MIAMI-DADE COUNTY, FLORIDA
COASTAL STORM RISK MANAGEMENT

MAIN AND KEY BISCAYNE SEGMENTS

Integrated Feasibility Study and Environmental Assessment

APPENDIX B
Economic Assessment

November 2021

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

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1 Introduction

Structures and infrastructure along the Miami-Dade County, Florida shoreline are vulnerable to damage from erosion, flooding, and waves caused by coastal storms. This study investigates alternatives for a plan that addresses these vulnerabilities, as well as provides incidental opportunities for maintaining recreation and habitat along the shoreline of Miami-Dade County, Florida. This study only evaluates the Atlantic Ocean shoreline. It does not evaluate in detail the coastal storm risks of the interior back bay shorelines of the barrier islands or the Miami-Dade County mainland.

It has been determined that there is Federal interest in a project for CSRM purposes along portions of the Atlantic Ocean shoreline of Miami-Dade County, Florida, based on the USACE Planning Process.

1.1 Study Location

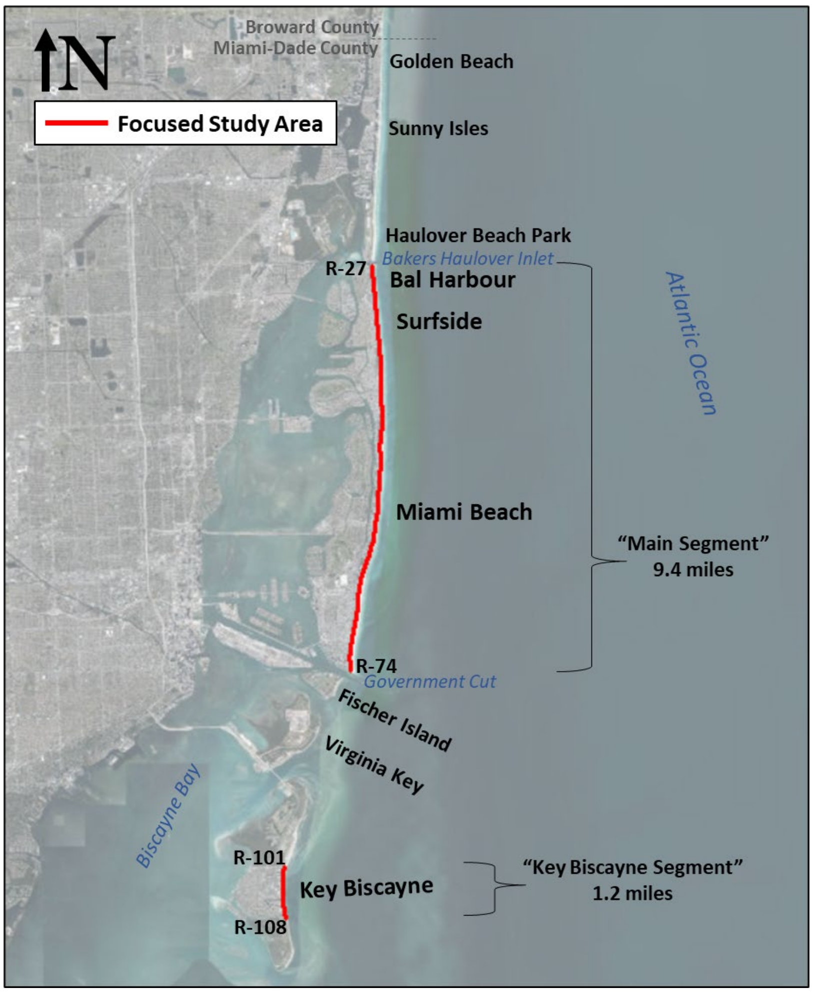


Figure 1: Study Location

Miami-Dade County is located along the southeast coast of Florida between Broward County (north of Dade) and Monroe County (south of Dade), and contains the city of Miami. The Miami-Dade County Atlantic Ocean shoreline extends along several barrier island segments separated from the mainland by Biscayne Bay. The barrier islands vary in width from about 0.2 to 1.5 miles, with an average width of approximately 0.5 miles. Elevations along the entire coastal region (and much of the mainland) are generally low, whereas elevations along the barrier islands are generally the highest along the Atlantic Ocean shorefront, and slope gradually downward toward the bay.

1.2 Problems & Opportunities

Existing problems in the study area include:

- Storm damages due to erosion, inundation, and waves threaten structures and infrastructure
- Loss of natural habitat due to beach erosion
- Loss of recreational opportunities due to beach erosion
- Loss of national and regional income associated with tourism due to beach erosion

Erosion, wave attack, and inundation are all problems in the study area. As erosion causes the loss of the protective beach and dunes, structures and infrastructure become more vulnerable to damages being from wave attack and inundation. Persistent erosion in the absence of beach nourishment would also reduce the habitat available for shorebirds and sea turtles and would threaten recreational opportunities. The study area experiences some natural beach recovery following storm events, but the long-term trend throughout most of the focused study area is erosional.

A Federal beach nourishment project for the purposes of beach erosion control and hurricane storm surge protection has existed in the Main Segment since 1975, protecting structures and infrastructure. When the existing Federal project reaches the end of its period of Federal participation, the project area is expected to remain in an erosive state where properties are susceptible to storm damages and individual property owners will likely seek to protect their property using erosion control measures such as seawalls on a property-by-property basis. As these hard structures limit or eliminate the natural interaction where dunes feed sand to the eroded beach during storm events, limiting this natural protective function makes infrastructure and the environment adjacent to protected properties more susceptible to storm damages. Sea level change will continue to exacerbate the potential for erosion, inundation, and wave damages in the study area.

Opportunities are positive conditions in the study area that may result from implementation of a Federal project such as:

- Reduce economic loss due to coastal storm damages
- Maintain coastal habitat, the character of coastal beach communities, and other cultural resources
- Maintain existing recreation opportunities (beach and nearshore)
- Support the local and national tourism industry through the maintenance of stable beaches and healthy coastal ecosystems
- Implement a regional approach to sediment management by utilizing material from nearby accretional areas as a sand source
- Increase community understanding of coastal resilience
- Maintain current life safety or reduce risk to life safety

There is an opportunity to reduce storm damage to structures and infrastructure by implementing measures which control development in the project area and/or by engineering features which protect infrastructure. These are “management measures” and will be discussed in detail later in this chapter. There is also the opportunity to maintain recreational opportunities that the current beach and dune systems provide in all reaches such as beach access, surfing, fishing, and wildlife viewing.

Coincident with some management measures like beach nourishment and dune creation are opportunities to protect and enhance habitat for sea turtles, etc., as well as protecting or enhancing the beach/dune interaction. In areas where infrastructure has prevented landward migration of coastal beaches and dunes, engineered beaches provide habitat for protected species such as sea turtles and shorebirds that utilize these habitats for nesting and foraging. Management measures requiring sand for construction provide an opportunity to implement a Regional Sediment Management (RSM) strategy where maintenance of inlets can be combined with a Federal CSRM project to realize significant cost savings to the Federal government and to the non-federal project sponsors.

1.3 Objectives & Constraints

The Federal objective is to contribute to national economic development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. The planning objectives are:

- Reduce coastal storm damage to structures and infrastructure within the study area for the 50-year planning horizon.
- Maintain environmental quality for human and natural use within the study area through the 50-year planning horizon.
- Maintain existing recreation (beach and nearshore) and tourism opportunities within the study area for economic benefit over the 50-year planning horizon.

The planning constraints for this study area are to avoid conflict with Federal regulations, as stated in Federal law, USACE regulations, and executive orders. There are no local constraints on plan formulation.

1.4 Metrics, Models, & Validation

1.4.1 Metrics

Section provides discussion on the types of metrics that are the basis for the economic benefit estimation. As of now this section is split up into three of the four national accounts. Discussions with the team are needed to determine if, how, and to what degree the other accounts will be addressed.

- Damages to Property & Infrastructure
- Armor Construction & Repair Cost
- Emergency Nourishment Cost
- Recreation Value

1.4.2 Models

BFX explanation: Beach-*fx* was developed by the USACE Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi. 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. Beach-*fx* fully incorporates risk and uncertainty and is used to simulate future hurricane and storm damages at existing and future years and to compute accumulated present worth damages and costs. Storm damage is defined as the damage incurred by the temporary loss of a given amount of shoreline as a direct result of waves, erosion, and inundation caused by a storm of a given magnitude and probability. Beach-fx is an event-driven life-cycle model that estimates damages and associated costs over a 50 year period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Damages or losses to developed shorelines include buildings, pools, patios, parking lots, roads, utilities, seawalls, revetments, bulkheads, replacement of lost backfill, etc. Beach-*fx* also provides the capability to estimate the costs of certain future measures undertaken by state and local organizations to protect coastal assets.

Beach-fx is a life-cycle, event-based simulation model. Each simulated life-cycle (or model iteration) represents the full lifespan (typically 50 years) of a hypothetical Federal project. Each iteration will estimate different damages, based on the frequency, timing, and intensity of the simulated storms in that iteration. Enough iterations must be modeled to capture a wide range of possible outcomes. Mean damages overall all iterations are usually reported as the "expected case", with all the individual iterations providing information about variability in the results. One improvement in Beach-fx over older models is that is captures more than just erosion damage. It also has the capability to estimate flood damage (called inundation in the model), and the damage from the energy in waves and storm surge (called "wave attack" in the model). These capabilities allow the model to provide a more complete picture of how coastal damage might occur over time.

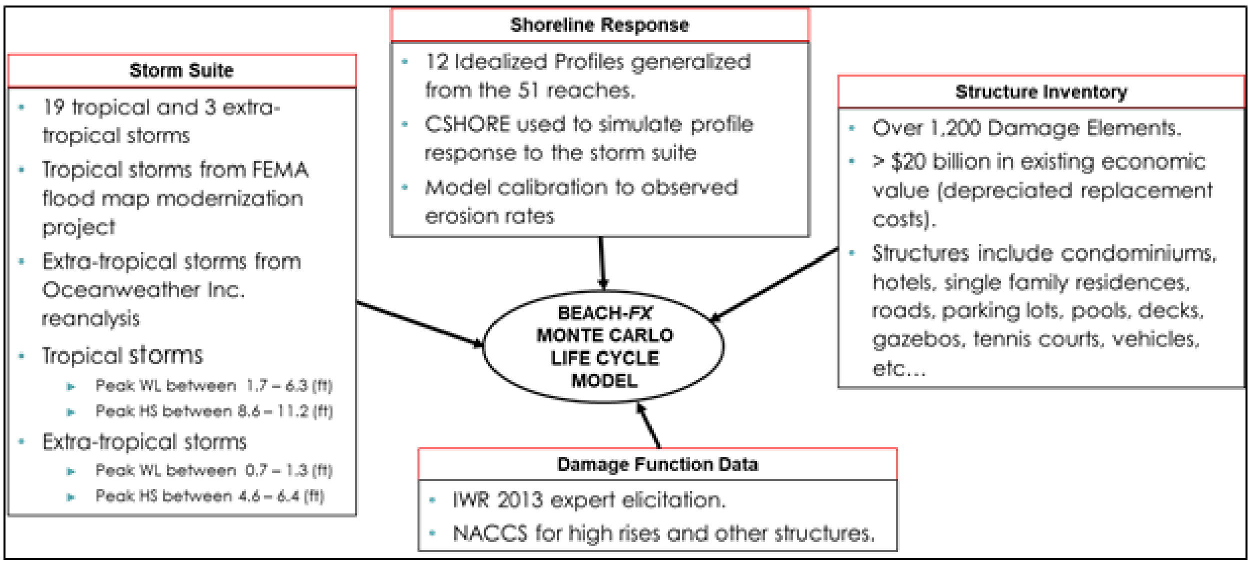


Figure 2: Beach Fx Conceptual Framework

1.4.3 Validation

The study area is characterized by a robust beach because of the federal project. As such, damages are anticipated to occur later in the period of analysis. To validate the modeling process, the profiles, reaches, and damage elements were evaluated to gain some sense of each component's relative contribution to the risk. This was to verify the proper functioning of the model and ensuring that damages occur in areas that make sense.

2 Existing Condition Inventory

2.1 Planning Reaches

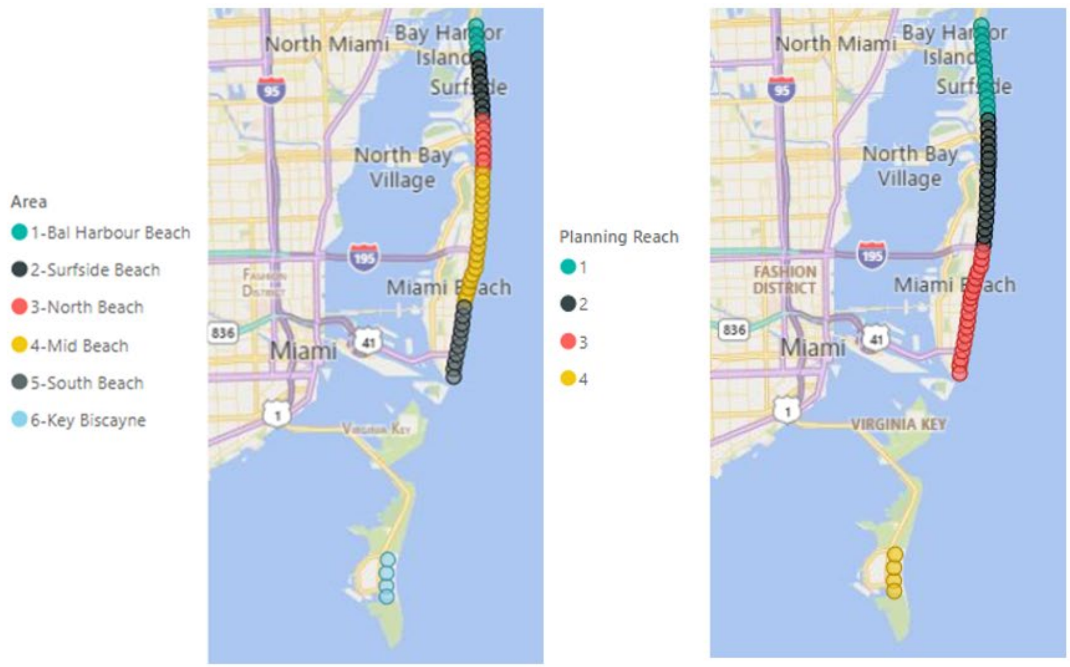
The delineation of planning reaches is shown in Figure 3.

Study Location Areas, Range Monuments, & Lengths

Area	R-Monuments	Length (ft.)
1-Bal Harbour Beach	R028 - R031	4,472
2-Surfside Beach	R032 - R039	8,730
3-North Beach	R040 - R046	7,080
4-Mid Beach	R047 - R064	18,356
5-South Beach	R065 - R074	11,091
6-Key Biscayne	R102 - R107	6,381
Total		**56,110**

Area Distribution by Planning Reach (length in ft.)

