Coastal Texas Protection and Restoration Feasibility Study
Final Feasibility Report

Appendix E-2 – Annex 1:

South Padre Island Economic Analysis

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1 INTRODUCTION

1.1 STUDY AREA AND HISTORY

Since 1988, dredged material from the Brazos Santiago Pass has been placed either in a nearshore berm, or on the beach at South Padre Island, TX (Perry, 2017). The U.S. Army Corps of Engineers (USACE) Galveston District (CESWG) has requested a feasibility study of permanent beach nourishment alternatives for South Padre Island. This study requires the identification of a Tentatively Selected Plan (TSP) for coastal flood reduction, and focuses on future conditions in the absence of the presently implemented beneficial use project.

The area under consideration spans approximately five miles north of the Brazos Santiago Pass (Figure 1), and includes the entire area of development for South Padre Island. The island is vulnerable to coastal erosion, ocean-side inundation, and direct wave impact. The project alternatives analyzed considered beach renourishment as a sacrificial solution to reduce the damages produced by these three damage-driving parameters.

Figure 1: South Padre Island

1.2 BEACH-FX MODEL

The planning model Beach-fx was used to analyze both the future without project conditions and planned nourishment alternatives. Beach-fx is an engineering economic model that implements Monte-Carlo methods to quantify the uncertainty associated with future beach renourishment projects (Gravens et. al. 2007). The model is event-driven, and provides estimates of storm damages along coastal zones. Beach-fx simulates the condition of a beach profile, as it evolves due to storms and background erosion. Typical Beach-fx simulations include 100-300 lifecycles, each with a unique sequence and number of storm events. Across all lifecycles, the model returns average historically observed rates (number and frequency of storm events, shoreline erosion, etc.).

Input to Beach-fx includes meteorology, coastal morphology, economics, and planning processes. A simplified model architecture of Beach-fx can be seen in Figure 2. Beach-fx is a data-driven model, in that it relies on relational databases that are accessed at runtime. The input database (IDB) contains information that defines the study area, and includes initial conditions, plausible storm events, storm occurrence rates, and damageable elements. The output database (ODB) stores various model simulation statistics and output.

Within Beach-fx, no profile response computations are performed at runtime. Rather, the shore response database (SRD) is populated externally, and contains the profile responses to storm events as well as cross-shore profiles of damage driving parameters (inundation, erosion, and waves). At runtime, the SRD serves as a lookup table providing post-storm profile information and cross-shore profiles of damage drivers for each pre-storm profile and storm event.

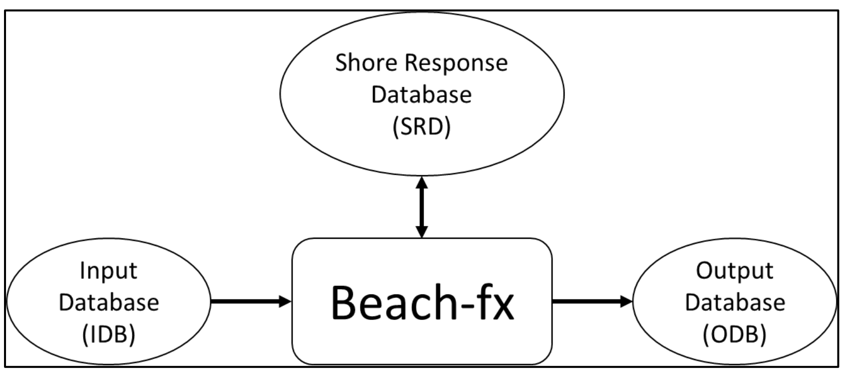

Figure 2: Simplified Beach-fx computational architecture

1.3 Appendix Overview

The purpose of this appendix is to describe in detail the input employed in the application of Beach-fx to South Padre Island, as well as the results of the model runs. This appendix is divided into seven subsequent sections detailing the environmental/meteorological forcing, beach profile analysis, population of the Beach-fx SRD, calibration of Beach-fx and model assumptions, future without project model runs, and future with project model runs.

2 Environmental Forcing

This section provides details into the development of environmental forcing for South Padre Island. Within Beach-fx, a representative storm suite (consisting of storm surge hydrographs and coincident wave information), and storm seasons describe the environmental forcing for the area under consideration. The representative storm suite was used to populate the SRD.

2.1 Probabilistic Storm Database

A comprehensive suite of synthetic tropical storm surge hydrographs spanning the entire probabilistic space was previously developed through the application of high fidelity numerical models for hydrodynamics (ADCIRC; Hench, 1994) and waves (STWAVE; Massey, et. al. 2011) in support of the Federal Emergency Management Agency's Flood Insurance Study: Coastal Counties, Texas (USACE, 2011). The numerically generated storm surge hydrographs resulting from this study are stored in the Coastal Hazards System (CHS; https://chs.erdc.dren.mil) at over 4,000 save points. Each of the 446 plausible tropical storms have been assigned spatially dependent relative probabilities of occurrence based on the storm characteristics and intensities (Melby et. al. 2015).

2.2 Identification of a Save Point

Because there are multiple save points near South Padre Island, a single one was selected to provide environmental forcing for Beach-fx. The selection of a save point considered both the water depth and spatial location. Because the seaward boundary in SBEACH (storm response model used for this study; Larson, et. al. 1990) is near the depth of closure, the save point must be located in a similar water depth (approximately 30 ft.; 9 m.). Likewise, the ideal save point is spatially located near the center of the entire study area. In the CHS there were approximately 15 save points that were available for consideration on the ocean-side of South Padre Island. The save points were first filtered based on the water depth and then the location. ADCIRC Station 86 (Figure 3) met the water depth criteria at approximately 35.7 ft. Although Station 86 is near the northern end of the study domain, it was deemed appropriate because deviations in the storm surge hydrograph time series are not expected to be significant between the location of the save point and the center of the study area (~3 miles).

Figure 3: Location of ADCIRC Save Point 86

2.3 IDENTIFICATION OF REPRESENTATIVE STORMS

At each save point, there are 446 unique storm surge hydrographs and coincident significant wave height time series corresponding to each synthetic tropical storm event. It is not feasible to populate the shore response database in Beach-fx using all available storms, therefore a representative storm suite was developed (Gravens and Sanderson; 2017). Because storms possess locational characteristics, the storm suite was first reduced based on storms whose storm track fell within a 200km radius of the project site (Figure 4). Use of a 200km radius is consistent with the methodology used to generate the storm recurrence rates (Melby, 2015). This step reduced the storms under consideration from 446 to 286.

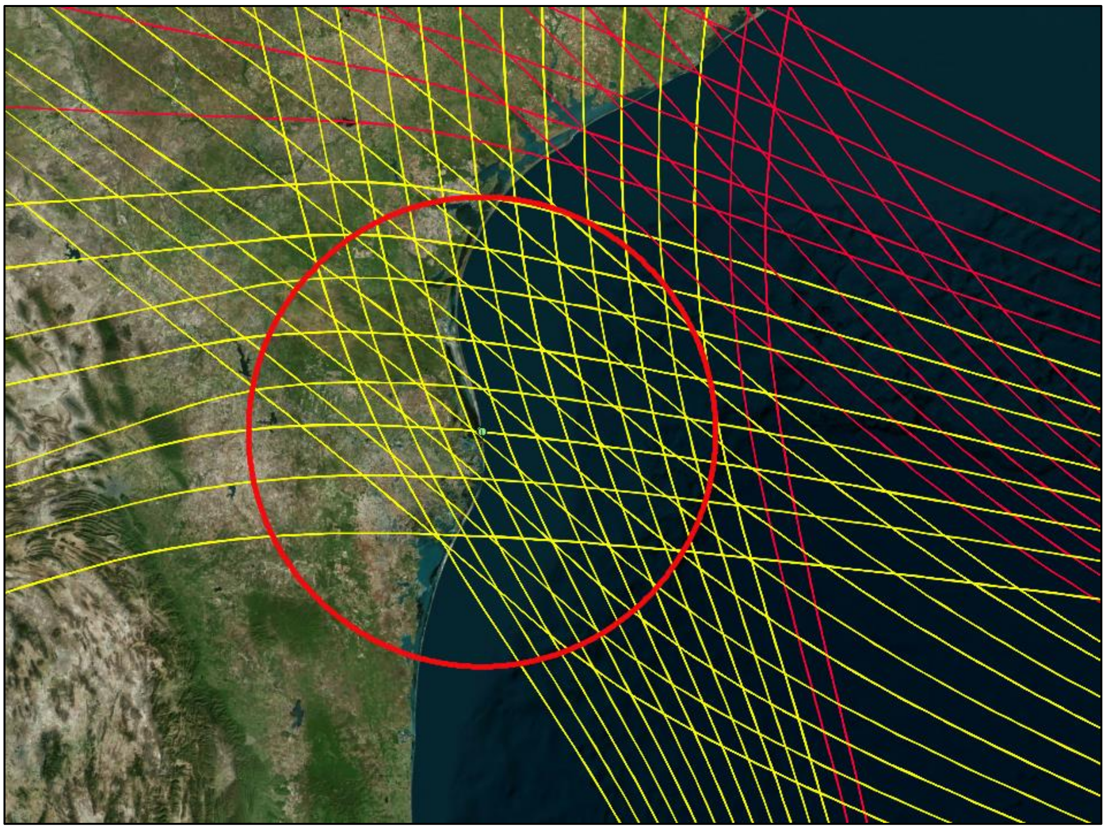

Figure 4: Selection of Storms within 200km Radius; yellow storm tracks are those that pass within a 200km radius.

The remaining 286 storms were classified based on the peak surge (ranging from approximately 0.5-3.5m) and grouped into 12 clusters (

Table 1). The lower and upper cluster ranges were defined such that there were a similar number of storms in each cluster. If the range of peak values that each cluster is composed of had equal spacing throughout, the number of storms in each cluster would have resulted in a significantly uneven distribution. For example, comparing the number of storms in range 0.5-1.0 m vs. 3.0-3.5 m results in 112 storms vs. 7 storms respectively. The spacing seen in Table 1 results in the cluster with the largest amount of storms containing 42 storms and the smallest cluster containing 7 storms.

Table 1: Cluster (Greater than or equal to lower value)

Cluster Number	Cluster Spacing (m.)	Range of Peak Values (m.)	Number of Storms
1	0.2	0.5-0.7	15
2	0.1	0.7-0.8	28
3		0.8-0.9	42
4		0.9-1.0	27
5		1.0-1.1	33
6	0.2	1.1-1.3	35
7		1.3-1.5	24
8	0.25	1.5-1.75	22
9		1.75-2.0	20
10	0.5	2.0-2.5	16
11		2.5-3.0	17
12		3.0-3.5	7

The storms contained within each cluster were subsequently aligned at the peak surge and plotted together. When selecting representative storms, the goal was to identify a single storm in each cluster that has a peak surge near the mean of the cluster's range and possesses an average storm duration. Of the 12 clusters, there were 8 in which this was possible. Figure 5 shows an example of a representative storm.

The remaining 4 clusters were not representable by a single storm, and consequently, these storms were divided into sub-clusters. From the sub-clusters two representative storms could be identified. Three of the remaining four clusters had notable long and short duration storms (example of selection shown in Figure 6). In Cluster 11, a single representative storm could not be identified, nor could short and long duration storms, thus storms with small and high amplitudes were selected (Figure 7). The identification of clusters and subsequent storms used to represent each (sub-) cluster resulted in 16 representative storm events.

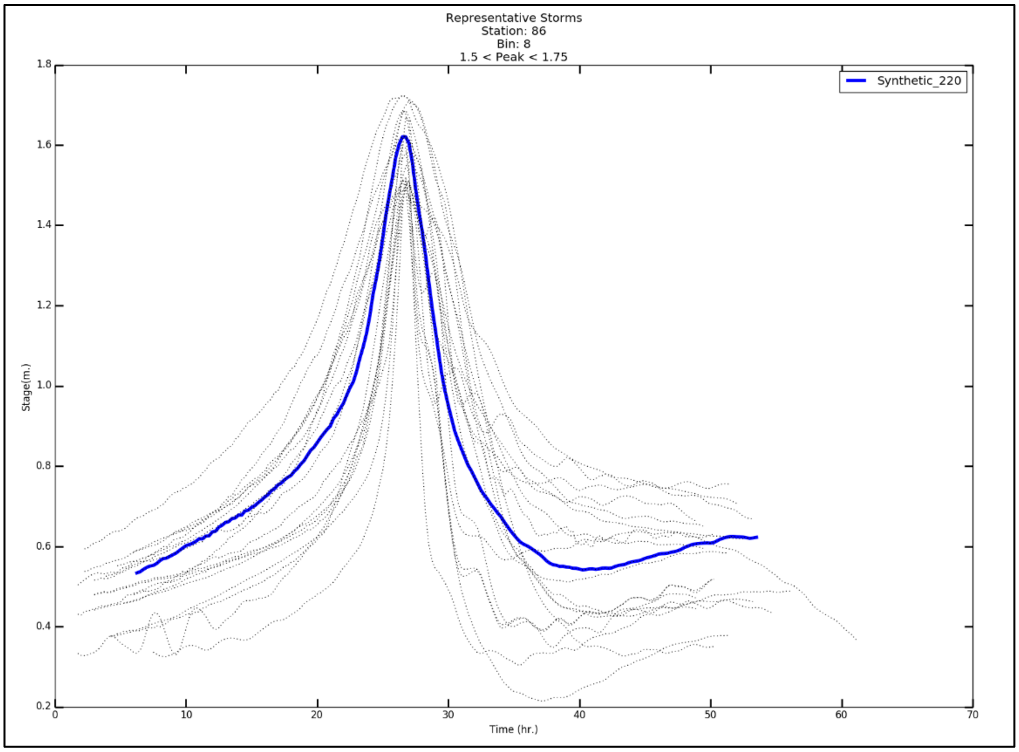

Figure 5: Single Representative Storm for Cluster 8

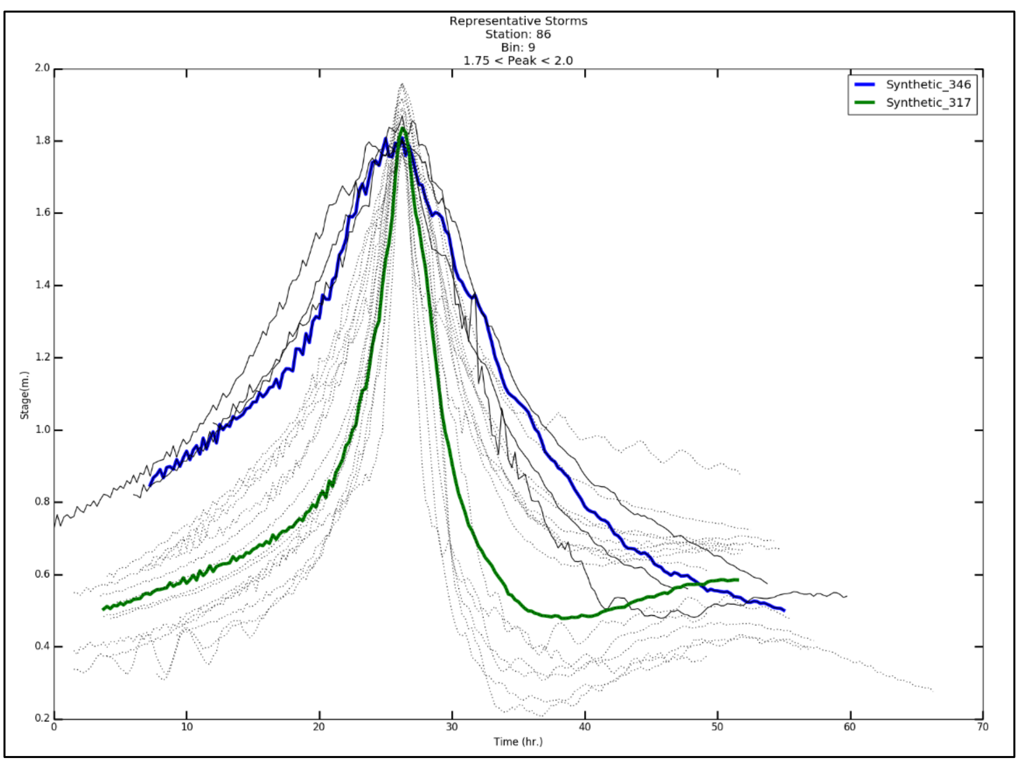

Figure 6: Two Representative Storms for Cluster 9 (Short and Long)

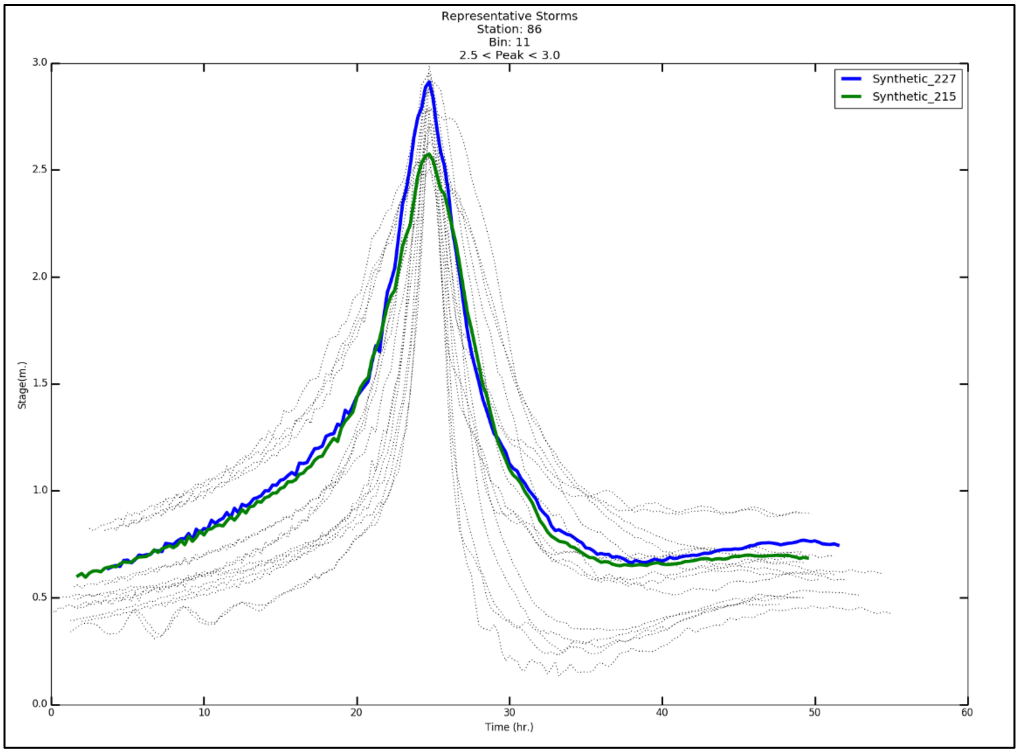

Figure 7: Two Representative Storms for Cluster 11 (Short and Tall)

Each representative storm was assigned a relative probability that facilitates the storm selection process in Beach-fx. The probabilities assigned to each storm event dictate how often one storm event is selected relative to other storms. As a part of the FEMA study, each storm was allocated an individual probability of occurrence that is dependent on the storm characteristics and intensities. Each of the selected 16 representative storms were assigned a relative probability that is the sum of the probabilities that the storm represents (Table 2). For example, storm 133 represents the 15 storms in Cluster 1, therefore the relative probability of the representative storm of Cluster 1 is the sum of the 15 storms represented.

