Storm-Induced Beach Change (SBEACH)
High-Frequency Storm Erosion
Model Study for Gulf County

Division of Water Resource Management

Florida Department of Environmental Protection

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1. Background

Since 2009, high-frequency storm tide studies have been conducted by the Beaches and Shores Resource Center (BSRC) of Florida State University and the Department of Environmental Protection's (DEP's) Division of Water Resource Management (DWRM) for the 24 Coastal Construction Control Line (CCCL) studied counties. Hydrographs with 15- and 25-year return intervals were developed for the application of dune erosion models. Due to increased usage of the Storm-Induced Beach Change (SBEACH) by coastal engineers for coastal projects in Florida, DEP contracted with the BSRC to conduct the model calibration and application on a county-by-county basis. A total of eight counties were completed: Walton, Okaloosa, Brevard, St. Johns, Volusia and Indian River by Leadon and Nguyen (2009 and 2010); and Sarasota and Palm Beach by Wang and Manausa (2013). Since 2014, the SBEACH calibration study has been conducted by DWRM's Engineering, Hydrology and Geology Program (EHG); Lee and Franklin were completed by Wang and Manausa (2015 and 2016) before the current Gulf County study. The SBEACH model, Version 4.03, for high-frequency storm event is used in verification for armoring projects and shore/dune protection project permit applications.

The SBEACH model developed by the U.S. Army Corps of Engineers (USACE) is an empirically based numerical model for predicting short-term profile response to storms. The SBEACH model calculates beach profile changes with emphasis on beach and dune erosion and bar formation and movement. It is a cross-shore sediment transport model, so the longshore processes are considered to be uniform and neglected in the calculation of profile changes. The model was initially formulated using data from prototype-scale laboratory experiments, and further developed and verified based on field measurements and sensitivity testing (Larson and Kraus, 1989).

To accurately apply the SBEACH model for a high-frequency storm event, it is essential to have the model calibrated in the project area under similar storm conditions. This requires detailed pre- and post-storm beach profile surveys that represent a storm's effects on cross-shore beach change, and coincident information regarding the wind, wave, and water level conditions. This study presents eroded dune and beach profiles due to high-frequency storm events with return intervals of 15 years and 25 years in Gulf County using the latest version of the SBEACH model. All data resources for calibration and input files required to run the SBEACH model are documented.

2. Model Calibration

Searches for available surveyed beach profiles associated with a tropical storm or hurricane for Gulf County resulted in a data set with sufficient completeness and quality for model calibration. A set of beach profiles in Gulf County were surveyed before and after Hurricane Earl of 1998. The model calibration became possible with the BSRC's 2-D Storm Surge Model and the measured storm tides on the open coast.

2.1 Storm Data

The tropical depression became Tropical Storm Earl while centered about 500 n mi south-southwest of New Orleans, Louisiana near 1800 UTC August 31, 1998, based on aircraft reconnaissance data. The center remained difficult to locate by satellite, and, in fact, multiple centers were reported by aircraft reconnaissance for the next couple of days. Occasionally, a new center would appear to form, which made tracking extremely difficult. Although the best track shown in Figure 1 indicates a general motion toward the north and then northeast near 10 knots while Earl was over the Gulf of Mexico, a certain amount of "smoothing" was necessary to account for the multiple centers and any possible center reformations.

Based on aircraft reconnaissance data, Earl was estimated to have reached hurricane status at 1200 UTC September 2 while centered about 125 n mi south-southeast of New Orleans, Louisiana. The system never exhibited a classical hurricane appearance. Instead, satellite imagery showed the deepest convection confined primarily to the eastern quadrants of the circulation, and aircraft reconnaissance data indicated a very asymmetric wind field with the strongest winds located well east and southeast of the center.

After briefly reaching Category 2 status, Earl made landfall near Panama City, Florida as a Category 1 hurricane near 0600 UTC September 3. The strongest winds remained well to the east and southeast of the center, which resulted in the highest storm surge values in the Big Bend area of Florida, well away from the center. The tropical cyclone weakened to below hurricane strength soon after making landfall, and became extratropical at 1800 UTC September 3, while moving northeastward through Georgia (Mayfield, 1998).