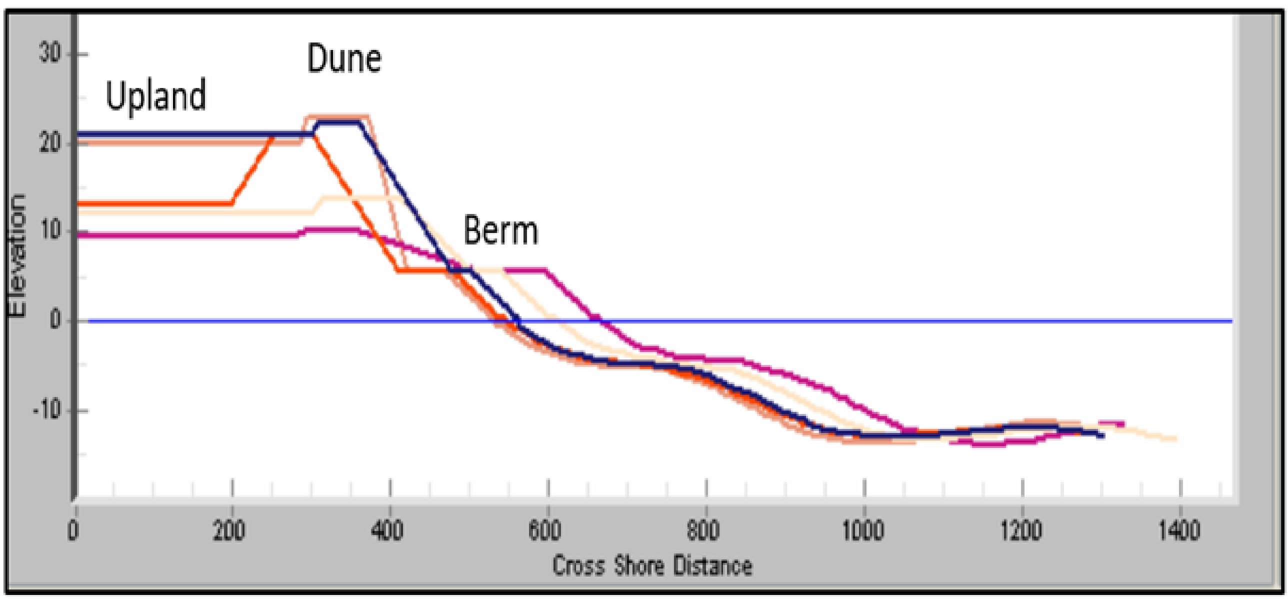
Area	1	2	3	4	Total
1-Bal Harbour Beach	4,472				**4,472**
2-Surfside Beach	8,730				**8,730**
3-North Beach		7,080			**7,080**
4-Mid Beach		10,998	7,358		**18,356**
5-South Beach			11,091		**11,091**
6-Key Biscayne				6,381	**6,381**
Total	**13,202**	**18,078**	**18,449**	**6,381**	**56,110**



The focused study area was divided into planning reaches. These planning reaches were established based on existing physical conditions and the FWOP damages to reflect areas where alternatives could be implemented, and benefits could be achieved independently. The Main Segment was divided into three planning reaches. Planning Reach 1 extends 2.5 miles from Bakers Haulover Inlet to R-39.3. In the FWOP condition, erosion is the primary damage driver in Planning Reach 1, with the greatest damages expected to occur in the areas of highest erosion between R-27 and R-34.5. The breakpoint between Planning Reaches 1 and 2 is the relatively stable stretch of shoreline at the southern portion of Planning Reach 1 where erosion rates are relatively low and minimal FWOP damages are expected. Planning Reach 2 extends 3.4 miles from R-39.3 to R-56.5. In the FWOP condition, erosion is the primary damage driver in Planning Reach 2, with the damages expected to occur along the length of the reach. The breakpoint between Planning Reaches 2 and 3 is the relatively stable stretch of shoreline at the northern portion of Planning Reach 3 where erosion rates are relatively low and minimal FWOP damages are expected. Planning Reach 3 extends 3.5 miles from R-56.5 to Government Cut. In the FWOP condition, erosion is the primary damage driver in Planning Reach 3, with the damages expected to occur in the small area located immediately to the south of the existing breakwaters at 32nd Street (R-59 to R-60). The Key Biscayne Segment consists of a single planning reach, Planning Reach 4. The primary damage driver in Planning Reach 4 is flooding. While Planning Reaches 1, 2, and 3 are physically connected, they are also considered to be separable elements where alternatives could be implemented separately, and benefits could be achieved regardless of the implementation of alternatives in the other planning reaches.

2.2 Profiles

A group of Beach-fx profiles serve as a simplified representation of the study shoreline, including the berm, the dune, and upland areas. These profiles coastal processes over time, including the damaging erosion, inundation, and wave attack (i.e., energy in waves and storm surge). The appropriate number of profiles in each model depends in part on the variability in the existing shoreline. A relatively stable, consistent shoreline may need relatively few profiles, while a highly variable shoreline with differing heights and widths may need many profiles to adequately capture its shape and dimensions. Typically,



each profile is associated with several model reaches. A conceptual example of Beach-fx profiles is provided in. Each color line represents a different profile.

Table 1 provides detail on each profile and that profile's relative risk factors. The 'Profile Characteristics' column is a concatenation of each profile's dune height, dune width, and berm width. The beach width column is the sum of the dune and beach widths. Risk factors for each profile are based on the dune height and the beach width. This is because taller dunes and wider beaches usually provides more protection against erosion, wave attack, and inundation.

Table 1: Profiles and Relative Risk Factors

Profile Number	Profile Characteristics	Dune Height	Beach Width	Dune Height Risk Factor	Beach Width Risk Factor	Profile Risk Rating
1	11'DH x 60'DW x 40'BW	11.0	100	M	L	M
2	9'DH x 60'DW x 19'BW	9.0	79	M	M	M
3	10'DH x 30'DW x 53'BW	10.0	83	M	M	M
4	10'DH x 70'DW x 27'BW	10.0	97	M	L	M
5	10'DH x 40'DW x 56'BW	10.0	96	M	L	M
6	10'DH x 80'DW x 228'BW	10.0	308	M	L	M
7	10'DH x 50'DW x 75'BW	10.0	125	M	L	M
8	14'DH x 50'DW x 183'BW	14.0	233	L	L	L
9	13'DH x 40'DW x 200'BW	12.5	240	L	L	L
10	16'DH x 20'DW x 73'BW	16.0	93	L	L	L
11	9'DH x 40'DW x 7'BW	9.0	47	M	H	H
12	8'DH x 40'DW x 2'BW	8.0	42	H	H	H

Profiles 1 through 7 and 11 have moderate risk ratings, because they have relatively higher dunes and/or larger beach widths. Profiles 8 through 10 have low risk ratings because they have the highest dunes in the study along with large beach widths. The highest risk profiles in the study are 11 & 12. These profiles are associated with the lowest dune heights and the smallest beach widths.

2.3 Model Reaches

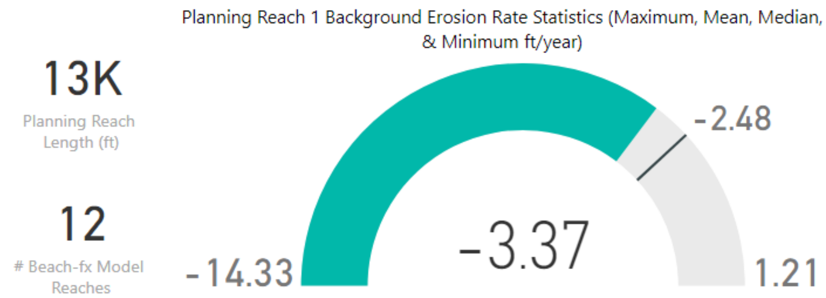
While profiles are a key part of the engineering inputs, the broadest spatial category of socioeconomic inputs into Beach-*fx* is the model reach. Model reaches define the full extent of areas in which damages (and therefore, potential benefits of a project) will be captured. The reaches provide useful increments that will allow the study team to determine how damage estimates vary spatially.

To be consistent with other CSRM studies in Florida, the Miami-Dade model reaches have been drawn in roughly 1,000-foot increments, each one corresponding with one Florida Department of Environmental Protection Range monument (FDEP R-monuments). It should be noted that the reaches are not precisely 1,000 feet long; they vary slightly based on features of the shoreline (roads, parcel boundaries, profile boundaries, etc.). Some of the Miami-Dade reaches are more than 1,000 feet; some are less. Each reach though does correspond to a single R-monument, which is useful for tracking and labeling the reaches.

The width of the reaches varies, buy generally, they go as far back as the profiles (i.e., they represent the areas likely to receive erosion, inundation, or wave attack damages over time). For much of the shoreline, Collins Avenue in Miami Beach serves as a kind of de facto landward boundary. The road itself, and all properties seaward of it, will be included in the Beach-fx model.

Model reach risk ratings are based on two factors: 1) the risk rating of the model reach's associated profile, and 2) the model reach's background erosion rate. Relatively speaking, a model reach with a riskier profile, and a higher erosion rate is expected to show greater risk to the lots /damage elements within that model reach.

2.3.1 Model Reaches: Planning Reach 1



Model Reach Characteristics and Risk Rating

Reach Description	Profile Characteristics	Beach Width	Length	Background Erosion Rate	Profile Risk Rating	Background Erosion Risk Factor	Reach Risk Rating
R028	11'DH x 60'DW x 40'BW	100	1,369	-10.06	M	H	H
R029	9'DH x 60'DW x 19'BW	79	934	-14.12	M	H	H
R030	9'DH x 60'DW x 19'BW	79	1,233	-14.33	M	H	H
R031	11'DH x 60'DW x 40'BW	100	936	-9.17	M	H	H
R032	11'DH x 60'DW x 40'BW	100	1,323	-5.39	M	H	H
R033	11'DH x 60'DW x 40'BW	100	998	-2.82	M	M	M
R034	11'DH x 60'DW x 40'BW	100	805	-2.13	M	M	M
R035	11'DH x 60'DW x 40'BW	100	1,346	0.04	M	L	M
R036	11'DH x 60'DW x 40'BW	100	1,021	0.18	M	L	M
R037	11'DH x 60'DW x 40'BW	100	1,189	0.66	M	L	M
R038	11'DH x 60'DW x 40'BW	100	979	1.21	M	L	M
R039	11'DH x 60'DW x 40'BW	100	1,069	0.15	M	L	M

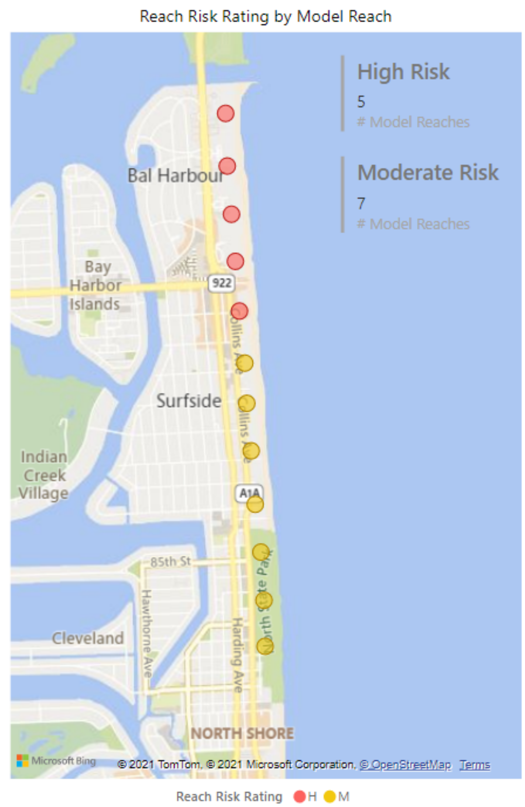


Figure 5:Planning Reach 1 Model Reaches

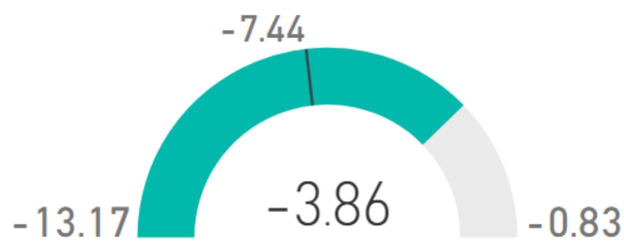
Figure 5 provides detail and illustration for the model reaches in planning reach 1. All the reaches for planning reach 1 have profiles with moderate risk. However, R028 through R032 are assumed to be higher risk model reaches because they have relatively high background erosion rates. Model reaches R033 to R039 have moderate risk ratings due to moderate to low background erosion. Depending on the structure inventory profile, one would expect to see relatively greater erosion damage at the northern end of the planning reach.

2.3.2 Model Reaches: Planning Reach 2

18K
Planning Reach Length (ft)

17
Beach-fx Model Reaches

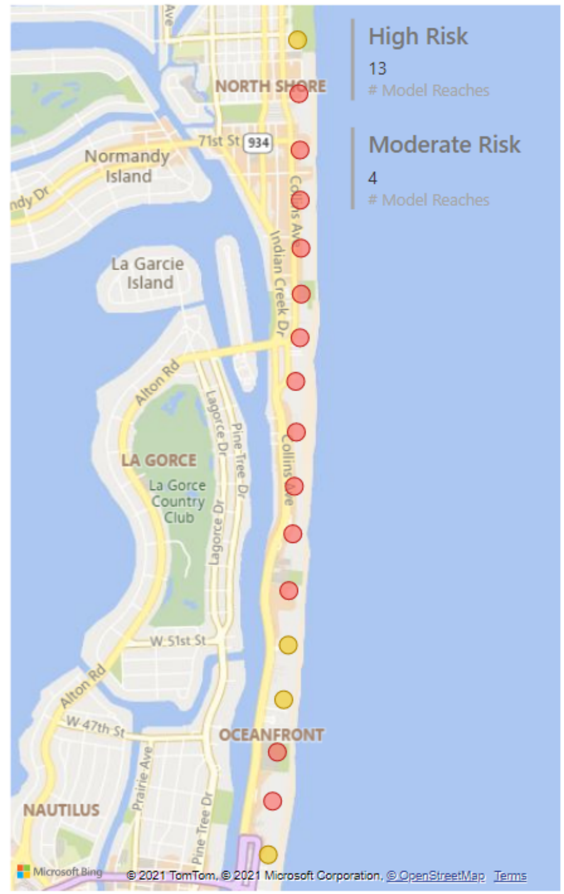
Planning Reach 2 Background Erosion Rate Statistics (Maximum, Mean, Median, & Minimum ft/year)



Model Reach Characteristics and Risk Rating

Reach Description	Profile Characteristics	Beach Width (ft)	Length (ft)	Background Erosion Rate (ft/year)	Profile Risk Rating	Background Erosion Risk Factor	Reach Risk Rating
R040	11'DH x 60'DW x 40'BW	100	943	-1.83	M	L	M
R041	11'DH x 60'DW x 40'BW	100	1,327	-5.25	M	H	H
R042	11'DH x 60'DW x 40'BW	100	1,027	-5.27	M	H	H
R043	11'DH x 60'DW x 40'BW	100	1,047	-5.07	M	H	H
R044	11'DH x 60'DW x 40'BW	100	966	-9.47	M	H	H
R045	11'DH x 60'DW x 40'BW	100	944	-13.17	M	H	H
R046	11'DH x 60'DW x 40'BW	100	826	-7.44	M	H	H
R047	10'DH x 30'DW x 53'BW	83	997	-5.55	M	H	H
R048	10'DH x 30'DW x 53'BW	83	1,232	-10.40	M	H	H
R049	10'DH x 70'DW x 27'BW	97	996	-10.22	M	H	H
R050	11'DH x 60'DW x 40'BW	100	985	-8.46	M	H	H
R051	11'DH x 60'DW x 40'BW	100	1,406	-8.26	M	H	H
R052	11'DH x 60'DW x 40'BW	100	943	-0.83	M	L	M
R053	10'DH x 70'DW x 27'BW	97	1,361	-1.87	M	L	M
R054	10'DH x 70'DW x 27'BW	97	842	-10.95	M	H	H
R055	10'DH x 40'DW x 56'BW	96	1,207	-8.31	M	H	H
R056	10'DH x 40'DW x 56'BW	96	1,029	-2.60	M	M	M

Reach Risk Rating by Model Reach



Reach Risk Rating ● H ● M

Figure 6 provides detail and illustration for the model reaches in planning reach 2. These model reaches have profiles with moderate risk, but thirteen of the 17 model reaches have high risk, due to the greater background erosion rates. (R041 through R051, R054, & R055). Overall, planning reach 2 is the most erosional planning reach in the study.