Table 2: Representative Storms and Relative Probabilities

Bin	**Storm**	**Number of Storms Represented**	**Probability**
1	133	15	0.0889
2	131	28	0.0857
3	238	42	0.1819
4 – long	282	22	0.0953
4 – short	470	5	0.0207
5	229	33	0.1230
6	279	35	0.1391
7 – long	230	15	0.0715
7 – short	447	9	0.0202
8	220	22	0.0560
9 – long	346	4	0.0181

9 - short	317	16	0.0443
10	214	16	0.0295
11 – high	227	9	0.0028
11 - small	215	8	0.0222
12	218	7	0.0008

Each of the selected representative storms have associated significant wave height time series that were generated as a part of the FEMA study. The 16 surge and wave time series associated with the representative storms were used as input to the shore response model SBEACH.

2.4 Tide Analysis

Within Beach-fx, tides are represented by three statistically defined cosine tides (low, medium, and high amplitude) combined at four variations in phase shifts with the storm surge hydrograph peaks (high tide, mid-tide falling, low tide, and mid-tide rising). A discrete 19-year long equilibrium tidal record at South Padre Island was generated. The tidal record did not exceed ±0.46 m. (~1.5 ft.). From the discrete time series, a cumulative distribution function (CDF) was created, ranging from -0.46 m. to +0.46 m. with increments of 0.00025 m. The probability of the tide having a value that fell within each bin was computed, and the CDF generated (Figure 8).

From the CDF, only the upper and lower quartiles were considered because it is assumed that regardless of the tide amplitude (high, medium, or low), all tides pass through the middle 50% (Figure 9). Furthermore, the upper and lower quartiles were each divided into an upper quartile, middle half, and lower quartile. The tide values associated with the midpoint of each of these ranges were identified (Figure 10). These are the tide values associated with the cumulative probabilities of 0.03125, 0.125, 0.21875, 0.78125, 0.875, and 0.96875.

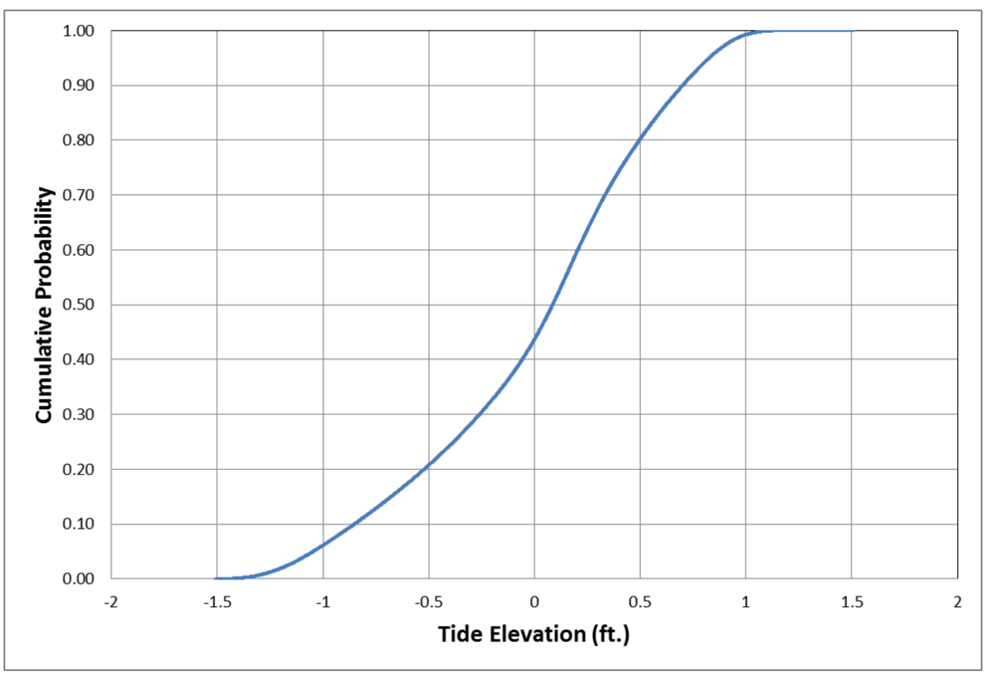

Figure 8: Tidal CDF

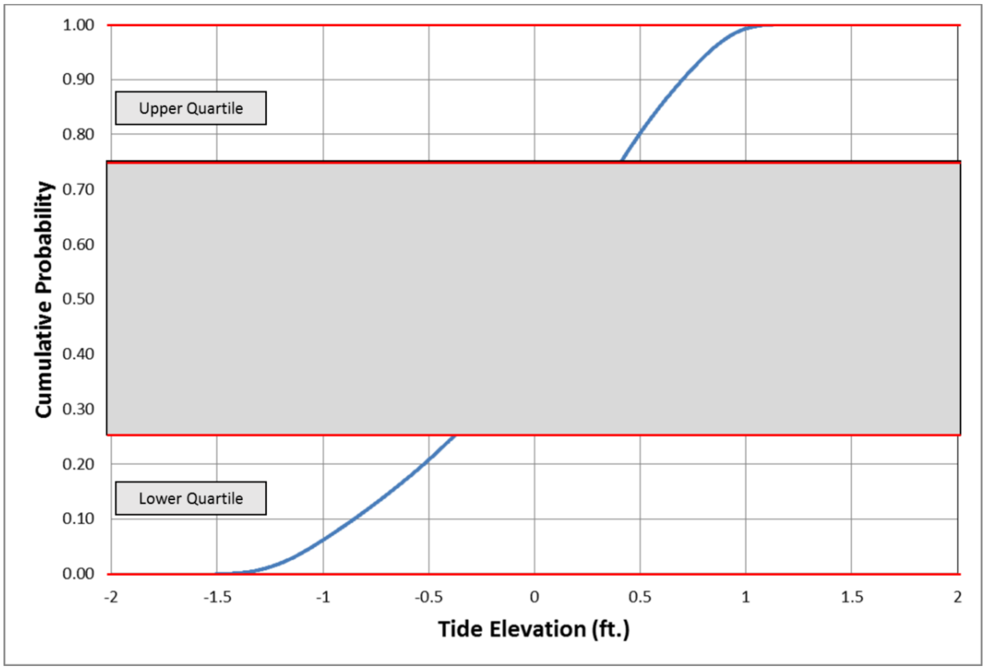

Figure 9: Upper and Lower Quartile

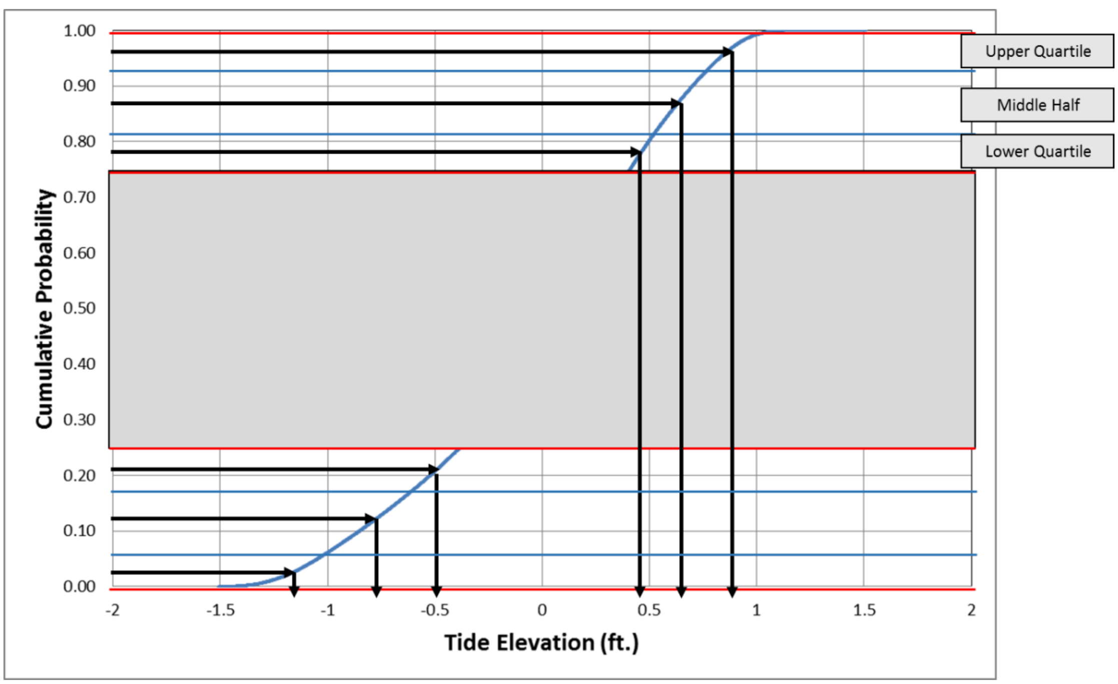

Figure 10: Identification of tide elevations

The tide ranges were then computed as the difference between the high, medium and low values. The idealized cosine approximations are then centered about zero. The results from this process are shown in Table 3.

Table 3: Results from Tidal Analysis

Tide	CDF Lower Bound	CDF Upper Bound	CDF Midpoint	Elevation (ft.)	Cos. Approx. (ft.)
HL	0	0.0625	0.03125	-1.15037	-1.027
ML	0.0625	0.1875	0.125	-0.7671	-0.707
LL	0.1875	0.25	0.21875	-0.46889	-0.466
M	0.25	0.75	-	-	-
LH	0.75	0.8125	0.78125	0.462482	0.466
MH	0.8125	0.9372	0.875	0.647435	0.707
HH	0.9375	1.00	0.96875	0.902695	1.027

From the idealized cosine approximations, three diurnal tides were developed and combined with each storm surge hydrograph. The tides underwent a phase shift such that the peak surge of the hydrograph aligned with each tide at high tide, mid-tide falling, low tide, and mid-tide rising (Figure 11). The combination of the three tidal ranges at the four phase shifts resulted in 12 possible total water elevations for each storm (192 total water elevations).

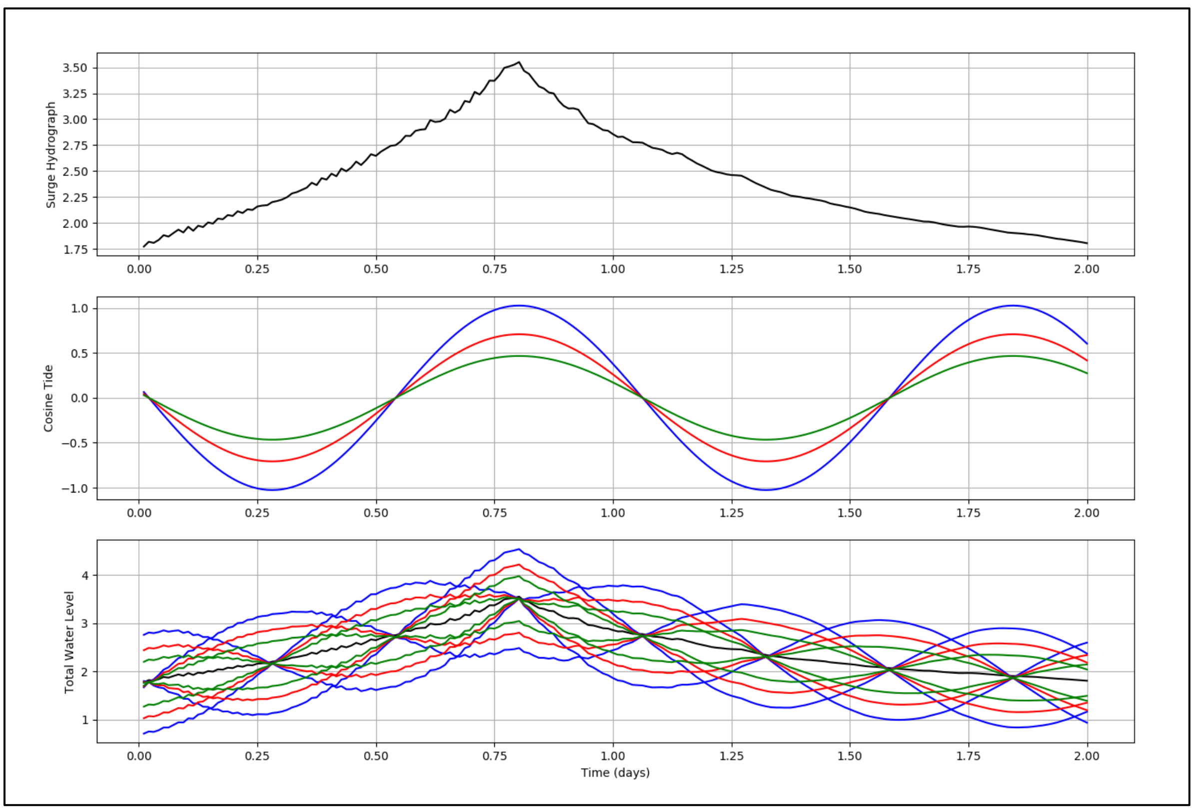

Figure 11: Combining storm surge hydrograph with idealized tides

Because the spring-neap tide cycle follows a harmonic pattern (e.g. low, medium, high, medium, low, etc.), then the probability of a total water elevation that was combined with a medium amplitude tide is twice that of the low and high counterparts. Each of the total water elevation's relative probabilities were updated to reflect this cyclical behavior. Table 4 shows an example of storm 229's updated relative probabilities.

Table 4: Total water elevation relative probabilities

Storm 229	**Original Relative Probability: 0.1230**	
Tide Amplitude	**Phase Shift**	**Relative Probability**
High	High Tide	0.007688
High	Mid-tide Falling	0.007688
High	Low Tide	0.007688
High	Mid-Tide Rising	0.007688
Medium	High Tide	0.015375
Medium	Mid-tide Falling	0.015375
Medium	Low Tide	0.015375
Medium	Mid-Tide Rising	0.015375
Low	High Tide	0.007688
Low	Mid-tide Falling	0.007688
Low	Low Tide	0.007688
Low	Mid-Tide Rising	0.007688

2.5 Storm Seasons

Whereas each storm's assigned relative probability determines when storms are sampled relative to each other, storm seasons in Beach-fx dictate how often storm events occur. Storm seasons for South Padre Island were specified on a monthly basis using the storm rates available on the CHS, and the distribution of storm occurrence published in the NACCS report (Cialone et. al. 2015). The monthly rates of occurrence are as follows: June – 0.04, July – 0.04, August – 0.26, September – 0.48, October – 0.12, November – 0.06. The storm occurrence rates in the CHS are available as both high- and low-intensity storm rates and are defined as storms/year/km. The storm rates were summed and multiplied by the diameter of the area under consideration (in this case 400 km). The storm occurrence rate was then multiplied by the monthly weights to determine the monthly occurrence rates, or storm seasons (Table 5).

Table 5: Storm Seasons

High Intensity Storm Rate (storms/year/km)	1.36E-04	Storm Occurrence Rate (storms/year)	0.1512
Low Intensity Storm Rate (storms/year/km)	2.42E-04		
Month	***Distribution***	***Storm Season Probability***	
June	0.04	0.006048	
July	0.04	0.006048	
August	0.26	0.039312	
September	0.48	0.072576	
October	0.12	0.018144	
November	0.06	0.009072	

2.6 Sea Level Rise

Within Beach-fx, sea level rise is computed according to ER 1100-2-8162 (USACE, 2013). The tide gauge at Port Isabel, TX (Gauge 8779770) was chosen to represent the relative sea level change. The sea level change trend at Port Isabel, TX is +0.01289 feet/year. Figure 12 shows the three possible sea level change scenarios, low, intermediate, and high. All Beach-fx runs were conducted under the intermediate scenario to be consistent with the Texas Coastal Study.

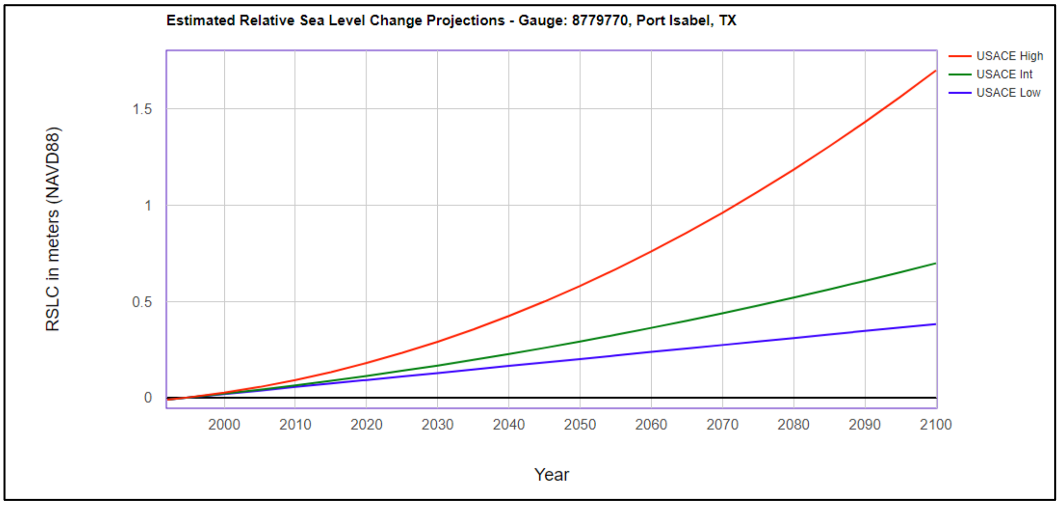

Figure 12: Sea Level Change at Port Isabel (Gauge 8779770)

3 Beach Profile Analysis

This section provides details into the development of the idealized existing upper beach profiles and averaged submerged profiles. Combined with the representative storm suite, the idealized profiles were used in the profile response modeling (Section 4).

