage is considerably different, see **Table 2-2**. The percent of population living below poverty in Rincon, 41%, is over twice that of the average population living in poverty in the San Juan census tracts (17%). The average income in Rincon ($27,432) is less than one-third that of the entire United States' average income ($84,938).

Within the study area there is a middle school, Jorge Seda Crespo, which serves the student population of Rincon grades 6-8.[2] For the 2017-2018 school year, 90% of the students at Jorge Crespo were eligible for free (83%) or reduced (7%) school lunch.

Category	Rincon Focus Area - Census Tract 9596
Population	6,859
% Below Poverty	41%
Unemployment %	8%
Median Income (2018 Inflation-Adjusted Dollars)	$ 25,249
Mean Income (2018 Inflation-Adjusted Dollars)	$ 27,432

Table 2-2: Rincon Area Socioeconomic Information – 2018 5-Year American Community Survey

[2] The school is located in Rincon Planning Reach A (reference below sections on segmentation of the study area) which was screened out.

2.2 **Study Area**

The initial study area included 11 municipalities, displayed in **Figure 2-2** but was pared down to two, Rincon and San Juan. Four focus areas were established: Rincon, Condado, Ocean Park, and Isla Verde. These focus areas were further delineated into planning reaches as described in Figure 1-1. Preliminary modeling indicated that the federal project should screen Rincon A and all of the Isla Verde model segment due to estimated low impacts to structure and contents from coastal storms. All benefit and cost analysis performed and described in this appendix refer specifically to this reduced study area.

Figure 2-2: Map of Initial Study Area

2.3 **Data Collection**

Economists and real estate specialists have collected and compiled detailed structure information for the four focus areas. In total, 838 damageable structures were collected for economic modeling using Beach-fx. The structure inventory includes all structures that are within approximately 600 feet of the mean-high-water line[3].

Real estate professionals from the USACE Savannah District (SAV), using geo-spatial parcel data from Puerto Rico's Centro de Recaudación de Ingresos Municipales (Municipal Revenues Collection Center or

[3] In some areas the landward extent of the model was increased based on topography (i.e. extended to accommodate further risk estimation).

CRIM), provided detailed data on each structure including: geographic location, structure type, foundation type, construction type, number of floors, depreciated replacement value, and approximate foundation height[4].

The PR CSRM study area consists of 25 profiles, and 51 model reaches, and over 100 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. Each model reach is separately subjected to environmental forcing irrespective of neighboring reaches.
- **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 also used for estimation of emergency clean-up costs (e.g. debris removal) and evacuation costs. These assets 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 four focus areas' coastline was collected for economic modeling purposes. The information on the coastal assets detailed in this section was collected from SAV real estate and site visits. 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 structure inventory represents the depreciated replacement costs of damageable structures (i.e. damage elements or assets) and their associated contents along the coastline. Real Estate professionals from the USACE SAV district worked together with economists and planners to provide economic valuations for all of the 800+ damageable structures and their contents. These damage elements have an overall estimated value of $2.9B, with structure and content valuations of $2.5B and $400M respectively. Content values were established as a ratio to overall structure value. When applicable, content-to-structure ratios were based off the USACE IWR 2012 "*Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation"* report. Many items in the structure inventory had a CSVR of 0% (e.g. roads, dunewalks, parking lots). It is also important to note that content valuation considers only those contents anticipated to be at risk from flood, wave, and erosion and, specifically in

[4] Estimated foundation height was used to establish a structure's first-floor elevation.

cases of high-rise structures, may not include total contents[5]. As a result, the average CSVR across the entire study area is roughly 20%. The overall distribution of value by focus area is summarized in **Table 2-3**. **Table 2-4** through **Table 2-7** characterize the inventory for each specific focus area.

Focus Area	Structure	Contents
Condado	$ 854,793,000	$ 72,814,000
Ocean Park	$ 473,928,000	$ 75,973,000
Isla Verde	$ 965,683,000	$ 178,106,000
Rincon	$ 264,409,000	$ 67,248,000
Total	$ 2,558,813,000	$ 394,141,000

Table 2-3: Distribution of Structures & Structure Value by Study Reach

Structure Type	Count	Total Value (FY21 $1,000)	Average First-Floor Elevation (PRVD02)
MULTI-FAMILY RESIDENCE	64	$ 632,700	11.4
HOTEL	11	$ 437,700	10.9
SINGLE-FAMILY RESIDENCE	69	$ 34,700	5.7
RESTAURANT	17	$ 12,000	7.4
VEHICLE	130	$ 7,300	8.0
MEDICAL OFFICE	2	$ 4,700	8.2
RETAIL	10	$ 4,600	7.8
OFFICE	2	$ 2,400	17.2
Total	305	$ 1,136,100	9.6

Table 2-4: Isla Verde Structure Inventory

Structure Type	Count	Total Value (FY21 $1,000)	Average First-Floor Elevation (PRVD02)
MULTI-FAMILY	227	$ 131,700	14.9
SINGLE-FAMILY	313	$ 88,700	9.6
HOTEL	7	$ 51,900	11.5
HOSPITAL	2	$ 13,000	16.7
INDUSTRIAL	2	$ 7,900	14.0
OFFICE	12	$ 7,200	11.9
OTHER	3	$ 5,500	12.4
RETAIL	5	$ 3,800	11.1
RESTAURANT	3	$ 800	9.7
TOTAL	574	$ 310,500	12.4

Table 2-5: Rincon Structure Inventory

[5] Users of the NACCS damage functions for high-rise buildings are advised that "the damage to high rise buildings should be calculated as a percent of the first ten stories" and this guidance was followed for the PRCS study.

Structure Type	Count	Total Value (FY21 $1,000)	Average First-Floor Elevation (PRVD02)
HOTEL	7	$ 335,100	18.2
MULTI-FAMILY	36	$ 235,100	21.0
OTHER	21	$ 7,200	14.1
SINGLE-FAMILY	5	$ 4,700	16.2
RESTAURANT	4	$ 4,400	15.4
Vehicle	38	$ 3,900	13.5
COMMERCIAL	2	$ 1,900	22.7
OFFICE	1	$ 900	12.8
RETAIL	1	$ 500	14.6
TOTAL	115	$ 593,700	16.5

Table 2-6: Condado Structure Inventory

Structure Type	Count	Total Value (FY21 $1,000)	Average First-Floor Elevation (PRVD02)
MULTI-FAMILY	126	$ 414,300	10.9
SINGLE-FAMILY	207	$ 91,900	6.7
HOSPITAL	5	$ 27,900	9.0
Vehicle	333	$ 9,800	7.1
OTHER	119	$ 5,400	13.8
SCHOOL	3	$ 5,000	8.5
RESTAURANT	4	$ 4,500	9.7
TOTAL	797	$ 558,800	9.4

Table 2-7: Ocean Park Structure Inventory

3. COASTAL STORM RISK MANAGEMENT BENEFIT APPROACH

This section of the appendix covers the approach used to estimate the economic benefits of managing coastal storm risks in the study area using Beach-fx. The topics covered include:

- Benefit Estimation Approach Using Beach-fx
- FWOP Condition
- 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) and in accordance with EC 1105-2-412 (Assuring Quality of Planning Models). The model was reviewed by the PCX for Coastal and Storm Damage and found to be appropriate and certified for use in CSRM studies and is therefore the required model for use in the PR CSRM Study. 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 coastal storm risks 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. Additional categories of evacuation and emergency clean-up costs are also estimated using Beach-fx and added to the content and structure damages for inclusion in the benefit base. 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 individual property owners as well as state and local organizations to protect coastal assets. Based on these attributes, Beach-fx is an ideal economic modeling tool for use in the PR CSRM study.

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.

The future structure inventory and values are the same as the existing condition. This approach neglects any increase in value accrued from future development. Using the existing inventory is considered preferable due to the uncertainty involved in projections of future development. However, it should be noted that the risk to life safety can change over time. For this study it is not anticipated that there will be an increase in life safety over the period of analysis since population estimates in Puerto Rico show a declining trend (Trading Economics, 2020).

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 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 Beach-Fx 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 PR CSRM study and the resulting consequences. It is important to note that each focus area (Rincon, Condado, Ocean Park, and Isla Verde) were all modeled separately, with four separate modeling databases. This was required due to the complexity of the shoreline shape as well as the differences in the coastal processes subjected to each individual focus area.

3.2.1 Timeframe and Discount Rate

- **Start Year:** The year in which the simulation begins is 2019. This year determines the starting shoreline position which will be impacted by standard erosion and storm forces throughout the period of analysis. It is also the starting point for the sea-level rise projections.
- **Base Year:** The year in which the benefits of a constructed federal project would be expected to begin accruing is 2028.
- **Period of Analysis:** 50 years, from 2028 to 2077.
- **Discount Rate:** 2.75% FY2020 Federal Water Resources Discount Rate
- **Iterations:** The number of iterations run within Beach-fx was decided based on model run time and model stabilization. The model was run with the fewest number of iterations possible to allow for stabilization using 25 iteration increments. For Rincon, 100 iterations were run. For the remaining planning reaches 50 iterations were run. The moving average of FWOP damages stabilized by this point and was thus determined an adequate number of iterations. The tentatively selected plan (TSP) will be updated with at least 100 iteration run for economic justification considerations and will be included in the final report.

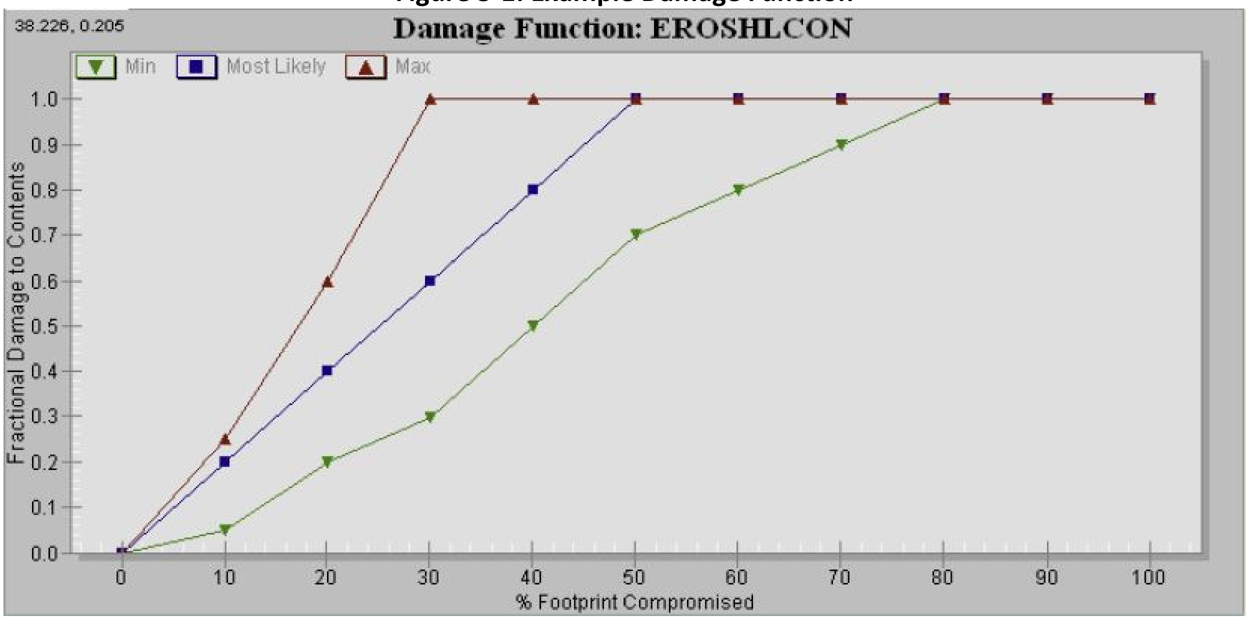
3.2.2 Rebuilding

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. Another item for modeling consideration is that within these FEMA high-hazard zones a rebuilding permit is technically not allowed on a structure that is not up to current code if said structure incurs damages of 50% or greater in a single event. In the parlance of municipal coding, these structures are called "non-conforming structures". The structure inventory within Beach-fx is static, which makes reflecting this behavior a difficult task for modelers. The approach taken for the PR CSRM in San Juan was to assign rebuilding parameters in a way that targeted a maximum life-time damage threshold per structure (as a percent of initial structure value) in order to minimize the risk of overstating repetitive damages to non-conforming structures. The threshold targeted was 150% and each modeled area was simulated repetitively and the rebuilding assumption adjusted on an asset level in order to achieve this target (i.e. the model was calibrated to determine the number of rebuilding on an asset level). This differs slightly from the more common approach of assigning a uniform number of rebuilds based on occupancy type. The calibrated approach was most applicable in the planning reaches of Ocean Park since many structures have FFE's below the base flood elevation (BFE) and are thus non-conforming. For Rincon rebuilding was controlled at the lot condemnation level since background erosion had greater influence in this focus area. Lots were drawn and modeled in such a way that each individual damage element was housed on its own lot and when that lot was no longer buildable due to erosion it was removed from the inventory.

3.2.1 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 3-1**.

Figure 3-1: Example Damage Function



For the vast majority of aforementioned residential combinations within this study the damage functions used were those developed by the USACE North Atlantic Division in the "North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk" (NACCS Report), section "Physical Depth Damage Function Summary Report" (January, 2015). For non-residential damage functions, the Institute for Water Resource (IWR) publication "Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation" (Davis, 2013) was used. However, the wave damage functions needed to be adjusted for certain damage elements based on their relative position in the upland. In order to account for the fact that property and structures in the first row would attenuate wave energy, properties in the second and third rows were assigned altered wave damage functions. Properties located in the second row had a downward revision to the fractional damage at every wave height whereas the properties in the third row had the null wave damage function assigned since it is assumed that properties set that far back would not incur damages from wave attack due to the aforementioned attenuation.

3.2.2 Coastal Armoring

Beach-fx allows for assumptions surrounding coastal armoring (e.g. sandbags, breakwaters, seawalls, rip rap) as well. A user can define the different types of armoring applied to individual damage elements as well as a distance trigger, applied at the lot level, which will prompt construction of said armor. A detailed inventory of lots that are already armored was developed by SAJ economists for input into Beach-fx based on detailed site visit photography provided by SAJ Coastal EN.

A new policy implemented by the local permitting agency and NFS pertaining to armoring is that no armoring in the future is to be permitted in areas where a sandy beach exists or once existed[6]. Armoring along rocky coastlines or headlands is, however, permitted. See the Main Report Section 3.5.2 for more details. Therefore, in areas where armor does not exist and is outside of a headland area it is assumed that armoring is not buildable in the future (denoted as a “2” within the Beach-Fx Model). In areas where armor already exists but will no longer be permitted in the future the model has been setup in a way such that the protective capacity of the armoring is realized up until the point of failure and then is removed from the inventory.

For the PR CSRM the coastal armoring assumptions differed in the San Juan modeled areas from Rincon. This difference was based on the design level and construction condition of the armoring. Within Ricon it was common for large boulders (i.e. riprap) to simply be placed at the lot line in a haphazard manner. This riprap placement was not of engineering design and was assumed to have low failure thresholds[7] whereas in San Juan more robust seawalls and revetments were the more common armor types in each of the planning reaches. These seawalls had higher failure thresholds. Failure thresholds were informed by the *“Lee County, Florida Shore Protection Project Gasparilla Island Segment – Section 934 Report*” as well as based on based professional judgment with input from SAJ Coastal EN. Picture examples of the various seawall types that helped inform these assumptions and cataloging of armor inventory are provided in the following figures. Due to the poor design quality of rip rap armoring in Rincon the Beach-fx model predicted failure at every point prior to the base year and thus this armoring had no impact during the period of analysis and was removed from inventory.