Figure 6: Planning Reach 2 Model Reaches

2.3.3 Model Reaches: Planning Reach 3

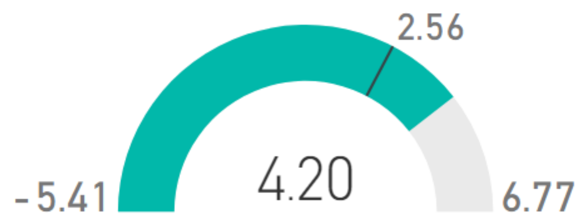
Planning Reach 3 Background Erosion Rate Statistics (Maximum, Mean, Median, & Minimum ft/year)

18K

Planning Reach Length (ft)

18

Beach-fx Model Reaches



Model Reach Characteristics and Risk Rating

Reach Description	Profile Characteristics	Beach Width (ft)	Length (ft)	Background Erosion Rate (ft/year)	Profile Risk Rating	Background Erosion Risk Factor	Reach Risk Rating
R057	10'DH x 40'DW x 56'BW	96	1,022	0.61	M	L	M
R058	10'DH x 30'DW x 53'BW	83	999	2.14	M	L	M
R059	10'DH x 80'DW x 228'BW	308	1,084	2.27	M	L	M
R060	10'DH x 50'DW x 75'BW	125	896	-0.48	M	L	M
R061	11'DH x 60'DW x 40'BW	100	900	-5.41	M	H	H
R062	9'DH x 60'DW x 19'BW	79	1,226	-4.41	M	M	M
R063	10'DH x 30'DW x 53'BW	83	727	-3.77	M	M	M
R064	10'DH x 80'DW x 228'BW	308	504	-0.31	M	L	M
R065	10'DH x 80'DW x 228'BW	308	1,165	1.53	M	L	M
R066	14'DH x 50'DW x 183'BW	233	1,184	2.84	L	L	L
R067	14'DH x 50'DW x 183'BW	233	1,014	4.77	L	L	L
R068	14'DH x 50'DW x 183'BW	233	948	6.22	L	L	L
R069	14'DH x 50'DW x 183'BW	233	1,311	6.77	L	L	L
R070	14'DH x 50'DW x 183'BW	233	876	6.45	L	L	L
R071	13'DH x 40'DW x 200'BW	240	1,408	5.69	L	L	L
R072	13'DH x 40'DW x 200'BW	240	881	6.10	L	L	L
R073	13'DH x 40'DW x 200'BW	240	694	6.27	L	L	L
R074	16'DH x 20'DW x 73'BW	93	1,610	5.55	L	L	L

Reach Risk Rating by Model Reach

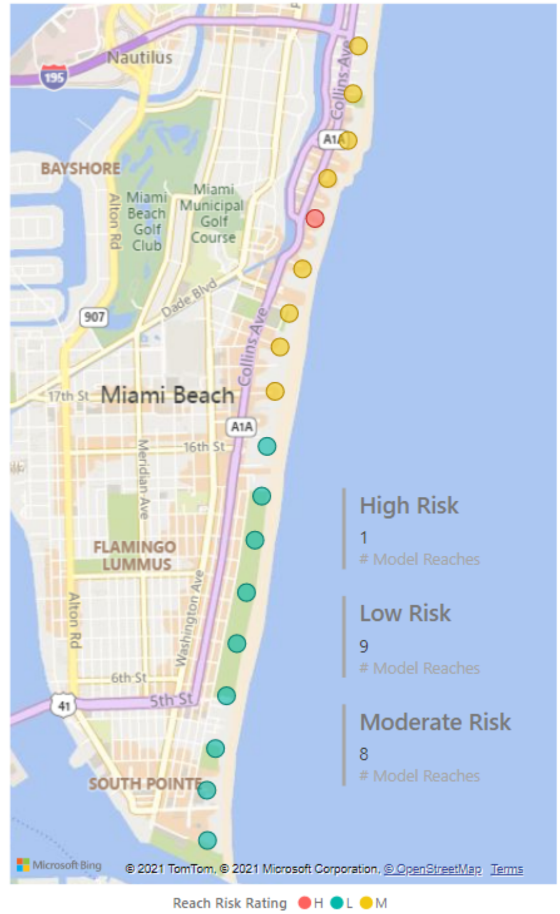


Figure 7: Planning Reach 3 Model Reaches

Planning Reach 3 is the most accretional in the study area. Figure 7 provides detail and illustration for the model reaches in planning reach 3. All the reaches for planning reach 3 have profiles with moderate to low risk. However, R060 through R064 are erosional. The remaining model reaches have large beach widths that are evidence of the accretion that is occurring in the South Beach area. To the extent that there are damages in this reach, one would expect to see them in the R060 – R064 section.

2.3.4 Model Reaches: Planning Reach 4

6K
Planning Reach Length (ft)

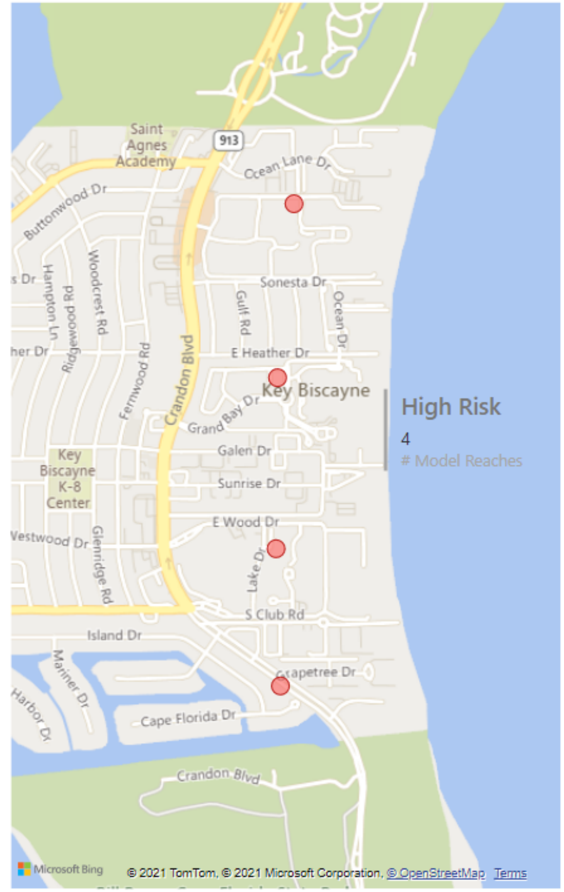
4
Beach-fx Model Reaches

Planning Reach 4 Background Erosion Rate Statistics (Maximum, Mean, Median, & Minimum ft/year)

Model Reach Characteristics and Risk Rating

Reach Description	Profile Characteristics	Beach Width (ft)	Length (ft)	Background Erosion Rate (ft/year)	Profile Risk Rating	Background Erosion Risk Factor	Reach Risk Rating
R107	8'DH x 40'DW x 2'BW	42	1,186	7.10	H	L	H
R106	8'DH x 40'DW x 2'BW	42	1,582	2.40	H	L	H
R102	9'DH x 40'DW x 7'BW	47	1,619	2.20	H	L	H
R104	8'DH x 40'DW x 2'BW	42	1,994	2.10	H	L	H

Reach Risk Rating by Model Reach



Reach Risk Rating ● H

Figure 8 Planning Reach 4 Model Reaches

Figure 8 provides detail and illustration for the model reaches in planning reach 3. All model reaches in planning reach 4 are high risk, due to the lower dune heights, and small beach widths. The background erosion rates are higher (accretional) due to the periodic emergency nourishment events that take place here.

2.4 Lots

Lots represent plots of land on which damageable proprieties can be found. They often (though not always) correspond with ownership parcel boundaries (as defined by the County Property Appraiser). The lots are designed to be flexible spatial category; a Beach-fx lot can be the entire size of the Reach or the size of an actual plot of land in the study area. Typically, each reach will contain multiple lots. The lots serve as the connection between the reaches and the damage elements. They are built into the model as quadrilaterals encapsulated within model reaches and are used to transfer the effect of coastal morphology changes to the damage element. Lots are also the repositories for coastal armor costs, specifications, and failure threshold information. Within Beach-fx, armor is defined at the lot level. Lots also serve as an organizational container in the system for Damage Elements.

2.4.1 Armor Assumptions

One aspect of shorelines that must be accounted for in Beach-*fx* is coastal armoring (seawalls, revetments, groins, breakwaters, etc.). Coastal armor can reduce or prevent damage in the future; it must be considered (where applicable) when simulating shoreline change over time. In Beach-fx, the prevents of armor prevents erosion damage. However, the armor itself can also fail, which inflicts a different kind of damage (referred to as “armor costs” in model outputs). Damages to structures, contents, vehicles, as well as emergency nourishment and armor costs, constitute all of the FWOP damages estimated in beach-fx (and, therefore, the source of potential damage reduction benefits).

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

It should be noted that coastal armor included in the FWOP condition is distinct armoring alternatives that might be considered as part of the Federal project. Various structural alternatives include seawalls may be considered in the FWP condition. This document though is focused exclusively on the FWOP; future documents (including the draft feasibility report itself) will address proposed project alternatives.

2.4.2 Existing Armor in the FWOP

The Miami-Dade project area contains three instances of existing coastal armor: the jetty and revetment at the north end of the Bal Harbor segment, five deteriorated pile groins also in the Bal Harbor segment, and the South Beach jetty.

Though these elements of existing armor affect shoreline processes, they would not be expected to eliminate erosion damage in a realistic FWOP condition. Therefore, they will be not be modeled directly in the Beach-fx model. Instead, the background erosion rates in the Bal Harbor and South Beach Planning reaches account for the effects of the existing armor in these areas.

2.4.3 Future Armor in the FWOP

It is assumed that new armor will be constructed in cases where property was being threatened in the absence of Federal project based on the fact that armor has been constructed in the past. Therefore, lots are landward of the dune are designated “armorable in the future”.

Table 2: Armor Typically found in Florida

Armor Type	Description
Vinyl Seawall	5' tall Vinyl Sheeetpile wall
Small Stone Revetment	Approx imately 4' tall large stone riprap revetment
Large Stone Revetment	Approx imately 6' tall large stone riprap revetment
Small Concrete Sewall	12" thick concrete wall, rebar reinforced, 18" wide, 4' tall
Medium Concrete Sewall	12" thick concrete wall, rebar reinforced, 18" wide, 6' tall
Large Concrete Sewall	12" thick concrete wall, rebar reinforced, 18" wide, 8' tall
Buried Sewall	12" thick concrete wall, rebar reinforced, 18" wide,

Modeling parameters for proposed seawalls will be based on previous CSRM studies in Florida that included coastal armor (Table 2). A wide variety of coastal armor is used throughout Florida, including vinyl sheetpile seawalls, concrete seawalls, and stone revetments. In Miami-Dade County, given the tremendous economic value contained in the upland of the study area (billions of dollars in value), it seems likely that future armor would consists of relatively large seawalls rather than small revetments or other smaller-scale measures. The proposed armor for Miami-Dade lots (a medium concrete seawall) is highlighted in yellow. Armor and armor cost and construction details are assumed to be steel sheet pile seawall w/concrete cap assumed to be constructed in the future.

$570K
Armor Construction Mobilization Cost

$3.31K
Armor Construction Cost Per Foot

20.00
Armor Construction Mobilization Time

0.14
Armor Construction Time Per Foot

Planning Reach	# of Reaches	# of Lots	Erosion Armor Failure Thresholds	Flood Armor Failure Thresholds	Wave Damage Armor Failure Thresholds
1	12	42	7.50	8.00	7.00
2	17	65	7.50	7.83	7.00
3	17	47	7.38	7.31	6.94
4	4	21	7.50	7.00	7.00

Estimated Armor Construction Length (ft) Assumptions per Planning Reach

Planning Reach	Mean	Median	Minimum	Maximum
1	313.90	327.38	119.00	610.00
2	277.32	258.00	144.00	595.00
3	365.23	340.00	190.00	642.00
4	531.67	550.00	233.00	996.00

Figure 9: Armor Cost Assumptions

Within Beach-fx, a number of input parameters define the nature of future armor, including: construction cost, rebuild time, as well as failure thresholds (defining precisely when and how the armor would fail) for erosion, inundation, and wave attack. A summary of Beach-fx armoring parameters used in this study is provided in Figure 9.

2.5 Damage Elements

A Damage Element (DE) represents any structure where damages can be incurred. This could be a house, commercial property, deck, pool, walkover structure, etc. Damage Elements are members of a specified lot and are defined by a single, representative central point (X, Y coordinates). The damage element inventory is a collection of all damage elements in the study, as organized by reaches and lots.

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

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

2.5.1 Damage Functions

Table 3. provides additional detail on damage element type descriptions, damage driving parameters, and associated damage functions. As previously described, Beach-fx simulates damage to structures and contents based on three damage driving parameters: inundation, erosion, and wave attack. A "Damage Function" defines the relationship between the damage driving parameter and the fractional loss to the structure or contents. For example, an inundation damage function defines the relationship between the depth of flooding and percent structure (or content) damage. Damage functions for each damage driving parameter are typically assigned for structures and contents for each type of damage element (as categorized by construction type). Table 3 provides information on the assignment of damage functions by damage element type.

Table 3: Damage Element, Construction, & Foundation Types with Damage Drivers.

Damage Element Categories	Damage Element Types	Damage Element Description	Damage Driving Parameters	Structure Damage Functions	Content Damage Functions
Single Family Residences	SFR1	One-story single-family residences, with wood construction on a slab foundation	Inundation; wave attack; erosion	NACCS Prototype 5	NACCS Prototype 5
High Rises & Parking Garages	COM-HT-HR	Multi-story high rise buildings with reinforced masonry construction on deep pile supported foundations	Inundation; wave attack; erosion	NACCS Prototype 4B	NACCS Prototype 4B
	UGPARK	Underground parking garages, masonry construction on deep pile supported foundation	Inundation; erosion	NACCS Prototype 3	Null Damage Function
Gazebos, Cabanas, Decks & Pools	CABANA	Hut with roof, walls, water, & electric. Typically, masonry construction with slab on grade foundation	Inundation; wave attack; erosion	NACCS Prototype 3	Null Damage Function
	GAZEBO	Wood constructed pavilions with no walls and a pier & post foundation	Inundation; wave attack; erosion	NACCS Prototype 3	Null Damage Function
	DECKS	Paved recreational outdoor spaces; masonry construction with slab foundations	Erosion; wave attack	NACCS Prototype 3	Null Damage Function
	POOL	Pools/spas/hot tubs; concrete/ gunnite construction	Erosion	NACCS Prototype 3	Null Damage Function
ROAD(S) PARKING LOT(S)	ROAD1	Single lane road with no shoulder	Erosion	NACCS Prototype 3	Null Damage Function
	PARKING LOT	Parking lots and paved surfaces	Erosion	NACCS Prototype 3	Null Damage Function
	TENNIS	Tennis courts, other paved recreational areas	Erosion	NACCS Prototype 3	Null Damage Function

2.5.2 Structure Values

Structure Values are a very important part of the damage element inventory because they define the damageable economic value of the property in the study area. Per Corps guidance, depreciated replacement values (rather than market values) should be used. This is because the deprecated replacement represents the resources that would be needed to repair or replace damaged property. Market values fluctuate dramatically based on macroeconomic and microeconomic conditions; they are not a good measure of resource investment.

The economic value of the existing structure inventory represents the depreciated replacement costs of damageable structures and their associated contents within the study area along the coastline. All damage element inventory structure value depreciated replacement costs were determined by SAJ Real

Estate personnel. The report documenting the results is included as an attachment (U.S. Army Corps of Engineers, Jacksonville District, 2020). It should be noted that the real estate depreciated replacement values will be updated from FY 2020 to FY 2022 price levels prior to the ADM.

2.5.3 Content Values

Estimating content values is an important part of developing the structure inventory. Typically, content-to-structure value ratios (CSRVs) are used to define content value as a percentage of the depreciated structure value. In this case, a ratio of 0.50 has been applied to all structures in the study. Given the lack of an appropriate empirical study about content values in south Florida, this is a conservative, reasonable assumption that is consistent with ER 1105-2-100. It should be noted that there were a few exceptions to the 0.50 ratio assumption, because there are several structures that typically do not have valuable contents. Gazebos, roads, and pools are examples of structures for which the CSVR was assumed to be zero.

2.5.4 First Floor Elevations

First floor elevations (FFE) define the vertical location of damageable structure above the ground elevation. Each structure in the damage element inventory has its own unique first floor elevation assigned (with a triangular distribution of low, high, and expected FFEs to account for uncertainty). This information is particularly important for determining inundation damage, which depend on the depth of flooding relative to the first floor. As with the structure values, the FWOP condition was developed based on existing data, and supplemented with detailed notes from a December 2018 site visit. FFEs will be verified (and, if necessary) refined in a future site visit after preliminary FWOP model results are available.

2.5.5 Structure Rebuild & Condemnation Assumptions

The number of rebuilds specifies the maximum number of times a class of damage elements (SFR1, MFR1, etc.) can be rebuilt or repaired. This assumption is important, because it effectively creates a cap after which structure and content damages cannot be incurred. In this study, most of the damage element classes are assumed to have a maximum number of rebuilds of once every two years (25 total rebuilds per simulation). The two exceptions are dune walks and roads, which are often damaged in storms and may be rebuilt more frequently. Therefore, the total number of rebuilds per simulation is 100 (twice per year over a 50-year period of analysis) for roads.

It should be noted that most of the structure classes in this study are considered condemnable. Once it is condemned, a damage element cannot be rebuilt. The ratio of post-storm structure value divided by initial structure value below which will result in the structure being marked as condemned, provided that the Damage Element Type is also marked as condemnable. The following language from p. 41 of the Beach-fx User's Manual has been copied to provide additional clarification:

For example, if a condemnation ratio of 0.7 is specified for single-family residential (SFR1), structures and SFR1 Damage Element Types are marked as condemnable structures then, a SFR1 Damage Element will be marked as condemned, if a storm produces damages that exceed 30 percent of the initially specified structure value."