3.1 Location of Surveys

Beach profile surveys are taken along a single transect that starts from the dry portion of the beach and extends into the water. These surveys result in distance-elevation coordinates that characterize beach conditions such as dunes, berms, and offshore bars.

Beach surveys at South Padre Island were available that spanned 1995-2015. The Conrad Blucher Institute (CBI) surveys were available beginning in 1995 and HDR Engineering in 2011. The Conrad Blucher Institute set up 25 survey reference monuments, starting from the southern end of the island approximately 0.4 miles north of the Brazos Santiago Pass (CBI 1) and spanning nearly 5 miles north, to their final survey reference monument (CBI 25). HDR surveys were available from 2011-2015, and were taken at the 25 CBI monuments, but were expanded approximately 1.4 miles further north than the CBI monuments. Furthermore, the HDR surveys taken at various intervals between the pre-existing CBI monuments. In total, HDR surveys were available at 53 survey locations. HDR survey points were labeled according to their location relative to the jetty at the southern end of the island, spanning from STA 5+00 just north of the jetty to STA 350+00 approximately 6.6 miles north of the jetty. All survey data was provided in NAVD88. The CBI (red) and HDR (cyan) survey start and end locations can be seen in Figure 13; all profile transects can be seen in Figure 14.

Figure 13: Location of start and end survey points

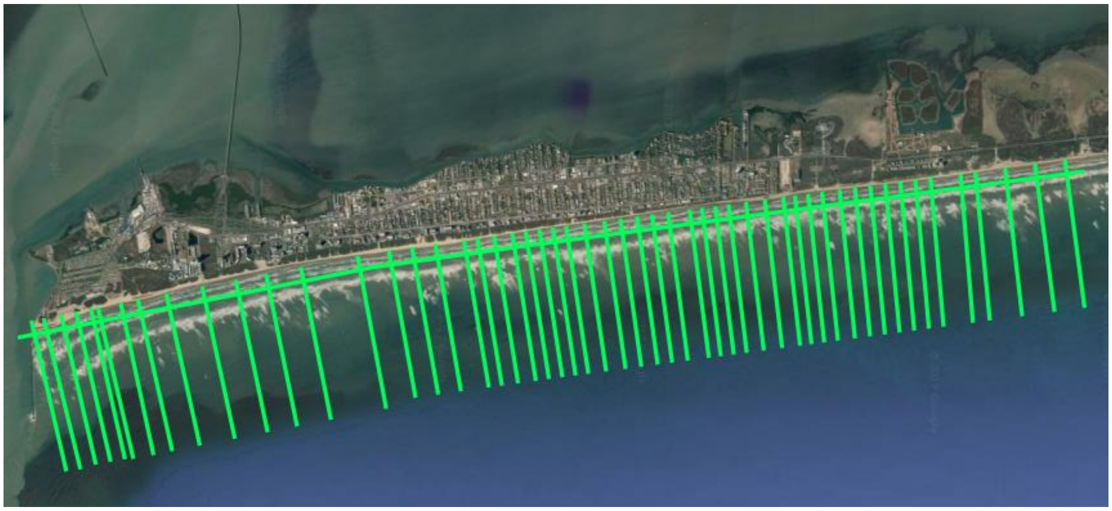

Figure 14: All Profile Transects

3.2 GROUPING SIMILAR PROFILES

A Beach-fx study is divided into project reaches that are areas of morphologic similarity. Depending on the beach conditions and the length of a study area, typical Beach-*fx* projects can contain between 3 and 9 reaches. Each reach is represented by a single cross-shore profile and is composed of two segments (upper and submerged profiles).

The upper beach profiles represent the initial project conditions and were developed from the most recent profile surveys available (in this case HDR surveys from 2015). The 53 available surveys were reduced to six reaches, each with a unique upper beach profile. The profiles in each reach were aligned at the dune and berm features present and averaged together. The resulting averaged features were then combined to develop the representative upper beach profiles.

The Andy Bowie County Park is present in Reach R6 where there are damageable elements north of the park and none within it. This reach was divided into two sub-reaches, “R6” and “R6_park” (Figure 15) such that the distinction is noted. Both R6 and R6_park share the same upper beach and submerged profile, although the division allows for the testing of different planned nourishment alternatives.

Figure 15: South Padre Island Beach-fx Reaches

The submerged profiles were developed from both spatially and temporally averaged surveys to represent the profile at any future date. Through an analysis of the submerged profiles, it was decided that there would be five unique submerged profiles. Reaches 4 and 5 are represented by submerged profile 4. Similar to the upper beach profiles, the submerged profiles were developed by aligning the profiles at key morphologic features (inshore bar, central bar, and if present offshore bar), then averaging. A summary is shown in Table 6.

Table 6: South Padre Island Beach-fx Reaches

Reach	Station Start	Station End	Reach Distance (ft.)	Submerged Profile
R1	STA 5+00	STA 40+84	4,558	1
R2	STA 50+32	STA 95+52	5,946	2
R3	STA 114+57	STA 179+50	7,667	3
R4	STA 183+93	STA 217+83	3,970	4
R5	STA 225+00	STA 256+10	4125	
R6_Park	STA 260+00	STA 290+00	2830	5
R6	STA 290+00	STA 305+00	1950	

3.3 Idealized Profiles

Beach-*fx* uses a simplified representation of the beach profile such that key morphological features are defined by single values such as dune height, dune width, berm width, etc. (Figure 16). Figures 17 - 22 show the representative upper beach profiles, as well as the idealized profiles for reaches R1-R6. Each of the idealized profiles were combined with the averaged submerged profiles as outlined in Table 6 (Reach R6 and R6_Park share the same upper and submerged profiles). The representative profile for Reach R5 resulted in a double dune feature. It is not possible to model this in Beach-fx, thus a single, wide dune was identified as the idealized profile.