[6] It is not clear at this point how this will be defined and enforced by the permitting agency.
[7] Rincon riprap was of a sufficiently low failure threshold that armor failed almost immediately in all simulations and thus was removed from the inventory in order to simplify the manner in which lots were organized and built.

Pictures from left to right: Robust seawall tied into the bedrock in Planning Reach Condado West Headland; Robust emergent seawall with buried foundation in Condado Punta Piedrita

Figure 3-2 Condado Seawall Examples

Figure 3-3 Isla Verde Seawall Examples

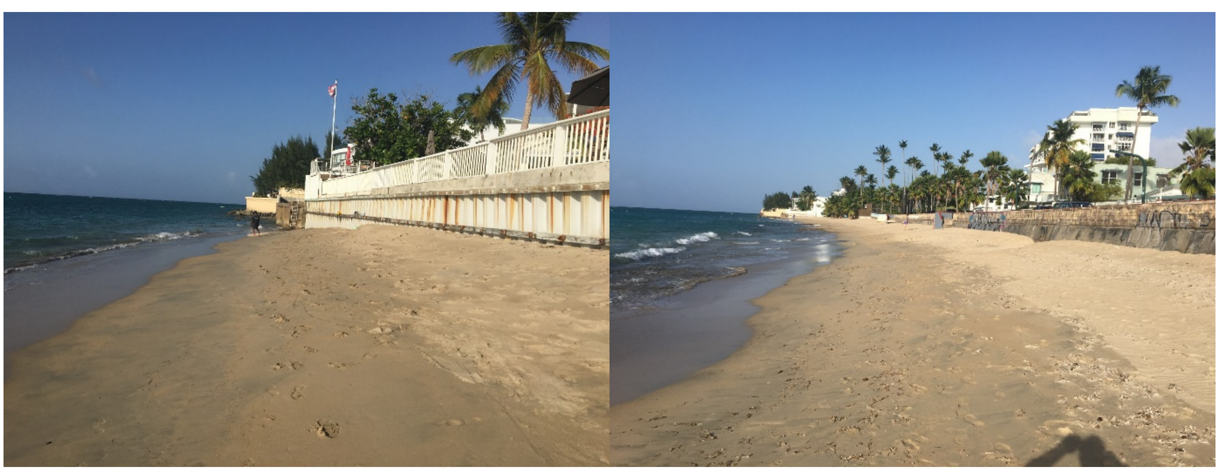


Figure 3-4: Ocean Park Seawalls

3.3 Emergency Clean-Up and Evacuation Cost Assignment Methodology

This category of costs are part of the NED analysis per section 3-4 of ER 1105-2-100 and are ultimately added to the FWOP damages to estimate the benefit base against which FWP alternatives are compared. Commercial and residential assets within the inventory were assigned a maximum emergency clean-up and evacuation (ERC&E) cost in order to estimate the impacts from coastal storms to these important NED benefit categories. Due to study schedule limitations and a large scope, site specific data was not available prior to release of this draft report. As a result, data was leveraged from the 2012 "*Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes*" to determine inputs for this PR CSRM. Clean-up and evacuation costs from the report were in 2010 price-levels and were therefore updated to FY21 using the Consumer Price-Index (CPI). Being an island, it is likely that Puerto Rico clean-up and evacuation costs would be higher than those estimated via expert elicitation for the Louisiana Study and thus represents a conservative estimate. However, this is deemed appropriate for this study under the 3x3 and risk-informed decision-making paradigm exemplified by the USACE. Maximum evacuation costs were estimated at $6,444 for each household, and maximum emergency clean-up costs are presented by occupancy type in **Table 3-1.** A separate Beach-fx model database was created strictly for computing ERC&E cost estimates in the FWOP and FWP. The structure inventory was manipulated such that the structure value was replaced with the emergency clean-up costs shown in **Table 3-1** and the content value was replaced with the abovementioned maximum evacuation cost for residential structures only. The damage function assigned to these costs estimates was also derived for the Louisiana Study and applied appropriately to each category and occupancy type.

Occupancy Type	**Maximum Emergency Clean-Up Cost**
One-Story Slab Home	$ 6,759
Two-Story Slab Home	$ 9,054
Multi-Family Residence	$ 12,227
General Nonresidential	$ 46,141

Table 3-1: PR CSRM Maximum Emergency Clean-Up Cost by Occupancy Type

3.4 Land Loss Estimation

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 the PRCS, annual reduction of upland width across all unarmored Beach-fx study reaches was obtained from the Beach-fx LandLoss.csv 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 upland width rather than changes in berm width are used as the appropriate measure of land loss.

For Beach-fx model reaches located within the study area the basis of the annual changes in upland width calculation for the FWOP is the width in each reach in the model base year (2028) and the width of each subsequent year. The same calculation is then done for each alternative and the comparison of upland width change from the FWOP and FWP in a given year results in the cumulative loss of land for that specific model reach. However, for the 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 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.

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. Currently the value being used per square-foot is $68 in San Juan and $19 in Rincon based on the report “Nearshore Waterfront Land Valuation” conducted by SAJ Real Estate Division specifically for the PRCS.

4. DELINEATION OF THE STUDY AREA FOR PLANNING PURPOSES

The focus area of San Juan was further segmented into planning reaches based on specific geographic locations (i.e. Condado, Ocean Park, Isla Verde, Carolina[8]) as well as geomorphic characteristics (i.e. rocky headlands versus pocket sandy beaches) since specific measures and alternatives would target the varied geomorphology uniquely. Additionally, it was necessary to segment the Beach-Fx model based on wave climate and environmental forcing (see the Engineering Appendix for more details) and so the San Juan focus area was broken up into three distinct modeling databases: Condado, Ocean Park, and Isla Verde[8]. Results from the modeled areas were then combined and analyzed based on the planning reaches as follows:

- Condado West Headland – Composed of Beach-Fx modeling reaches Condado R-06 to R-09
- Condado Pocket Beach – Composed of Beach-Fx modeling reaches Condado R-05 to R-02

[8] The Carolina Segment is a distinct area but was not modeled and therefore no Beach-Fx setup exists.

- Punta Piedrita – The eastern headland of Condado, western headland of Ocean Park, comprised of modeling reach Condado R-01 and Ocean Park R-16 to R-15
- Ocean Park Pocket Beach – Composed of Beach-Fx modeling reaches Ocean Park R-14 to R-03
- Punta Las Marias – Composed of Beach-Fx modeling reaches Ocean Park R-02 to R-01 and Isla Verde modeling reach R-15.
- Punta El Medio – Composed of Isla Verde Beach-fx modeling reaches R-01 to R-03 and the unmodeled Carolina segment[9].

Please refer back to **Figure 1-1** for a graphical image of the study area in San Juan by planning reach.

Rincon is comprised of two planning reaches geographically separated by a stream, Quebrada Los Ramos, to the north (Rincon A, green in figure) and south (Rincon B, blue in figure) as depicted in **Figure 4-1**.

Figure 4-1: Rincon Planning Reaches

[9] See the main report for the qualitative screening of the Carolina reach.

5. <u>FUTURE WITHOUT PROJECT CONDITION (FWOP)</u>

5.1 Rincon

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

- Mean: $1,377,234
- Standard deviation: $560,283
- Coefficient of Variance: 0.407
- Median: $1,228,404

The standard deviation is significantly smaller than the mean damage, seen in the coefficient of variance. This relation indicates little volatility of the FWOP damage incurred in the project area throughout the 100 iterations. The steady stream of damages is primarily due to the constant background erosion process. Pursuant to estimating FWOP damages and associated costs for the study area in Rincón, Beach-fx was used to estimate damages and costs in the following categories:

- <u>Damages:</u>
  - <u>Structure Damage:</u> Economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Structure damages account for 75% of the damages for the FWOP.
  - <u>Contents Damage:</u> The material items housed within the structures (usually air-conditioned and enclosed) that are potentially subject to damage. Content damages are 25% of the total damages.

5.1.1 <u>Rincon Damage Distribution by Structure Category and Type</u>

This section addresses what is being damaged in the FWOP by structure category and type. The coastal inventory was categorized as 'Commercial', 'Public Access', and 'Residential'. **Table 5-1Error! Reference source not found.** 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: 1.1%
- Public Access: <0.1%
- Residential: 94.5%

Category	Sub-Category	Structure	Contents	Total	Percent
Commercial	Grocery	$0	$0	$0	0.0%
	High-Rise	$72,374	$5,520	$77,894	5.7%
	Hospital	$0	$0	$0	0.0%
	Hotel	$113,795	$19,257	$133,052	9.7%
	Industrial	$0	$0	$0	0.0%
	Office	$19,227	$1,986	$21,213	1.5%
	Restaurant	$8,996	$3,774	$12,770	0.9%
	Retail	$11,359	$1,124	$12,483	0.9%
Public Access	Road	$310	$0	$310	0.0%
	School	$0	$0	$0	0.0%
	Service	$50	$42	$92	0.0%
Residential	Single-Family Single Story	$331,455	$220,190	$551,645	40.1%
	Single-Family Multiple Story	$149,362	$62,448	$211,810	15.4%
	Multi-Family Multi-Story	$329,438	$26,526	$355,964	25.8%
Total	-	$1,036,367	$340,867	$1,377,234	100.0%

Table 5-1: Distribution of Rincon Damages By Category ($ AAEQ)

5.1.2 Rincon Spatial Distribution of Without Project Damages

FWOP damages really spike in the southern portion of Rincón's shoreline. Reaches 11-19 make up 86.1% of the damages. The remainder are mainly distributed in reaches 7, 8, and 22, which account for 10.7% of total damage. The spatial damage results are summarized in **Figure 5-1**. The concentration of damages in reaches 11-19 was the focal point of alternative development within the PDT. More information on that process can be reviewed in the Main Report.

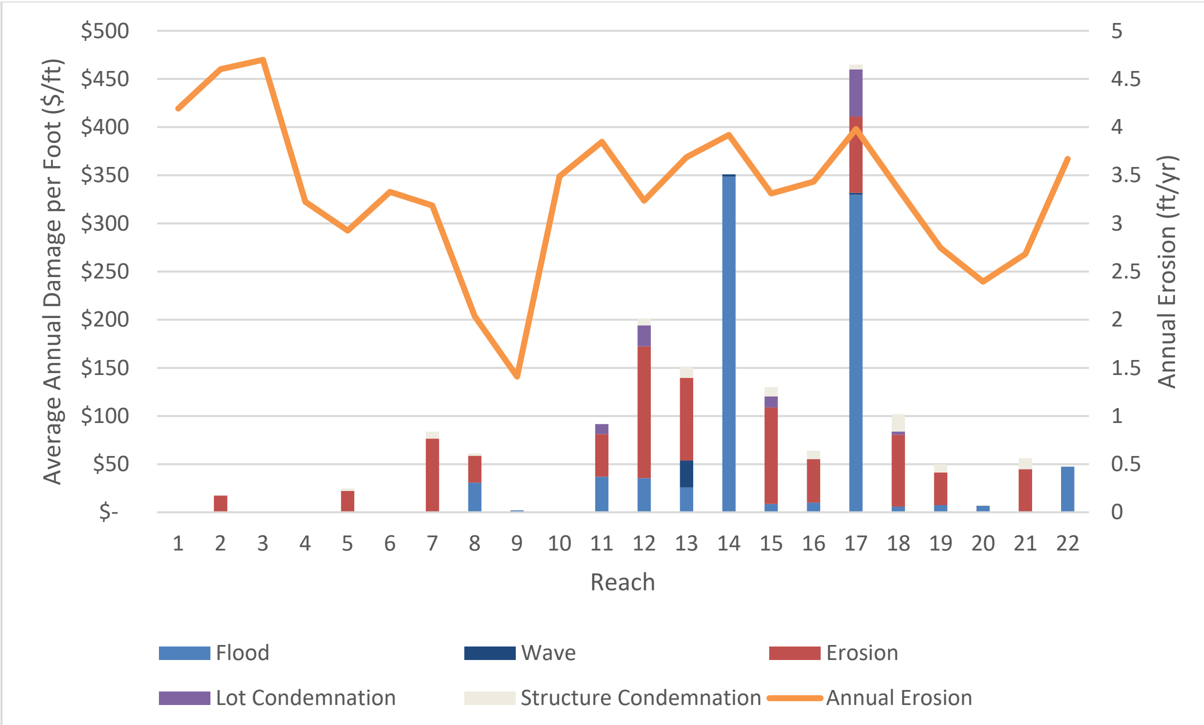


Figure 5-1: Rincon FWOP Damages by Reach (AAEQ $ and %)

The spatial distribution of erosion and damage shows the following pattern:

- **Reaches 1-6, 9, and 10**: These reaches have the lowest damages in the study area, at around 1.8% of the total, despite high erosion rates in reaches 1, 2, and 3. Reaches 2 and 5 are the main drivers of damages in this range.
- **Reaches 7 and 8**: There are moderate damages occurring in these two reaches. Erosion rates are lower than average for the project area. Despite moderate damage, it is unlikely any management measure would be justified for these reaches as any measure would have to bridge the gap made by reaches 9 and 10. Reaches 7 and 8 account for 7.8% of total FWOP damage.
- **Reaches 11-13, 15, 16, 18, and 19**: Reaches 11-19 have the highest damages in the study region. These reaches, while not as damage prone as reach 14 and 17, make up a substantial sum of FWOP damage at 36.6%. The main cause of damage in these reaches is erosion due to lack of protective armoring.
- **Reaches 14-18**: The largest damages are seen in reaches 14 and 17 totaling 49.5%. Damages in the two reaches are primarily from flooding due to the low lying nature of the area.
- **Reaches 20-22:** In these final reaches the erosion rate is slightly higher than average. Damages are low at 4.2%.

5.1.3 Rincon Damage Distribution by Damage Driving Parameter

A majority of the damage is from either erosion or inundation, with inundation being the primary damage driver. This is because FWOP modeling in Rincón did not allow for future armor construction. Lot condemnation damages are included in the erosion damage category calculation. Structure condemnation damages were not included for the purpose of this breakout. The distribution of damage is as follows:

- Erosion: 45.0%
- Inundation: 53.3%
- Wave Attack: 1.7%

5.1.4 Rincon Temporal Distribution of Damages

Damage in reaches that are susceptible to inundation have high damage in the initial years due to structures in these reaches being condemned and dropping out of the inventory throughout the lifecycle. In reaches where erosion is the leading damage driver, damages increase over time. This effect is due to the gradually eroding shoreline increasing the vulnerability of assets in that area. Figure 5-2 illustrates the damages over time by reaches in non-present value. The scale on the right of the figure provides a numeric description of the visualization.