In this case the condemnation ratio was set at 0.5, meaning that if more than 50% of a structure's value is lost in a single storm, it will not be rebuilt.

2.5.6 Damage Element Risk Factors & Risk Ratings

Damage elements were assigned risk ratings based on foundation type, first floor elevation, and SBeach reference position. Damage element foundation types are indicative of susceptibility to erosion damage driving parameters. More shallow foundations are more vulnerable to erosion. First floor elevation indicates vulnerability to inundation and wave attack. SBeach reference position provides an indication of susceptibility to wave attack and erosion forces based on its proximity to the shoreline. Assets closer to the hazard are more likely to be damaged.

This section provides a breakdown of the structure inventory breakdown overall, and per planning reach. Figure 10 provides detail on overall damage element counts, structure and content value, damage driving parameters, and distributions of value by planning reach, damage element type, and typical SBeach reference positions per planning reach. The structure inventory is comprised of over 1,234 damage elements with an estimated damageable value of over $21 billion. Most of the structure inventory value is mostly high rises and their associated recreational amenities such as cabanas, pools, gazebos, and decks. Most of these assets located in planning reaches 1, 2, and 3 are located in “lots” designated as “armorable in the future”. While there are some exposed single family residences, the majority of these assets are located in planning reach 4 (Key Biscayne).

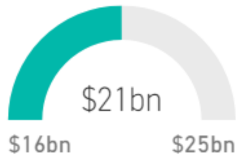
Figure 11 provides detail on the distribution of value as distributed by first floor elevation by damage element type and planning reach. High rises tend to be the most elevated structures in each planning reach. The remaining structures tend to be situated closer to the grade. The higher risk damage elements tend to be the recreational structures because they are closest to the shoreline, relatively lower elevation, and tend to have the most shallow foundation types. Meanwhile, the high rise structures contain the majority of the exposed value are lower risk because they tend to be more elevated with robust deep pile foundations. Figure 12, Figure 13, Figure 14, and Figure 15 provide details on the structure inventory profiles for planning reaches 1, 2, 3, and 4 respectively.

2.6 Existing Condition Summary

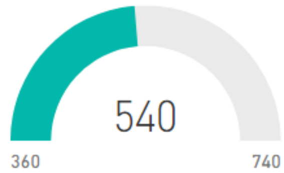
1234
\# of Damage Elements

$21bn
Exposed Structure Inventory Value

Distribution of Depreciated Replacement Value ($)



Distribution of Rebuild Times (#Days)



SBeach Position Distribution by Planning Reach

Planning Reach	Mean	Median	Minimum	Maximum
1	707	764	241	1,006
2	747	777	262	979
3	736	758	130	991
4	1,944	2,046	458	2,855

DEType	# DE(s)	Depreciated Replacement Value
COM-HT-HR	316	$20,472,207K
SFR1	125	$115,523K
ROAD1	205	$13,027K
POOL	197	$10,417K
PARKINGLOT	99	$6,514K
DECKS	137	$3,748K
TENNIS	50	$1,358K
UGPARK	14	$773K
CABANA	34	$217K
GAZEBO	57	$66K
Total	**1234**	**$20,623,852K**

Structure Value Distribution by Damage Element Type

DEType	Mean	Median	Minimum	Maximum
COM-HT-HR	$47,528,583	$18,345,801	$57,481	$806,557,068
SFR1	$753,127	$681,240	$194,206	$4,987,886
PARKINGLOT	$65,796	$40,185	$3,065	$707,220
ROAD1	$63,546	$54,000	$12,893	$322,157
UGPARK	$55,230	$34,719	$8,561	$230,976
POOL	$52,880	$23,984	$2,402	$3,085,421
DECKS	$27,361	$18,697	$834	$220,217
TENNIS	$27,167	$20,102	$1,958	$111,022
CABANA	$6,387	$6,459	$408	$34,574
GAZEBO	$1,159	$1,323	$282	$1,482

Content Value Distibution by Damage Element Type

DEType	Mean	Median	Minimum	Maximum
COM-HT-HR	$17,256,882	$5,513,909	$14,945	$306,491,686
SFR1	$171,058	$186,481	$78,522	$2,493,943
CABANA	$0	$0	$0	$0
DECKS	$0	$0	$0	$0
GAZEBO	$0	$0	$0	$0
PARKINGLOT	$0	$0	$0	$0
POOL	$0	$0	$0	$0
ROAD1	$0	$0	$0	$0
TENNIS	$0	$0	$0	$0
UGPARK	$0	$0	$0	$0

Damage Element Category	Damage Element Type	Construction	Foundation	Damage Drivers	# DE(s)
Single Family Residences	SFR1	WOOD	SLAB	Inundation, Wave Attack, & Erosion	125
Roads, Parking Lots & Tennis Courts	PARKINGLOT	PAVE	ROAD-FND	Erosion	99
Roads, Parking Lots & Tennis Courts	ROAD1	PAVE	ROAD-FND	Erosion	205
Roads, Parking Lots & Tennis Courts	TENNIS	PAVE	TENNIS-FND	Erosion	50
High Rises & Parking Garages	COM-HT-HR	RMAS	PILE-HR	Inundation, Wave Attack, & Erosion	316
High Rises & Parking Garages	UGPARK	MAS	PILE-FND	Inundation & Erosion	14
Gazebos, Cabanas, Decks, & Pools	CABANA	MAS	SLAB	Inundation, Wave Attack, & Erosion	34
Gazebos, Cabanas, Decks, & Pools	DECKS	MAS	SLAB	Inundation, Wave Attack, & Erosion	137
Gazebos, Cabanas, Decks, & Pools	GAZEBO	WOOD	PIERSPOSTS	Inundation, Wave Attack, & Erosion	57
Gazebos, Cabanas, Decks, & Pools	POOL	MAS	POOL-FND	Erosion	197

Damage Element Type Value by Planning Reach

DEType	1	2	3	4
CABANA	$48,569		$168,586	
COM-HT-HR	$6,232,460,366	$6,844,109,721	$4,900,969,292	$2,494,667,736
DECKS	$667,271	$1,763,149	$859,276	$458,738
GAZEBO	$5,214			$60,858
PARKINGLOT	$1,020,436	$2,678,747	$1,220,858	$1,593,738
POOL	$1,556,664	$5,286,892	$2,067,840	$1,506,027
ROAD1	$2,436,645	$3,363,615	$3,834,593	$3,392,160
SFR1	$5,109,300	$9,300,438		$101,113,360
TENNIS	$190,333	$209,720	$77,013	$881,281
UGPARK	$773,223			
Total	**$6,244,268,020**	**$6,866,712,283**	**$4,909,197,459**	**$2,603,673,897**

Figure 10: Overall Summary of Existing Condition Structure Inventory

PR1: Distribution of First Floor Elevations

DEType	# Damage Elements	Minimum FFE (ft)	Most Likely FFE (ft)	Maximum FFE (ft)
CABANA	8	3.00	5.75	7.00
COM-HT-HR	54	10.00	13.00	17.00
DECKS	32	4.30	4.83	6.30
GAZEBO	11	3.00	4.18	7.00
PARKINGLOT	25	4.30	4.78	6.30
POOL	44	4.30	4.75	6.30
ROAD1	53	4.30	4.83	6.30
SFR1	5	10.00	13.00	17.00
TENNIS	11	4.30	6.12	6.30
UGPARK	14	0.10	1.00	2.00

Distribution of Exposure Value per FFE by Planning Reach

FFEBin	1	2	3	4	Total
1	$773,223				**$773,223**
3			$438,455		**$438,455**
4	$4,265,932	$5,502,440	$2,374,629	$7,831,944	**$19,974,944**
5	$1,901	$3,432,291	$262,119	$30,926,693	**$34,623,004**
6	$1,657,298	$2,725,149	$2,862,830	$60,858	**$7,306,134**
7		$1,642,244	$2,290,135		**$3,932,379**
8				$70,186,667	**$70,186,667**
13	$6,237,569,666	$6,853,410,159	$4,900,969,292	$2,494,667,736	**$20,486,616,853**
Total	**$6,244,268,020**	**$6,866,712,283**	**$4,909,197,459**	**$2,603,673,897**	**$20,623,851,658**

PR2: Distribution of First Floor Elevations

DEType	# Damage Elements	Minimum FFE (ft)	Most Likely FFE (ft)	Maximum FFE (ft)
COM-HT-HR	63	10.00	13.00	17.00
DECKS	34	4.30	5.09	7.30
PARKINGLOT	34	4.30	5.30	7.30
POOL	60	4.30	5.12	7.30
ROAD1	65	4.30	5.07	7.30
SFR1	4	10.00	13.00	17.00
TENNIS	10	4.30	5.60	7.30

Distribution of Exposure Value per FFE by DE Category

FFEBin	Gazebos, Cabanas, Decks, & Pools	High Rises & Parking Garages	Roads, Parking Lots & Tennis Courts	Single Family Residences	Total
1		$773,223			**$773,223**
3	$122,930		$315,525		**$438,455**
4	$7,347,166		$12,627,778		**$19,974,944**
5	$3,061,811		$634,500	$30,926,693	**$34,623,004**
6	$2,570,209		$4,735,925		**$7,306,134**
7	$1,346,967		$2,585,412		**$3,932,379**
8				$70,186,667	**$70,186,667**
13		$20,472,207,115		$14,409,738	**$20,486,616,853**
Total	**$14,449,083**	**$20,472,980,338**	**$20,899,139**	**$115,523,098**	**$20,623,851,658**

PR3: Distribution of First Floor Elevations

DEType	# Damage Elements	Minimum FFE (ft)	Most Likely FFE (ft)	Maximum FFE (ft)
CABANA	26	5.00	6.96	8.00
COM-HT-HR	63	10.00	13.00	17.00
DECKS	42	3.30	5.37	7.30
PARKINGLOT	12	3.30	6.05	7.30
POOL	56	3.30	5.16	7.30
ROAD1	62	3.30	5.82	7.30
TENNIS	6	7.30	7.30	7.30

PR4: Distribution of First Floor Elevations

DEType	# Damage Elements	Minimum FFE (ft)	Most Likely FFE (ft)	Maximum FFE (ft)
COM-HT-HR	136	10.00	13.00	17.00
DECKS	29	4.00	4.00	4.00
GAZEBO	46	5.00	6.00	7.00
PARKINGLOT	28	4.00	4.00	4.00
POOL	37	4.00	4.00	4.00
ROAD1	25	4.00	4.00	4.00
SFR1	116	1.50	6.31	8.00
TENNIS	23	4.00	4.00	4.00

Figure 11: Overview of First Floor Elevation Information

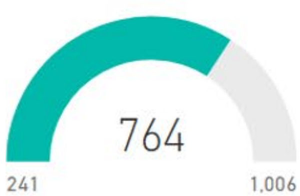
Planning Reach

1

Distribution of Depreciated Replacement Value ($)

First Floor Elevation Distribution (ft)

SBeach Position Distribution



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Damage Elements

Foundation Type Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	16%		21%	37%
High Rises & Parking Garages		26%		26%
Roads, Parking Lots & Tennis Courts	35%			35%
Single Family Residences	2%			2%
Total	52%	26%	21%	100%

First Floor Elevation Risk Factor

Damage Element Category	H	L	M	Total
Single Family Residences		2%		2%
Roads, Parking Lots & Tennis Courts	23%		12%	35%
High Rises & Parking Garages	5%	21%		26%
Gazebos, Cabanas, Decks, & Pools	26%		11%	37%
Total	55%	23%	22%	100%

Proximity to the Shoreline Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	23%		14%	37%
High Rises & Parking Garages	1%		25%	26%
Roads, Parking Lots & Tennis Courts	1%	12%	22%	35%
Single Family Residences			2%	2%
Total	25%	12%	63%	100%

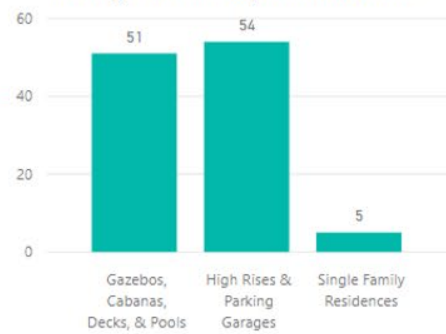
Risk Factor Distribution by Damage Element Category

Damage Element Category	H	L	M	Total
Single Family Residences	2%			2%
Roads, Parking Lots & Tennis Courts	1%	12%	22%	35%
High Rises & Parking Garages		25%	1%	26%
Gazebos, Cabanas, Decks, & Pools	16%		21%	37%
Total	18%	37%	45%	100%

Damage Element Value Distribution by Model Reach

Reach Description	Reach Risk Rating	# DE(s)	Structure Value	Contents Value	% of Exposed Value
R028	H	45	$739,015,620	$280,448,293	16.33%
R029	H	35	$681,463,602	$258,647,391	15.06%
R030	H	40	$594,924,300	$225,612,874	13.14%
R031	H	20	$665,283,791	$252,491,384	14.70%
R032	H	29	$666,787,651	$253,122,535	14.73%
R033	M	19	$221,390,295	$83,871,933	4.89%
R034	M	18	$93,065,200	$35,250,616	2.05%
R035	M	15	$550,131,982	$208,948,031	12.16%
R036	M	19	$310,328,542	$117,791,682	6.86%
R037	M	4	$205,560	$0	0.00%
R038	M	3	$179,640	$0	0.00%
R039	M	10	$3,604,000	$1,703,100	0.08%
Total		257	$4,526,380,182	$1,717,887,838	100.00%

Damage Elements Susceptible to Wave Attack



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Damage Elements Susceptible to Wave Attack

Damage Element Risk Factor Distribution

DE Risk Rating	% of Damage Elements	% of Total Value
H	18.29%	0.09%
M	44.75%	7.13%
L	36.96%	92.78%
Total	100.00%	100.00%

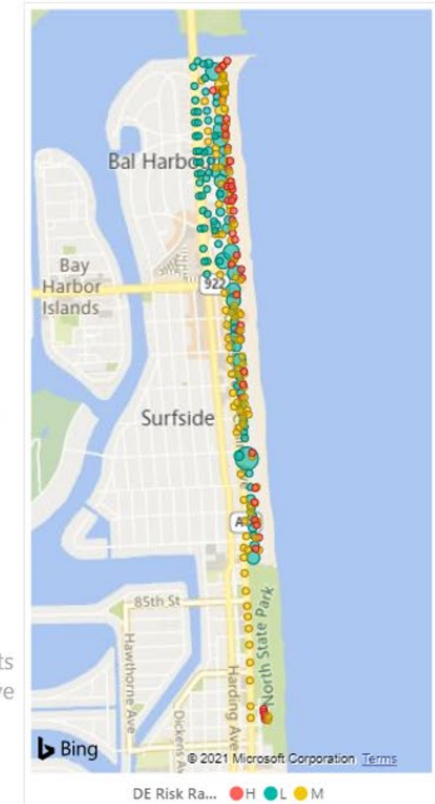
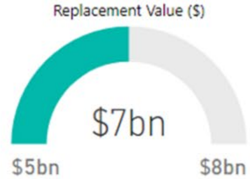


Figure 12: Planning Reach 1 Structure Inventory Profile

Planning Reach

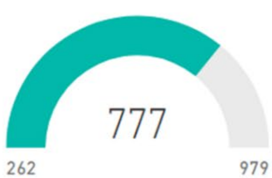
2

Distribution of Depreciated Replacement Value ($)



First Floor Elevation Distribution (ft)

SBeach Position Distribution



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Damage Elements

Foundation Type Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	13%		22%	35%
High Rises & Parking Garages		23%		23%
Roads, Parking Lots & Tennis Courts	40%			40%
Single Family Residences	1%			1%
Total	**54%**	**23%**	**22%**	**100%**

First Floor Elevation Risk Factor

Damage Element Category	H	L	M	Total
Single Family Residences		1%		1%
Roads, Parking Lots & Tennis Courts	23%		17%	40%
High Rises & Parking Garages		23%		23%
Gazebos, Cabanas, Decks, & Pools	20%		14%	35%
Total	**44%**	**25%**	**31%**	**100%**

Proximity to the Shoreline Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	27%		8%	35%
High Rises & Parking Garages	1%	0%	22%	23%
Roads, Parking Lots & Tennis Courts	2%	5%	33%	40%
Single Family Residences			1%	1%
Total	**30%**	**5%**	**65%**	**100%**