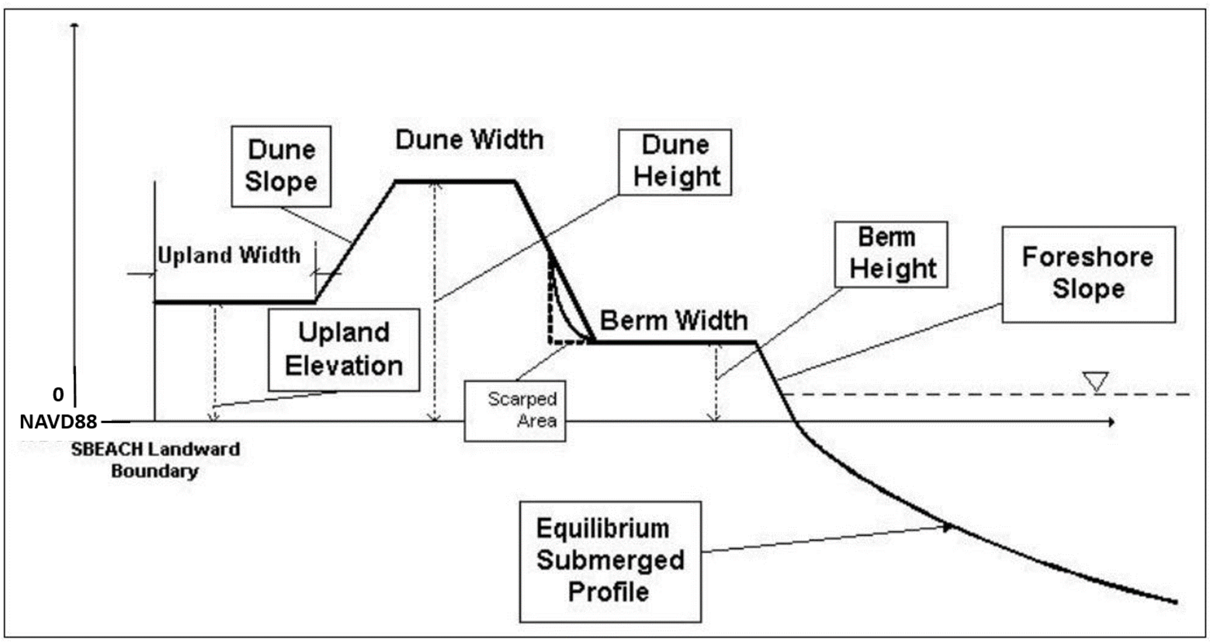

Figure 16: Beach-fx idealized upper beach profile

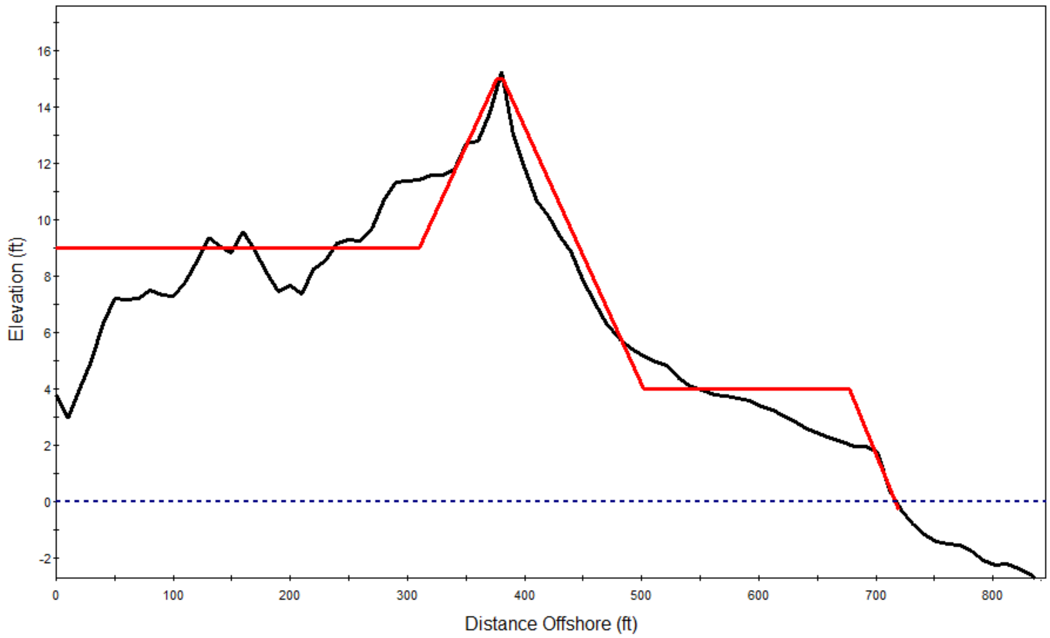

Figure 17: Reach R1

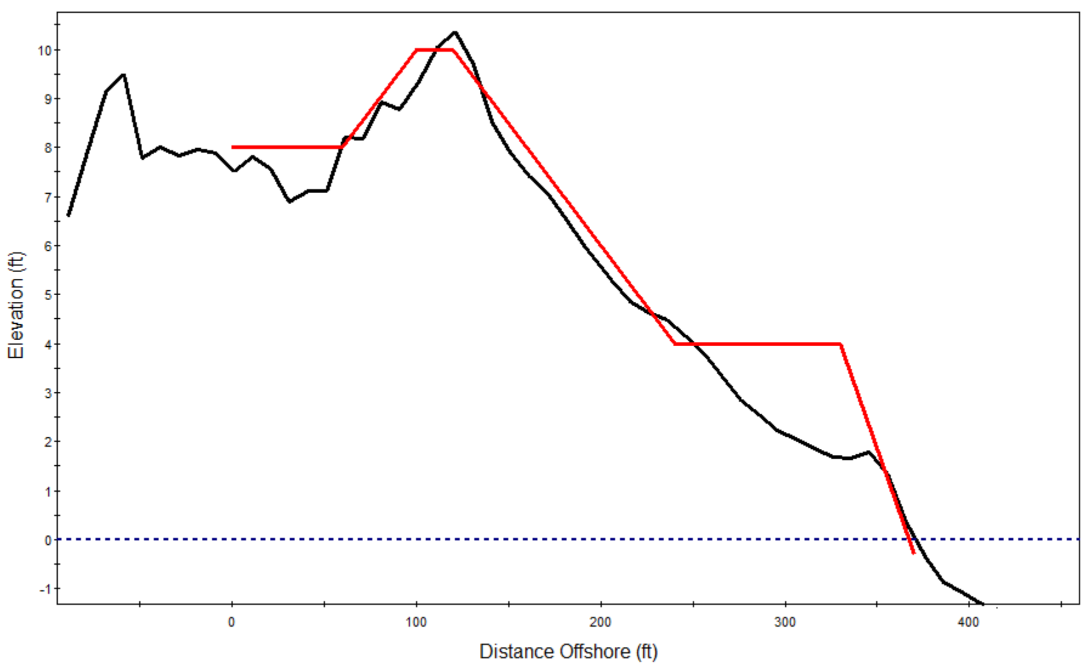

Figure 18: Reach R2

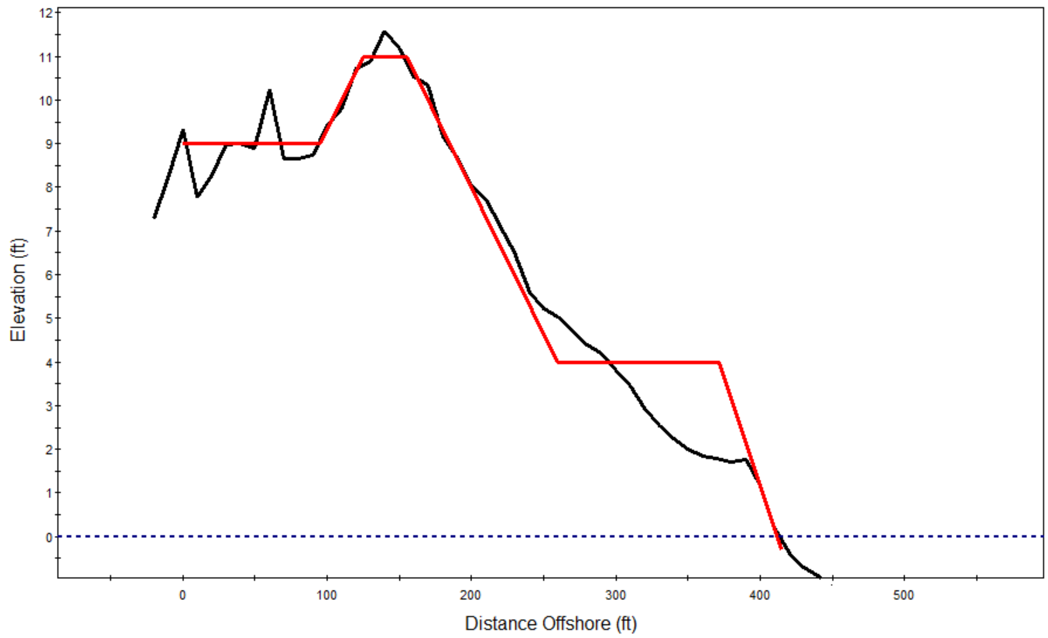

Figure 19: Reach R3

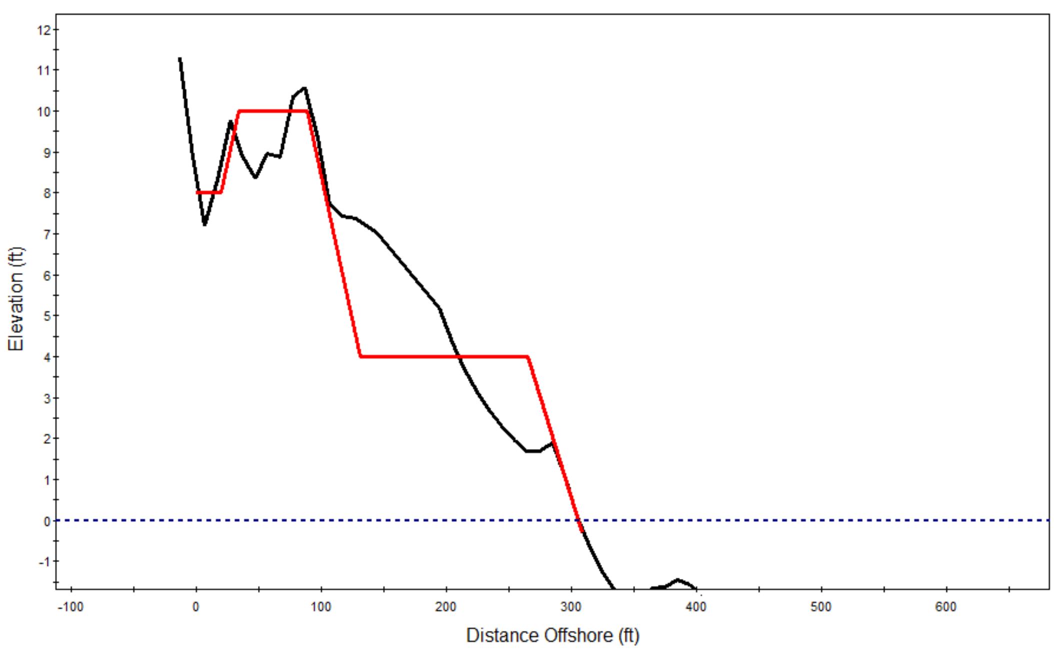

Figure 20: Reach R4

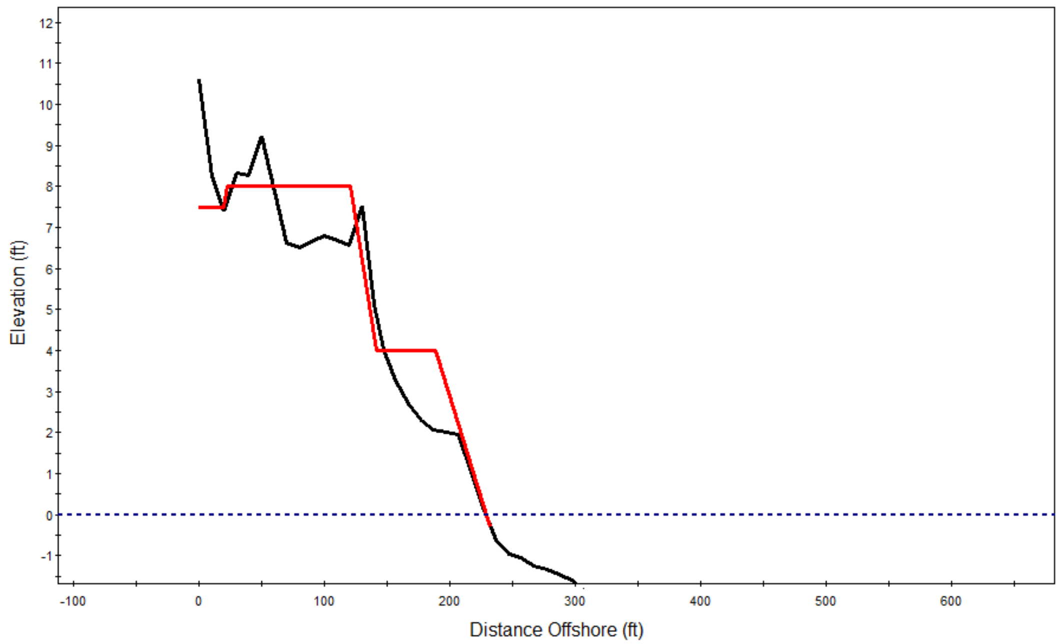

Figure 21: Reach R5

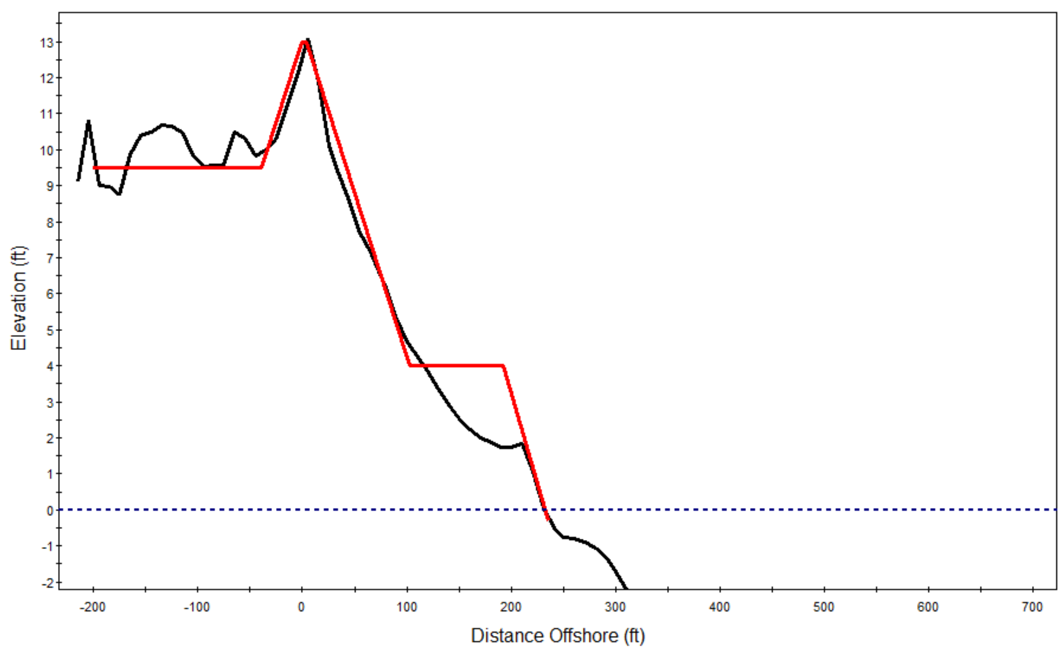

Figure 22: Reach R6 and R6_Park

4 Profile Response Model Runs

This section provides details into the SBEACH runs performed to populate the Beach-fx Shore Response Database (SRD). Because no shore response computations are performed at runtime, and instead the SRD is used as a look-up table, then the SRD must contain all of the profiles that are expected to be encountered over a lifecycle. Maximum beach template conditions were specified, and the profile parameter space was populated between the maximum and minimum possible conditions. The profile parameter space, combined with the plausible storm suite, resulted in over 500,000 SBEACH runs.

4.1 Maximum and Minimum Profile Conditions

On South Padre Island, a robust dune system is present north of the project study domain, with an existing dune height of approximately 20ft. Based on these conditions, SPI's Erosion Response Plan, and discussion with CESWG, idealized maximum conditions for the entire project domain were developed (Table 7).

Table 7: Maximum Dune Conditions

Parameter	Maximum Values
Dune elevation	20 ft.
Dune Width	30 ft.
Berm Elevation	4 ft.
Berm Width	200 ft.
Dune Slope	1:4

A 20ft dune elevation, and a 200ft berm width were chosen based on the existing conditions north of the study domain. A 30ft dune width was chosen to meet the requirement outlined in SPI's erosion response plan specified as, "the base dune depth should be a minimum of 60 feet, with 100 feet preferable" (Ravella et. al., 2012). The existing berm elevation of 4ft was not increased as a part of the dune template. A dune slope of 1:4 was chosen as being typical for beach renourishment projects. Figures 23 - 28 show the existing idealized upper beach profiles (blue) along with the proposed maximum conditions for the six reaches in the project domain.

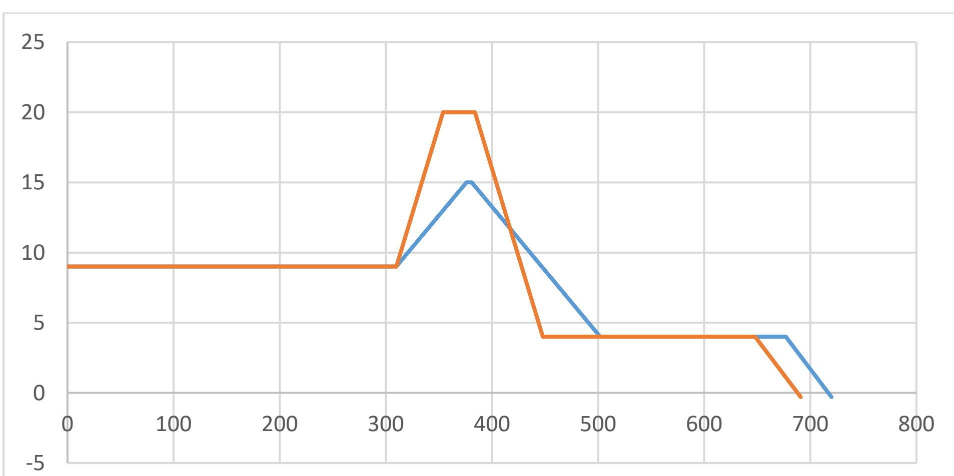

Figure 23: Reach 1 existing idealized (blue) and maximum (orange) upper beach profiles

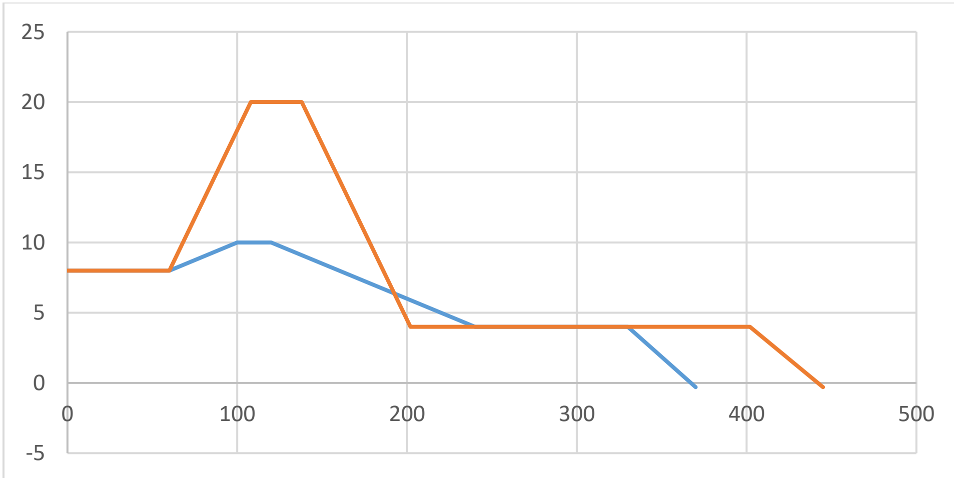

Figure 24: Reach 2 existing idealized (blue) and maximum (orange) upper beach profiles

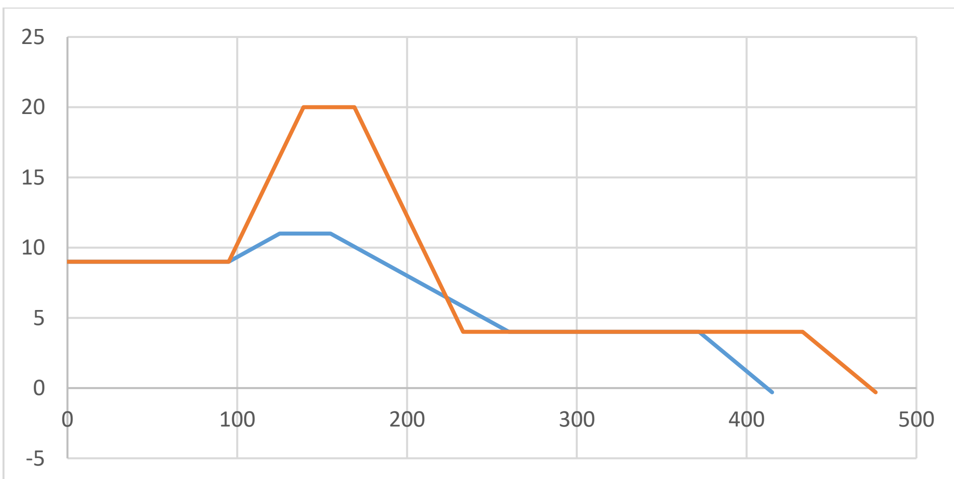

Figure 25: Reach 3 existing idealized (blue) and maximum (orange) upper beach profiles

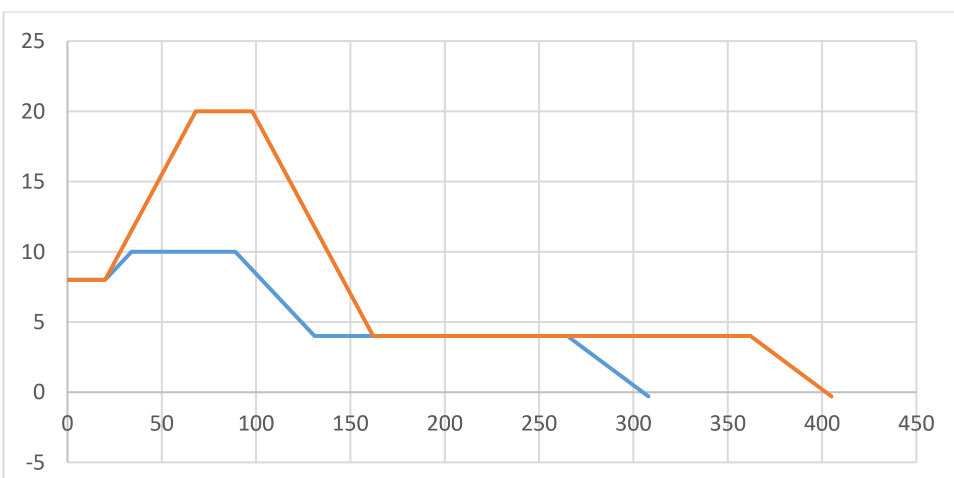

Figure 26: Reach 4 existing idealized (blue) and maximum (orange) upper beach profiles

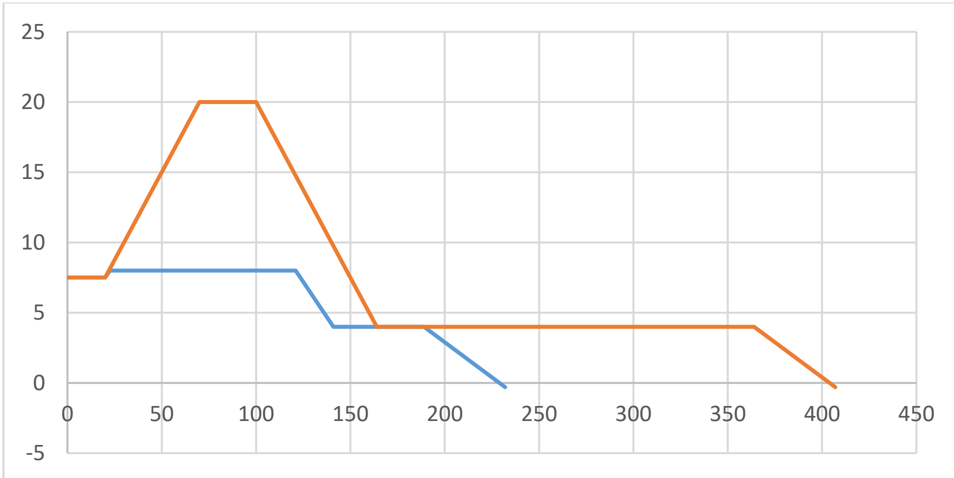

Figure 27: Reach 5 existing idealized (blue) and maximum (orange) upper beach profiles

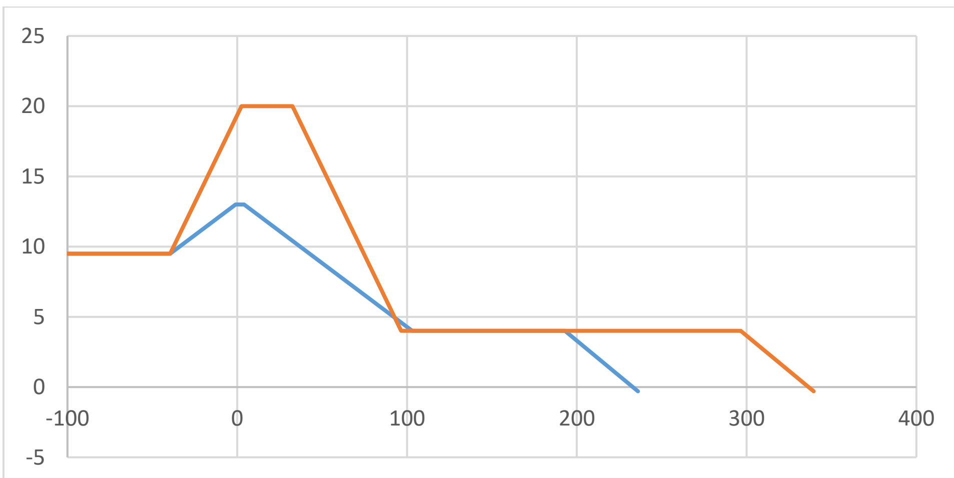

Figure 28: Reach 6 existing idealized (blue) and maximum (orange) upper beach profiles

The minimum conditions in the SRD were composed of a beach that has no dune and berm. The minimum dune height was specified as the larger of the upland elevation or the berm elevation (in this case, the upland elevation was used for all reaches, as it is higher than the berm elevation). By incrementally adjusting the dune height (2ft.), dune width (5ft.), and berm width (20ft.) from the maximum conditions to the minimum conditions, the profile parameter space was populated. The resulting number of profiles in each reach are shown in Table 8.

Table 8: Number of profile configurations in profile parameter space

Reach	# DH Conditions	# DW Conditions	# BW Conditions	# of profiles
R1	6	7	11	462
R2	7	7	11	539
R3	6	7	11	462
R4	7	7	11	539
R5	7	7	11	539
R6	6	7	11	462
Total	-	-	-	**3,003**

Any combination of dune height, dune width, and berm width that fell between the maximum and minimum conditions were available to be tested as planned nourishment alternatives.

4.2 SBEACH Runs

To populate the SRD, the profile response model SBEACH (Larson and Kraus, 1990) was utilized. SBEACH was calibrated, and the final parameter values were determined as shown in Table 9. Considering that it is necessary for every profile to have a response to every plausible storm event, a total of 576,576 SBEACH runs were computed. (Table 10).

Table 9: SBEACH Calibration parameters

Parameter	Value Used
Median grain size	0.16 mm.
Maximum slope prior to avalanching	20 deg.
Transport rate coefficient, K	1.50E-06 (m^4/N)
Overwash transport parameter	5.0E-04
Coefficient for slope dependent term, ε	2.0E-03 (m^2/s)
Transport rate decay coefficient multiplier, λ	0.5 (m^{-1})
Water temperature	20 °C

Table 10: Total SBEACH runs

Reach	Profiles	Water Elevation Time Series	SBEACH Runs
R1	462	192	88,704
R2	539	192	103,488
R3	462	192	88,704
R4	539	192	103,488
R5	539	192	103,488
R6	462	192	88,704
Total	**3,003**	**--**	**576,576**

5 HISTORIC EROSION RATES AND CALIBRATION

This section provides details into the analysis of the historically observed shoreline change rates and calibration of Beach-fx. Beneficial use of dredged material (BUDM) has taken place on South Padre Island since 1988. Shoreline change rates were estimated in the absence of this project, and Beach-fx was calibrated to these values.

5.1 BENEFICIAL USE PROJECT

BUDM placement has been implemented on South Padre Island since 1988, resulting in dredged material from the Brazos Santiago Pass placed either in a nearshore berm or directly on the beach. Table 11 gives an overview of the dates, location, and amount of placement from 1988-2014. The shaded boxes indicate material that was placed directly on the beach and the distance from the Brazos Santiago Pass, whereas a location of "Berm" indicates material that was placed in a nearshore berm.

Table 11: History of Dredged Material Placement at South Padre Island

Year	Location (mi.)	Amount (cy)
1988	Berm	220,000
1991	Berm	580,000
1995	Berm	750,000
1997	3.45-4.59	490,000
1997	Berm	396,000
1999	1.52-2.27	495,000
1999	Berm	195,000
2000	3.90-4.51	370,000
2002	3.48-4.13	330,000
2002	Berm	329,000
2003	Berm	356,000
2005	0.18-0.57	49,000
2005	3.45-4.03	229,000
2006	Berm	340,000
2007	Berm	443,000
2008	Berm	500,000
2009	3.95-4.83	407,000
2010	0.13-0.64	90,000
2010	4.45-5.02	130,000
2011	0.19-0.47	199,000
2011	4.55-5.06	368,000
2012	0.19-0.47	140,000
2012	4.45-4.92	210,000
2014	Berm	305,000

This feasibility study considered future conditions at South Padre Island in the absence of continued BUDM. The nourishment projects evaluated (Section 7), were modeled as an alternative, more permanent solution, to the informal BUDM that has occurred in the past.