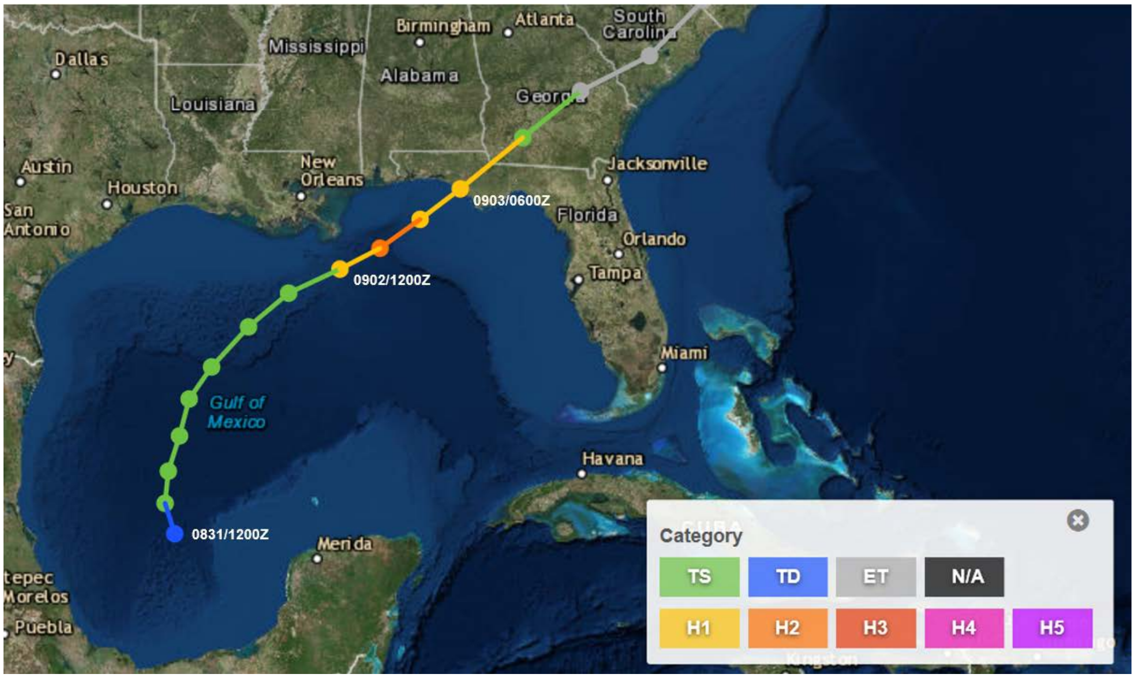

Figure 1: *Hurricane Earl Track, 1998 (NOAA).*

2.1a Storm Tide Data

For the model calibration, the measured storm tide generated by Hurricanes Earl is essential. However, there was no measured storm tide data available in Gulf County during Hurricane Earl in 1998. The only available measured water elevation data was from a National Ocean Service (NOS) tide gauge located at Panama City Beach Station, 8729210, Bay County (Figure 2). Although the BSRC's 2-D Storm Surge Model has been verified throughout the Coastal Construction Control Line (CCCL) studies and various storm events, and has been proven to be an accurate and reliable model, it was reverified using Gulf County bathymetry and Hurricane Earl storm data to generate a storm tide for Panama City Beach. Figure 3 shows the comparison between model calculated and measured storm tides in Panama City Beach. The model calculated storm tide is generally agreed well with the measured one. The calculated peak storm tide (3.24 ft.) is 0.58 ft. lower than the measured one (3.82 ft.). It is due to the fact the tide gauge is located about 830 feet offshore, where a partial wave setup should be recorded, but it was unable to be determined quantitively in the model calculation. Therefore, the 2-D grid systems and associated hydrological data of Gulf County from the CCCL study were used to generate storm tide data from Hurricane Earl for Gulf County. Hurricane track, pressure deficit, and radius to the maximum wind of Earl were input to the 2-D Storm Surge Model. The model then ran and calculated the total storm tide, i.e. surge from barometric pressure deficit and wind stress plus wave dynamic setup and astronomical tide, for a total of six locations along the study area. Figure 4 displays the model calculated results. By comparing the calculated total storm tides with the Total Storm Tide Values for Various

Return Periods listed in Table 1, it shows that Hurricane Earl generated total storm tides ranging between 17 and 27 years return period for the Gulf County area. Therefore, Hurricane Earl was selected as a high-frequency storm, and the hydrograph calculated for Profiles 2 and 4 were applied for the SBEACH Model calibration.