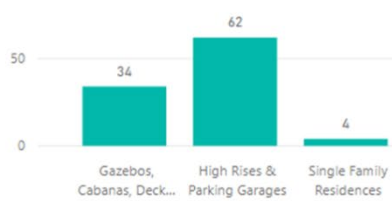
Risk Factor Distribution by Damage Element Category

Damage Element Category	H	L	M	Total
Single Family Residences	1%			1%
Roads, Parking Lots & Tennis Courts	2%	5%	33%	40%
High Rises & Parking Garages		23%	1%	23%
Gazebos, Cabanas, Decks, & Pools	13%		22%	35%
Total	**16%**	**27%**	**56%**	**100%**

Damage Element Value Distribution by Model Reach

Reach Description	Reach Risk Rating	# DE(s)	Structure Value	Contents Value	% of Exposed Value
R056	M	17	$151,272,494	$57,374,651	3.04%
R055	H	13	$769,981,536	$291,397,610	15.46%
R054	H	8	$53,266,196	$19,904,075	1.07%
R053	M	28	$720,813,468	$273,582,967	14.48%
R052	M	15	$270,380,606	$102,557,290	5.43%
R051	H	30	$331,296,988	$125,389,598	6.65%
R050	H	15	$284,046,839	$107,723,669	5.71%
R049	H	13	$161,775,669	$61,102,428	3.25%
R048	H	22	$301,464,864	$114,107,551	6.05%
R047	H	10	$509,770,748	$193,537,929	10.24%
R046	H	19	$364,508,054	$138,327,811	7.32%
R045	H	16	$108,469,338	$41,073,403	2.18%
R044	H	9	$39,416,515	$14,655,421	0.79%
R043	H	18	$664,744,570	$252,399,670	13.36%
R042	H	17	$211,159,456	$80,075,852	4.24%
R041	H	10	$30,250,200	$11,400,000	0.61%
R040	M	10	$6,384,672	$3,100,146	0.14%
Total		**270**	**$4,979,002,213**	**$1,887,710,069**	**100.00%**

Damage Elements Susceptible to Wave Attack



100

Damage Elements Susceptible to Wave Attack

Damage Element Risk Factor Distribution

DE Risk Rating	% of Damage Elements	% of Total Value
H	16.30%	0.17%
M	56.30%	2.36%
L	27.41%	97.47%
Total	**100.00%**	**100.00%**

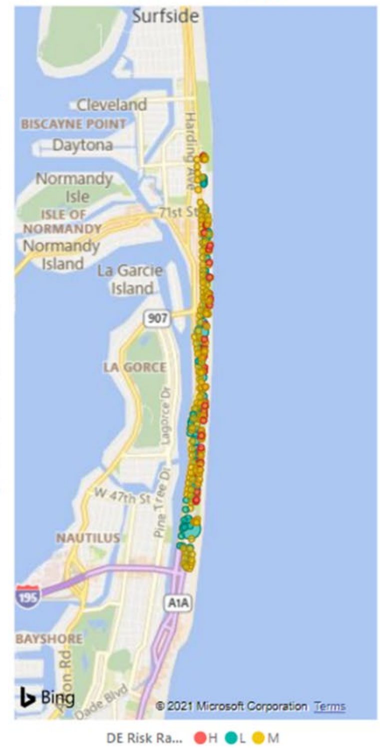
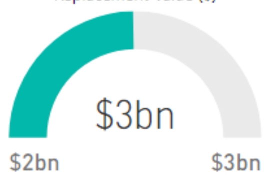


Figure 13: Planning Reach 2 Structure Inventory Profile

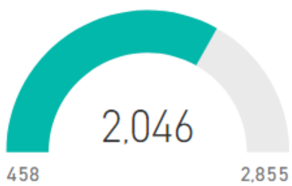
Planning Reach: 4

Distribution of Depreciated Replacement Value ($)



First Floor Elevation Distribution (ft)

SBeach Position Distribution



440

Damage Elements

Foundation Type Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	7%		19%	25%
High Rises & Parking Garages		31%		31%
Roads, Parking Lots & Tennis Courts	17%			17%
Single Family Residences	26%			26%
Total	**50%**	**31%**	**19%**	**100%**

First Floor Elevation Risk Factor

Damage Element Category	H	L	M	Total
Single Family Residences		14%	13%	26%
Roads, Parking Lots & Tennis Courts	17%			17%
High Rises & Parking Garages		31%		31%
Gazebos, Cabanas, Decks, & Pools	15%		10%	25%
Total	**32%**	**45%**	**23%**	**100%**

Proximity to the Shoreline Risk Factor

Damage Element Category	H	L	M	Total
Gazebos, Cabanas, Decks, & Pools	17%	0%	8%	25%
High Rises & Parking Garages	12%	3%	16%	31%
Roads, Parking Lots & Tennis Courts	1%	2%	14%	17%
Single Family Residences		5%	22%	26%
Total	**30%**	**10%**	**60%**	**100%**

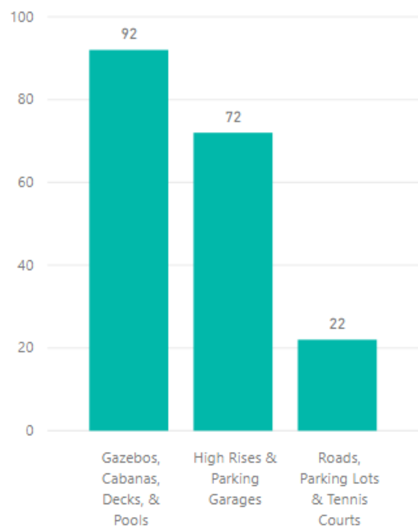
Risk Factor Distribution by Damage Element Category

Damage Element Category	H	L	M	Total
Single Family Residences	26%			26%
Roads, Parking Lots & Tennis Courts	1%	2%	14%	17%
High Rises & Parking Garages		19%	12%	31%
Gazebos, Cabanas, Decks, & Pools	7%		19%	25%
Total	**34%**	**21%**	**45%**	**100%**

Damage Element Value Distribution by Model Reach

Reach Description	Reach Risk Rating	# DE(s)	Structure Value	Contents Value	% of Exposed Value
R102	H	74	$663,516,336	$160,014,293	31.63%
R104	H	222	$399,713,042	$88,759,076	18.76%
R106	H	100	$788,673,416	$229,073,870	39.09%
R107	H	44	$232,354,197	$41,569,668	10.52%
Total		**440**	**$2,084,256,991**	**$519,416,907**	**100.00%**

Damage Elements Susceptible to Wave Attack



186

Damage Elements Susceptible to Wave Attack

Damage Element Risk Factor Distribution

DE Risk Rating	% of Damage Elements	% of Total Value
H	34.09%	3.92%
L	20.68%	79.73%
M	45.23%	16.35%
Total	**100.00%**	**100.00%**

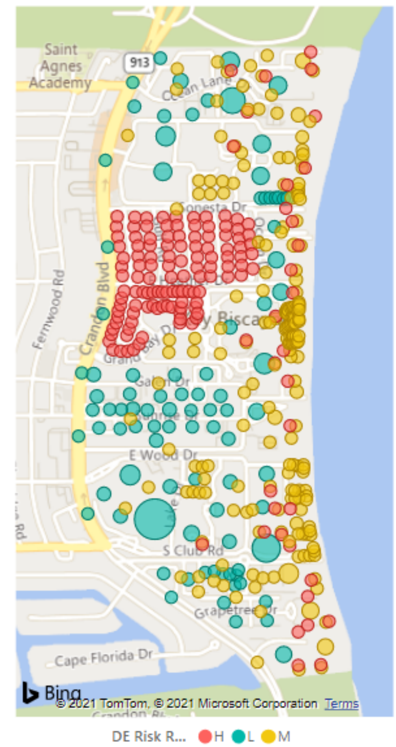


Figure 14: Planning Reach 4 Structure Inventory Profile

3 Future without Project Condition

3.1 FWOP Assumptions

3.1.1 Study Area

As noted above, the Beach-fx model area consists of the main segment of Miami Beach: from Bal-Harbor inlet through South Beach, and Key Biscayne. This entire area will be included in the FWOP model.

3.1.2 Period of Analysis & Discount Rate

A period of analysis must be selected, which represents the hypothetical life-cycle of a Federal project. Typically, for feasibility studies, the period of analysis extends through the period of project authorization. The previous Miami-Dade CSRM was authorized for 50 years; it was constructed in 1975 and will expire in 2025. Therefore, base year is in this analysis will be 2026. The base year also represents the point of divergence between the FWOP and FWP conditions (ie., when a proposed project would be constructed). So, in this case, the model start year will be 2025. Thus, the full simulation time will consist of 50-51 years.

In order to take into account the time value of money, a discount rate is used on estimated costs and benefits of different alternatives. Even in the FWOP condition, future damages beyond the base year must be discounted in Beach-fx. In the feasibility study, the Federal water resources discount rate will be used (currently 2.5%) for preliminary FWOP model simulations.

3.1.3 Land Loss

Typically, in CSRM studies, prevention of land loss is also part of the primary project benefits. These benefits arise from preventing permanent loss of the upland (areas landward of the existing dune). Upland has economic value, as it is the location of current and future development (residential, commercial, etc). Beach-fx estimates net shoreline changes over time, including changes to the upland width. However, in this case all lots are defined as “armorable” in the future. The armor prevents erosion damage to the upland in both the FWOP and FWP conditions. Therefore, land loss benefits are not estimated in this study.

3.1.4 Sea Level Rise

In accordance with ER 1100-2-8162, *Incorporating Sea Level Change in Civil Works Programs*, dated December 31, 2013, all three USACE sea level change curves will be simulated in the FWOP condition. The full plan formulation strategy, with regard to sea level change in Miami-Dade county is described in an SAJ/NAO memo, dated January 18, 2019.

3.1.5 Accounting for Uncertainty

The Beach-fx storm suite is a key input that defines all plausible storms that can be simulated in the model. Each simulation (or, “iteration”) represents a full 50-year life-cycle of the FWOP condition. Each storm is based on data from an actual storm event and is assigned a probability of occurrence. The storms then occur randomly throughout the different iterations, and at different times. This event-based approach makes it possible to simulate a wide range of possible outcomes in the FWOP. In some iterations shoreline erosion and storm damage may be quite significant; in others the damages may be minimal (depending on the frequency and intensity of simulated storms). To account for additional uncertainty, a number of model input parameters are described with ranges rather than exact values.

These include a triangular distribution (i.e., a low, medium, and high estimate) around structure values, content values, first floor elevations, and structure rebuild times. As mentioned above, in Section 1.3.4, uncertainty around the rate of sea level rise is accounted for in differing background erosion rates associated with the SLR scenarios. All these parameters will vary in different iterations, based on the assigned probabilities and triangular distributions.

One issue facing any Beach-fx study concerns the appropriate number of iterations (each representing a life cycle simulation). To determine the ideal number of iterations, the modeler must find a balance between results stability and a reasonable simulation time. Too few iterations may not provide a complete picture of variability and uncertainty in the results; too many can lead to very slow model run times in challenges with data post processing. The number of iterations used in the Miami-Dade study will depend on the observed variability in the FWOP results. Typically, in Florida CSRM studies 50 to 300 iterations have been used. At this time 50 iteration runs will be used to inform plan formulation decisions.

3.1.6 Emergency Nourishment

At this time, only emergency nourishment in Planning reach 4 was accounted for.

3.1.7 Other Model Assumptions

In addition to all the assumptions described above, several other important modeling assumptions are noted below:

- **Storm Suite:** The Miami-Dade storm suite will include all relevant storms, including large tropical storms and smaller extra-tropical storms.
- **Back Bay Flooding:** Back bay flooding was assessed to determine whether flooding from the back of the barrier island would have an impact on project benefits.
- **Planned Nourishment:** As this is the FWOP condition, no planned nourishments will be assumed.
- **Emergency Nourishment:** A limited (small scale) emergency nourishment events will be simulated in cases where the dune is damaged in Planning Reach 4 (Key Biscayne)
- **Armor Construction Length:** Armor construction length is measured in feet as the parallel to shore lot length, measured in GIS (with the aid of aerial photography).
- **Seed Value:** The Beach-fx manual recommends using a large prime number as a simulation seed value. In this case, the number 1545863 will be used.

3.2 FWOP Damages

$23.16M

AAEQ Damages & Cost

Present Value FWOP Economic Summary

$536,256,759
Structure & Content Damages

$99,126,160
Armor Cost

$21,507,770
Emergency Nourishment Costs

$656,890,689
Total Damages & Cost

AAEQ Damages & Cost by Planning Reach

Planning Reach	AAEQ Damages & Cost	%
PR1_Alt0	$1,870,297	8.08%
PR2_Alt0	$2,501,217	10.80%
PR3_Alt0	$221,600	0.96%
PR4_Alt0	$18,567,537	80.17%

Present Value FWOP Damages & Cost by Planning Reach

Planning Reach	PV Armor Cost	PV Emergency Nourishment Cost	PV Damages	PVDamages & Cost
PR1_Alt0	$28,906,468	$0	$24,139,561	$53,046,029
PR2_Alt0	$64,438,599	$0	$6,501,821	$70,940,420
PR3_Alt0	$5,781,093	$0	$504,013	$6,285,106
PR4_Alt0	$0	$21,507,770	$505,111,364	$526,619,135

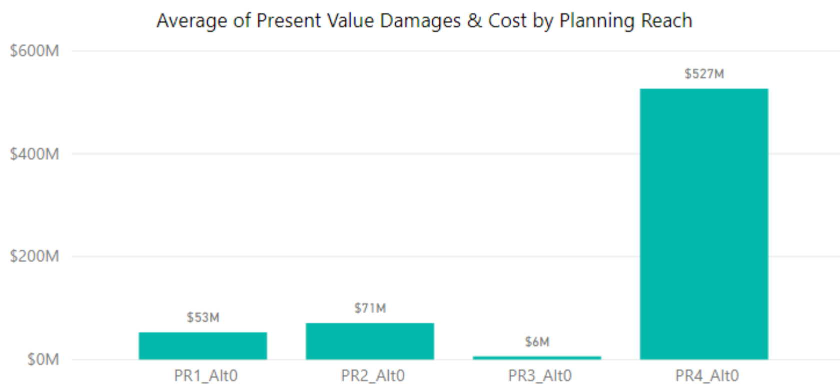


Figure 15: Summary FWOP Condition Damages & Cost

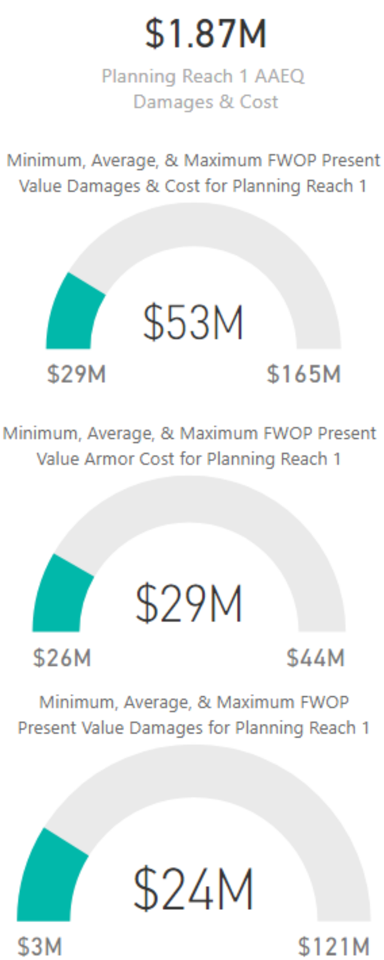
FWOP results indicate the following:

- Planning Reach 1 – The Bal Harbor & Surfside Beach ranked third in overall FWOP damages and cost. Anticipated future damages and cost come from future armor construction cost and erosion driven damages to high rises and recreational assets. Armor cost begin to accrue after 2030, while high rise and recreational asset damages occur at the end of the period of analysis. The major damage driving parameter is erosion. The results provided no significant evidence of back bay flooding influencing the damages. Figure 17 provides additional detail on the FWOP condition for planning reach 1.
- Planning Reach 2 – Reach 2 took the 2nd greatest FWOP cost. The overwhelming majority of the damages and cost come from future armor construction ($64 M present value). Asset damages consist of primarily of wave attack damages to decks and erosion to pools and other recreational assets. The results provided no significant evidence of back bay flooding influencing the damages. Figure 18 provides additional detail on the FWOP condition for planning reach 2.
- Planning Reach 3 – This area took the least amount of damage, which consisted mostly of future armor construction cost ($5.7 M present value). Asset damages consist of primarily wave attack damages to decks. Armor costs don't begin to happen until after 2040, and mostly in model reaches R061 – R063. The results provided no significant evidence of back bay flooding

influencing the damages. Figure 19 provides additional detail on the FWOP condition for planning reach 3.