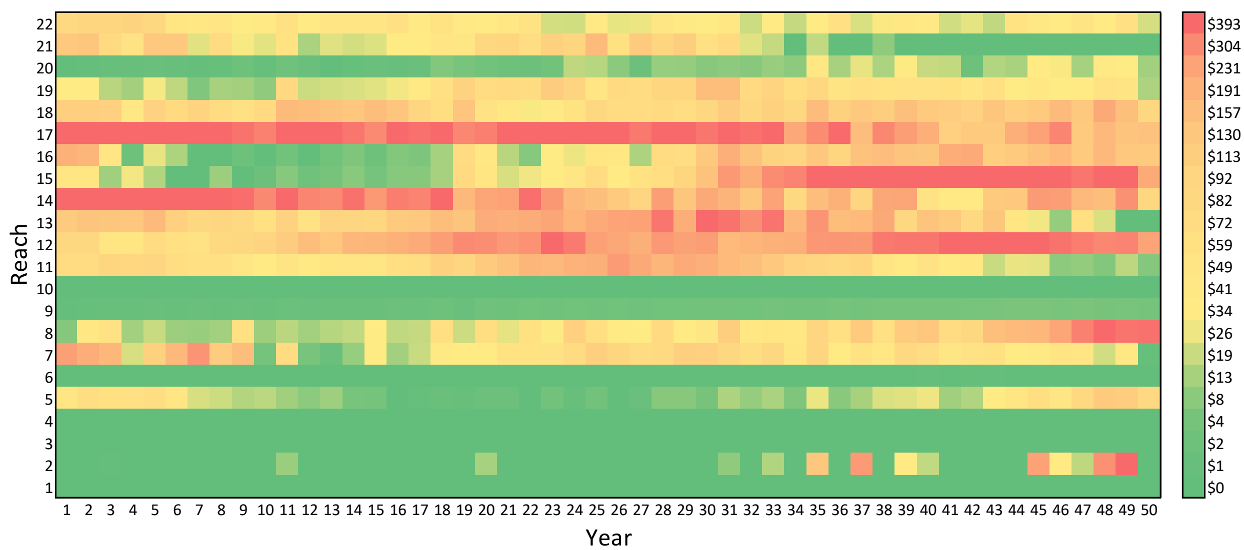


Figure 5-2: Rincon Damages over Time and Space ($/ft, non-PV)

5.1.5 Rincon Emergency Clean-up and Evacuation Costs

Emergency clean-up and evacuation (ERC&E) costs were computed for Rincon following the methodology outlined in **Section 3.3** and applied to the structure inventory as appropriate. Since the PDT was aware that Planning Reach Rincon-B was the only likely location for an action alternative only model reaches 11-22 were used for estimations of ERC&E impacts and only the intermediate sea-level rise curve was modeled. The FWOP model used to determine physical structure and content damages was then run under ceteris paribus engineering conditions in order to estimate ERC&E impacts to Rincon. **Table 5-2** shows the FWOP estimated ERC&E impacts in Rincon for Planning Reach Rincon-B. The

$6,000 (AAEQ) ERC&E impacts were added to the $1,377,000 structure and content damages for a total of $1,383,000 (AAEQ).

Price Level (FY21)	Rincon Future Without Project ERC&E Costs		
	Emergency Clean-Up	Evacuation	Total
Present-Value	$ 127,000	$ 34,000	$ 161,000
Average Annual Equivalent	$ 5,000	$ 1,000	$ 6,000

Table 5-2: Rincon FWOP Emergency Clean-up and Evacuation Costs[10]

5.1.6 Rincon 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 Rincón the average baseline (SLR1), intermediate (SLR2) and high (SLR3) rates were found to be 0.0098 feet/yr, 0.0218 feet/yr, and 0.0596 feet/yr, respectively. The Beach-*fx* results that were presented above refer strictly to the intermediate scenario. The results comparing the SLR scenarios are presented here. Figure 5-3 provides an overall summary of damages in each SLR scenario; **Table 5-3** shows how those damages are distributed amongst the different structure types.

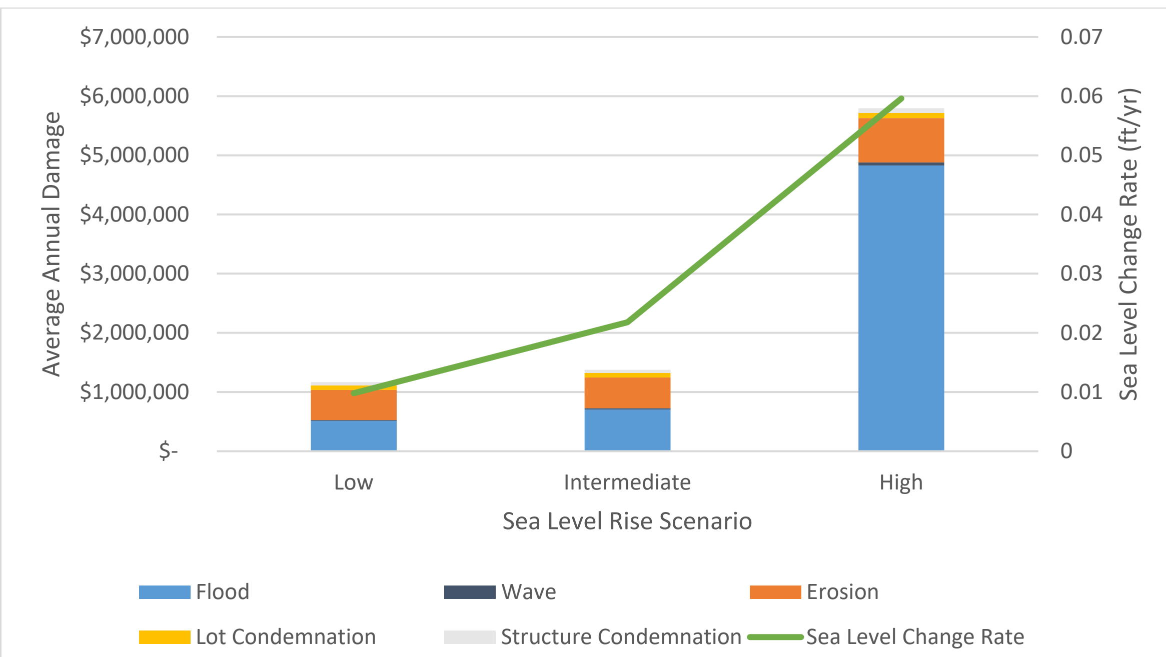


Figure 5-3: Rincon Total Damages by SLR Scenario

[10] Estimates are for modeling reaches 11-22 only which represent Planning Reach Rincon-B

Category	Sub-Category	Low	Intermediate	High
Commercial	Grocery	$0	$0	$4
	High-Rise	$76,257	$77,894	$98,889
	Hospital	$0	$0	$174
	Hotel	$109,049	$133,052	$362,017
	Industrial	$0	$0	$0
	Office	$9,878	$21,213	$174,566
	Restaurant	$4,844	$12,770	$82,568
	Retail	$4,953	$12,483	$155,976
Public Access	Road	$311	$310	$238
	School	$0	$0	$13,899
	Service	$113	$92	$3,447
Residential	Single-Family Single Story	$460,987	$551,645	$2,432,751
	Single-Family Multiple Story	$176,089	$211,810	$1,035,142
	Multi-Family Multi-Story	$324,804	$355,964	$1,436,543
Total	-	$1,167,285	$1,377,234	$5,796,214

Table 5-3: Distribution of Damages by Category in the SLR scenarios

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 period of analysis so do damages). What is important to note, however, is the magnitude of the effect. From the low to intermediate scenario the difference was a mere 0.012 ft/yr in average SLR and resulted in an increase of roughly 18.0%, or $210,000 in annual damages. From the intermediate to high scenario there was a 0.0378 ft/yr average rise difference with a corresponding increase of 320%, or roughly $4,420,000 in annual damage. From the low to high scenario damages increase by 397%. There is very little shift in what drives the damages from the low to the intermediate scenario. In the high sea level rise scenario, flood damages skyrocket. Figure 5-3 displays the changing trend in how damages are occurring.

The majority of the difference between the low and intermediate sea level rise is in reaches 8, 14, 17, and 22. Due to the high concentration of flood damages in these reaches they experience significantly more damage in the high sea level rise scenario. A visual representation of spatial damages in the three sea level rise scenarios can be seen below in **Figure 5-4**.

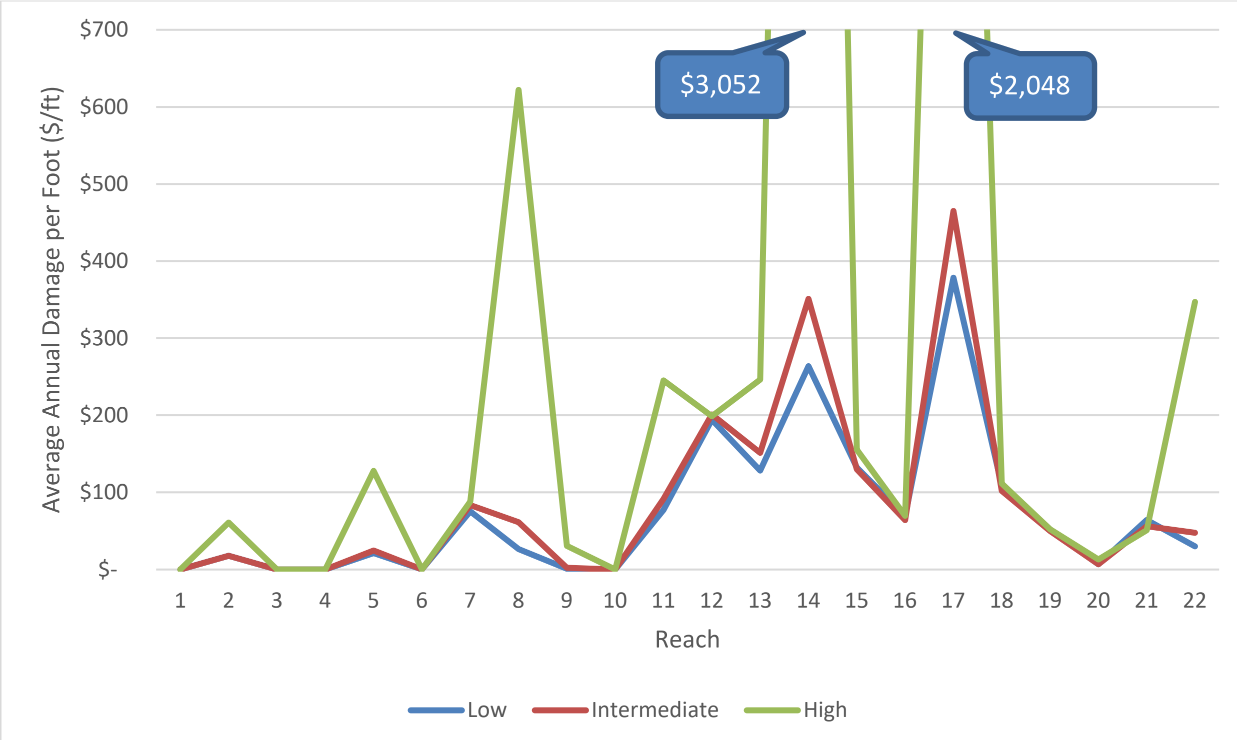


Figure 5-4: Rincon Distribution of Damages by Driver and SLR Scenario

5.1.7 Rincon FWOP Condition Conclusion

- Damages are largely driven by flood and erosion damage.
- The majority of the damage is structural in nature. Residential structures account for over 80% of all damages.
- Damages in the FWOP increase significantly in the high sea level rise scenario.
- Damages, specifically in the intermediate sea-level curve being used for plan formulation, are concentrated almost entirely in planning reach Rincon B.

6. CONDADO FUTURE WITHOUT PROJECT CONDITION

Damages per the Condado FWOP model results are as follows:

- Mean Structure, Content, Armor Damage: $758,000 (AAEQ)
- Average ERC&E Costs: $10,000 (AAEQ)

- 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 87% 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 13% of the total damages.
- Armor Damage: Damage to existing armor and construction of new armor could potentially benefit with the existence of a federal project. Armor damages are responsible for 1% of FWOP damages.
- ERC&E Damages: Monetary costs resulting from emergency clean-up efforts and emergency evacuation are responsible for 1% of FWOP damages.

6.1 Spatial Distribution of Damages

The Condado modeling area is made up of nine Modeling Reaches and three Planning Reaches. The Planning Reaches (West Headland, Pocket Beach, Punta Piedrita Headland) are areas with distinct engineering characteristics and areas that are separable in their potential for project implementation. The western headland and is characterized by a rocky outcropping and heavy existing armor. Early engineering assessments concluded technical feasibility of measures in this area would be difficult due to the need to tie into existing structures on private property as well as the challenges presented by the offshore environment. Additionally, early modeling results indicated an extremely low chance of implementing a cost effective measures. Therefore, more detailed modeling excluded the Western Headland. Condado Pocket Beach represents the sandy pocket beach where there are many high-rise hotels very near MHW and the presence of armoring is very minimal in the existing condition. Damages in Condado Pocket Beach are the highest total as well as the highest per linear-foot. Punta Piedrita Headland is the eastern headland and is also characterized by a rocky outcropping. However, unlike the West Headland, Punta Piedrita Headland is a relatively smaller reach and damages are high in this area per linear foot. See Table 6-1 for the damages by linear-foot.

Planning Reach	Total Structure, Content, Armor, and ERC&E Damage (AAEQ)	Total by Linear Foot (AAEQ)
Condado Pocket Beach	$575,000	$286
Punta Piedrita Headland	$194,000	$192
Total	$768,000	$254

Table 6-1: Condado FWOP Damages by Planning Reach

6.1.1 Damages by Damage Driving Parameter

The damages in Condado are majority erosion, driven primarily by damages in the Pocket Beach area. Erosion counts for more than 75% in the Pocket Beach. For the Punta Piedrita Headland, damages are primarily flooding (~66%) and wave (~33%) with no damages coming from erosion due to existing armoring in this area. **Figure 6-1** shows the breakdown for the entire Condado focus area.

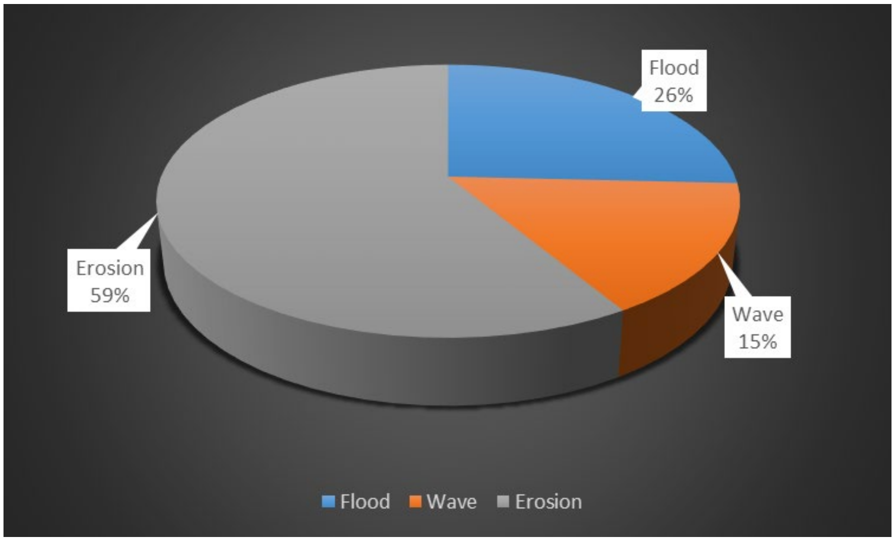


Figure 6-1: Condado FWOP Damages by Damage Driving Parameter

6.1.2 Temporal Distribution of Damages

The distribution of FWOP damages over time in Condado shows that storm impacts play a large role in damages. In study areas where long-term gradual erosion is a severe problem, damages gradually increase over time with spikes when storms hit. In Condado, damages are sporadic and spike up and down from the start indicating vulnerability to the random nature of storm occurrences versus gradual long-term erosion; **Figure 6-2** below corresponds to this fact. The area has lower susceptibly to high-frequency events, but has a much higher vulnerability with respect to low-frequency higher-impact events.