5.2 Historic Erosion Rates

Beach-fx was calibrated to return on average across 300 lifecycles, the historically observed shoreline change rates. Each reach (R1, R2 …) was calibrated to a single value representing the average observed shoreline change rates within that reach.

Historic shoreline positions at South Padre Island were available for 1937 and 1995 (Figure 29). By computing the distance between the shorelines at each profile transect and dividing by the time span (59-years), the shoreline change rates were determined (ft./year).

Figure 29: Historic shoreline positions; 1937 (red) and 1995 (black).

HDR Engineering has been providing South Padre Island with annual reports that document the history of the beneficial use placement on the island as well as rates of shoreline change. HDR reports from 2015 (Perry, 2015) and 2016 (Perry, 2017) were provided to ERDC-CHL. The 2016 surveys were taken in the winter months where "larger wave events, and at times higher water elevations/tides, tend to occur", and often result in a winter profile that is "typically narrow and steeper" than its summer counterpart. These narrow profiles resulted in shoreline change rates that were lower than expected. Because of the inconsistencies in when the surveys were conducted, the shoreline change rates in the 2015 HDR report were employed to characterize the erosion rates at South Padre Island. Figure 30 shows the shoreline changes from 1995-2015 (blue), 1937-1995 (black), as well as the location of each reach (varying colors along the x-axis). The Brazos Santiago Pass is located at *x=0*.

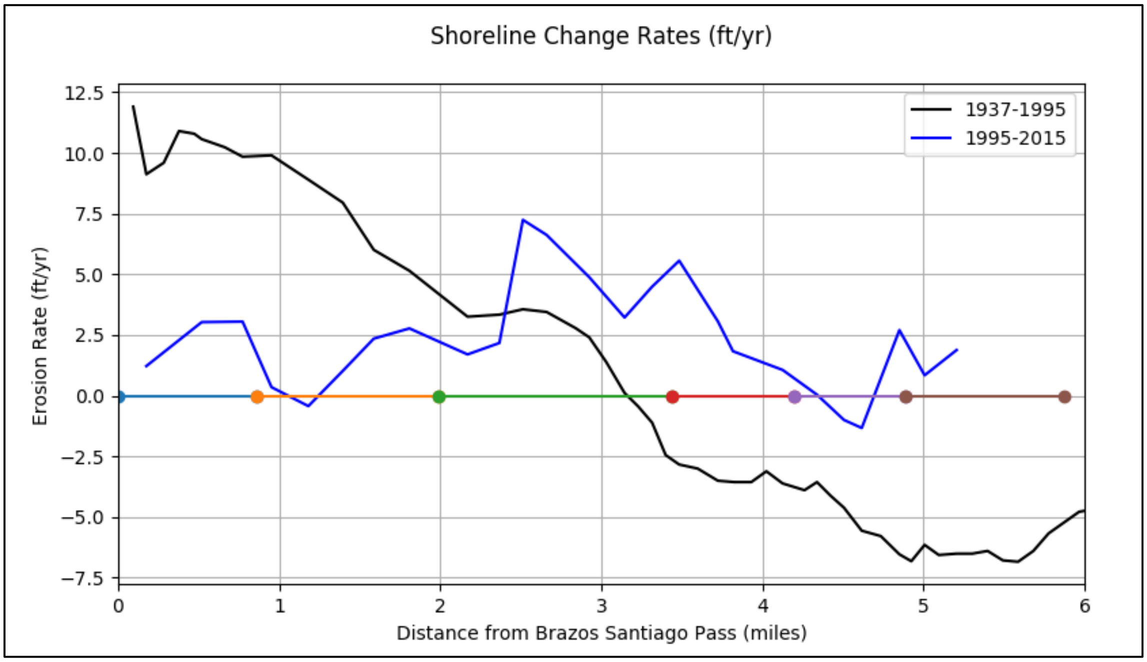

Figure 30: Shoreline change rates at South Padre Island

Due to the construction of the jetty at the Brazos Santiago Pass, the 1937-1995 shoreline shows accreting tendencies to the south that transition to erosion at the north. It can also be seen that since the beneficial use project has been implemented, the shoreline has been accreting across nearly the entire island.

The large accretion at the southern end of the island from 1937-1995 has stabilized and it is expected that in the absence of beneficial use placement, the shoreline will not return to these values. This is likewise evident from the decreased shoreline change rates in Reaches R1 and R2 comparing 1937-1995 (no beneficial use) and 1995-2015 (beneficial use). With the beneficial use project in place, the shoreline at the southern end of the island has not shown increased accretion rates.

Therefore, to determine shoreline change rates in the absence of a beneficial use project, the 1937-1995 shoreline change rates could not be directly used. Rather, the 1995-2015 rates were used in conjunction with the history of material placed on the beach (Table 11).

Shoreline Change Rates in Absence of Beneficial Use

The amount of sand placed through the beneficial use projects were converted to a contribution to shoreline change (yd^3 to ft./year). It was assumed that the active profile at South Padre Island is 27 feet (23 ft. depth of closure plus 4 ft. berm height). From the nourishment start and end positions available in Table 11, the total volume placed in each reach was computed. If a nourishment project spanned more than one reach, it was assumed that the material was placed equally across the segment of beach. The total volume in each reach was assumed to stay in that reach, and the amount of additional beach was determined by dividing the placed volume by the length of reach and the depth of the active profile. The average additional change per year due to the nourishment projects was then computed by dividing by the number of years that the nourishment projects have been in place (1995-2015; 21 years). These values were then subtracted from the average shoreline change rates of each reach. Figure 31 shows the resulting shoreline change rates in the absence of a beneficial use project (green) along with the observed average shoreline change rates for 1995-2015 (blue).

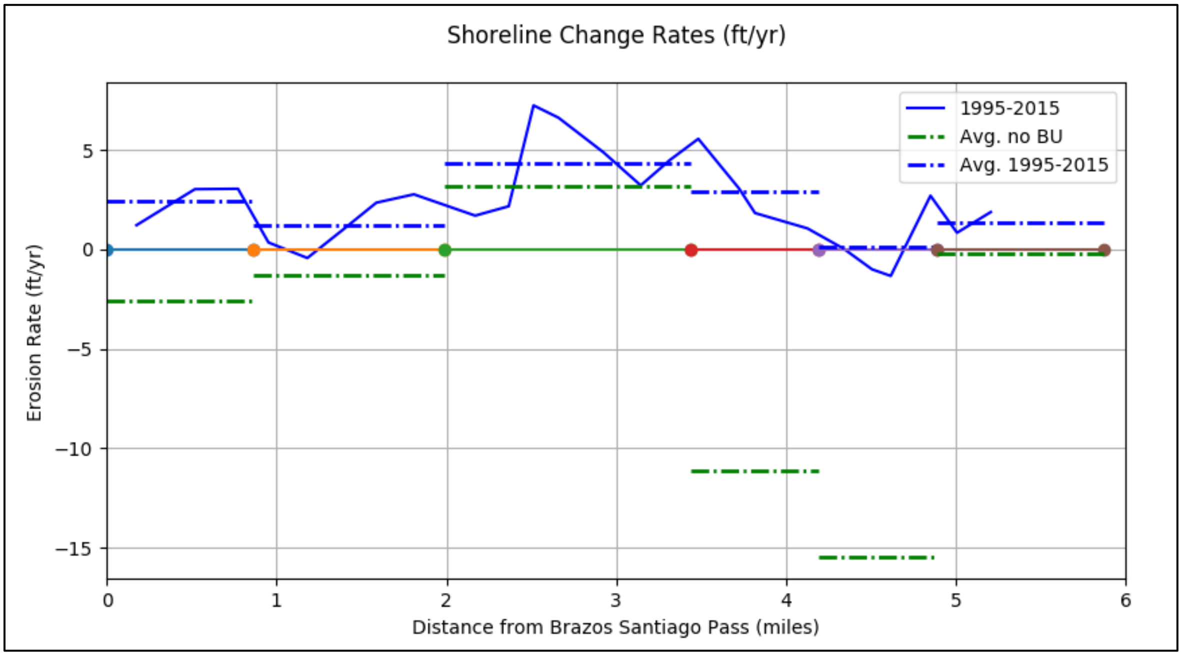

Figure 31: Average computed shoreline change rates in absence of beneficial use project.

The resulting shoreline change rates for reaches R1-R3, returned reasonable values, whereas reaches R4-R6 did not. Erosion greater than 10ft./year is not expected to occur at South Padre Island, when the long-term trends show erosion up to approximately 7ft./year. Furthermore, comparing reaches R5 and R6, it is not expected that the former has an erosion rate greater than 15ft/year, whereas the latter results in almost no erosion.

To alleviate these inconsistencies, the average erosion rates in reaches R4-R6 were represented by the shoreline change data available from 1937-2015. Figure 32 shows the historical shoreline change from 1937-1995 (black), the shoreline change from 1995-2015 (blue) and the average shoreline change rates in each reach (horizontal lines). Table 12 summarizes the average shoreline change rates that were used in the Beach-fx calibration.

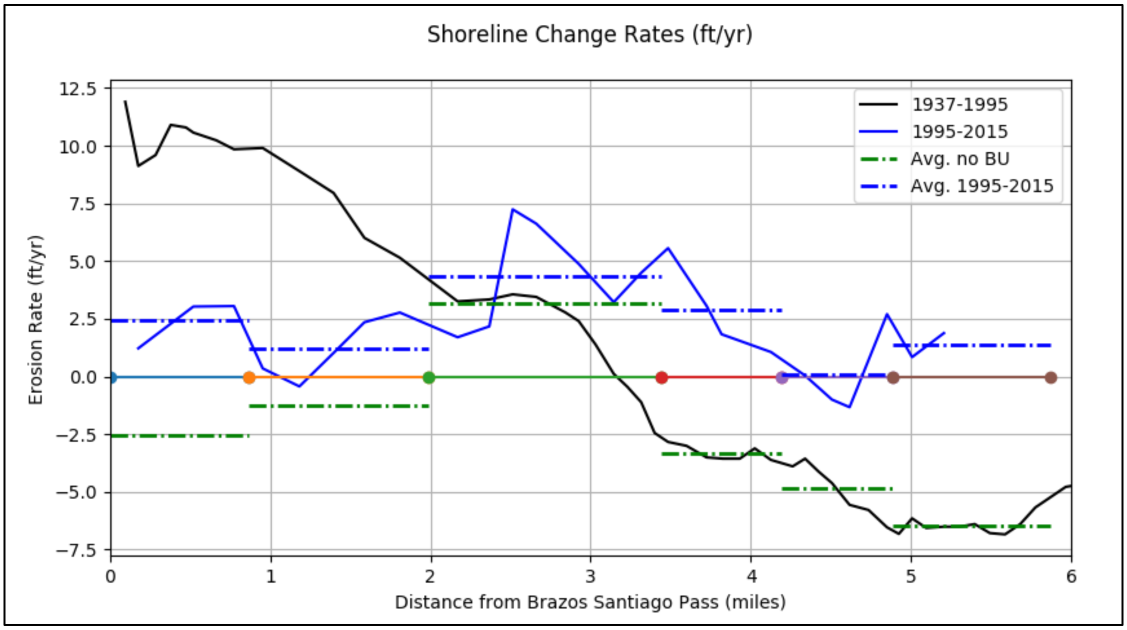

Figure 32: Final average shoreline change rates

Table 12: Average Shoreline Change rates at SPI in the absence of the beneficial use project

Reach	Shoreline Change Rate (ft./year)
1	-2.561
2	-1.269
3	3.181
4	-3.313
5	-4.866
6	-6.462

5.3 Calibration

Calibration in Beach-*fx* ensures that the average erosion rate over a project simulation (300 iterations) is equal to the available historical data. The average erosion rate is a function of the storm induced erosion rate, berm width recovery factor, and the Applied Erosion Rate (AER). To determine the AER an iterative method was implemented. The berm width recovery factor was set to 90% for all iterations.

To initiate the calibration process, the AER was first set to zero, and the storm induced erosion rates were determined. The AER was then updated in subsequent iterations such that the storm induced erosion rates in conjunction with the AER, equaled the target shoreline change rate. This process was repeated until the average shoreline change rates observed in each reach were equal to the target historical shoreline change rates. Table 13 shows the results from the calibration procedure.

Table 13: Results from calibration procedure

Reach	Target Shoreline Change Rate (no BU)	AER (no BU)
1	-2.561	-0.366
2	-1.269	0.851
3	3.181	5.294
4	-3.313	-1.341
5	-4.866	-2.813
6	-6.462	-4.645

6 FUTURE WITHOUT PROJECT CONDITIONS

This section details the Future without Project (FWOP) conditions at South Padre Island. In keeping with the rest of the Texas Coastal Study, the project start date was defined as 2035. Beach-fx simulations typically occur over a 50-year period, resulting in an end date of 2085. To compare the FWOP and FWP conditions, the same period of analysis is considered. Beach-fx was configured to simulate 2031-2085, with a four-year base period (2031-2035) in which no project is implemented. The FWOP conditions provide the potential benefit pool that is available in the absence of a shore protection project.

6.1 POTENTIAL BENEFIT POOL

The FWOP analysis involved the simulation of 300 unique 54-year lifecycle simulations (2031-2085), in which no federal coastal flood reduction project was implemented. All economic calculations are expressed in 2035 dollars (base year 2035), and use an interest rate of 2.75%. This analysis considered the damages done to both structures and contents as potential benefits. The distribution of combined structure and content damages for the 300 lifecycles can be seen in Figure 33.

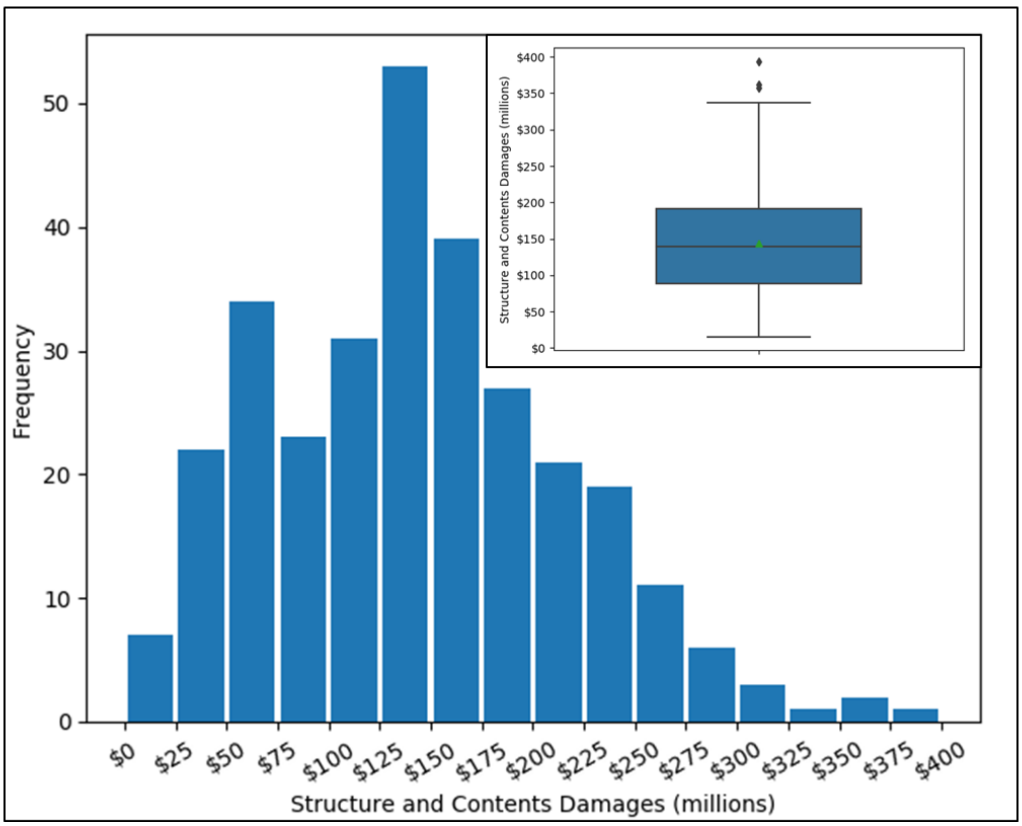

Figure 33: FWOP Structure and Contents Damages

It can be seen that the damages approach a normal distribution with a slight skew to the right. The structure and contents damages average $144.00 million. As seen in the box and whisker plot of Figure 33, there are three statistical outliers corresponding to damages greater than approximately $350 million. The frequency of damages between $125 and $175 million account for 30% of all Beach-fx lifecycles (92/300 simulations).

The combined structure and contents damages by reach can be seen in Figure 34 and the number of damage elements and average damages by reach can be seen in Table 14. The majority of damages occur in Reach R5 with an average damage value of $66.98 million. Reaches R3-R6 have significant damages with each reach averaging above $10 million. As expected, larger damages occur at the northern portion of the island, where the shoreline is erosive (R4-R6). Although Reach R3 is accretional, it has a large number of damageable elements (53) that result in considerable damages. From Figure 34 and Table 14, it can be seen that the potential net benefit pool is the largest at the northern end of the island.