- Planning Reach 4 – Key Biscayne accrued the greatest amount of FWOP damages and cost. The overwhelming majority of the damages come from storm surge inundation to single family residences in model reach R104. Damages exceed the overall structure inventory value within the model reach. Most of the damages occur between the base year and just after 2040. The results produced significant evidence of back bay flooding influencing the damages. Figure 20 provides additional detail on the FWOP condition for planning reach 4.

3.2.1 FWOP: Planning Reach 1 (Bal Harbor Beach & Surfside Beach)

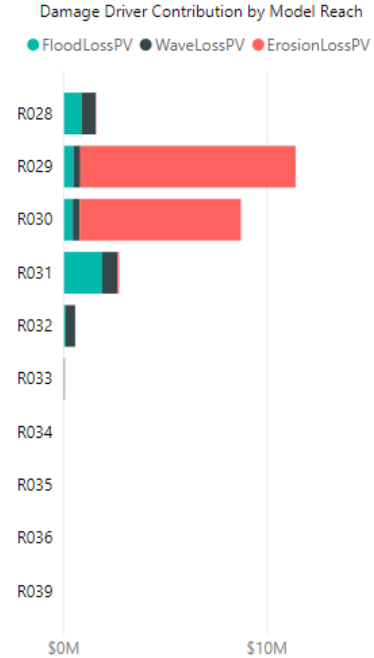


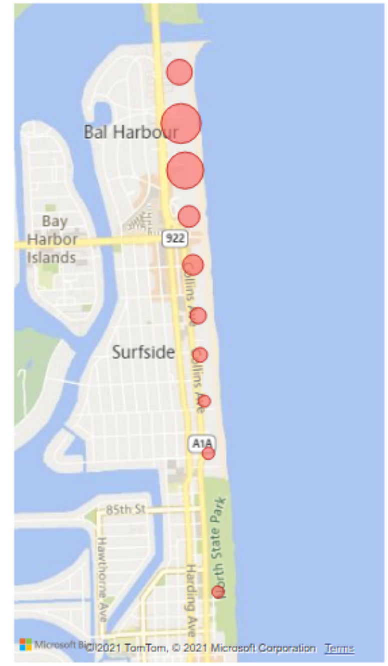
Present Value Damages per Damage Driver by Damage Element Type

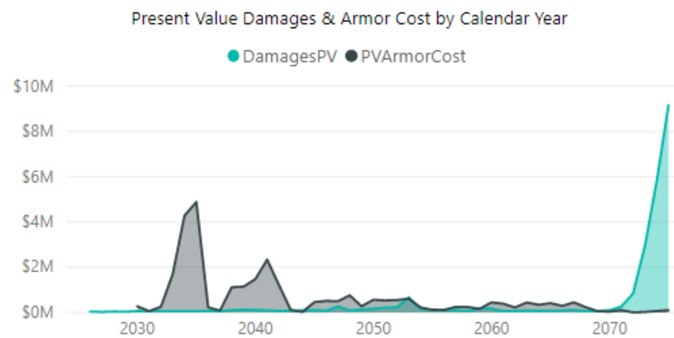
DEType	% Flood	% Wave Attack	% Erosion	DamagesPV
CABANA	2.19%	3.17%	0.03%	$116,277
COM-HT-HR	30.25%	39.20%	98.29%	$19,666,326
DECKS	0.00%	57.15%	0.57%	$1,573,988
GAZEBO	0.48%	0.48%	0.00%	$21,879
PARKINGLOT	0.00%	0.00%	0.28%	$52,177
POOL	0.00%	0.00%	0.45%	$83,131
ROAD1	0.00%	0.00%	0.21%	$38,919
SFR1	0.00%	0.00%	0.00%	$90
TENNIS	0.00%	0.00%	0.17%	$31,535
UGPARK	67.08%	0.00%	0.00%	$2,555,239
Total	**100.00%**	**100.00%**	**100.00%**	**$24,139,561**

Present Value Damages & Cost by Model Reach

Reach Description	PVArmorCost	DamagesPV	PVDamages & Cost
R028	$6,402,712	$1,433,546	$7,836,258
R029	$4,877,061	$11,255,625	$16,132,686
R030	$5,732,594	$8,661,184	$14,393,777
R031	$3,299,744	$2,227,056	$5,526,800
R032	$4,500,699	$512,865	$5,013,564
R033	$2,379,711	$47,903	$2,427,614
R034	$1,519,233	$1,049	$1,520,282
R035		$2	$2
R036	$161,672	$242	$161,914
R039	$33,042	$90	$33,132
Total	**$28,906,468**	**$24,139,561**	**$53,046,029**







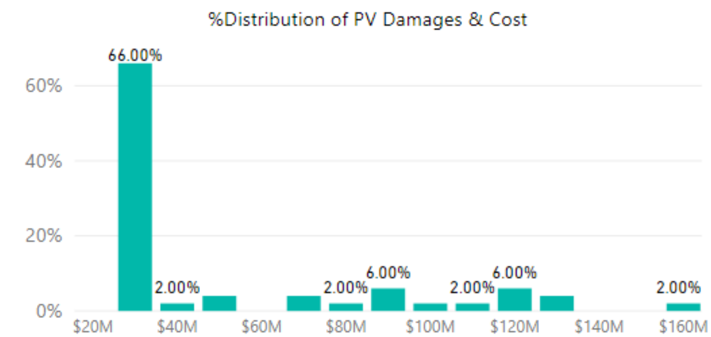


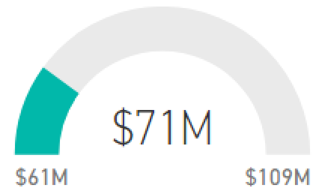
Figure 16: Planning Reach 1 FWOP Summary

3.2.2 FWOP: Planning Reach 2 (North Beach & Mid Beach)

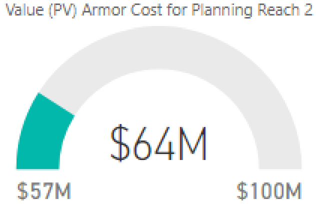
$2.5M

AAEQ Damages & Cost for Planning Reach 2

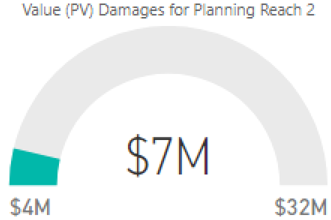
Minimum, Average, & Maximum FWOP Present Value (PV) Damages & Cost for Planning Reach 2



Minimum, Average, & Maximum FWOP Present Value (PV) Armor Cost for Planning Reach 2



Minimum, Average, & Maximum FWOP Present Value (PV) Damages for Planning Reach 2



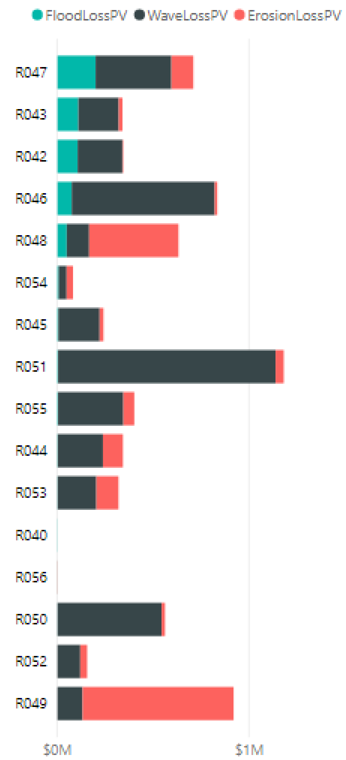
Present Value Damages per Damage Driver by Damage Element Type

DEType	% Flood	% Wave Attack	% Erosion	DamagesPV
COM-HT-HR	99.73%	15.54%	7.94%	$1,020,454
DECKS	0.00%	84.46%	62.93%	$4,946,530
PARKINGLOT	0.00%	0.00%	7.00%	$128,103
POOL	0.00%	0.00%	19.31%	$353,533
ROAD1	0.00%	0.00%	1.97%	$36,129
SFR1	0.27%	0.00%	0.00%	$1,552
TENNIS	0.00%	0.00%	0.85%	$15,519
Total	**100.00%**	**100.00%**	**100.00%**	**$6,501,821**

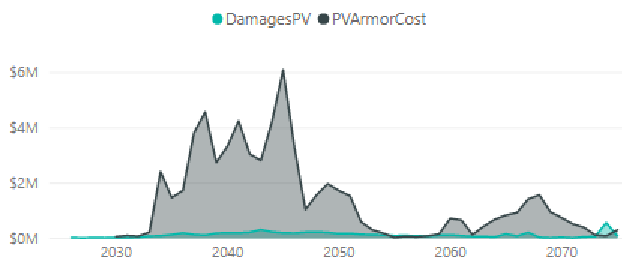
Present Value Damages & Cost by Model Reach

Reach Description	PVArmorCost	DamagesPV	PV Damages & Cost
R040	$1,879,924	$1,552	$1,881,476
R041	$3,774,798		$3,774,798
R042	$4,243,858	$261,402	$4,505,260
R043	$3,188,787	$268,454	$3,457,241
R044	$4,367,282	$311,158	$4,678,440
R045	$4,941,225	$241,167	$5,182,392
R046	$3,706,628	$757,554	$4,464,181
R047	$3,727,725	$513,925	$4,241,649
R048	$5,905,970	$609,489	$6,515,459
R049	$3,771,200	$886,290	$4,657,490
R050	$3,717,950	$561,425	$4,279,375
R051	$7,022,455	$1,174,328	$8,196,783
R052	$1,254,877	$141,748	$1,396,625
R053	$3,401,258	$294,715	$3,695,973
R054	$3,436,878	$74,512	$3,511,391
R055	$3,962,775	$401,052	$4,363,827
R056	$2,135,009	$3,050	$2,138,059
Total	**$64,438,599**	**$6,501,821**	**$70,940,420**

Damage Driver Contribution by Model Reach



Present Value Damages & Armor Cost by Calendar Year



%Distribution of PV Damages & Cost

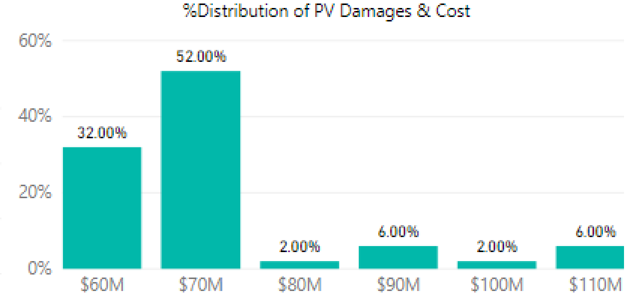


Figure 17: Planning Reach 2 FWOP Summary

3.2.3 FWOP: Planning Reach 3 (Mid Beach & South Beach)

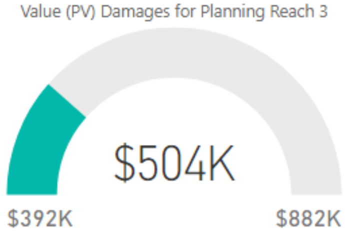
$222K

AAEQ Damages & Cost for Planning Reach 3

Minimum, Average, & Maximum FWOP Present Value (PV) Damages & Cost for Planning Reach 3

Minimum, Average, & Maximum FWOP Present Value (PV) Armor Cost for Planning Reach 3

Minimum, Average, & Maximum FWOP Present Value (PV) Damages for Planning Reach 3



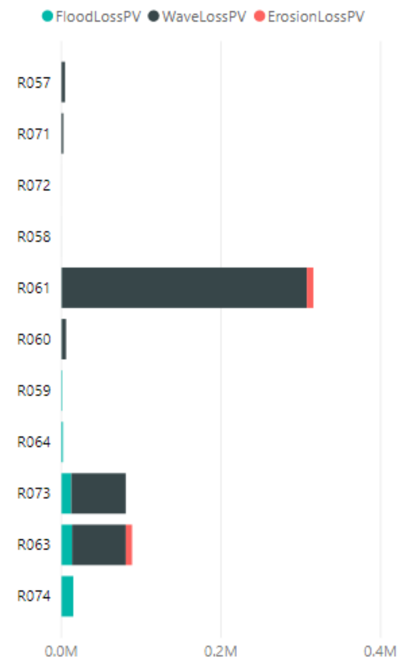
Present Value Damages per Damage Driver by Damage Element Type

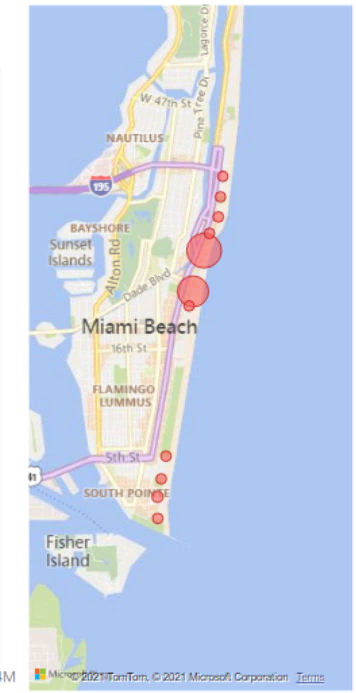
DEType	% Flood	% Wave Attack	% Erosion	DamagesPV
CABANA	90.94%	4.97%	0.17%	$51,839
COM-HT-HR	9.06%	0.00%	0.00%	$4,026
DECKS	0.00%	95.03%	4.43%	$432,880
POOL	0.00%	0.00%	64.11%	$10,260
ROAD1	0.00%	0.00%	27.91%	$4,466
TENNIS	0.00%	0.00%	3.38%	$540
Total	**100.00%**	**100.00%**	**100.00%**	**$504,013**

Present Value Damages & Cost by Model Reach

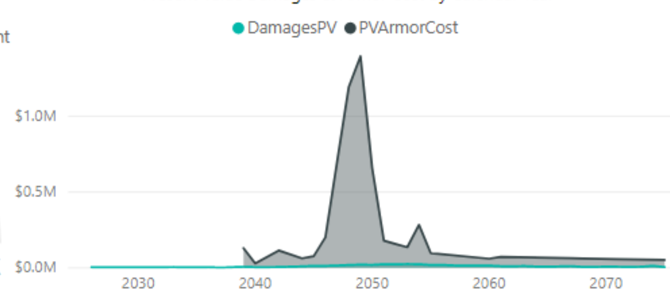
Reach Description	PVArmorCost	DamagesPV	PVDamages & Cost
R057		$4,553	$4,553
R058		$41	$41
R059		$1,028	$1,028
R060		$5,894	$5,894
R061	$3,028,034	$315,319	$3,343,353
R063	$2,753,059	$77,177	$2,830,235
R064		$1,943	$1,943
R071		$2,444	$2,444
R072		$14	$14
R073		$80,652	$80,652
R074		$14,949	$14,949
Total	**$5,781,093**	**$504,013**	**$6,285,106**

Damage Driver Contribution by Model Reach





Present Value Damages & Armor Cost by Calendar Year



%Distribution of PV Damages & Cost

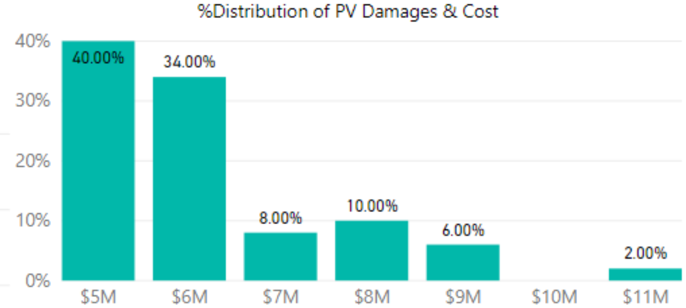


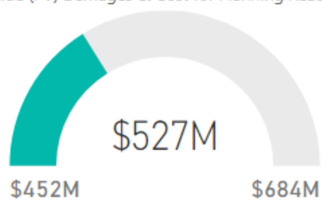
Figure 18: Planning Reach 3 FWOP Condition Summary

3.2.4 FWOP: Planning Reach 4 (Key Biscayne)

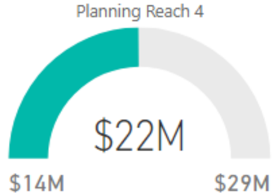
$19M

AAEQ Damages & Cost for Planning Reach 4

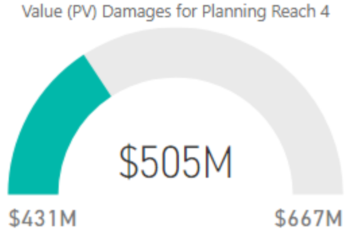
Minimum, Average, & Maximum FWOP Present Value (PV) Damages & Cost for Planning Reach 4