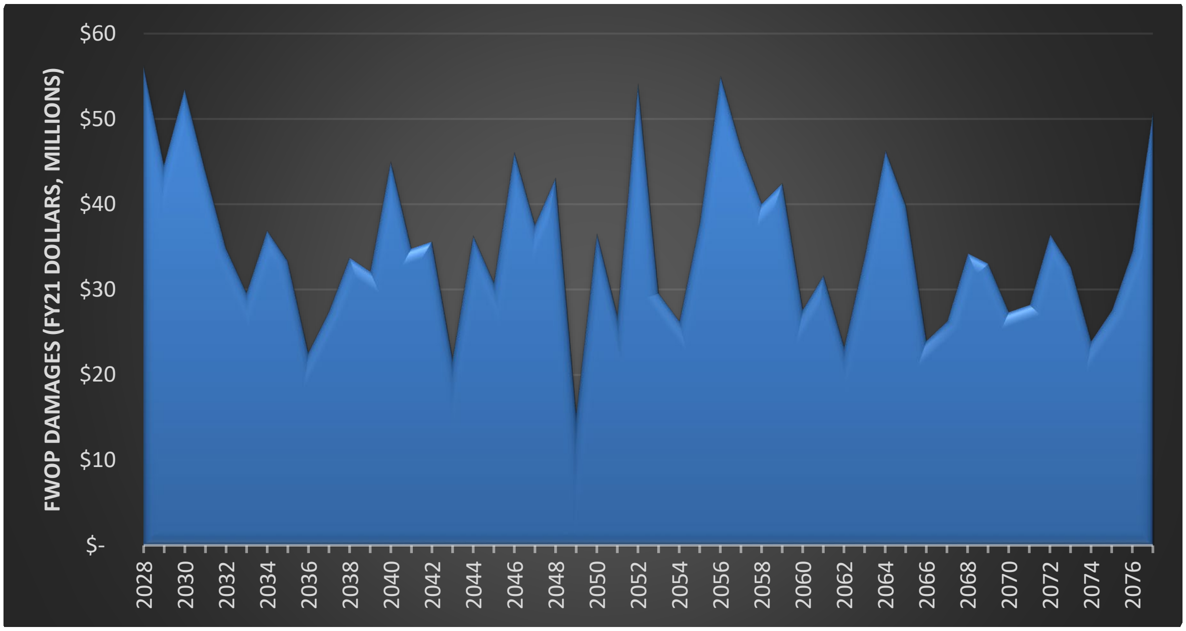


Figure 6-2: Condado FWOP Damages By Year (Non-PV)

6.1.3 Clean-up and Evacuation Cost

Emergency clean-up and evacuation (ERC&E) costs were computed for Condado following the methodology outlined in **3.3** and applied to the structure inventory as appropriate. Condado has relatively fewer residential structures in the near-shore and as a result evacuation costs are virtually non-existent. However, emergency clean-up costs are a much larger factor and are estimated at $10,000 (AAEQ).

6.1.4 Damages in Sea-Level-Rise Scenarios

The change in damages from the low curve to the intermediate curve has a relatively muted impact, with an estimated increase of only 8%. However, under the high scenario damages increase 53% from the intermediate curve and 65% from the low curve. Again, this demonstrates the increased susceptibility and vulnerability of these Puerto Rico coastal structures in the face of more severe increases in the sea level over time.

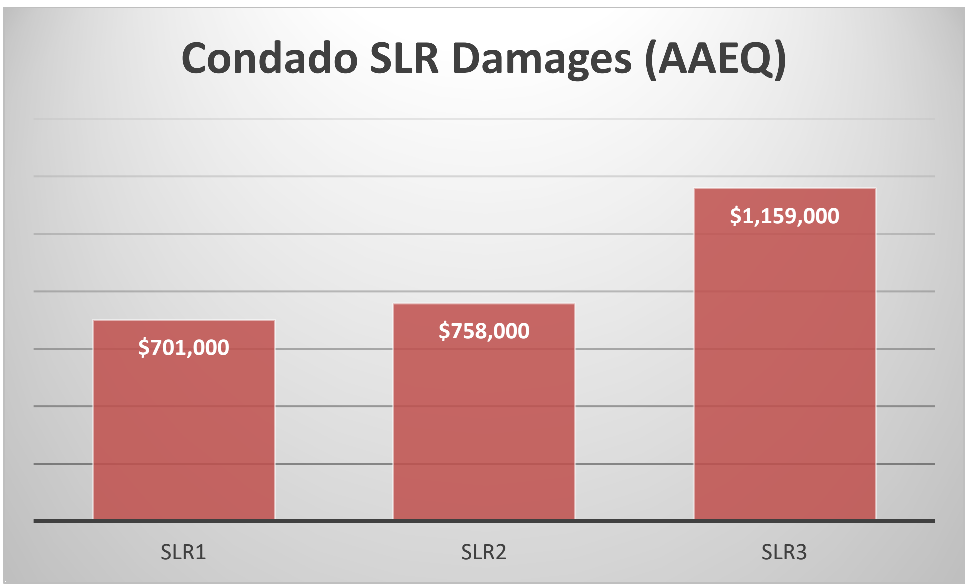


Figure 6-3: Condado FWOP Damages in Each Sea-Level Rise Scenario

6.1.5 Condado FWOP Conclusion

Total damages in the FWOP condition, including ERC&E, are $768,000.

- Damages are largely driven by storm events instead of gradual erosion.
- Damages in the Pocket Beach are both higher overall and relative with respect to size than Punta Piedrita.
- Damages in the FWOP increase dramatically in the high SLR scenario.

6.2 Ocean Park Future-Without Project Condition

Ocean Park has by far the largest amount of damages estimated in the FWOP condition. This is a fairly large focus area and is densely populated with a large contingent of single-family and multi-family homes. Many of the structures within Ocean Park have very low FFE's and make this focus area extremely vulnerable in the future if no action is taken. Many of these structures are not up to current code (i.e. they are non-conforming structures) due to their FFE positioned below BFE in this high-hazard zone.

- Mean: $6,728,000 (AAEQ)
- ERC&E Costs Average $350,000 AAEQ

6.2.1 Ocean Park Spatial Distribution of Damages

Like each of the San Juan focus areas, the planning reaches are characterized by headland points in the east and west (Punta las Marias and Punta Piedrita) and a sandy pocket beach formation between the rocky headlands (Ocean Park Pocket Beach). FWOP damages are the highest of all the focus areas, and the damages per linear-foot in each of the three planning reaches are also relatively high. Punta Piedrita reach contains the hospital which is at-risk in the FWOP as well as many high-rise condominium complexes and as a result has a high density of damages, the most in all planning reaches per linear foot throughout the PRCS. Ocean Park Pocket Beach is the sandy pocket beach where there is a high density of single-family residents and the damages per linear foot are quite large there as well. Punta Las Marias falls in between the other two reaches in terms of damages per linear foot.

Planning Reach	Total PV	Total AAEQ	Total AAEQ By Linear Foot
Punta Piedrita (East Side)	$43,072,331	$1,595,000	$1,152
Ocean Park Pocket Beach	$123,332,632	$4,568,000	$761
Punta Las Marias (west side)	$15,220,275	$564,000	$318
Total	$181,625,238	$6,727,000	$673

Table 6-2: Ocean Park FWOP Damages by Economic Reach

6.2.2 Ocean Park Damages by Damage Driving Parameter

Overall, FWOP damages in Ocean Park are largely driven by flooding (71%) with wave damages next (20%) and lastly erosion (9%). However, when we look at the planning reaches one can see an intuitive trend emerge. The Punta Piedrita reach, which has the most damages, drives the flooding risk (84%). In the Ocean Park Pocket Beach, erosion begins to play a little more of a role (11%) as one would expect. In Punta Las Marias where exposure to wave energy is greater, damages are increasingly attributed to wave impacts (50%).

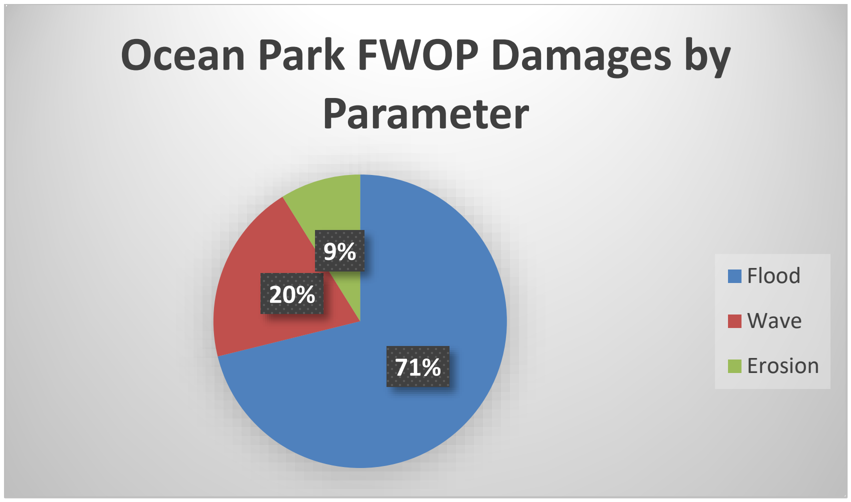


Figure 6-4: Ocean Park Overall FWOP by Parameter

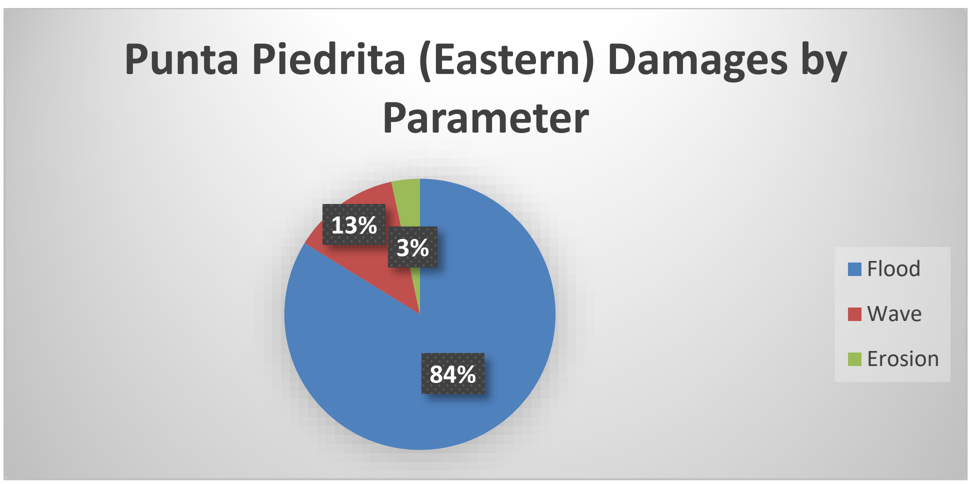


Figure 6-5: Ocean Park Portion of Punta Piedrita FWOP Damages by Parameter

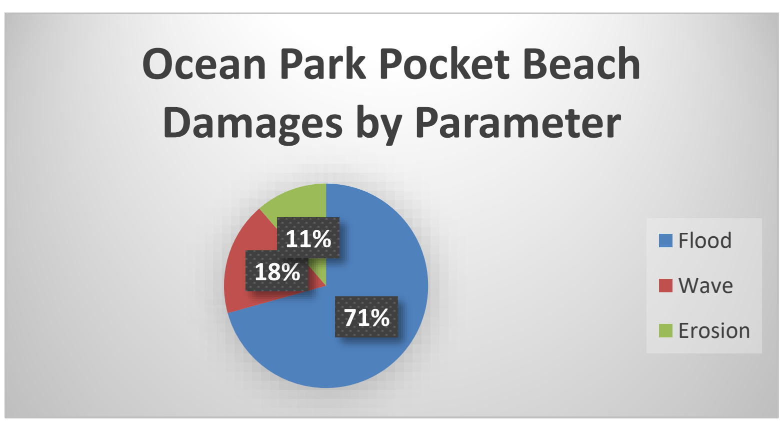


Figure 6-6: Ocean Park Pocket Beach FWOP Damages by Parameter

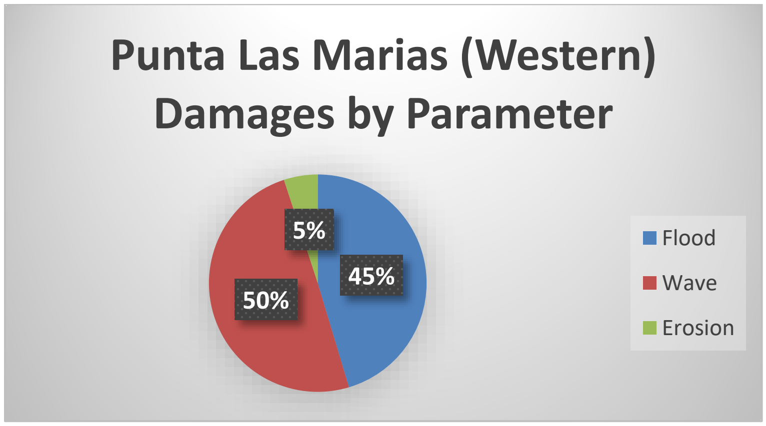


Figure 6-7: Ocean Park Portion of Punta Las Marias FWOP Damages by Parameter

6.2.3 Ocean Park Temporal Distribution of Damages

Damages are somewhat evenly distributed throughout the period of analysis. A perfectly equal distribution would see 2% of damages in every year, but the random nature of storm impacts is demonstrated by the small peaks and valleys throughout **Figure 6-8.** The damages are somewhat higher in the first several years of the analysis since structures and lots have not yet been condemned.

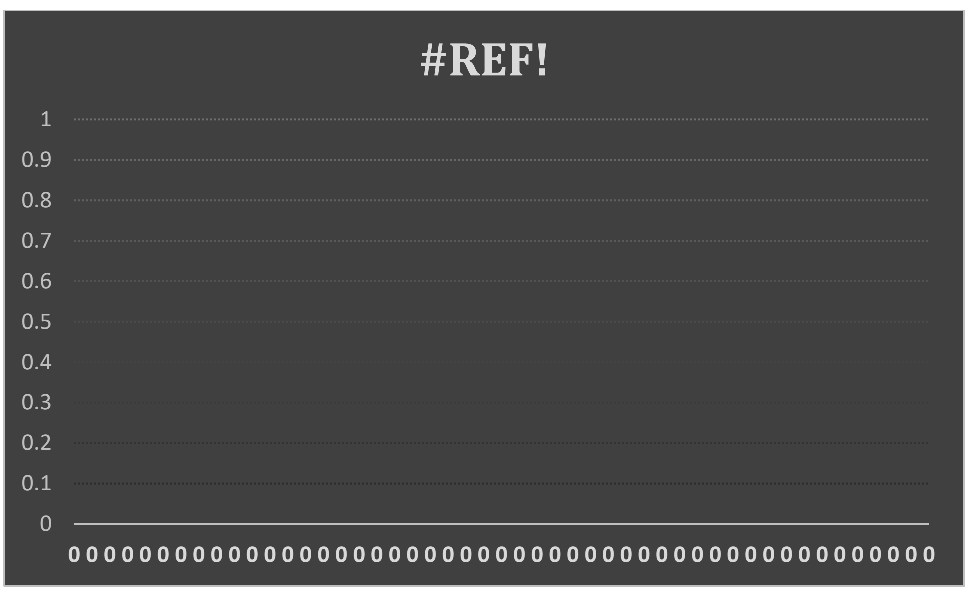


Figure 6-8: Ocean Park FWOP Damages by Time

6.2.4 Ocean Park Damages in Alternative Sea-Level-Rise Scenarios

Damages in the SLR scenarios shows similar patterns as the other focus areas. Damages only increase 13% from the baseline to the intermediate scenario, which emphasizes the high vulnerability of Ocean

Park even if the baseline SLR scenario continues into the future. Again, though, damages escalate very quickly in the high SLR scenario and shows an 120% and 94% increase from the baseline and intermediate respectively. All the San Juan focus areas demonstrate an increased vulnerability in the future if sea-level rise begins to track the USACE high curve.