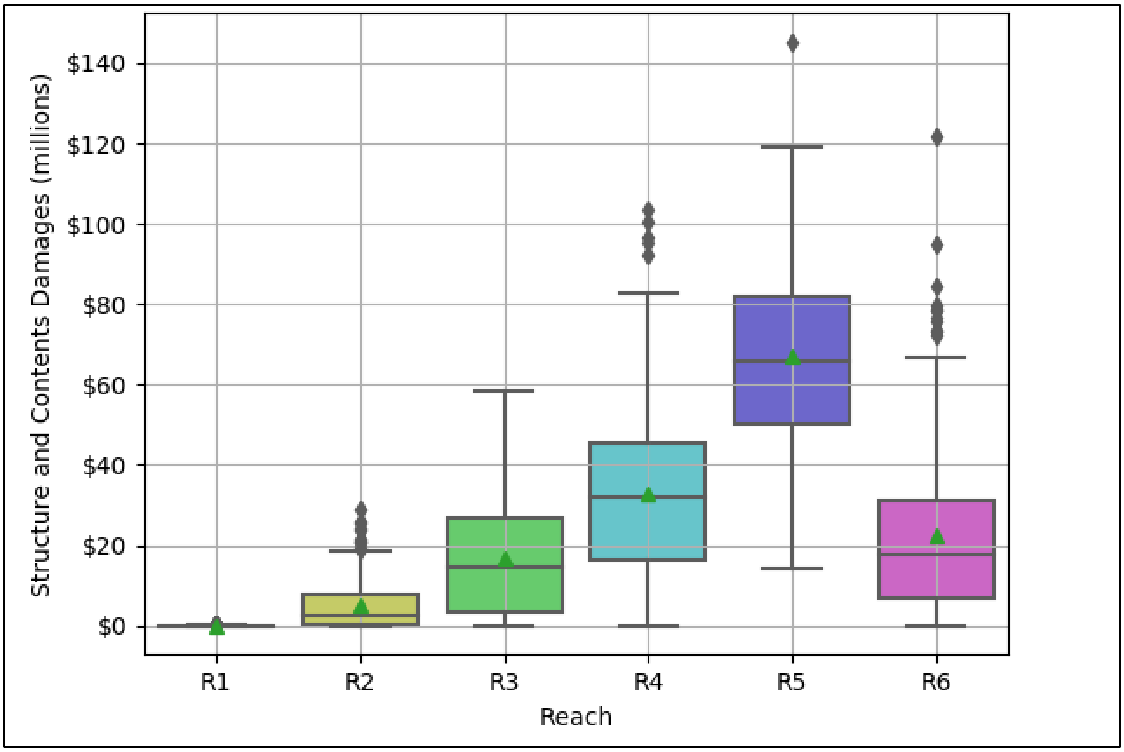

Figure 34: FWOP Structure and Contents Damages by Reach

Table 14: Number of Damage Elements in each Reach

Reach	Number of Damage Elements	Average Damages (millions)
R1	2	$.056
R2	29	$4.921
R3	53	$16.856
R4	36	$32.906
R5	53	$66.984
R6	33	$22.283
R6_park	0	n/a

7 FUTURE WITH PROJECT CONDITIONS

This section details the Future with Project (FWP) test conditions at South Padre Island, as well as the net benefits associated with each alternative. In total, 18 dune and berm templates were considered with variations in dune height, dune width, and berm width.

7.1 EVALUATION OF NOURISHMENT ALTERNATIVES

Net Benefits and Benefit to Cost Ratio

To measure the feasibility of a project, both the net benefits and the benefit to cost ratio (BCR) were considered. The net benefits are defined as

$$Net\ Benefits = Benefits_{Damages} + Benefits_{Costs\ Avoided} - Costs_{PN} \qquad (7.1)$$

Where $Benefits_{Damages}$ represent the reduction in damages due to the implementation of a project (FWOP damages – FWP damages), and $Benefits_{Costs\ Avoided}$ represent any collateral costs that are circumvented due to the implementation of the project (for example armor construction and emergency nourishment costs).

Additionally, the BCR is defined as

$$BCR = \frac{Benefits_{Damages} + Benefits_{Costs\ Avoided}}{Costs_{PN}} \qquad (7.2)$$

Typically, the net benefits and BCR consider benefits associated with both damage reduction and costs avoided. In this case, no armor (Section 8.9) or emergency nourishment was considered, thus the benefits only considered those related to a reduction in damages. The costs associated with a project include mobilization ($3,000,000) as well as the placement of planned nourishment material ($40/yd^3).

Identification of nourishment template

Nourishment templates in Beach-fx are defined by variations in dune height, dune width, and berm width. Following initial sensitivity runs consisting of select renourishment templates (e.g. maximum conditions in SRD, and current beach conditions), three variations in dune height, three variations in dune width, and two variations in berm width were identified to be tested. The combination of dune height, dune width, and berm width values resulted in a total of 18 permutations (Table 15).

Table 15: Nourishment Alternatives

	Min (ft.)	Max (ft.)	Change (ft.)	Permutations
Dune Height	10	15	2.5	3
Dune Width	10	20	5	3
Berm Width	100	150	50	2
			Total	**18**

For each of the 18 resulting templates, a Beach-fx simulation occurred in which the entire study area (R1-R6; excluding the park) was renourished on an “as-needed” basis. A relative BCR was computed for each reach that did not consider mobilization costs (Figure 35). It should be emphasized that the relative BCR is not reflective of the actual BCR in each reach, but rather allows the reaches that benefit the most from implementation of a renourishment project to be identified. In Figure 35, the darker hues indicate a higher relative BCR. It can be seen that reaches R3, R4, and R5 returned the largest relative BCRs. Note that although Reach R5 returned the largest damages (Section 6.1), it did not receive the largest relative BCRs due to the high cost of renourishing.

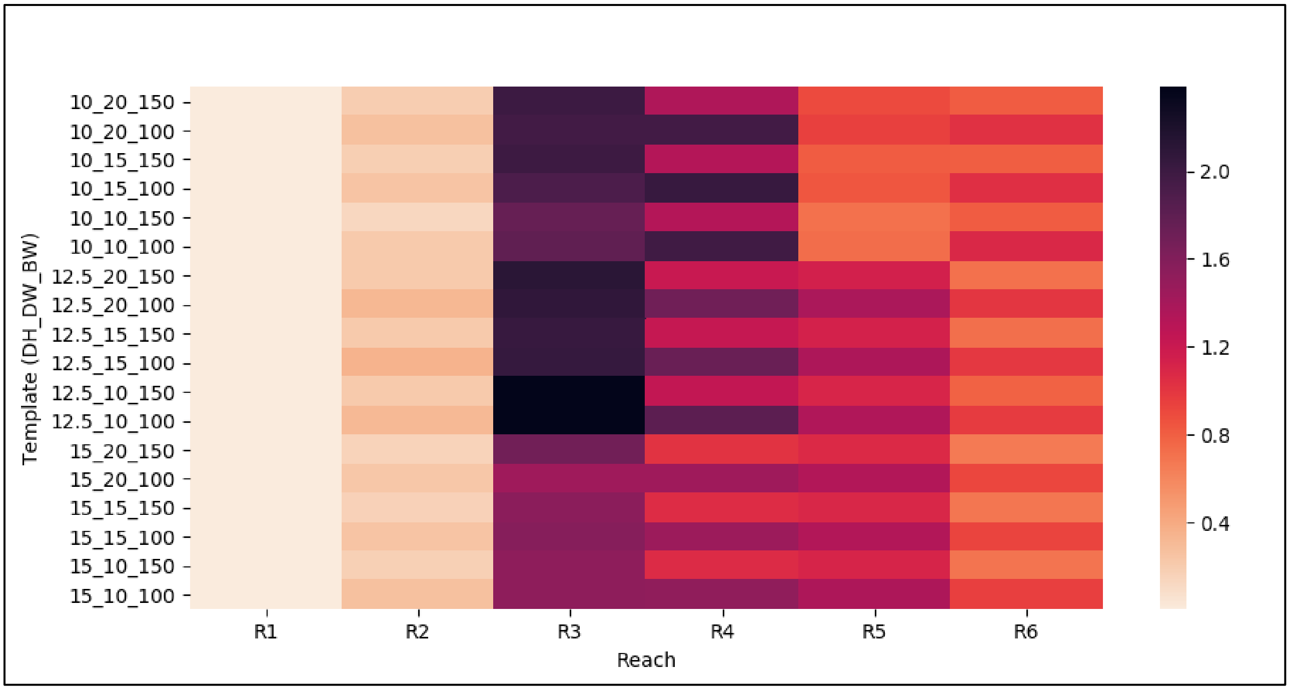

Figure 35: Heat map of Relative BCRs

Of the 18 original nourishment templates, 8 were considered for further analysis by running additional Beach-fx simulations (Table 16). One set of simulations considered renourishing only reaches R3 and R4, whereas the other considered reaches R3, R4, and R5. Similar to the previous simulations, Beach-fx was configured to be renourished on an “as-needed” basis. The resulting average BCRs[1] across 300 lifecycles are shown in Table 16. The results show that simulations in which reach R5 is included, result in a 13-43% reduction in the average BCR. As previously discussed, this is due to the high cost of renourishing reach R5. From Table 16, it can be seen that the template corresponding to a dune height of 12.5 ft., a dune width of 20 ft., and a berm width of 100 ft. returned the largest BCR. This template was considered for further analysis.

[1] Note that the simulations shown in Table 16 and the resulting average BCRs do not consider reach planform rates, and are thus not reflective of the actual average BCR. Reach planform rates were applied following the identification of a nourishment dune and berm template.

Table 16: Average BCR when renourishing separate reaches

Template (DH_DW_BW)	R3 and R4	R3, R4 and R5
10_20_100	0.895	0.752
10_15_100	0.897	0.780
12.5_20_100	**1.189**	**0.733**
12.5_15_100	1.167	0.726
12.5_10_100	1.129	0.734
12.5_10_150	0.949	0.543
15_15_100	0.958	0.650
15_10_100	0.924	0.649

7.2 Reach Planform Rates

In Beach-fx, reach planform rates (feet/year) are an additional shoreline change rate that is applied due to the placement of nourishment material. To determine the project induced shoreline change, an analytical model was implemented (Pelnard-Considere, 1956). This model assumes a rectangular beach fill with a user specified berm width of 100ft., and a longshore placement width of approximately 11,600 ft. (length of reaches R3 and R4). The equation implemented in the model is given by:

$$y(x,t) = \left(\frac{Y}{2}\right)\{\mathrm{erf}\left[\left(\frac{l}{4\sqrt{Gt}}\right)\left(\frac{2x}{l}+1\right)\right] - \mathrm{erf}\left[\left(\frac{l}{4\sqrt{Gt}}\right)\left(\frac{2x}{l}-1\right)\right] \qquad 7.3$$

Where, *x* and *t* are the longshore distance and time respectively. *Y* is the placement length, *l* is the project length, and *G* is the diffusivity parameter, given by:

$$G = \frac{KH_b^{5/2}\sqrt{g\gamma}}{8(s-1)(1-n)(d_c+B)} \qquad 7.4$$

Where *K* is the longshore transport coefficient, H_b is the breaking wave height, *g* is the acceleration of gravity, γ is the wave breaker index, *s* is the specific gravity of the sediment, *n* is the porosity of the sediment, d_c is the depth of closure and *B* is the berm height. The longshore transport coefficient, *K*, was estimated using del Valle et. al. (1991), and given by:

$$K = 1.4e^{-2.5d_{50}} \qquad 7.5$$

The resulting shoreline position at 1, 2, 3, 4, 5, 7, 10, 12, 15, 20, and 50 years after placement are shown in Figure 36. The reach planform rates specified in Beach-fx were computed based on the average change from the initial shoreline position to that of the shoreline at year *N.* A single value was identified for both the placement area (reaches R3 and R4), and the reaches adjacent to the placement area (reaches R2 and R5). The resulting reach planform rates in feet/year are shown in Table 17.

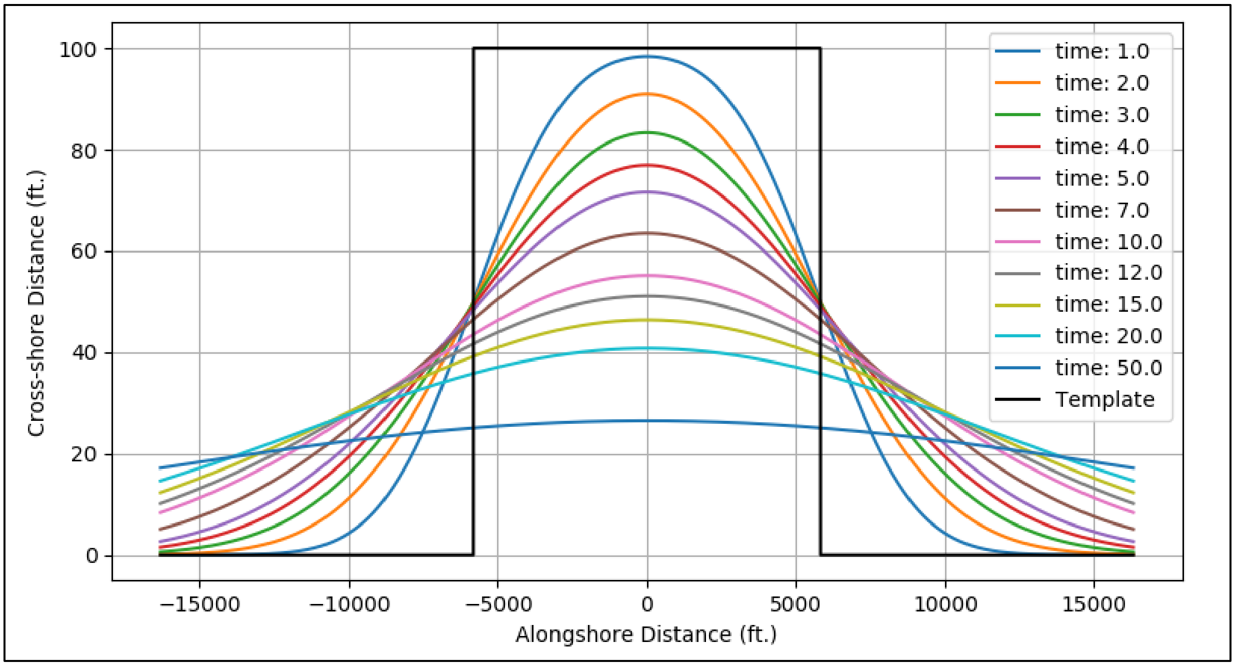

Figure 36: Analytical Solution to shoreline change rates

Table 17: Reach Planform Rates

Renourishment Interval	Placement Area Rate (ft./year)	Adjacent Area Rate (ft./year)
1	-16.7	9.2
2	-11.8	6.5
3	-9.6	5.3
4	-8.3	4.5
5	-7.3	4.0
7	-6.1	3.2
10	-4.9	2.4
12	-4.3	2.1
15	-3.7	1.7
20	-3.0	1.3

7.3 Renourishment Intervals

By utilizing the reach planform rates, and the selected template (dune height of 12.5 feet, dune width of 20 feet, and a berm width of 100 feet), additional Beach-fx simulations were completed with varying renourishment intervals. In total, 10 renourishment intervals were considered (1, 2, 3, 4, 5, 7, 10, 12, 15, and 20 years), and both the BCR and net benefits were computed for each lifecycle (300 lifecycles). Figure 37 and Figure 38 show box and whisker plots representing the distribution of BCRs and net benefits at each renourishment interval.

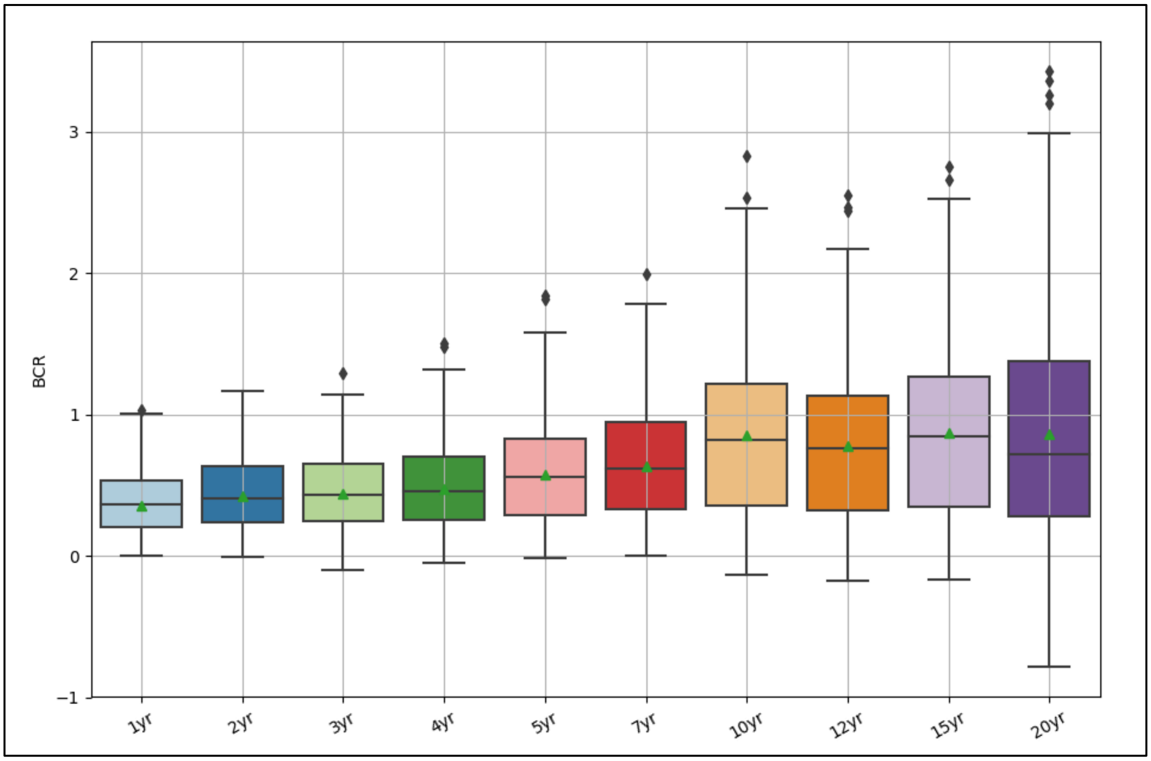

Figure 37: Box and whisker plot of BCRs at varying nourishment intervals

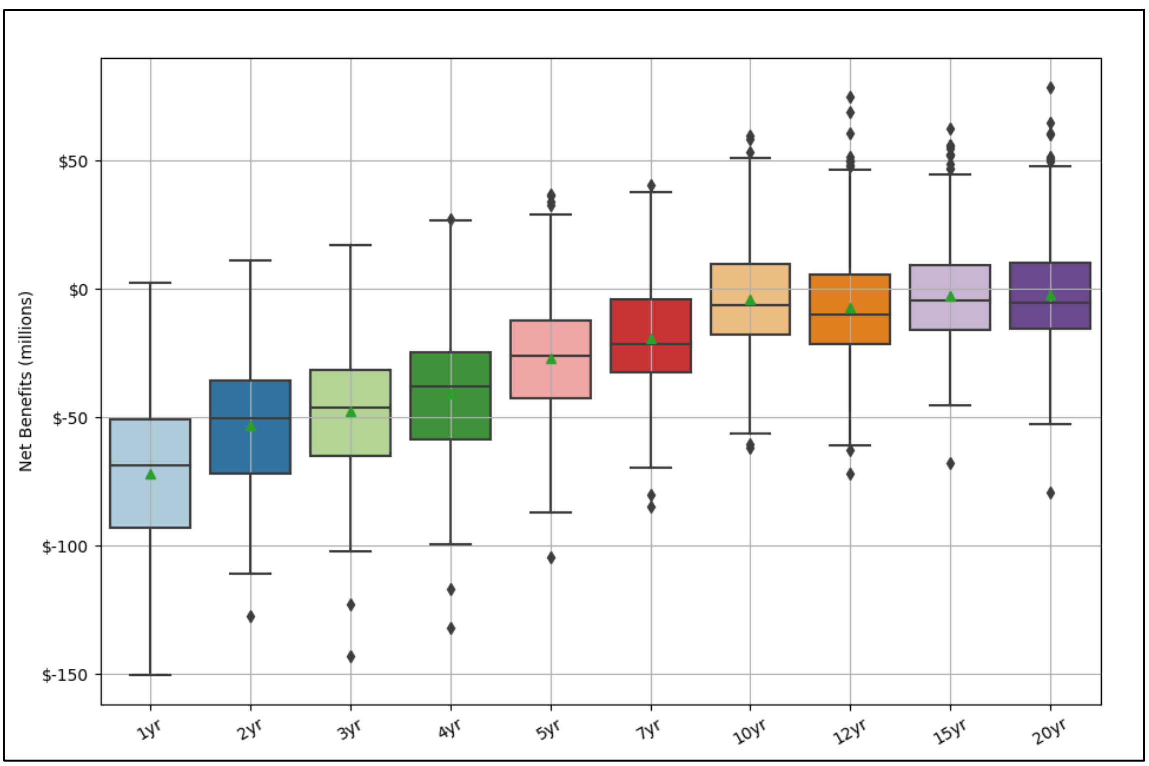

Figure 38: Box and whisker plot of net benefits at varying nourishment intervals

It can be seen that, in general, larger benefits result from increasing the nourishment interval up to the 10-year cycle. Beyond the 10-year cycle, there is no significant increase in the benefits, with the 12-year cycle showing a slight decrease. Figure 37 shows that there are some simulations that result in a negative BCR. This indicates that with the implementation of a renourishment project, larger damages occur than the identical without project conditions. This is due to both the robust initial conditions at South Padre Island, as well as the increased erosion rates due to the placement of additional material (reach planform rates).