Minimum, Average, & Maximum FWOP Present Value (PV) Emergency Nourishment Cost for Planning Reach 4



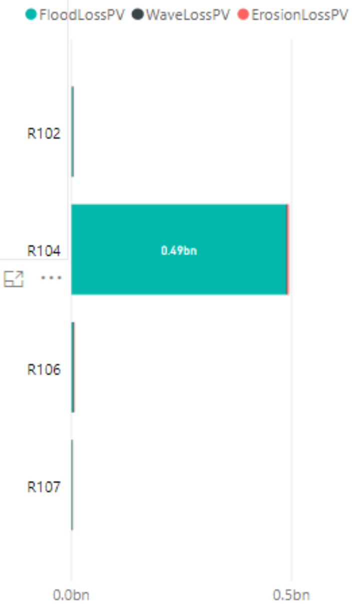
Minimum, Average, & Maximum FWOP Present Value (PV) Damages for Planning Reach 4

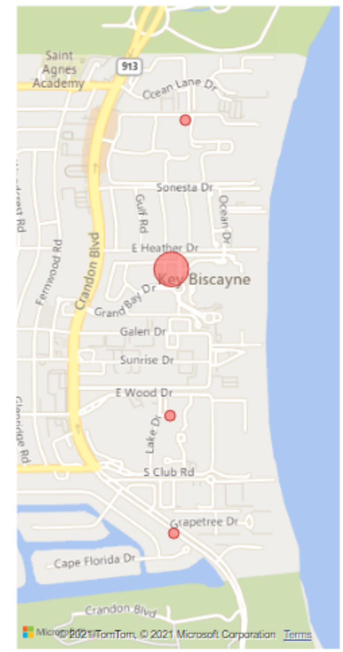


Damages per Damage Driver by Damage Element Type

DEType	% Flood	% Wave Attack	% Erosion	DamagesPV
COM-HT-HR	1.63%	45.98%	0.00%	$9,175,392
DECKS	0.00%	49.16%	0.00%	$5,094,565
GAZEBO	0.11%	4.86%	0.00%	$623,729
PARKINGLOT	0.00%	0.00%	11.57%	$489,977
POOL	0.00%	0.00%	75.08%	$3,178,747
ROAD1	0.00%	0.00%	0.42%	$17,811
SFR1	98.26%	0.00%	0.02%	$485,984,528
TENNIS	0.00%	0.00%	12.91%	$546,614
Total	**100.00%**	**100.00%**	**100.00%**	**$505,111,364**

Damage Driver Contribution by Model Reach

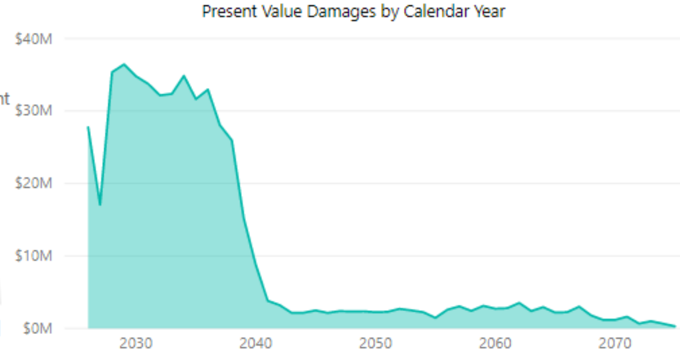




Present Value Damages by Model Reach

Reach Description	DamagesPV
R102	$3,776,689
R104	$492,846,109
R106	$6,064,920
R107	$2,423,646
Total	**$505,111,364**

Present Value Damages by Calendar Year



%Distribution of PV Damages & Cost

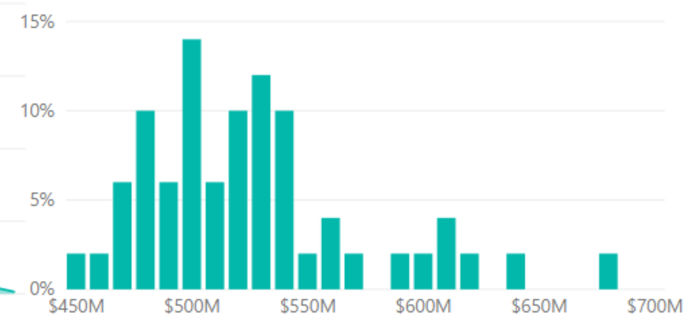


Figure 19: Planning Reach 4 FWOP Condition Summary

4 Future with Project Condition

4.1 Alternative Description

Table 5: Planning Reach 1 Alternatives

Alternative Description			
Alternative	Description	Nourishment Source	Erosion Control Structure Description
PR1_Alt0	PR1 FWOP		
PR1_Alt1	Small BN	Bakers Haulover + New Sand (Alternating cycles)	
PR1_Alt2	Medium BN	Bakers Haulover + New Sand (Alternating cycles)	
PR1_Alt3	Large BN	Bakers Haulover + New Sand (Alternating cycles; Initial is a mix)	
PR1_Alt4	ECS + Small BN	Bakers Haulover + New Sand (Alternating cycles)	Bal Harbour Groins (5 groins)
PR1_Alt5	ECS + Medium BN	Bakers Haulover + New Sand (Alternating cycles)	Bal Harbour Groins (5 groins)
PR1_Alt6	ECS + Large BN	Bakers Haulover + New Sand (Alternating cycles; Initial is a mix)	Bal Harbour Groins (5 groins)

Table 4: Planning Reach 2 Alternatives

Alternative Description			
Alternative	Description	Nourishment Source	Erosion Control Structure Description
PR2_Alt0	PR2 FWOP		
PR2_Alt1	Small BN	IV: Lummus Park; RV: Lummus Park + Upland Truck Haul (Mix)	
PR2_Alt2	Medium BN	IV: Lummus Park; RV: Lummus Park + Upland Truck Haul (Mix)	
PR2_Alt3	Large BN	Lummus Park + Upland Truck Haul (Mix)	
PR2_Alt4	ECS at R046 + Small BN	IV: Lummus Park; RV: Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46
PR2_Alt5	ECS at R046 + Medium BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46
PR2_Alt6	ECS at R046 + Large BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46
PR2_Alt7	ECS at R046 & R050 + Small BN	IV: Lummus Park; RV: Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50
PR2_Alt8	ECS at R046 & R050 + Medium BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50
PR2_Alt9	ECS at R046 & R050 + Large BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50
PR2_Alt10	ECS at R046, R050 & R055 + Small BN	IV: Lummus Park; RV: Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50 + Submerged BW @ R-55
PR2_Alt11	ECS at R046, R050 & R055 + Medium BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50 + Submerged BW @ R-55
PR2_Alt12	ECS at R046, R050 & R055 + Large BN	Lummus Park + Upland Truck Haul (Mix)	Reef Balls @ R-46 + Submerged BW @ R-50 + Submerged BW @ R-55

Table 4 provides detail on the alternatives studied for planning reach 1. The sand source of beach nourishment for this area is anticipated to come from Bakers Haulover Inlet and new sand sources in alternating cycles. Alternatives 1 through 3 consist of small, medium, and large beach nourishments. Alternatives 4 through 6 are small medium and large beach nourishment with erosion control structures (ECS). The erosion control structures in this reach are groin fields.

Table 5 provides detail on the alternatives studied for planning reach 2. The beach nourishment sand source for this area is anticipated to come from Lummus Park and upland truck haul. Alternatives 1 through 3 consist of small, medium, and large beach nourishments. The remaining alternatives have beach nourishment with different configurations of erosion control structures. Alternatives 4 through 6 are small medium and large beach nourishment with reef balls near R046. Alternatives 7 through 9 are small medium and large beach nourishment with reef balls near R046 and a submerged breakwater near R050. Alternatives 10 through 12 are small medium and large beach nourishment with reef balls near R046, and submerged breakwaters near R050, and R055.

Table 6: Planning Reach 3 Alternatives

Alternative Description				
Alternative ID	Alternative	Description	Nourishment Source	Erosion Control Structure Description
0	PR3_Alt0	PR3 FWOP		
1	PR3_Alt1	BW Mod + BW Extension		Attached BW Mod + Breakwater Ext.
2	PR3_Alt2	BW Mod + BN	Lummus Park	Attached BW Mod

Table 7: Planning Reach 4 Alternatives

Alternative Description			
Alternative	Description	Nourishment Source	Erosion Control Structure Description
PR4_Alt0	PR4 FWOP		
PR4_Alt1	Small BN	Upland Truck Haul	
PR4_Alt2	Large BN + Tieback Walls	Upland Truck Haul	Seawall
PR4_Alt3	ECS		Groins
PR4_Alt4	ECS + Small BN	Upland Truck Haul	Groins
PR4_Alt5	ECS + Large BN + Tieback Walls	Upland Truck Haul	Seawall + Groins
PR4_Alt6	Reinforced Dune + BN + Tieback Walls	Upland Truck Haul	11' Seawall

Table 6 provides details on the alternatives for planning reach 3. Alternative 1 is to modify and extend and existing breakwater, and alternative 2 is basically a beach nourishment in addition to alternative 1.

Table 7 provides detail on the alternatives evaluated for planning reach 4. Alternatives 1 and 2 are small and large beach nourishment. However, alternative 2 has a tieback wall in addition to the large beach nourishment. Alternative 3 is a groin field. Alternatives 4 and 5 are small and large beach nourishments with erosion control structures. Alternative 6 is essentially a floodwall with tiebacks covered with a dune (reinforced dune).

4.2 FWP Alternative Evaluation and Comparison

- FWP Condition Alternative Evaluation & Comparison: Planning Reach-1
  Figure 20 summarizes the details of the alternative comparison for planning reach 1. Alternative 5 (Medium BN + Groins) most reasonably maximizes net NED benefits. The alternative reduces over 92% of the erosion damages with approximately 9 nourishments over the life cycle using nearly 2.6 million cubic yards of sand. This alternative is also anticipated to generate incidental recreational benefits.
- FWP Condition Alternative Evaluation & Comparison: Planning Reach-2
  Figure 21 summarizes the details of the alternative comparison for planning reach 2. Alternative 2 (Medium BN) most reasonably maximizes net NED benefits. The alternative reduces over 92% of the erosion damages with approximately 11 nourishments over the life cycle using nearly 5.9 million cubic yards of sand. This alternative is also anticipated to generate incidental recreational benefits.
- FWP Condition Alternative Evaluation & Comparison: Planning Reach-3
  Figure 22 summarizes the details of the alternative comparison for planning reach 3. None of the alternatives were able to generate benefits that were at least 50% of the alternative NED costs. Since planning reach 3 is mostly accretional, no incidental recreation benefits are anticipated.
- FWP Condition Alternative Evaluation & Comparison: Planning Reach-4
  Figure 23 summarizes the details of the alternative comparison for planning reach 4. Alternative 6 (Medium BN + 11’ floodwall + tiebacks) most reasonably maximizes net NED benefits. The alternative reduces 41% of the erosion damages with approximately 11 nourishments over the life

cycle using nearly 5.9 million cubic yards of sand. This alternative is also anticipated to generate incidental recreational benefits.

The plan formulation process for planning reach 4 was subject to additional challenges. Once the modeling for the initial array of alternatives was complete, the PDT was made aware of constraints on the footprint of alternatives to avoid impacts to submerged aquatic vegetation. The initial alternative 6 was a fairly large beach with a 40'dune width, 11' dune height, and a 45' berm. That alternative was shrunk to a 15' dune width and a 5' berm.

The benefits for alternative 6 were based on the model runs mentioned above, and not based on a reinforced dune. More information on this will be covered in the risk and uncertainty section.

PR1: Evaluation & Comparison of Alternative Physical Performance

Alternative ID	Alternative	Description	Nourishment Interval	# Nourishments	Initial Volume	Renourishment Volume	Total Volume Needed	% of Damages Reduced
1	PR1_Alt1	Small BN	4.00	10	283,443	284,134	2,840,645	56.5%
2	PR1_Alt2	Medium BN	3.82	11	276,071	291,038	3,186,449	80.4%
3	PR1_Alt3	Large BN	6.00	8	447,434	570,688	4,442,253	94.8%
4	PR1_Alt4	ECS + Small BN	4.75	8	261,203	261,066	2,088,668	65.9%
5	PR1_Alt5	ECS + Medium BN	4.44	9	247,039	289,469	2,562,789	92.2%
6	PR1_Alt6	ECS + Large BN	6.86	7	431,682	535,703	3,645,901	98.9%

PR1: Selected Alternative

PR1_Alt5

$4,114,965
Damages

$48,931,064
Benefits

$72,212,008
PV Total Cost

($23,280,944)
Net Benefits

0.68
BCR

92.2%
% of Damages Reduced

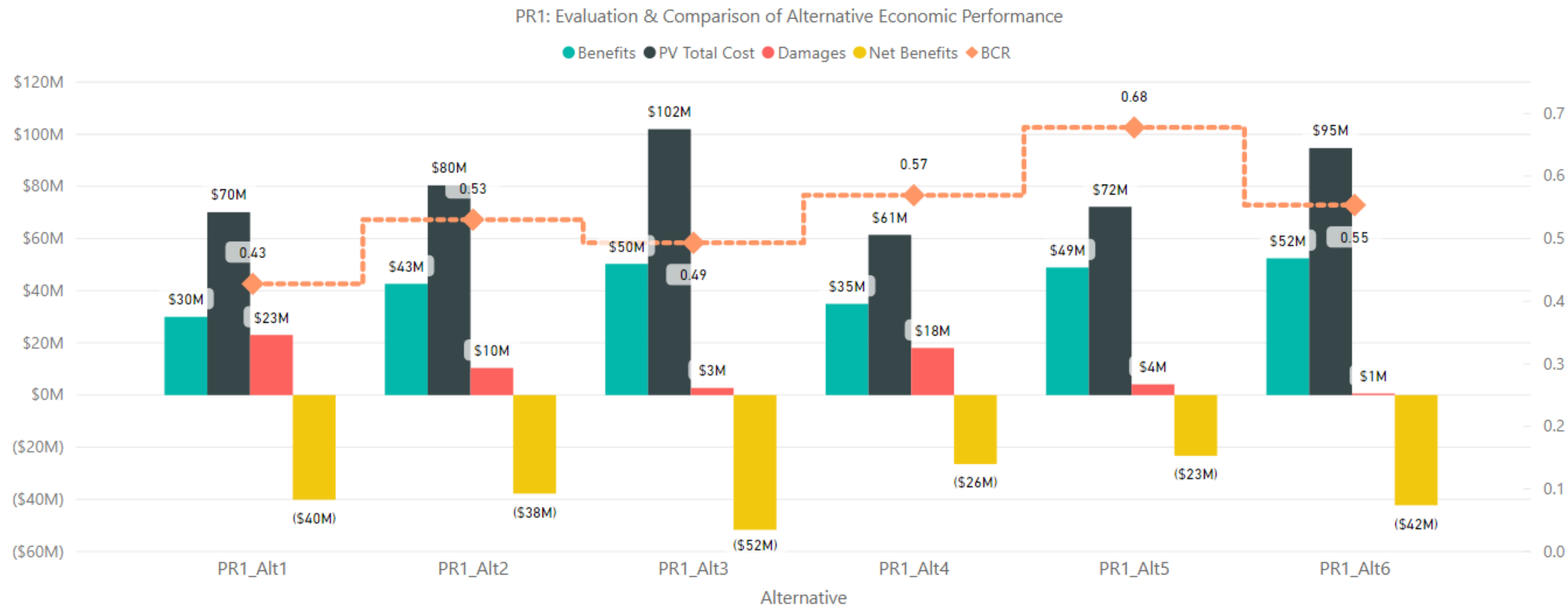


Figure 20: Evaluation & Comparison of Planning Reach 1 Alternatives

PR2: Evaluation & Comparison of Alternative Physical Performance

Alternative ID	Alternative	Description	Nourishment Interval	# Nourishments	Initial Volume	Renourishment Volume	Total Volume Needed	% of Damages Reduced
1	PR2_Alt1	Small BN	4.00	10	386,510	564,619	5,468,084	80.3%
2	PR2_Alt2	Medium BN	3.82	11	409,477	545,588	5,865,361	92.4%
3	PR2_Alt3	Large BN	5.75	8	1,346,129	1,038,142	8,613,123	98.3%
4	PR2_Alt4	ECS at R046 + Small BN	3.91	11	473,346	605,655	6,529,900	81.4%
5	PR2_Alt5	ECS at R046 + Medium BN	5.00	9	619,258	790,200	6,940,859	91.1%
6	PR2_Alt6	ECS at R046 + Large BN	5.00	9	685,609	808,327	7,152,221	85.7%
7	PR2_Alt7	ECS at R046 & R050 + Small BN	4.30	10	442,147	662,356	6,403,352	82.1%
8	PR2_Alt8	ECS at R046 & R050 + Medium BN	4.89	9	670,172	739,232	6,584,024	91.8%
9	PR2_Alt9	ECS at R046 & R050 + Large BN	5.00	9	723,641	796,265	7,093,762	94.9%
10	PR2_Alt10	ECS at R046, R050 & R055 + Small BN	4.78	9	424,961	660,533	5,709,223	83.0%
11	PR2_Alt11	ECS at R046, R050 & R055 + Medium BN	4.89	9	661,202	722,010	6,437,281	92.6%
12	PR2_Alt12	ECS at R046, R050 & R055 + Large BN	5.00	9	697,113	746,303	6,667,540	93.8%