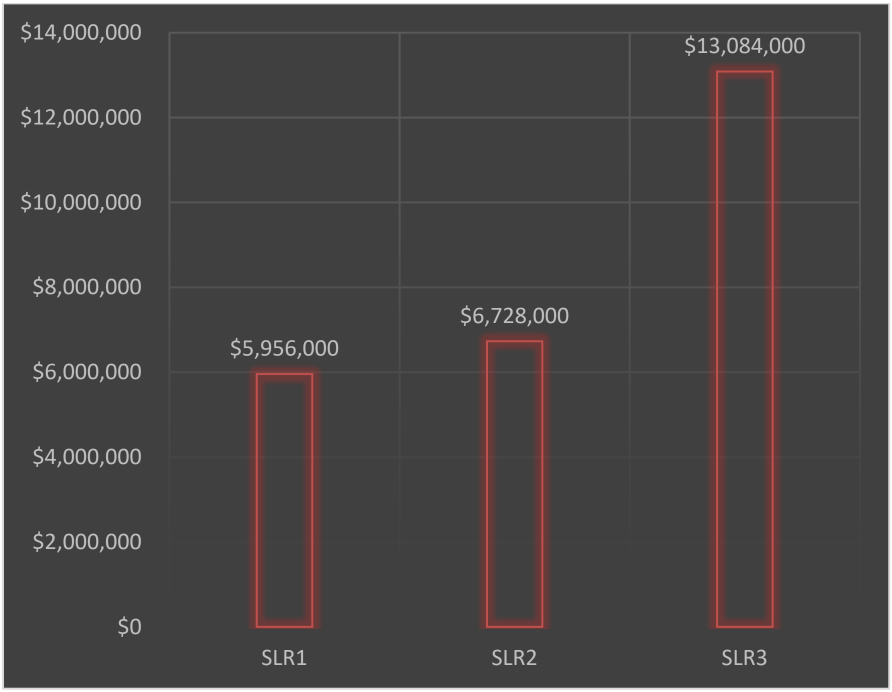


Figure 6-9: Ocean Park FWOP Damages in the Sea-Level Rise Scenarios

6.2.5 Ocean Park Clean-Up and Evacuation Cost

Ocean Park has some of the highest estimated ERC&E damages in the FWOP condition. This is again a result from the structures being mostly residential in nature which increases evacuation risk, which was estimated at $71,000 (AAEQ) in the FWOP. It is also a function of the density of structures in this focus area and each commercial and residential structure is at risk of incurring emergency clean-up costs, which is estimated at $279,000 (AAEQ) for a total combined ERC&E cost of $350,000.

6.2.6 Ocean Park Future-Without Project Conclusion

Total FWOP damages including ERC&E costs are estimated at $7,078,000.

- Ocean Park is relatively more vulnerable due to the many structures with low FFE's and a lower ground-surface elevation across the entire focus area.
- Damages are relatively evenly distributed throughout the period of analysis.
- Each of the three planning reaches has relatively high damages per linear foot and are candidates for action.
- Damages in the FWOP increase dramatically in the high SLR scenario but are also very high in the baseline condition indicating a high level of vulnerability for Ocean Park.

6.3 Isla Verde Future-Without Project Condition

Early modeling of Isla Verde indicated very low FWOP damages. As a result, the PDT concluded early on that no-action was the most likely outcome (as described in more detail in the Main Report). As a result, Isla Verde will not have as detailed a description of damages as the previous focus areas have. However, a graphs and table will be displayed so that readers and decision makers can review the low damages in this area and understand the PDT's decision to limit the modeling efforts in this focus area (i.e. no ERC&E modeling runs were performed and only the intermediate sea level scenario was run). Average FWOP damages in Isla Verde are $221,000 (AAEQ).

Planning Reach	Total PV	Total AAEQ	AAEQ Per Linear Foot
Punta Las Marias (East Side)	$1,004,879	$37,000	$134
Isla Verde Pocket Beach	$4,157,420	$154,000	$23
Punta El Medio (West Side)	$823,091	$30,000	$11
Total	**$5,985,390**	**$221,000**	**$23**

Table 6-3: Isla Verde FWOP Damages By Planning Reach

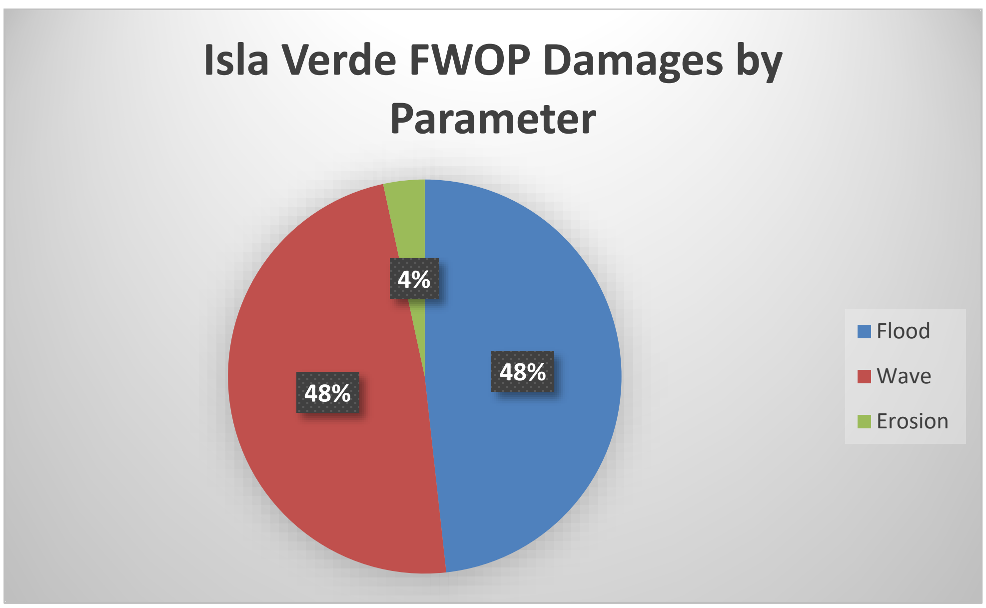


Figure 6-10: Isla Verde FWOP by Damage Driving Parameter

6.4 Land Loss Damages in the Future-Without Project by Planning Reach

Section 3.4 describes the methodology used for estimating land loss. In this section the FWOP land loss will be estimated for each applicable pocket beach since these are the only areas not currently armored or armored in the future subject to land loss. For PRCS, the only reach where land loss is a significant factor across the period of analysis is the Ocean Park Pocket Beach. Over the 50-years approximately 250,000 square feet of land is estimated to be lost in this planning reach which, in FY20 dollars is valued at approximately $17M. The average annual equivalent losses are approximately $308,000 (FY20 discount rate).

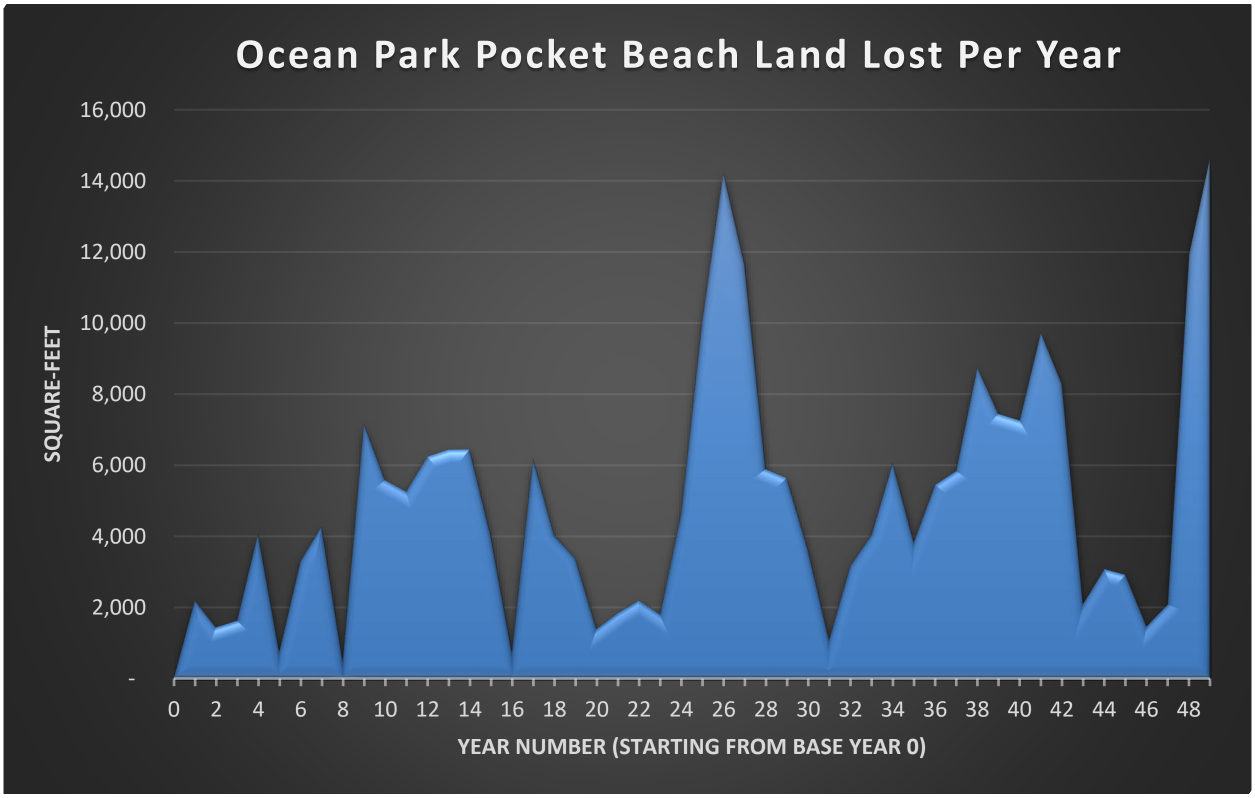


Figure 0-11: Ocean Park Pocket Beach Land Loss by Year

6.5 Summary of Future-Without Project by Planning reach

The above sections of the report detailed the FWOP damages as recorded and modeled by Beach-Fx per focus area. This section will summarize the FWOP damage estimates by planning reach since some planning reaches (Punta Piedrita, Punta Maria, and Punta El Medio) overlap model domains and need to be reported out separately for planning purposes. It is important to note, damage estimates were not double counted for structure inventory where overlap exists. The following table describes overall damages in these planning reaches and summarizes total for the entire study area, if modeled.

Planning Reach	Present Value Damages	AAEQ Damages
Rincon A	$ 3,594,600	$133,000
Rincon B	$ 33,621,000	$1,245,000
Conadado West Headland	Not Modeled	Not Modeled
Condado Pocket Beach	$ 15,512,077	$ 575,000
Punta Piedrita	$ 48,305,756	$ 1,789,000
Ocean Park Pocket Beach[11]	$ 131,655,125	$ 4,876,000
Punta Las Marias	$ 16,225,155	$ 601,000
Isla Verde Pocket Beach	$ 4,157,420	$ 154,000
Punta El Medio (West Only)[12]	$ 823,091	$ 30,000
Total	**$ 208,356,132**	**$ 7,717,000**

Table 0-4: FWOP Damages by Planning Reach

7. MEASURE SCREENING AND ALTERNATIVE DEVELOPMENT

This section of the appendix tells the story behind the evaluation and comparison of the PRCS 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.

7.1 Management Measures Considered

Management measures were identified to accomplish at least one of the planning objectives for the PRCS CSRM. Both nonstructural and structural measures were identified. The following is a summary of the management measures considered:

- **Structural Measures:**
  - S-1: Seawalls
  - S-2: Revetments
  - S-3: Beach/Dune Nourishment
  - S-4: Groins/T-Head Groins
  - S-5: Perched beach
  - S-6: Nearshore Placement
  - S-7: Breakwaters
  - S-8: Dunes and vegetation

- **Non-structural Measures:**
  - NS-1: No-Action
  - NS-2: Coastal Construction Control Line
  - NS-3: Moratorium on Construction
  - NS-4: Establish a No-Growth Program
  - NS-5: Relocation of Structures
  - NS-6: Floodproofing of Structures (Dry)
  - NS-7: Floodproofing of Structures (Wet)

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[11] Includes Land Loss
[12] The east end of Punta El Medio is part of Carolina Focus area, which was not modeled.

- NS-8: Condemnation of Structures and Land Acquisition
- NS-9: Improved Hurricane Evacuation Plan

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 prior to any full quantitative analysis. Please refer to the Main Report Section 3 for more in-depth information on the screening of measures. The following measures were carried forward into the final array of alternatives.

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. Periodic nourishment would be completed using a hydraulic dredge or truck haul to transport material from an off-shore borrow source. Dunes and vegetation was not considered in the headland areas of the San Juan focus areas due to technical feasibility issues.

Beach Nourishment: This measure includes initial construction of a beach fill and future periodic nourishments at regular intervals. Periodic nourishment of the beach would be undertaken to maintain the erosion control features within design dimensions. There were several combinations of project dimensions initially considered for beach nourishment and rough-order-of-magnitude (ROM) costs were developed for those initial dimensions in each focus area. 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 as well as hydraulic dredging. Beach nourishment was not considered in the headland areas of the San Juan focus areas due to technical feasibility issues.

Revetment: Revetments of varying crest elevations were considered in order to reduce erosion as well as flood and wave risk in the areas proposed.

Breakwaters: Breakwaters were considered in areas where wave energy, and thus risk to infrastructure from waves as described in each of the FWOP sections above, was high. Breakwaters were considered easily scalable and as a result the ROM cost for a single breakwater was used during initial screening.

7.2 Measure Combining and Alternative Screening

Costs were developed for measures in planning reaches Condado Pocket Beach, Punta Piedrita, Ocean Park Pocket Beach, and Punta Las Marias. Condado West Headland, Punta el Medio and Isla Verde Pocket Beach were screened from further analysis due to the low estimate of FWOP damages. Carolina focus area was screened based on best professional judgment and risk-informed planning (see Main Report for more details). The PDT determined that revetment in the headlands would be best from both an engineering and economic standpoint and thus only revetment was developed as a measure in the headlands (Punta Piedrita and Punta Las Marias) and was also carried forward for all areas as it was the lowest cost measure. For the two pocket beaches, Ocean Park and Condado, as well as Rincon B, several measures had costs developed and were compared to FWOP damages to begin screening in order to have a focused array of alternatives for modeling. In every planning reach the No Action alternative is carried forward as a potential recommendation. The alternatives considered in both pocket beaches and Rincon are as follows:

- Nourishment – Placement of material to form a berm and/or a dune with a range of volume. The estimated number of nourishment events is initial construction plus two periodic nourishments for Condado and Ocean Park Pocket Beach and initial plus five periodic nourishments in Rincon. Costs were generated for a relatively larger template and relatively smaller template in each of the areas[13]. The templates and number of periodic nourishments will be further refined after optimization modeling has occurred but currently only costs have been developed for these configurations and therefore will be the only ones displayed in this draft report.
- Breakwaters – A configuration of offshore breakwaters is being considered for both pocket beaches. The number of breakwaters and the length of protection provided is scalable. The current cost estimate is considered to be an aggressive level of protection (i.e. on the higher end of necessary breakwaters).
- Breakwaters and Nourishment – This measure is a combination of the above measures and is also scalable in terms of number of breakwaters, volume, and nourishment events. The costs displayed in the figures below represent the full cost of breakwaters and then a one-time nourishment event happening at the base year.