Because the benefits plateau beyond the 10-year renourishment interval, this cycle is selected as the optimal renourishment interval. When considering the renourishment interval, it is beneficial to select the plan that returns the largest BCRs at the shortest renourishment interval. This reduces the vulnerability of the beach between nourishment cycles. Although, the 15 and 20-year renourishment intervals return slightly higher net benefits, they is not recommended as the optimal plan because of the long duration between renourishment events. There is no significant increase in net benefits beyond the 10-year renourishment interval that would justify the increased vulnerability.

7.4 Selected Plan – Overview and Discussion

The beach template (DH-12.5ft, DW-20ft, BW-100ft), coupled with a 10-year renourishment interval make up the selected beach renourishment plan at South Padre Island. The average BCR and net benefits across all 300 lifecycles are 0.85 and -$3.84 million respectively. Although the average BCR is less than one and the net benefits are negative, these values only consider National Economic Development (NED) benefits. In addition to the NED benefits, implementation of a beach renourishment project at South Padre Island would likely result in additional Regional Economic Development (RED) benefits. The distribution of net benefits across all lifecycles can be seen in Figure 39 and Figure 40.

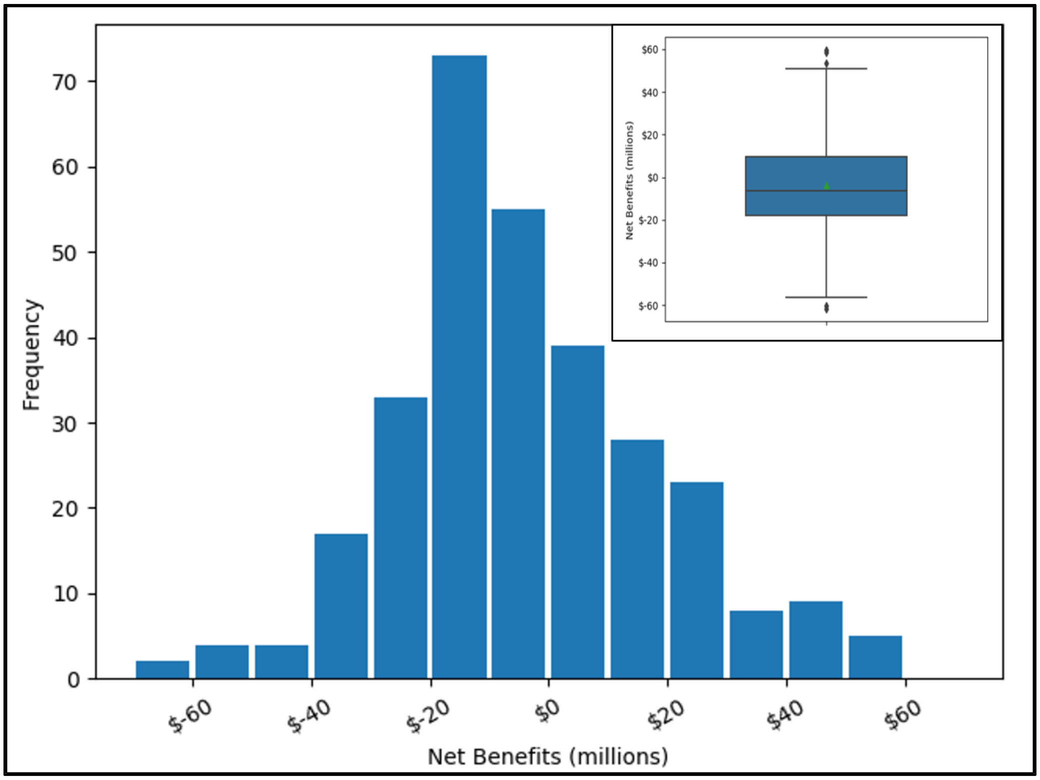

Figure 39: Distribution of Net Benefits of TSP

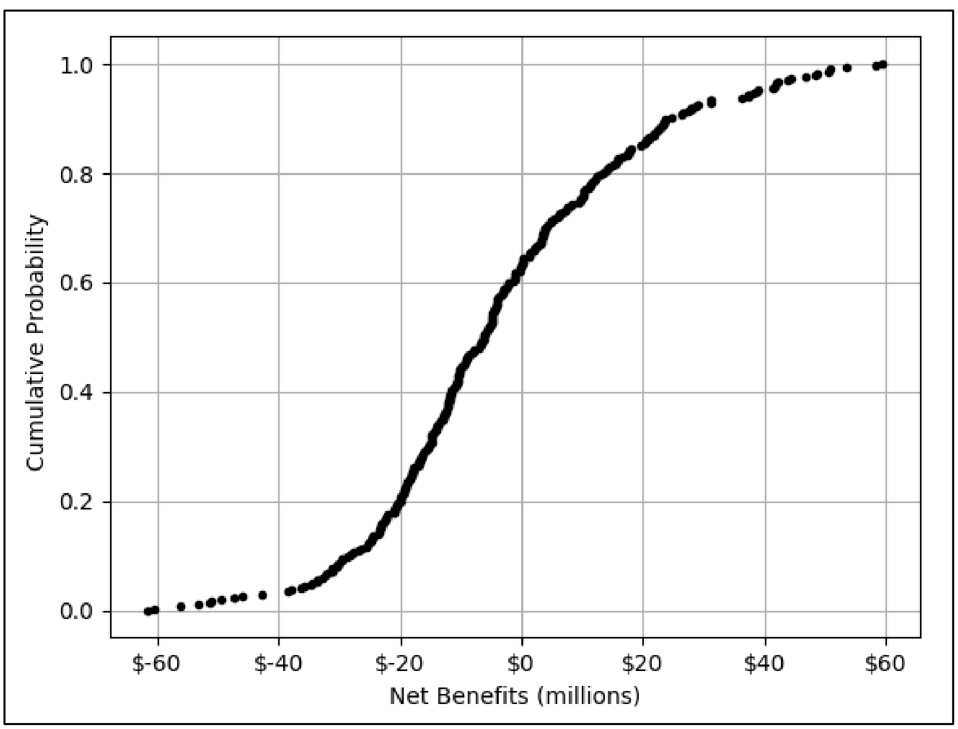

Figure 40: Empirical Cumulative Distribution Function of Net Benefits

The net benefits are normally distributed with five statistical outliers (three upper and two lower). Of the 300 lifecycles, 112 lifecycles returned positive net benefits (37.3%), whereas the remaining 188 lifecycles returned negative net benefits (62.7%).

Each lifecycle was classified as returning either positive or negative net benefits, and plotted as a histogram grouped by the number of storms (Figure 41). It can be seen that, in general, lifecycles with few storm events returned negative net benefits (e.g. 2-6 storms). Conversely, lifecycles with a relatively large number of storm events showed a higher chance of returning positive net benefits (e.g. 8-12 storms). Across all 300 lifecycles, Beach-fx returned an average of 8.227 storms. If 8 storms are expected to occur over the 50-year, then the selected project has a 57% chance of being economically justified (e.g. with 8 storm events, 25 lifecycles returned positive net benefits, whereas 19 returned negative). Figure 41 can similarly be read in the same way for varying number of potential storm events over a 50-year period.

As previously mentioned, the average NED-BCR and net benefits are both below 1 and $0 respectively. The benefits computed herein do not consider RED benefits, which could increase the total benefits. The negative net benefits are most likely driven by the robust initial beach conditions at South Padre Island.

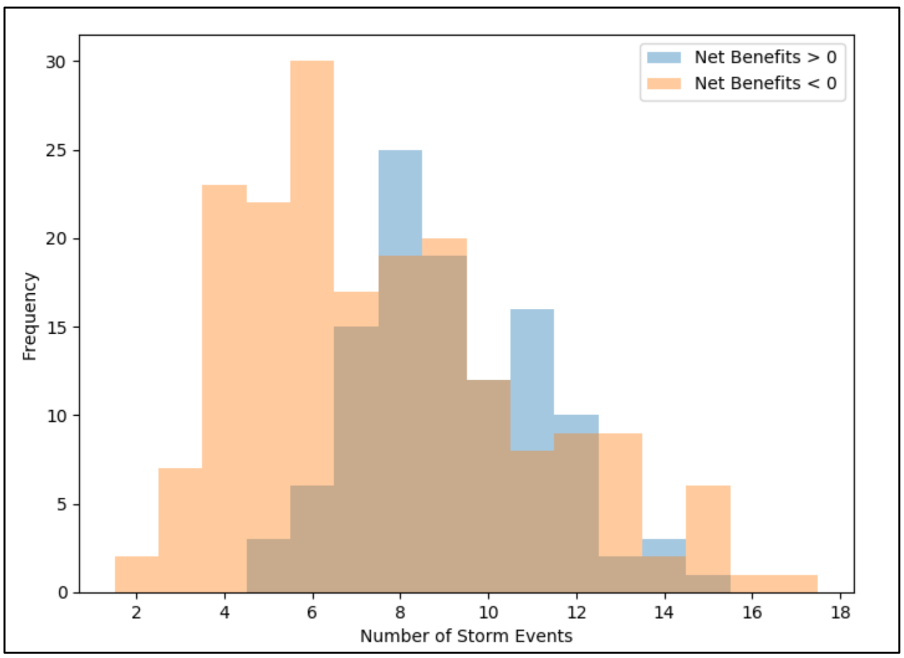

Figure 41: Histograms of positive and negative net benefit lifecycles vs. number of storm events. .

7.5 Depth of Closure Modifications Following Identification of TSP

Following the selection of the beach template and renourishment interval that returned the largest net benefits and BCR, minor modifications to Beach-fx were implemented. Additional model reviews were completed by both AECOM and CE-SAJ. The primary takeaway from these conversations resulted in modifications to the Beach-fx depth of closure and width of active profile. Within Beach-fx, these two values dictate how nourishment material is placed, as well as how much material is eroded due to sea level change (Bruun, 1954). The depth of closure and width of active profile were originally specified as 30ft. and 4000ft. respectively. These values were updated to 23ft. and 3000ft. A depth of closure of 23ft.

was selected to be consistent with the depth of closure implemented in the volume calculations (Section 5.2). Furthermore, WIS data at the South Padre Island indicates a depth of closure of 19-23ft. (Brutsché et. al, 2014). The width of active profile was determined from the submerged profile data based on the updated depth of closure.

Changes to the depth of closure and width of active profile resulted in minor variation in the without project conditions. The distribution of FWOP damages can be seen in Figure 42. The average damages with the update depth of closure and width of active profile increased from $144.00 million to $144.20 million.

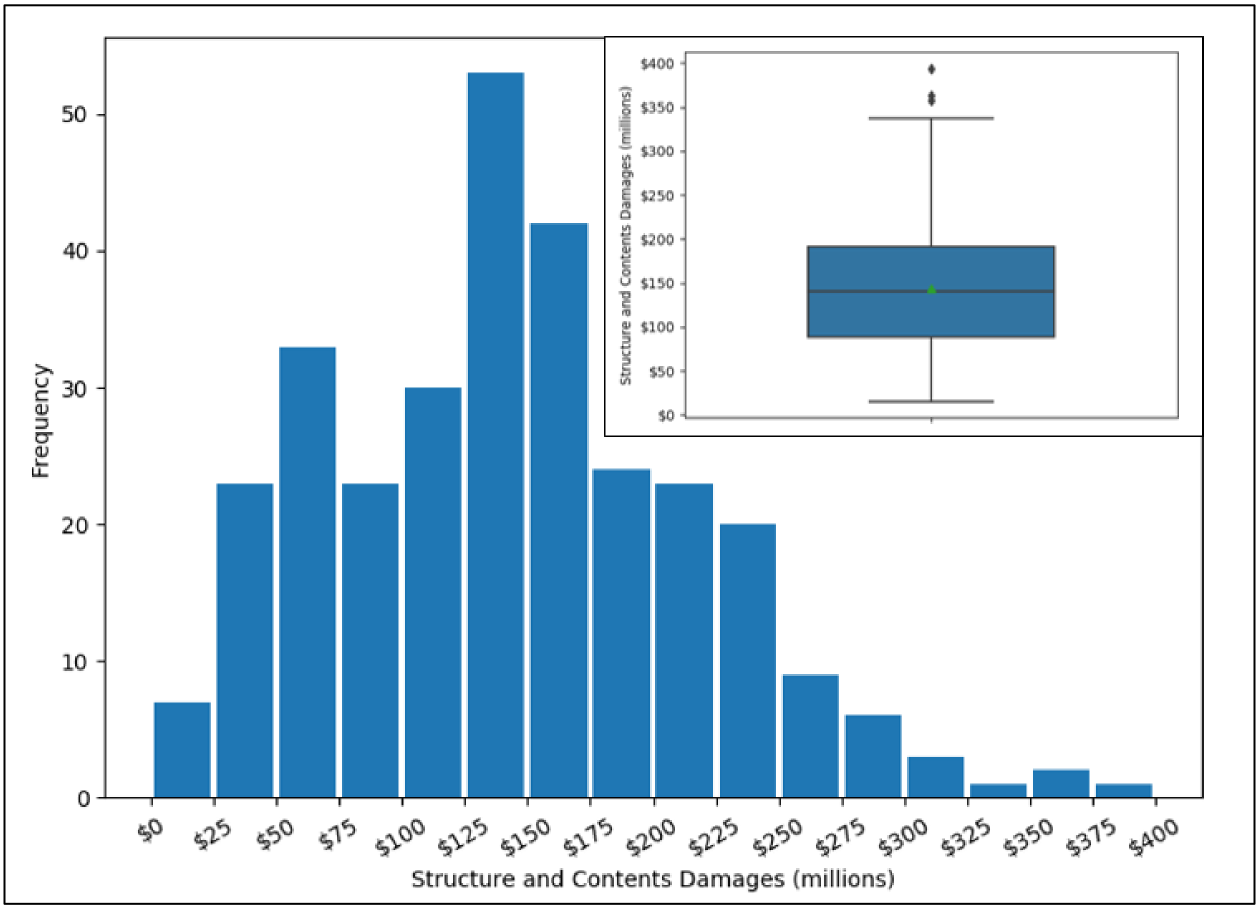

Figure 42: FWOP damages following modifications to depth of closure and width of active profile.

Whereas the updated depth of closure and width of active profile resulted in negligible changes to the FWOP conditions, the FWP conditions saw more significant changes. Table 18 shows the averages of the orginal model runs and the updated model runs.

Renourishment cycles of 5, 10, and 15 years were re-simulated. It can be seen that the BCR and net benefits resulting from the new depth of closure increase regardless of the renourishment interval. Additionally, it can be seen that there is little variation in the FWP Damages, but that the change in BCR and net benefits are caused by a reduction in project costs. The larger variation between the FWP costs are attributed to the decreased depth of closure. Within Beach-fx, the volume (and costs) are proportionately related to the depth of closure. Therefore, a decreased depth of closure results in a decreased cost. For all three simulations, the resulting BCRs increase between 18-20%, and the rank ordering of the BCRs are the same as that of the original runs. It is expected that regardless of the plan or renourishment interval selected, the increase in BCR will remain the same (~20%). Consequently, it is not necessary to rerun all of the simulations. Rather, the originally selected TSP remains the selected plan, although there are changes to the economic values.

Table 18: Comparison of original and new depth of closure

		Depth of closure/ Width of Active Profile (ft.)	
	PN interval	30/4000 (original)	23/3000 (new)
BCR	5	0.574	0.688
Net Benefits		-$26,930,182	-$15,603,320
FWP Damages		$103,634,456	$103,874,211
FWP Costs		$67,302,557	$55,929,689
BCR	10	0.850	1.008
Net Benefits		-$3,842,351	$2,230,348
FWP Damages		$109,239,669	$109,497,650
FWP Costs		$38,609,514	$32,472,582
BCR	15	0.869	1.026
Net Benefits		-$2,482,384	$2,714,841
FWP Damages		$112,619,297	$112,873,620
FWP Costs		$33,869,918	$28,612,118

As outlined in the Section 7.3, although the 15-year renourishment interval returned a larger BCR and Net Benefits, it is not recommended due to the increased vulnerability of the beach between renourishment intervals. As a result, the 10-year renourishment interval is selected. The distribution of net benefits for the TSP can be seen in Figure 43 and Figure 44.