PR2: Selected Alternative

PR2_Alt2

$5,356,416
Damages

$65,584,004
Benefits

$120,999,935
PV Total Cost

($55,415,931)
Net Benefits

0.54
BCR

92.4%
% of Damages Reduced

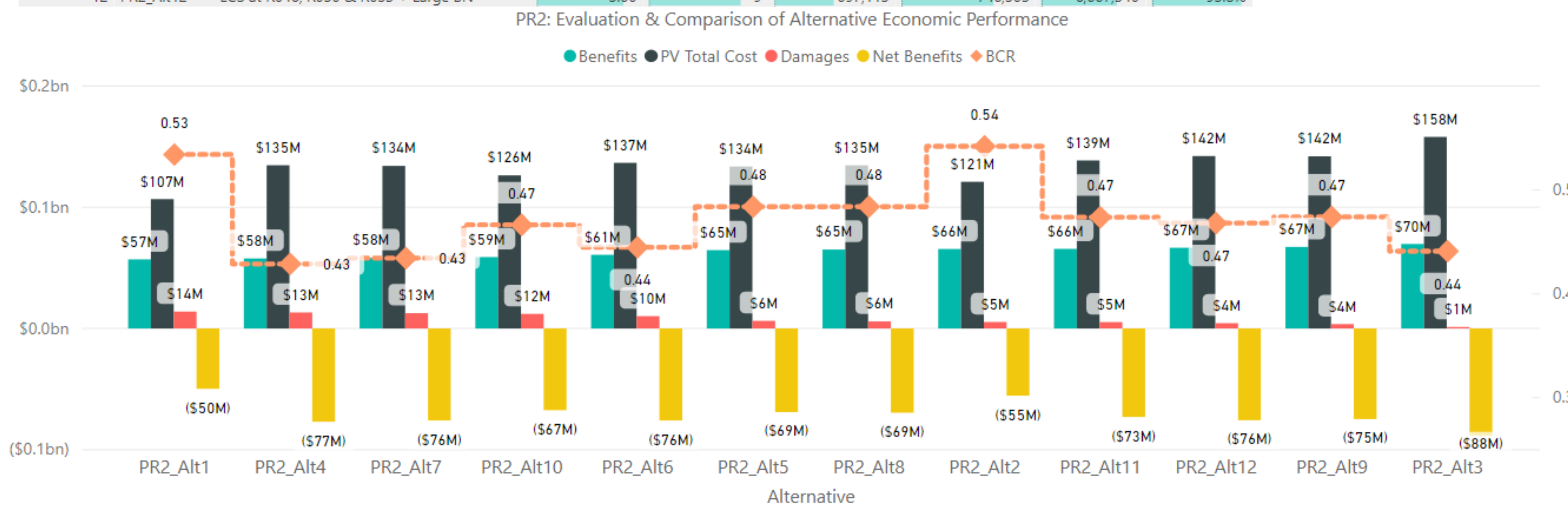


Figure 21: Evaluation & Comparison of Planning Reach 2 Alternatives

PR3: Evaluation & Comparison of Alternative Physical Performance

Alternative ID	Alternative	Description	Nourishment Interval	# Nourishments	Initial Volume	Renourishment Volume	Total Volume Needed	% of Damages Reduced
1	PR3_Alt1	BW Mod + BW Extension		0			0	97.0%
2	PR3_Alt2	BW Mod + BN	6.67	6	75,822	107,365	612,648	74.9%

PR3: Evaluation & Comparison of Alternative Economic Performance

Figure 22: Evaluation & Comparison of Planning Reach 3 Alternatives

PR4: Evaluation & Comparison of Alternative Physical Performance

Alternative ID	Alternative	Description	Nourishment Interval	# Nourishments	Initial Volume	Renourishment Volume	Total Volume Needed	% of Damages Reduced
1	PR4_Alt1	Small BN	5.44	9	135,156	131,892	1,190,295	6.9%
2	PR4_Alt2	Large BN + Tieback Walls	7.00	7	435,220	232,164	1,828,206	36.4%
3	PR4_Alt3	ECS		0			0	3.5%
4	PR4_Alt4	ECS + Small BN	10.00	5	134,899	137,647	685,487	5.6%
5	PR4_Alt5	ECS + Large BN + Tieback Walls	8.17	6	434,425	205,024	1,459,547	36.3%
6	PR4_Alt6	Reinforced Dune + BN + Tieback Walls	1.68	28	26,172	24,460	686,601	41.2%

PR4: Selected Alternative

PR4_Alt6

$309,757,734
Damages

$216,861,400
Benefits

$60,364,560
PV Total Cost

$156,496,840
Net Benefits

3.59
BCR

41.2%
% of Damages Reduced

PR4: Evaluation & Comparison of Alternative Economic Performance

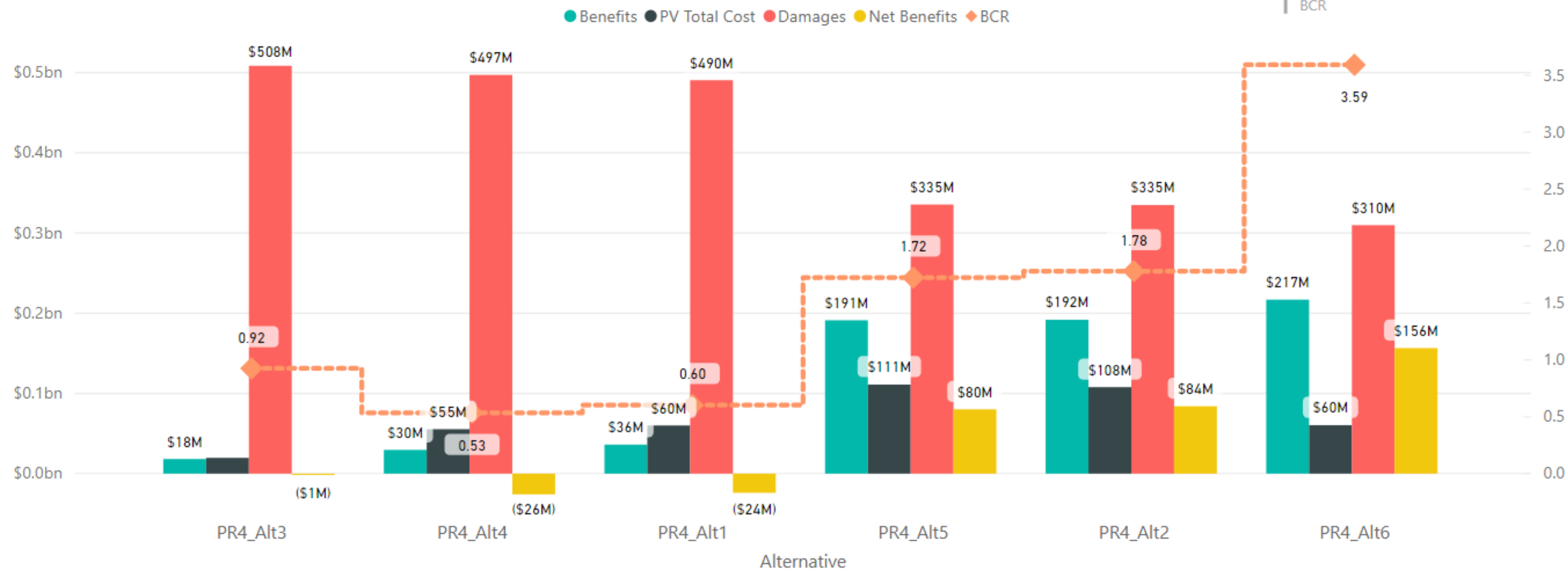


Figure 23: Evaluation & Comparison of Planning Reach 4 Alternatives

4.3 Incidental Recreation Benefit Analysis

According to ER 1105-2-100, *Planning Guidance Notebook*, dated April 22, 2000, incidental recreation benefits can be calculated in CSRM studies. While recreation benefits cannot make up more than 50% of the total benefits needed for project justification, the guidance states that "if the criterion for participation is met, then all recreation benefits are included in the benefit to cost analysis."

4.3.1 Travel Cost Method

ER 1105-2-100 specifies that benefits arising from recreation opportunities created by a project be measured in terms of willingness-to-pay (WTP). Three acceptable calculation methods are outlined: (a) the travel cost method (TCM), (b) the contingent valuation method, and (c) the unit day value method (UDV). The team determined that a region specific TCM model was appropriate due to the high levels of visitation to Miami Beach.

ER 1105-2-100 Appendix E explains the travel cost method and states:

> The basic premise of the travel cost method is that per capita use of a recreation site will decrease as out-of-pocket and time costs of traveling to the site increase, other variables being constant. TCM consists of deriving a demand curve by using the variables costs of travel and the value of time as proxies for the price.

For this study, evaluating recreation TCM benefits included two primary efforts: determine the willingness-to-pay for Miami Beach and estimate annual equilibrium visitation over the period of analysis.

4.3.1.1 *WTP Model*

USACE contracted out the first step of the TCM analysis to recreation demand experts at the University of Georgia – Athens (UGA). The researchers were hired as part of a joint effort organized by multiple USACE studies, including, but not limited to the Folly Beach, Miami-Dade, Pinellas County, and Collier County Feasibility Studies. They were able to use data from the Deepwater Horizon Oil Spill to estimate WTP for different recreation locations within the regional footprint of USACE South Atlantic Division (SAD). Their analysis included modern statistical techniques to derive WTP estimates with the Deepwater Horizon data. While the tools for demand estimation have improved in the last few decades, the basic premise outlined in ER 1105-2-100 is still the guiding principle. The report from UGA is included as a sub-appendix to this report to provide further information on the data and analytical techniques used in the analysis.

4.3.1.2 *Equilibrium Visitation Model*

The analysis by UGA provides the WTP based on the study area's current condition, as well as a method for evaluating changes to the beach's condition. USACE economists developed a supplemental spreadsheet model that takes the WTP values and applies them to a supply and demand framework. This framework, which incorporates site specifics, provides a total recreational benefit of the Tentatively Selected Plan (TSP) over the period of analysis, relative to the future without.

Beach visitors need a certain amount of space to recreate, and a large beach can accommodate more visitors. In the spreadsheet model, this is the supply. Supply determines the maximum number of possible daily visitors, based on the size (length and width) of the beach. The supply varies between the FWOP and FWP, and can also vary within the FWP, for example following a nourishment.

Demand in the spreadsheet model is based on annual visitation demand. Visitation demand can be determined by different factors, such as traffic data, hotel bookings, surveys, or other site-specific information. Demand could also be limited by parking and access availability or hotel capacity. Demand is constant across the FWOP and FWP. This is unlikely to be true, but there is no way to estimate the difference, so this conservative approach is used.

The model disaggregates the annual demand into daily demand estimates. The estimated daily demand is capped by the maximum daily supply (for both the FWOP and FWP) and then the WTP values provided by UGA are applied to the equilibrium visitors. Note, the WTP values are applied to more visitors in the FWP (more beach space, assuming sufficient demand) and at a higher value (better recreation experience, as estimated by UGA researchers). Finally, the total benefits for the FWOP and FWP are aggregated over the period of analysis and the difference is taken.

4.3.2 Recreation Benefit

Based on information provided by UGA, the WTP for a day visit is $33.53 for a saltwater beach user event in Miami Dade. Data from Beach-*fx* was used to determine the beach supply for the FWOP and FWP. Annual visitation was set using a combination of data from the Deepwater Horizon dataset and information in a report entitled “The Greater Miami 2020 Visitor Industry Overview” which was conducted by the Greater Miami Convention & Visitors Bureau. Based on this information, annual visitation demand of roughly 23 million user events held constant over the period of analysis was assumed. User events were distributed throughout the study based on model reach length.

Using the WTP numbers from UGA researchers and the Beach-fx results from the landloss.csv model output, in an estimated average annual recreation benefits of $36.8M for the Main Segment, and $102K for Key Biscayne. (FY2021 prices at a discount rate of 2.5%).

Table 8: Incidental Recreation Benefits

Planning Reach	Present Value (PV) Benefits	AAEQ Benefits
1	$302,920,000	$10,681,000
2	$741,290,000	$26,136,000
3	$0	$0
4	$2,900,000	$102,000
Main Segment	$1,044,210,000	$36,817,000
Key Biscayne	$2,900,000	$102,000

4.4 The Tentatively Selected Plan

Table 9 provides detail on the TSP for the Miami Dade CSRM study. The benefits from the incidental recreation benefits analysis was added to the primary NED benefits for the alternatives for planning reaches 1, 2, and 4. Other changes include the removal of back-bay damage considerations from the planning reach 4 economic results based on the assumption that the back bay issues would be addressed by the NFS. Approximately $61 million was added to the cost for planning reach 4 to account for real estate cost.

Table 9: TSP Economic Summary

Planning Reach	Alternative	Description	AAEQ CSRM Benefits	AAEQ Recreation Benefits	AAEQ Benefits	AAEQ Cost	AAEQ Net Benefits	BCR
1	PR1_Alt5	ECS + Medium BN	$1,725,000	$10,681,000	$12,406,000	$2,546,000	$9,860,000	4.9
2	PR2_Alt2	Medium BN	$2,010,000	$26,136,000	$28,146,000	$3,763,000	$24,383,000	7.5
1+2	Main Segment TSP	PR1_Alt5 + PR2_Alt1	$3,735,000	$36,817,000	$40,552,000	$6,309,000	$34,243,000	6.4
4	PR4_Alt6 (Key Biscayne TSP)	Reinforced Dune + BN + Tieback Walls	$9,872,000	$102,000	$9,974,000	$4,279,000	$5,695,000	2.3

4.5 Risk & Uncertainty

This analysis was conducted using the "high" sea level rise rate. Additional analyses will be conducted using the historical and intermediate sea level change rates prior to the agency decision milestone (ADM). Other analyses to be conducted will be an update of all discount rates and price levels.

Sources of risk and uncertainty in the economic evaluation are attributable to limitations in Beach fx with respect to representing the impact of groins, breakwaters, reefballs, and seawalls. Groins, breakwaters, and reefballs were accounted for by adjusting the background erosion rates in certain model reaches and minimizing the amount of time between the start year and the base year.

The primary takeaways from the modeling of Key Biscayne were that the primary driver of damages is inundation, and back bay flooding is expected to be significant. That said, there is significant risk in using the Beach-fx results for the planning reach 4 FWOP and FWP conditions. Those are as follows:

- The model is predicting only 41% risk reduction, despite a dune height of 11 feet.
- Experiments with taller dune heights did not yield any significant benefit increases.
- Beach fx is not designed to measure the performance of flood walls.
- The modeling process does not account for the likelihood that property owners may elevate or floodproof their homes.
- The model is predicting significant flood damages within the 1st 20-25 years of the period. It is expected to take approximately 10 to 15 years before the back bay measures will be in place. This discrepancy is not accounted for in the economic analysis.

Given the significance of the flood risk in Key Biscayne, assessing the economic impact of storm surge inundation would require the use of G2CRM (Generation 2 Coastal Risk Model). Unfortunately, including G2CRM in the economic evaluation for Planning Reach 4 is beyond the scope of this effort.

5 References

U.S. Army Corps of Engineers, Jacksonville District. (2020). *Miami Dade County Beach Report, Estimated Depreciated Replacement Cost of Damage Elements.* Jacksonville, Florida: Jacksonville District.