The following three figures demonstrate the potential of each of the measures in the two Pocket Beach planning areas and Rincon B. The plot compares the FWOP damages (i.e. the maximum level of storm-damage reduction benefits attainable) to the cost of each of the measures. If the cost is higher than the FWOP damages then recreation benefits will need to be required to reach unity. Any measures that are more than twice the cost of the FWOP damages will not be able, per policy, to utilize recreation benefits as part of the NED analysis and this is denoted in the figures below by the red dot on the cost bars.

[13] In the figures, the smaller template is denoted as “Nourishment50” for the SJ Pocket Beaches and “25’ Berm” for Rincon. For the larger templates it is denoted as “Nourishment50” for the SJ Pocket Beaches and “75’ Berm” for Rincon.

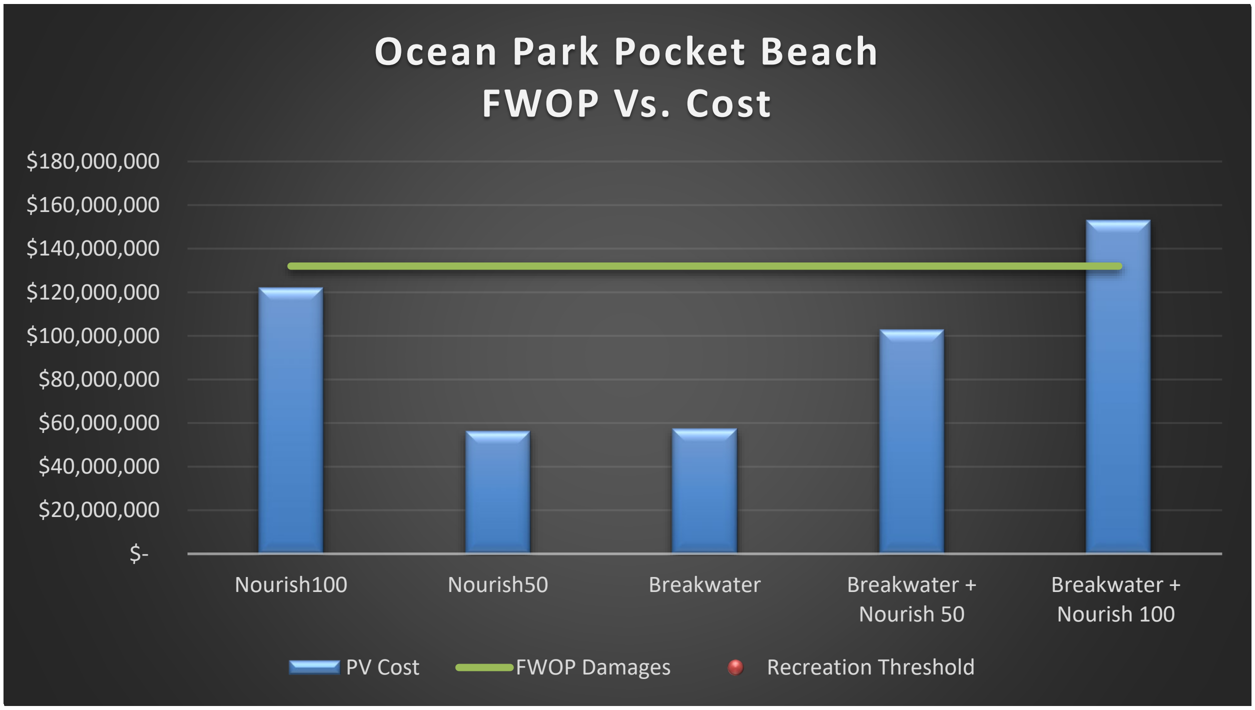

Figure 7-1: Ocean Park Measure Screening

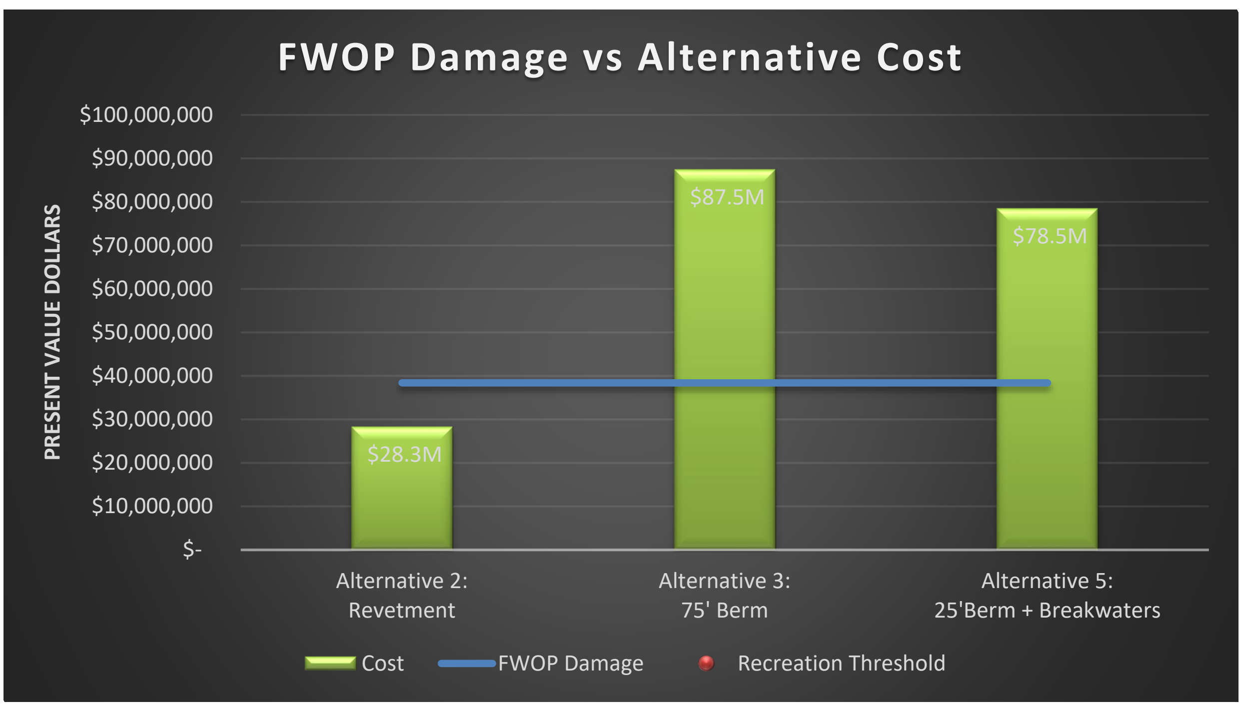

Figure 7-2: Rincon Measure Screening

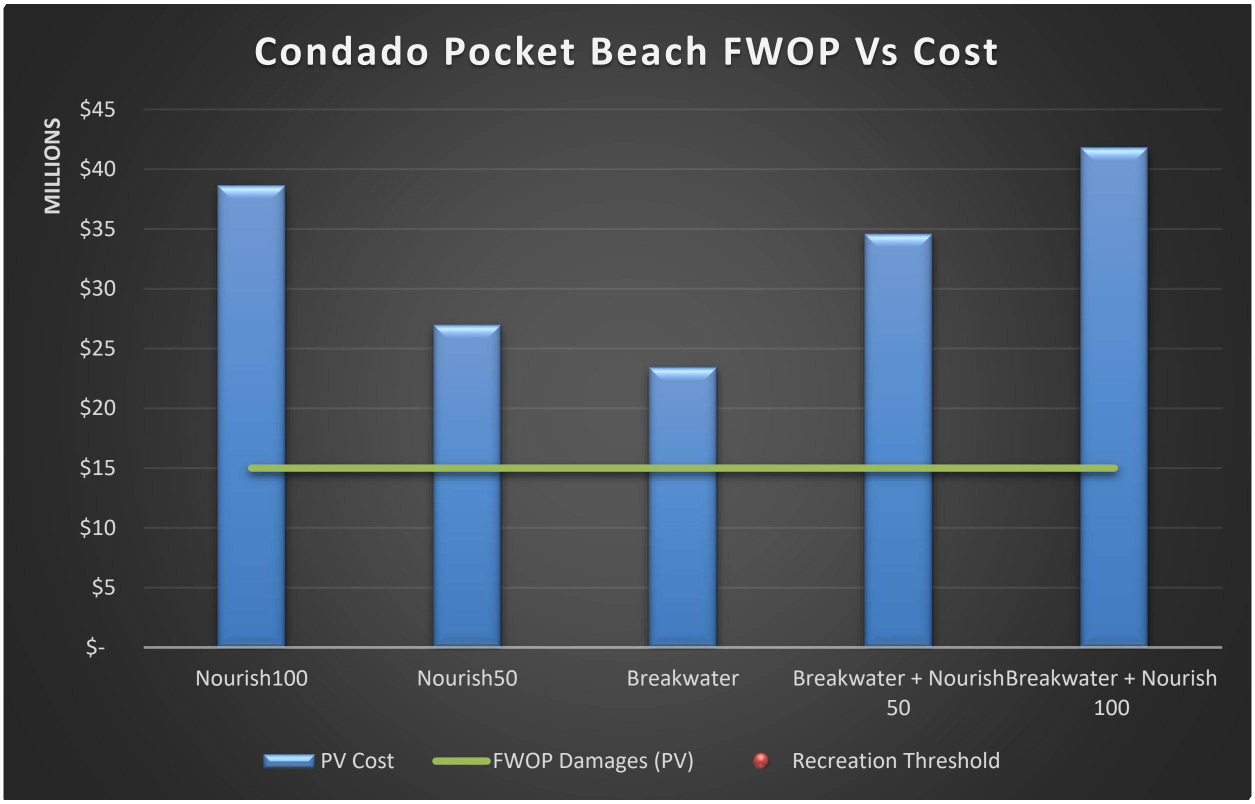

Figure 7-3: Condado Measure Screening

Based on the above information, the following decisions were made on alternatives to analyze:

- Condado West Headland – This planning reach was screened out due to the relatively low risk of damages (as estimated by original modeling). Most of the shoreline along the West Headland is already heavily armored with robust seawalls and revetments. Any additional measures in this area would likely incur large real estate cost or would likely require a volume of stone that would make action economically unjustifiable. Risks in this planning reach are relatively low overall.
- Condado Pocket Beach - It was initially assumed that Dune replenishment via truck haul was the best option for Condado Pocket beach and so templates were generated and modeled. However, as **Table 8-2** describes below, a dune template was not economically justified and had a potentially net-negative impact on recreation potential. Therefore, the PDT used the screening process demonstrated in **Figure 7-3** to determine which additional alternatives would be modeled. It was determined that the nourishment alternative would be the only additional alternative modeled based on best professional judgment that a nourishment will provide more risk reduction than breakwaters as a standalone alternative. Additionally, there is more recreation potential from a standalone nourishment than from breakwaters. Since the two alternatives are relatively similar in cost the team exercised risk-informed planning to select only

the nourishment for modeling. Therefore in Condado Pocket Beach the TSP component is beach nourishment primarily in the form of a berm[14].

- Punta Piedrita – Seawalls and revetment were considered for this rocky headland. Revetments were a less costly option and estimated to provide similar benefits to a seawall. Additionally, vertical structures are not preferred by the locals and the NFS and therefore revetment was the measure most applicable in this planning reach. It is the only alternative carried forward for modeling.
- Ocean Park Pocket Beach – The Ocean Park Pocket Beach has the most potential for a varied and optimized alternative. As a result, all nourishment and breakwater combinations will be carried forward for modeling as well as revetment.
- Punta Las Marias – The exact same selection and screening as described for Punta Piedrita is applicable for this planning reach as well. Revetments are the alternative selected for modeling. However, due to the low estimated risk from the eastern portion of Punta Las Marias, only the western portion of this planning reach is being considered for action.
- Isla Verde Pocket Beach – Damages were far lower than the cost of any potential measures. A single breakwater could potentially be placed but that single breakwater would need to prevent nearly all damages to be justifiable and it was clear that would not be the case. No further modeling will be conducted in this reach and No Action is the TSP.
- Punta El Medio – Due to low estimated risk from the western side of this reach (see Table 6-3) all measures have been screened. The eastern end, which falls within the Carolina Focus area, was never modeled. However the risk to infrastructure in the eastern area, as well as the entirety of Carolina Focus area, was qualitatively assessed and estimated to have similar low risk as the segments within Isla Verde. See the Main Report for discussions on that qualitative assessment.
- Rincon – Rincon A was screened for any additional modeling and alternative analysis due to the very low estimate of FWOP damages. For Rincon B, revetment was the only economically viable alternative. It was determined that breakwaters would not be able to be constructed as a standalone alternative and as a result the addition of nourishment made the alternative cost prohibitive. The alternative would require 100% risk reduction to bring the primary BCR to a .5, and is thus seen as a highly unlikely alternative (see **Figure 7-2**). The PDT is currently analyzing smaller configurations of breakwaters and nourishment templates to see if any combination would be worth additional modeling but that information has yet to be acquired. Therefore this alternative is still seen as a potential alternative but is extremely high risk in terms of economic justification.

7.3 Alternative Development

The above measures that made it past screening were combined to formulate an array of alternatives for modeling in each planning reach. Please review Main Report Section 3.7.2 (PRELIMINARY ARRAY OF ALTERNATIVES) for more details on alternative development. This appendix will focus more on the

[14] The majority of quantity will be used to form a berm. However, it may be necessary for some sand placement in the dune and/or to maintain the existing dune after storm damages necessitate repair. Therefore dune placement is also part of the TSP here.

alternative comparison with specific respect to the economic analysis in the following section. **Table 7-1** below summarizes the alternatives that were considered.

Alternative Number	Alternative Description	Planning Reaches Considered for Alternative
1	No Action	All
2	Revetment	All
3	Nourishment - Dune/Berm	Condado Pocket Beach, Ocean Park Pocket Beach
3a	Nourishment - Dune Only	Condado Pocket Beach
3b	Nourishment - Berm Only	Condado Pocket Beach
4	Breakwater	Ocean Park Pocket Beach, Condado Pocket Beach
5	Breakwater and Nourishment	Ocean Park Pocket Beach

Table 7-1: Focused Array of Alternatives

8. FUTURE WITH PROJECT MODELING AND ALTERNATIVE COMPARISON

Not all modeling results were completed by publication of this draft report so some alternatives carried forward for consideration do not have quantified results. Those alternatives will not have data populated in the tables and figures of this section but will be discussed qualitatively in **Section 8.1** below. Further, only the expected value of BCR and net-benefit will be described in this section whereas a probabilistic analysis of the modeled alternatives will appear in **Section 8.1.**

At this point during the plan formulation process, Alternative 2 (revetments) has been modeled in Rincon B, Punta Piedrita, Punta Las Marias (west side only), and both the Pocket Beaches of Ocean Park and Condado. Also, a specific dune-only nourishment configuration has been modeled in Condado. The remaining alternatives considered for each planning reach are currently being configured for Beach-Fx modeling. In this section, only the CSRM benefits will be compared (i.e. storm-damage reduction to infrastructure). Potential recreation benefits will be discussed below in **Section 8.3**, and ERC&E benefits will be modeled solely on the TSP. **Table 8-1 and Table 8-2** show the results from the only two alternatives modeled in the applicable Planning Reaches. Error! Reference source not found. shows the information available to date on the breakwater in Ocean Park Pocket Beach. Based on this data, revetment is potentially economically viable in Ocean Park Pocket Beach, Punta Piedrita and Punta Las

Marias (reduced)[15] and a dune-only nourishment option is unlikely justified in Condado Pocket Beach. The results of the current modeled alternatives provided insight to the PDT to formulate new potential alternatives for modeling and recommendation. As mentioned above, those alternatives are not quantified but will be discussed in the next section.