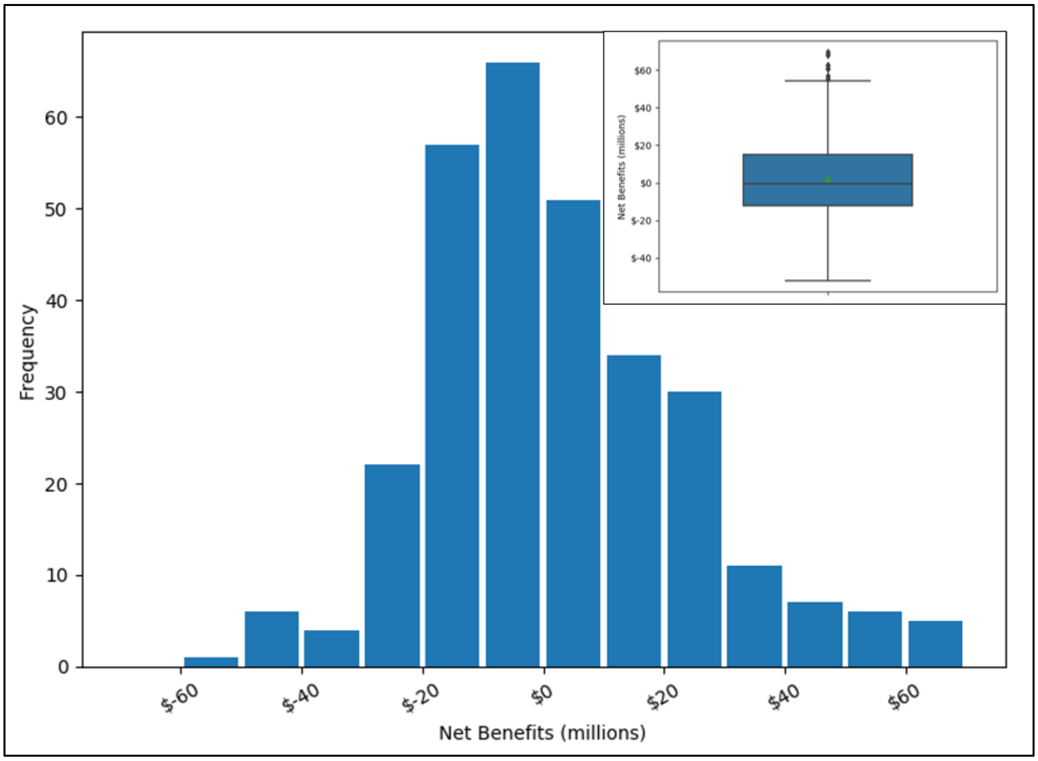

Figure 43: Distribution of Net Benefits of TSP

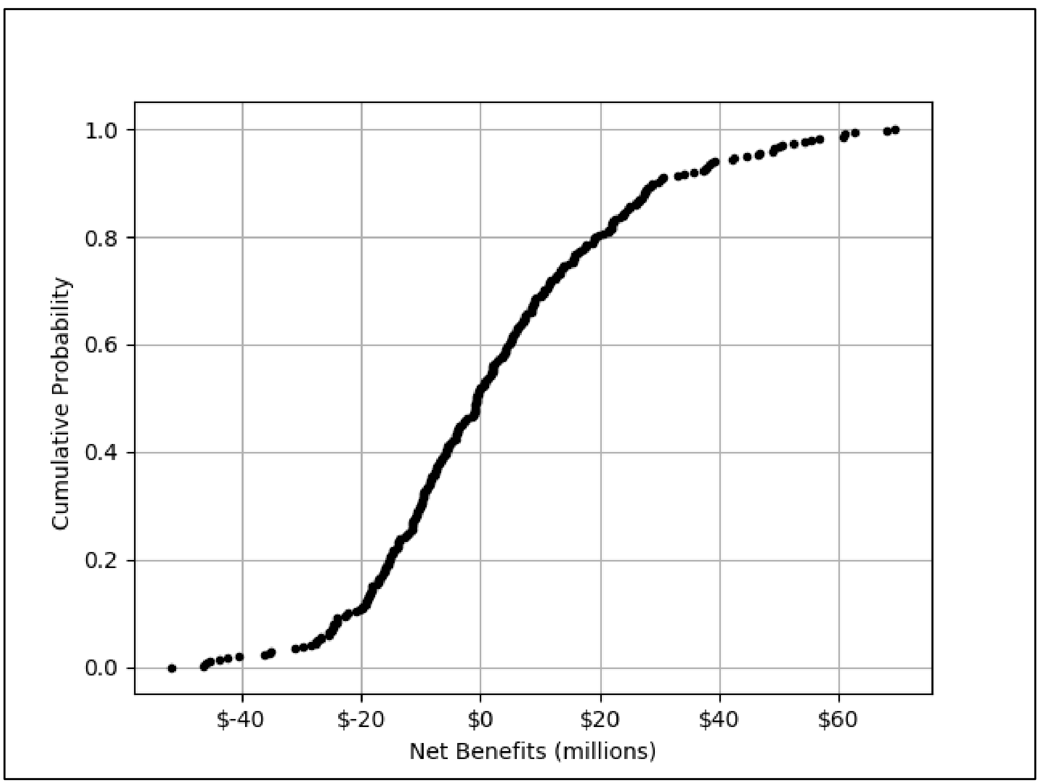

Figure 44: Empirical CDF of net benefits

8 Comments Arising from DQC Review

As a part of the Beach-fx modeling at South Padre Island, a District Quality Control (DQC) review was completed by the USACE North Atlantic Philadelphia District (CENAP). A number of comments were received and addressed by the project PDT. This section details the comments that have been received to date, as well as the responses from the PDT. Some of the comments outlined in this section were "not a [part of a] formal DQC comment list, but rather… some initial questions".

8.1 Mobilization Threshold

In Beach-fx, the mobilization threshold is specified as a volume in cubic yards that must be exceeded to justify mobilization for placement of nourishment material. The mobilization threshold was initially set to 100,000 cubic yards.

<u>CENAP Comment(s):</u> *Mobilization Threshold - probably unnecessary to have a value greater than 0 here. Can assume all nourishment cycles will be completed.*

<u>PDT Response:</u> Although not specified as *0*, the mobilization threshold was updated to *1* to ensure that mobilization and nourishment occur at the nourishment cycle. The PDT did not specify a value of *0* due to the treatment of mobilization in Beach-fx. With the threshold set at *0*, at each nourishment cycle, the reach would be triggered for nourishment, and mobilization costs applied, regardless of if any material was placed. A mobilization threshold of *1*, ensured that at least 1 cubic yard of sand was required before mobilization costs were applied.

8.2 Back-Bay Flooding

In Beach-fx, back-bay flooding is a user option that allows one to simulate the bay-side flooding of barrier islands. It is possible to implement protective features in Beach-fx that prevent bay-side flooding. Back-bay flooding was initially turned off.

<u>CENAP Comment(s):</u> (1) *Back Bay Flooding - Boolean flag is unchecked. Is there evidence of co-incident inundation in this area? Can affect inundation reduction benefits.*

(2) *Investigate back bay flooding. If there is no evidence of co-incident flooding then this is a non-issue, but with back bay flooding turned off, you may be overstating inundation reduction benefits. If you feel that still water will flank the dune or flood from the back bay, then it would be prudent to turn on this flag.*

<u>PDT Response:</u> An investigation into bay side flood reduction alternatives was beyond the scope of the Beach-fx work at South Padre Island. Because no back-bay flooding alternatives were considered, then any damages resulting from the future with project conditions will negate the damages resulting from the future without project conditions. Regardless, a test simulation occurred in which back-bay flooding was turned on for both FWOP and FWP conditions. The results (Table 19), show that the differences are negligible. The PDT concluded that the remaining simulations will occur in the absence of back-bay flooding.

Table 19: Sensitivity test of with and without back-bay flooding

	No back-bay flooding	With back-bay flooding
FWOP Damages	$144,006,831	$144,028,188
FWP Damages	$125,241,602	$125,389,770
PN Costs	$15,479,983	$15,479,983
BCR	1.1654	1.1518

8.3 Maximum Number of Rebuilds

An option is available in Beach-fx that allows the user to specify the maximum number of rebuilds that will occur to a single damage element before the damage element is removed from the inventory. For all damage elements at South Padre Island, this value was set to 9,999.

CENAP Comment(s): (1) *Number of Rebuilds - why 9999?*

(2) *The number of rebuilds is set quite high. As it reads now, the owner of the building will repair his structure 9999 times in the exact same manner across the 50 year project life. If Damage Element condemnation is turned on (any damage over 50% results in removal from the inventory) then this is not a huge issue. Also removal from the inventory doesn't necessarily mean demolished, but could also include structure elevation. For large commercial or apartment structures, it's OK to not have damage element condemnation turned on as these structures are not easily elevated. Would require a full deconstruction and a new structure on the same parcel of land.*

PDT Response: The PDT specified the number of rebuilds to 9999 as a placeholder to allow an "infinite" number of rebuilds. Historically, there is no evidence at South Padre Island that land will remain vacant if a structure is removed. This applies even if the structure is completely destroyed.

8.4 Control Line Offset

The control line offset in Beach-fx allows the user to specify a distance from the centroid of a lot to the seaward toe of the dune, which will mark the lot as condemned. The condemnation of a lot prohibits rebuilding of damage elements within the lot. This option was initial set to *0*.

CENAP Comment(s): *Control Line Offset - affects timing of* [Lot] *condemnation. May consider moving back (negative number) depending on condemnation results.*

PDT Response: Sensitivity tests were performed with varying control line offset values ranging from *0* to *-100* feet. The PDT decided to keep the control line offset at *0* feet due to the fact that the majority of lots on seaward side of the island do not have land behind the structures. The PDT feels that a control line offset of *0* is the most feasible option.

8.5 Foundation Types

Foundation types in Beach-fx alter how a structure behaves to erosion damages. Three foundation types are pre-defined in the model (Slab, Pile, and Pile16), with an option for the user to define more to meet case specific needs. The predefined foundation types, Pile and Pile16, define to the depth of the pile below the surface (8 and 16 feet respectively).

CENAP Comment(s): (1) *Foundation Types - Pile vs Pile16 have different critical erosion amounts. Can drastically alter erosion damage results.*

(2) *I'm guessing that the model will be very sensitive to the selection of Pile16 vs Pile8 foundation types, so you'll need to develop a criteria for applying Pile16 or Pil8 for each structure. If the model results are not very sensitive, then it's a moot point and you don't need to worry about it.*

PDT Response: The selection of foundation type for each damage element was distinguished based on the type of structure. When creating the structure inventory, the PDT was informed that all structures in the damage element inventory are supported by a pile foundation. Within Beach-fx, all beach high rise structures were assigned a Pile16 foundation, whereas all other structures were assigned a Pile foundation.

8.6 Time to Rebuild

Beach-fx allows the user to specify the amount of time it takes a structure to be rebuilt from damages received. Each structure was assigned a unique time to rebuild.

CENAP Comment(s): *Time to Rebuild - not uniform; even among the same Damage Element type. How were these developed?*

PDT Response: The time to rebuild was based on best judgment from the size/type/number of floors of the structure.

8.7 Reach Planform Rates

Reach planform rates are discussed in detail in Section 7.2. The specification of reach planform rates in Beach-fx allow the user to model the project induced shoreline change rates that result from perturbations in the shoreline.

CENAP Comment(s): (1) *Reach Planform Rate - already discussed, but will alter alternative selection due to nourishment volume (and subsequent cost) changes.*

PDT Response: Reach planform rates were identified analytically as outlined in Section 7.2. An analytical solution was chosen over a longshore transport model such as GenCade or Genesis due to time constraints.

8.8 Depth of Closure/Width of Active Profile

The depth of closure and width of active profile options in Beach-fx are related to the Bruun rule (Bruun, 1954) and sea-level rise. These values were initially set as the default Beach-fx values.

CENAP Comment(s): *Depth of Closure / Width of Active Profile - were these developed together?*

PDT Response: The depth of closure and width of active profile were updated in the final model. The depth of closure was specified as 30ft. to be consistent with the SBEACH runs that were completed. The width of the active profile was specified as 4,000 ft. based on the average cross-shore distance to the depth of closure for each representative submerged profile.

8.9 Armoring

Armoring in Beach-fx is specified at the lot level, and protects damages elements within the lot from damages caused by erosion. Armoring units can fail, leaving the damage elements susceptible to erosion damages. Furthermore, if an armoring unit fails, there are costs associated with reconstruction. The vast majority of lots within Beach-fx were initially specified as armored.

CENAP Comment(s): (1) *Armor (Lot) / Armor (DE) - you have armor input for almost every Lot and Damage Element. Armor can have a massive impact on damage calculations and seems to have issues with high erosion rates. I would consider running a sensitivity test comparing your current model results (with armor) to an identical model that removes armor input (no armor) to measure the level of impact.*

(2) *Armor. This is probably the most important point. I would heavily recommend a sensitivity test with removing all Armor and comparing these results with the original estimates. If none of the alternatives are justified even after this sensitivity, then there is no actionable alternative. If the BCR does creep above 1.0, then the next step is to evaluate which armor meets Corps standards and can be included, and which armor cannot be considered to reliably reduce erosion/wave/inundation impacts. For NAP, two sites in a recent GI had extensive armoring, but these were private, ad hoc measures and none of them met Corps standards. As such they were not included in the final model.*

PDT Response: As noted by CENAP, Beach-fx was initially set up such that most units were considered armored. A typical example of a structure at South Padre Island with a retaining wall facing seaward is shown in Figure 45. The city of South Padre Island does not consider the protective structures shown in Figure 45 to be armoring, and refuses to use the term “seawall”. The PDT decided to run Beach-fx without armoring and place this option in the Risk Register, to be addressed later if necessary.

Figure 45: Example of retaining wall at South Padre Island

8.10 Increased Berm Width for Increased Nourishment Cycle

CENAP Comment(s): *When deciding on your berm width, consider the minimum berm acceptable at a given location. For example, if I want to maintain a 25ft berm width for Reach R4 with a With-Project erosion rate of 2ft per year, then the berm width for the one year nourishment cycle is 27ft. For the five year cycle, the berm width is 35ft. And so on. You'll have developed that matrix of Dune + Berm conditions and the resulting Reach Planform Rates and will need to apply that value for each alternative.*

PDT Response: Before a dune/berm template was identified, the PDT tested two variations in berm width (100, 150 ft.; Section 7.1). The berm width of 100ft. returned the greatest BCR when the selected reaches were specified to be renourished as needed. Due to time constraints, varying berm widths based on the nourishment cycle could not be tested. The PDT feels that because the 2 variations in berm width were initially tested, then additional variations will not alter the TSP significantly. Furthermore, the results showed that an increase in berm width from 100 to 150ft. did not cause an increase in the BCR, but rather caused a reduction.

8.11 Erosion Rate in Reach R3

Within Beach-fx, shoreline change rates are a result of storm induced changes, berm width recovery from the storms, the applied erosion rate, and (under FWP conditions) the reach planform rates. The applied erosion rate is adjustable, and allow the user to calibrate Beach-fx to historically observed shoreline change rates. At South Padre Island, an average shoreline change rate was computed for each reach based on the procedure outlined in Section 5.2. This procedure resulted in negative values for all reaches, except reach R3.

<u>CENAP Comment(s):</u> *Investigate the erosion rate at Reach R3 first. This is a fundamental variable that will heavily affect your Without- and With-Project Conditions. Whatever erosion rate you specify, you'll need to be prepared to justify that rate (and the rates for all the other Reaches as well).*

<u>PDT Response:</u> The PDT ran a sensitivity test with an arbitrary applied erosion rate of -1.5ft./year in reach R3. Although Beach-fx proved to be sensitive to the negative applied erosion rate, the PDT feels confident in the applied erosion rates that were originally specified in Section 5.3. HDR engineering completed a similar analysis in which they estimated the erosion rates in the absence of any beneficial use projects (HDR, 2010). Figure 46 shows the results from the HDR analysis, in which the segment of shoreline between survey stations 130+00 and 185+00 result in a positive shoreline change. Stations 130+00 to 185+00 correspond approximately to reach R3.

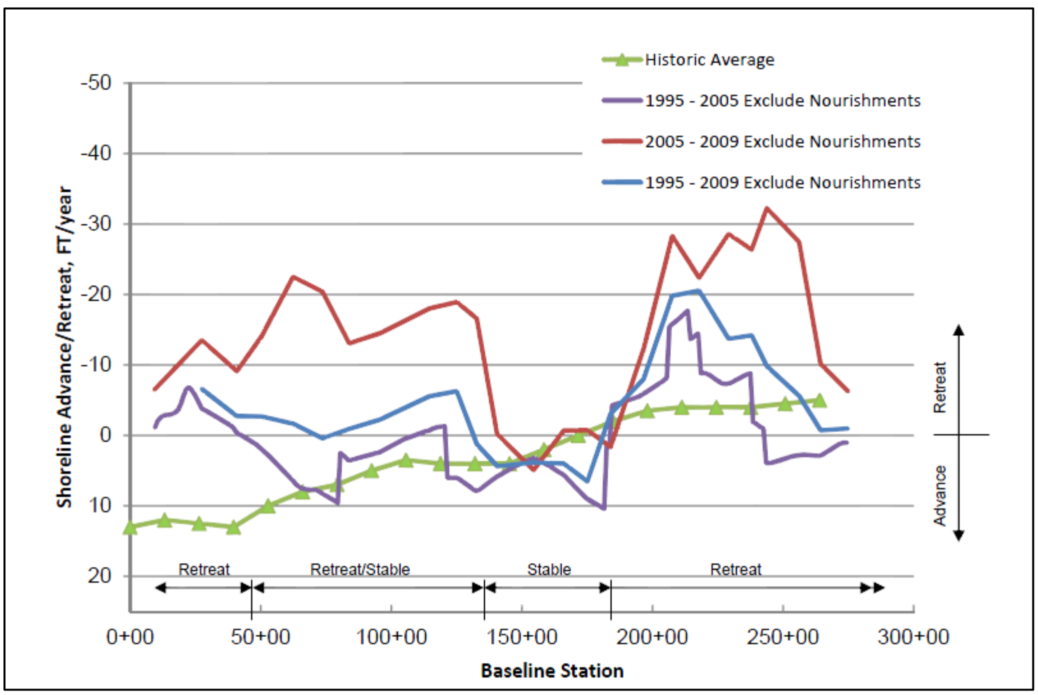

Figure 46: Shoreline Change from HDR Engineering.

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