Alternative 2: Revetment						
Planning Reach	FWOP Damages	FWP Damages	Benefits	Cost	Net-Benefits	BCR
Rincon B[16]	$ 1,373,000	$ 182,000	$1,175,000	$ 1,049,000	$ 125,000	1.12
Condado Pocket Beach	$ 568,000	$ 97,000	$ 471,000	$ 814,000	$ (343,000)	0.58
Punta Piedrita	$ 1,785,000	$ 835,000	$ 950,000	$ 857,000	$ 93,000	1.11
Ocean Park Pocket Beach[16]	$ 4,876,000	$ 2,566,000	$ 2,310,000	$ 2,309,000	$ 1,000	1.0
Punta Las Marias (West)	$ 564,000	$ 27,000	$ 537,000	$ 624,000	$ (87,000)	0.86
Punta Las Marias Reduced[15] (West)	$ 524,000	$ 17,000	$ 507,000	$ 473,000	$ 34,000	1.07

Table 8-1: Alternative 2 (Revetment) Analysis for Applicable Planning Reaches

Alternative 3a: Nourishment - Dune Only						
Planning Reach	FWOP	FWP	Benefits	Cost	Net-Benefits	BCR
Condado Pocket Beach	$ 568,000	$ 254,000	$ 314,000	$ 828,000	$ (514,000)	0.38

Table 8-2: Alternative 3a (Dune Nourishment) Analysis for Condado Pocket Beach

8.1 Tentatively Selected Plan

Though not all FWP modeling is complete, a TSP has been selected for each planning reach.

- Rincon A – No action (Alt 1)
- Rincon B – Revetment (Alt 2)
- Condado West Headland – No Action (Alt 1)
- Condado Pocket Beach – Beach Nourishment (Alt 3)
- Punta Piedrita – Revetment (Alt 1)
- Ocean Park Pocket Beach – Beach Nourishment and Breakwater (Alt 5)
- Punta Las Marias (West) – Revetment (Alt 2)
- Punta Las Marias (East) – No Action (Alt 1)
- Isla Verde Pocket Beach – No Action (Alt 1)
- Punta El Medio – No Action (Alt 1)
- Carolina – No Action (Alt 1)

[15] The revetment length was reduced from modeling reach R01-R03 to just R01-R02. Reach R03 will be analyzed alongside the Ocean Park Pocket Beach alternatives.
[16] Includes Land Loss

The following section will briefly discuss the rationale for choosing the TSP as well as the risk and uncertainty with respect to economic justification.

8.2 Risk and Uncertainty for the Tentatively Selected Plan

For those TSP components which have been modeled a probabilistic analysis of a BCR greater than 1.0 will be described, consistent with section 8-d of ER 1105-2-101 ("Risk Assessment for Flood Risk Management Studies"). However, as mentioned above there are alternatives that have not been fully quantified but are currently part of the TSP. Though the results are not quantified, risks associated with choosing those actions, or not choosing those actions, can be described qualitatively since the team has put extensive thought into their efficacy based on best professional judgment. This section of the economics appendix will explore the risks and uncertainties surrounding those potential alternatives as they pertain to economic justification and describe them by each planning reach. **Table 8-3** summarizes the costs, benefits, and uncertainties of the TSP while a more in-depth analysis on the risks and uncertainties each alternative has with respect to recommending them for action (i.e. plan selection) can be found in the Main Report.

Planning Reach Alternative	Benefits (Thousands AAEQ)	Cost (Thousands AAEQ)	Net Benefits (Thousands AAEQ)	BCR
Condado pocket beach Alt – 3 Beach nourishment	Requires 88% damage reduction to get to a .5 BCR	$999,000	Likely Negative Without Recreation Benefits	High Uncertainty Likely <1.0
Ocean Park Pocket Beach Alt – 5 Beach nourishment plus breakwaters	Requires 40% damage reduction to get to a .5 BCR	$3,812,000	A fair chance of positive net-benefits on primary benefits alone; highly probable with recreation benefits added.	High Confidence, Likely >1.0
Punta Piedrita Headland Alt – 2 Revetment	$950	$857	$93	1.11
Punta Las Marias Headland Alt – 2 Revetment	$507	$473	$34	1.07
Rincon Alt – 2 Revetment	$1,175,000	$ 1,049,000	$ 125,000	1.12

Table 8-3: Benefits, Cost, and Uncertainty for Tentatively Selected Plan

8.2.1 Rincon B

The only FWP modeling completed in Rincon was Alt 2, revetment, and is the TSP. On average the TSP is estimated to net $125,000 in storm-damage reduction benefits alone. There are no recreation benefits anticipated for a revetment as shore fishing is not a major draw to the Rincon area and the vast majority of the reveted area will not be accessible to the public.

The other main alternative being considered in Rincon B is a combination of breakwaters and nourishment (Alt 5). This alternative has an extremely unlikely chance of being economically justified. Costs were developed for this alternative and are estimated at ~$2.8M (AAEQ) and FWOP damages are only ~$1.4M (AAEQ) (see **Figure 7-2** for graphical display). The implications are that even if 100% of estimated risks from storm damages are reduced the BCR would be 0.5. At this point, the alternative would be at risk of not being able to utilize recreation benefits, per USACE policy[17]. The PDT is currently evaluating this alternative in order to determine if a reasonable reduction in size and scale of the alternative (and thus cost) can be achieved while still maintaining storm risk reduction at an acceptable level. If a reduction in cost can be achieved with a primary (i.e. storm damage risk reduction) BCR greater than 0.5, recreation benefits can be utilized in the benefit analysis. The change in value between FWOP and FWP of recreation per visitor with a nourishment alternative is anticipated to be high in this planning reach. However, visitation is, on average over the period of analysis, estimated to be only 200,000 visitors annually, so the impact of recreation may not be as great as more heavily visited regions. There is much uncertainty surrounding the damage reduction potential of Alt 5 in this planning reach but the numbers seem to be clear that economic justification would be very difficult to achieve. Further, the revetment cost is ~$1.1M (AAEQ) and provides damage reduction of over 95%. In order for Alt 5 to become the NED plan it would need to provide a commensurate level of risk reduction as revetment and the costs would need to be reduced by 61%. Therefore, it is pretty clear that revetment will remain the NED plan and is the rationale for the PDT's identification of Alt 2 as the TSP.

8.2.2 Condado Pocket Beach

Based on the above results (**Table 8-2**) showing that a Dune Only alternative (Alt 3a) is not economically justified, other alternatives need to be explored. It is not that the dune is completely ineffective at preventing damage, it is estimated to prevent a little over half of FWOP damages, but rather the high cost prevents economic justification. Additionally, the Alt 3a will potentially reduce recreation benefits (or at best be net neutral) by reducing the amount of recreational space (i.e. berm) available for visitors[18]. As a result, the PDT is explored alternatives 3b, 4, and 5 and costs were developed. The

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[17] ER 1105-2-100 "Under current policy, recreation must be incidental in the formulation process and may not be more than fifty percent of the total benefits required for justification. If the criterion for participation is met, then all recreation benefits are included in the benefit to cost analysis"

[18] A recreation analysis was not done on this specific alternative as it had a BCR below the point at which policy allows recreation benefits to be added to a CSRM alternative and because the best case scenario of a net-neutral impact rendered the recreation analysis unnecessary.

relatively low estimate of FWOP damages overall limited the magnitude of possible alternatives in this area. The risks of each alternative, and the PDT's recommendation, are outlined as follows:

- Berm Only (Alt 3b), Current TSP – The upside to a berm only option is it may allow for greater recreation benefits which, though not a basis for plan formulation, increases NED. There is likely to be high potential for recreation benefits in this area as beach visitation averages ~362,000 visitors annually. There is, however, high risk that this alternative will not reach the needed .5 BCR in order to utilize recreation. The current cost estimate of a nourishment, $999,000 (AAEQ), would necessitate nearly 90% storm-damage risk reduction in order to achieve a .5 BCR. The PDT is currently modeling this alternative in order to optimize the configuration to achieve maximum net-benefits. This alternative is currently the TSP in Condado Pocket Beach.
- Breakwater (Alt 4) – Due to the enclosed nature of the Condado Pocket Beach, a small breakwater configuration may be a relatively low cost way of preventing a large portion of damages. Erosion damages can be minimized since, historically, breakwaters have maintained sand in the system as well as minimizing risk to infrastructure from wave energy. However, the residual damages from flooding may require an additional measure to improve upon the risk reduction objective. Again, breakwaters will maintain, and possibly improve upon recreation by maintaining the recreation space and providing an increased potential in snorkeling and other wildlife viewing opportunities but the increase in recreation value is limited compared to a nourishment alternative. The high cost of breakwaters relative to FWOP damages, the uncertainty surrounding the damage reduction potential, and the limited recreation benefits are all reasons the PDT chose not to recommend this alternative as the TSP.
- Breakwater & Nourishment (Alt 5) – As mentioned in Alt 4, breakwaters alone may not sufficiently provide damage reduction. A nourishment activity may provide additional damage reduction by increasing the amount of sand in the system and reducing the risk of damages from all three primary drivers. Further, a nourishment activity could be postponed into the future when modeling indicates a significant amount of sand has been lost from the system. This delayed approach would discount the cost of the nourishment activity. Though, similarly the benefits derived from this nourishment would be discounted as well. There is a risk of this alternative being cost ineffective as compared to Alt 3b or 4. Additionally, based on current designs the cost of this alternative precludes the ability to claim recreation benefits and is extremely unlikely to achieve economic justification. Even after optimizing it is unlikely to be the NED plan and was not recommended as the TSP.

8.2.3 Ocean Park Pocket Beach

The only alternative that has been modeled in this planning reach was a revetment which had a 1.0 BCR with net-benefits of $1,000 on primary benefits alone. If recreation were to be factored in, the net-benefits would likely be further reduced since hard structures accelerate beach losses and would bring about the total loss of recreation space quicker than in the FWOP. There may be some fishing recreation benefits from the revetment but these would more than likely be offset by the loss in beach visitation. With that said, revetment is extremely unlikely to be the recommended action. The team is further refining alternatives for modeling to determine what the recommended action will be. The following alternatives represent what the team is considering as the recommended action and is very similar to Condado Pocket Beach. However, a key distinction between Condado Pocket Beach and Ocean Park

Pockt Beach is that the majority of alternatives are highly likely to be economically justified (review Figure 7-1). The risk and uncertainty for this planning reach is being sure the TSP, Alt 5, is the optimum alternative and the PDT is working to quantify that risk and uncertainty. The following is a qualitative summary of the risks and uncertainties that the PDT considered before recommended Alt 5 as the TSP.

- Nourishment Alternative (Alt 3) – This alternative includes some combination of berm and/or dune placement. There are some risks and significant uncertainty to this alternative, but it is highly likely that it would be economically justifiable. First, the quantity required may be significant relative to the length of shoreline, anywhere from 300,000 – 800,000 CY of initial placement. Additionally, it is unclear whether or not dredging will be possible or if the quantity will require truck hauling or some combination of the two. If dredging is not available and truck haul is required the quantity could cause this alternative to be prohibitively costly. The dune and berm combination will most likely be a viable option to reduce the risk from coastal storms. This planning reach has around 90% damages from flooding (~70%) and wave (~20%) and the remaining 10% from erosion. Based on these damage driving parameters it seems unlikely a nourishment action would be without a dune, which would increase the quantity needed as well as increase the potential nourishment interval if the dune is to be maintained. The absence of any hard structures to maintain sand in the system and reduce wave energy could mean that infrastructure is more at-risk in between nourishment cycles and that a higher quantity would be necessary achieve risk reduction.
- Breakwaters (Alt 4) – The risks of a breakwater only alternative are similar to those outlined in Condado Pocket Beach. Based on those risks the PDT concluded that this alternative is unlikely to optimize risk reduction, especially in higher sea-level rise scenarios since the efficacy of a breakwater, ceteris paribus, is reduced when ocean waters rise.
- Breakwaters and Nourishment (Alt 5), Current TSP – A nourishment event would provide additional protection from flood risks where breakwaters are lacking and also provide adaptability if sea levels rise. Additionally, it would increase the amount of sand in the system and further reduce the risk of damages from erosion. The combination of breakwaters and nourishment would certainly provide an enhanced level of risk reduction, but it is unclear if adding either measure to the other will provide a commensurate increase in benefits (i.e. high risk to incremental justification). However, the adaptability of nourishment when paired with breakwaters and the potential for optimization within this alternative lead the PDT to recommend it for TSP. This alternative is very low risk with respect to economic justification.

8.2.4 Punta Piedrita

Currently the only alternatives being considered in Punta Piedrita are revetment and the no action alternative. Revetment has been modeled and the average BCR of 1.12 is explained in **Table 8-1.** In this section the probabilistic results of positive net-benefits (i.e. a BCR greater than 1.0) will be described. FWP modeling consisted of 50 iterations and the probability of positive net-benefits will be based on this number of iterations. The cost of revetment was held constant through each of the 50 iterations since the contingency applied serves as a measure of uncertainty and will be refined once final cost certification is conducted. Each iteration of FWOP and FWP damages was then compared and the primary benefits of each iteration subtracted from the cost of the revetment. The minimum net-benefits achieved from revetment in this study reach is estimated at $(31,000) AAEQ while the maximum is estimated at $34,000. Only 22% of all iterations are estimated to have negative net-benefits and a plurality of iterations are anticipated to have slightly (~+$10,000 AAEQ) positive net-benefits. Around one-third of all iterations have net-benefits greater than $10,000. In other words, Punta Piedrita has a distribution of net-benefits that skews positive as demonstrated by **Figure 8-1.** It should be noted that around 22% of all iterations are estimated to be near net-neutral which indicates a high level of sensitivity to any upward or downward fluctuations in cost or benefits.

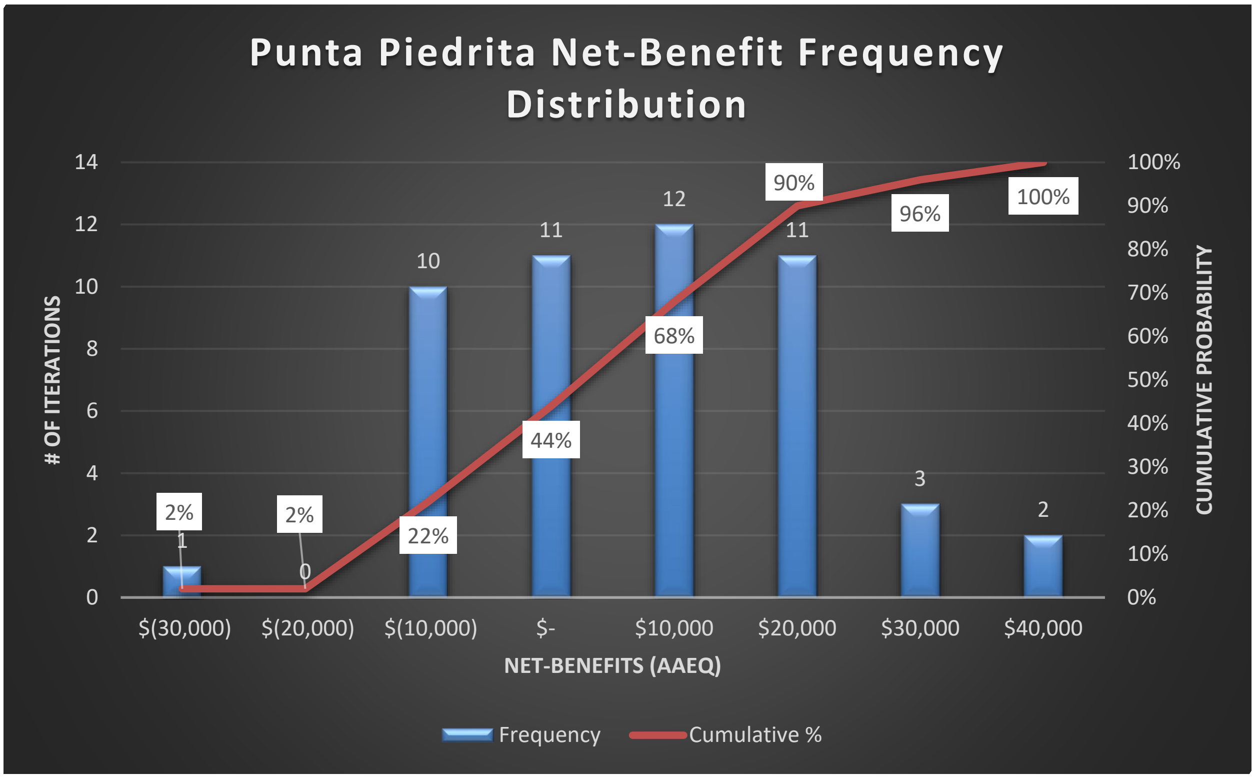
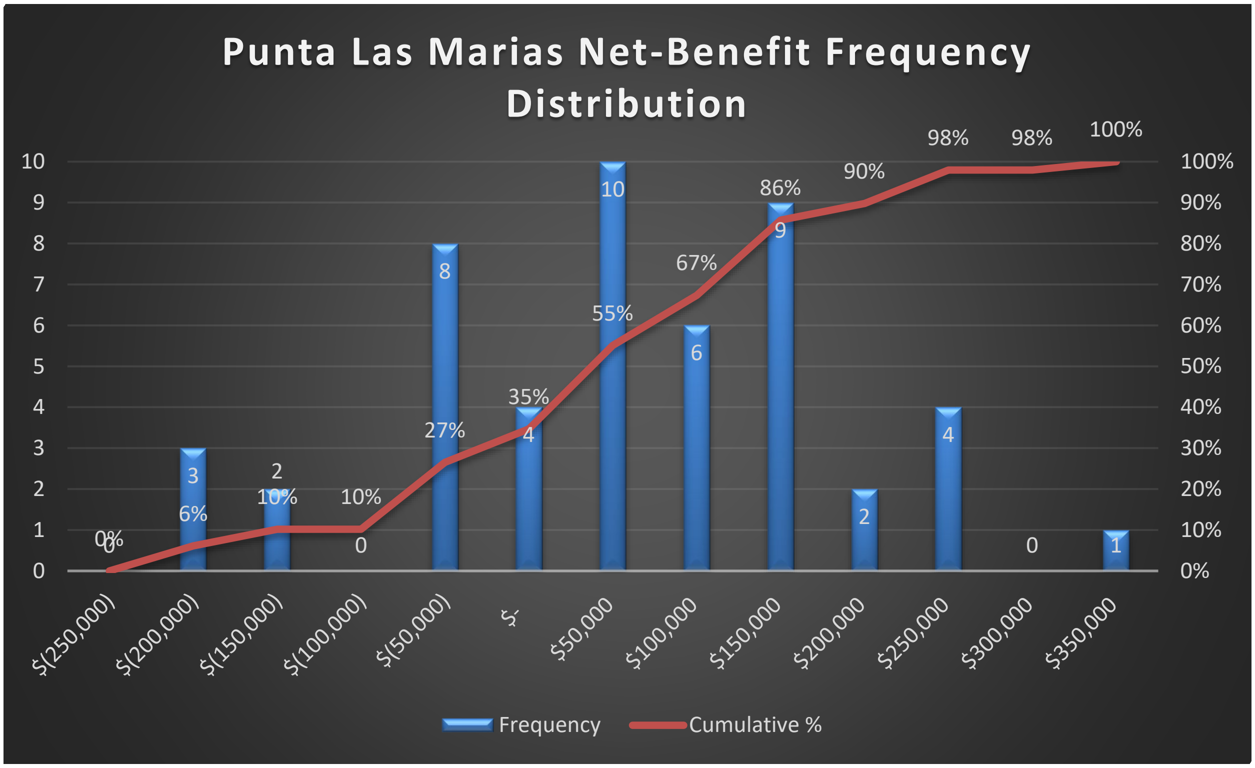


Figure 8-1: Punta Piedrita Net-Benefit Frequency Distribution

8.2.5 Punta Las Marias West

On average Punta Las Marias has a BCR of 1.07 with net-benefits of $34,000 AAEQ. Using the same process for Punta Piedrita the following describes the net-benefit frequency distribution for Punta Las Marias West. Minimum AAEQ net-benefits are $(241,000) and maximum $337,000.



8.3 Recreation Benefits

A full recreation analysis for the PRCS CSRM will not be conducted until an alternative has been selected and recommended for action. However, in this section the methodology, Unit Day Value (UDV), will be described and an estimate of recreation benefits in the FWOP condition will be documented for each planning reach. The recreation analysis will be updated prior to final reporting as there is currently a full recreation survey underway to utilize the contingent value methodology (CVM). The survey and CVM, conducted by Dr. Craig Landry, professor of agricultural and applied economics at the University of Georgia, will be a more comprehensive and higher resolution recreation analysis. The UDV methodology will be used as a placeholder valuation until the CVM results are obtained.

8.3.1 Unit Day Value Methodology

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 be included in total project benefits so long as primary benefits (i.e. CSRM and land loss benefits) constitute 51% of the benefits required for economic justification. Recreation benefits represent a vital component of a CSRM project and access for the public to use and recreate on the beach is the foundation for federal interest in the project. Though recreation cannot be used for plan formulation these benefits play a significant role in increasing net-benefits and contributing to NED.

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 applicable to PRCS, provided by USACE Economic Guidance Memo #20-03, *Unit Day Values for Recreation*, FY 2020, are presented in **Table 8-4.** Linear interpolation was used to estimate the dollar value of point scores between ranges.

Point Values	General Recreation Values	General Fishing and Hunting Values
0	$4.21	$6.06
10	$5.00	$6.85
20	$5.53	$7.37
30	$6.32	$8.16
40	$7.90	$8.95
50	$8.95	$9.74
60	$9.74	$10.80
70	$10.27	$11.32
80	$11.32	$12.11
90	$12.11	$12.38
100	$12.64	$12.64

Table 8-4: FY20 Unit Day Value Point to Dollar Conversion

8.3.2 Future-Without Project Recreation Estimate

The first step in estimating the benefit from recreation is to estimate visitation to the specific planning reaches.

For Rincon, the complete loss of sandy beach in Rincon B means there are no visitor estimates and the recreation benefit in the FWOP condition is $0.

For Condado Pocket Beach, hotel occupancy data[19] was combined with a 2017 visitor profile report "Perfil de los Vistantes" developed by the Junta de Planificacion which estimated that 39% of visitors to Puerto Rico engaged in beach activities. Hotel occupancy data was then multiplied by 39% to estimate number of annual visitors to Condado Pocket Beach. For Ocean Park Pocket Beach, a similar approach was used but since there are relatively few hotels and many more residential structures, visitation was increased by the population of the planning reach using the census tract data described in **Section 2.1.1** above. **Table 8-5** shows visitor estimates by decade for the three focus areas.

[19] Hotel occupancy data was used since the majority of occupancy types in the Condado Pocket Beach planning reach are hotels.

Year	Rincon	Ocean Park	Condado
2030	110,931	105,358	311,484
2040	140,346	106,097	332,242
2050	177,562	106,885	354,385
2060	224,647	107,726	378,001
2070	284,217	108,623	403,192

Table 8-5: Visitation Estimates By Focus Area

Following visitation estimation it is required to assign a UDV point score to the planning reaches in the FWOP. For the majority of model reaches within the sandy pocket beaches the berm width maintains sufficient carrying capacity throughout the period of analysis to support recreation and overall the beach in the planning reach has excess carrying capacity based on the estimated visitation. However, the quality of the recreation is diminished over time by repeated exposure to coastal storms. 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 and a comparison to the criteria outlined in USACE Economic Guidance Memo #20-03 (Table 1, Guidelines for Assigning Points for General Recreation) and then are converted to willingness-to-pay (WTP) dollar values as described in **Table 8-4.** WTP scores for Ocean Park Pocket Beach and Condado Pocket Beach are described in **Table 8-6.** Multiplying the annual visitation by the WTP values estimated by the UDV methodology the Condado Pocket Beach and Ocean Park Pocket Beach have an estimated recreation value of $109.4M and $32.6M (FY20 price level) respectively from 2028-2077. Amortized over the period of analysis using the FY20 discount rate of 2.75% you get an average annual recreation benefit in the FWOP of $746,000 and $269,000. Upon plan recommendation, this recreation benefit will be compared to the recreation benefit provided the plan and will constitute recreation benefits.

Year	Ocean Park Pocket Beach WTP (FY20)	Condado Pocket Beach WTP (FY20)
2028	$ 6.24	$6.64
2038	$ 6.16	$6.24
2048	$ 6.08	$6.00
2058	$ 6.00	$5.85
2068	$ 5.93	$5.69

Table 8-6: Ocean Park and Condado Pocket Beach Willingness-to-Pay Estimate (FWOP)

9. LIFE LOSS

In the absence of federal action the population of the study area will remain at risk from coastal storms. Storm surge from hurricanes are some of the most deadly phenomenon with respect to natural disasters and in the United States there have been over 1,900 fatalities from hurricanes since the year 2000 (see **Table 9-1).** The risk to life-loss is estimated to be reduced with all measures and alternatives proposed by the PRCS PDT. A quantitative approach to estimating life loss has not been conducted for PRCS but will be described qualitatively on whatever the final recommended action will be. The reason a quantitative approach has not been conducted is multi-fold and as follows:

- The measures/alternatives under consideration for PRCS will not induce life-loss risk. In certain studies considering particular alternatives (e.g. a dam or major reservoir impoundment structure) it is not uncommon for life-loss risks to be increased upon design failure. However, in a coastal environment where revetments, breakwaters, beach nourishment, etc. are being considered to reduce the risks from coastal storms there is no increase in life-loss risk but rather a decrease in life-loss risk.
- A primary component of CSRM analysis is ranking alternatives with respect to reduction in direct economic damages (i.e. NED analysis). Since the main drivers of risk to both life and property are storm surge and inundation from coastal storms, and no alternatives considered will induce life loss risk, the NED analysis is assumed to be forward compatible with a life loss risk estimation. That is, the plan which minimizes economic damages to structures will also likely minimize the risk of life loss.
- The USACE certified model for CSRM studies is Beach-Fx and this model lacks the functionality to estimate life loss. A separate model could be designed, approved for single use, and applied to all modeled areas within the PRCS but this would involve additional resources not currently available under the 3x3 paradigm. Therefore, a qualitative approach must be undertaken using RIDM.
- Life-loss is not estimated to be a large factor in plan selection. Though it is possible that some measures/alternatives may have incremental changes in the risk to life-loss these incremental variations are exceedingly difficult to quantify and are estimated to be extremely minor. For example, the difference in risk to life-loss between a berm extension of 40' versus a berm extension of 100' versus a revetment is unlikely to drive the plan selection and recommendation and is unlikely to be a very large difference.
- A non-structural measure recommending the local improvement of evacuation route planning and notification will accompany any alternative recommended by the study team. An improved local plan for evacuation will have an outsized role in reducing the risk of life-loss versus any structural measure.

Year	Total hurricanes (1)	Made landfall as hurricane in the U.S.	Deaths (2)
2000	8	0	4
2005	15	7	1,518
2006	5	0	0
2007	6	1	1

2008	8	4 (3)	41
2009	3	1 (4)	6
2010	12	0	11
2011	7	1	44
2012	10	1 (5)	83
2013	2	0	1
2014	6	1	2
2015	4	0	3
2016	7	3	36
2017	10	4	147
2018	8	2	48
2019	6	2	15 (6)

(1) Atlantic Basin.
(2) Includes fatalities from high winds of less than hurricane force from tropical storms.
(3) Includes one hurricane (Hanna) which made landfall as a tropical storm.
(4) Hurricane Ida, which made landfall as a tropical storm.
(5) Excludes Hurricane Sandy which made landfall as a post-tropical storm.
(6) All fatalities in 2019 are from storms that did not make landfall in the United States.
Source: Insurance Information Institute

Table 9-1: US Fatalities from Hurricanes 2000-2019

When a particular alternative is recommended, that alternative will be qualitatively compared to the FWOP condition in terms of life loss.

10. REGIONAL ECONOMIC DEVELOPMENT

When the economic activity lost in the study area can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts on the employment, income, and output of the regional economy are considered part of the Regional Economic Development (RED) account. The input-output macroeconomic model RECONS will be used to address the impacts of the construction spending only associated with the recommended alternative once that alternative has been identified. RECONS is the USACE certified model which measures the direct public investment (i.e. project-specific federal and non-federal construction expenditures) to estimate new levels of sales, value added, employment, and income for each industry impacted by the public investment. There are some shortcomings in using RECONS in the fact that, since investment spending is the input, quantification of RED *necessarily* increases as project costs increase. In CSRM projects this can be a particular drawback. For example, with beach nourishment alternatives it is dubious that the extra expenditure to go from, say, a 25’ berm to a 100’ berm will bestow the regional economy with vastly greater benefits but RECONS will quantify this as the case since the cost of a 100’ berm will be far greater than a 25’ berm, all else equal. Additionally, RECONS does not quantify the largest impact to a regional economy from coastal storm risks which is the high potential for economic disruption associated with natural disasters in the absence of a project and the temporal importance these disruptions have on output. A more effective analysis of impacts to RED would be a model that takes into account the duration and extent to which productive capacity is altered due to capital losses. However, we can again assume that the NED analysis, which ranks alternatives based on their effectiveness in reducing direct losses (i.e. risk to structures based on environmental forcing from natural disasters), is forward compatible with RED impacts. That is, the alternative which best reduces the risk of direct losses is also likely the alternative that reduces impacts to RED. This is further proved with the findings that total economic losses increase nonlinearly with respect to direct losses (Hallegate, 2008). Therefore alternatives with the highest residual risk of direct damages will also have the highest residual risk to the regional economy.

This study's RED analysis, using RECONS, will be conducted alongside final FWP modeling and will be focused on the NED/TSP.

11. CONCLUSION

The coastlines of San Juan and Rincon continue to face high levels of risk from coastal storms and environmental forcing and this risk will only increase in the future. The PRCS PDT have identified and preliminarily assessed many viable alternatives to reduce the risk to life and infrastructure in the study area outlined above. Though quantification of all the NED and RED benefits is still ongoing, the TSP is considered to be a robust and effective proposal for risk reduction. The TSP is effective, efficient, acceptable and complete. It provides enhanced life safety and positive economic benefits to the nation. The PRCS PDT will continue to optimize the proposed solutions in order to provide the public with the best available alternative.