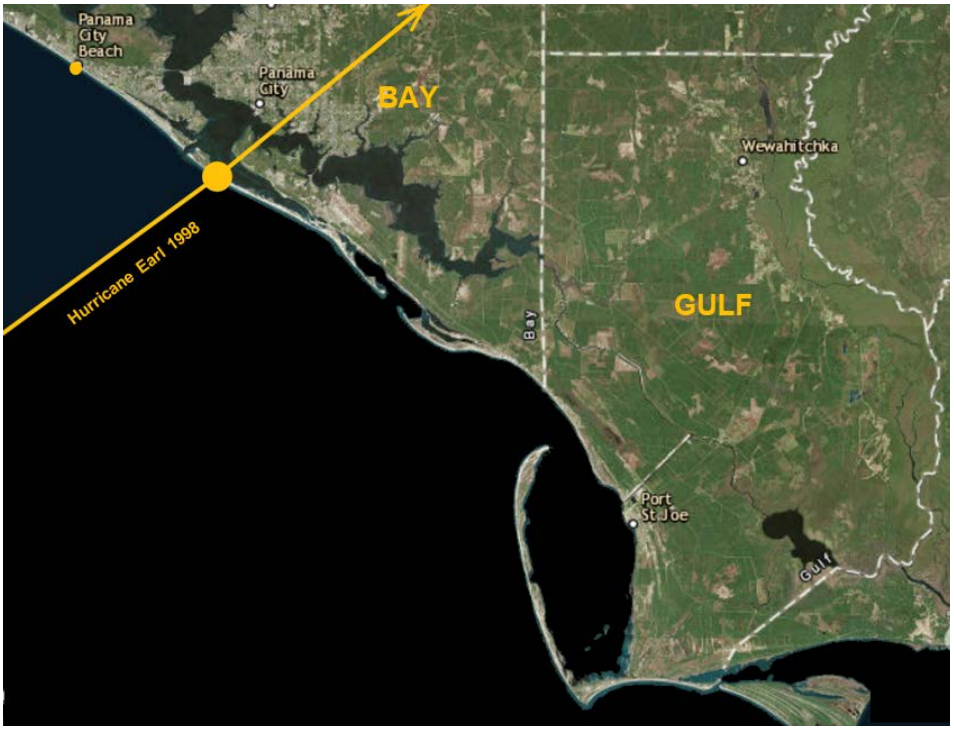

Figure 2: *Panama City Beach Gauge and Hurricane Earl Landfalling.*

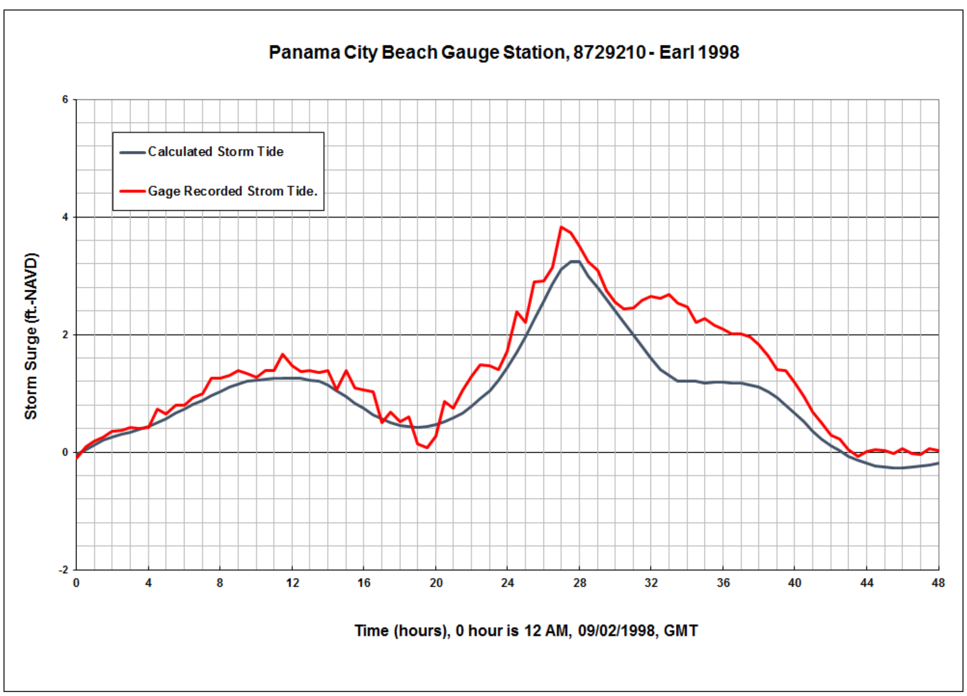

Figure 3: *Storm Tide Recorded and Calculated at Panama City Beach.*

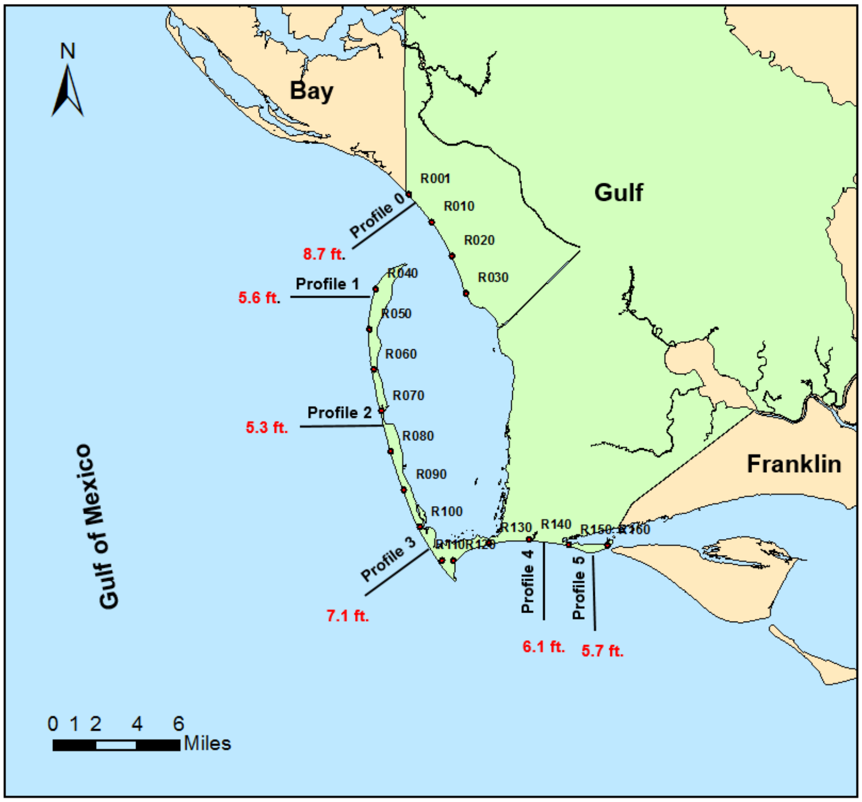

Figure 4: *Storm Tide Levels (NAVD) Calculated by 2-D Surge Model for Hurricane Earl 1998.*

***Table 1**. Total Storm Tide Values* (ft.-NAVD) for Various Return Periods*

Return Period, TR (years)	Profile 0	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5
50	7.9	6.7	6.6	7.3	9.2	9.3
30	6.8	5.9	5.7	6.4	8.1	8.2
25	6.1	5.1	5.2	5.9	7.3	7.3
20	5.4	4.6	4.6	5.2	6.6	6.6
15	4.6	3.9	4.0	4.5	5.8	5.8
10	3.4	3.0	3.0	3.5	4.6	4.6
5	2.3	2.4	2.7	1.8	1.9	2.2

* *Includes contributions of: wind stress, barometric pressure, dynamic wave set-up, and astronomical tide.*

2.1b Wind and Wave Data

From the wind speed data provided by the National Hurricane Center (Mayfield,1998), the significant deep wave height, H_s, and dominant period, T_p can be estimated by empirical equations as shown in the following:

$$H_s = \frac{U_{max}^2}{36g}$$

$$T_p = \frac{2U_{max}}{g}$$

where U_{max} is the maximum wind speed in m/s. These equations were developed and verified by Maynord et al (2011), and the calculated results were very close to the buoy data for Hurricanes Lili of 2002, Claudette of 2003, Ivan of 2004, Katrina and Rita of 2005. Figure 5 shows the resulting deep-water wave data by applying the measured wind speed to these equations for Hurricane Charley in 2004.

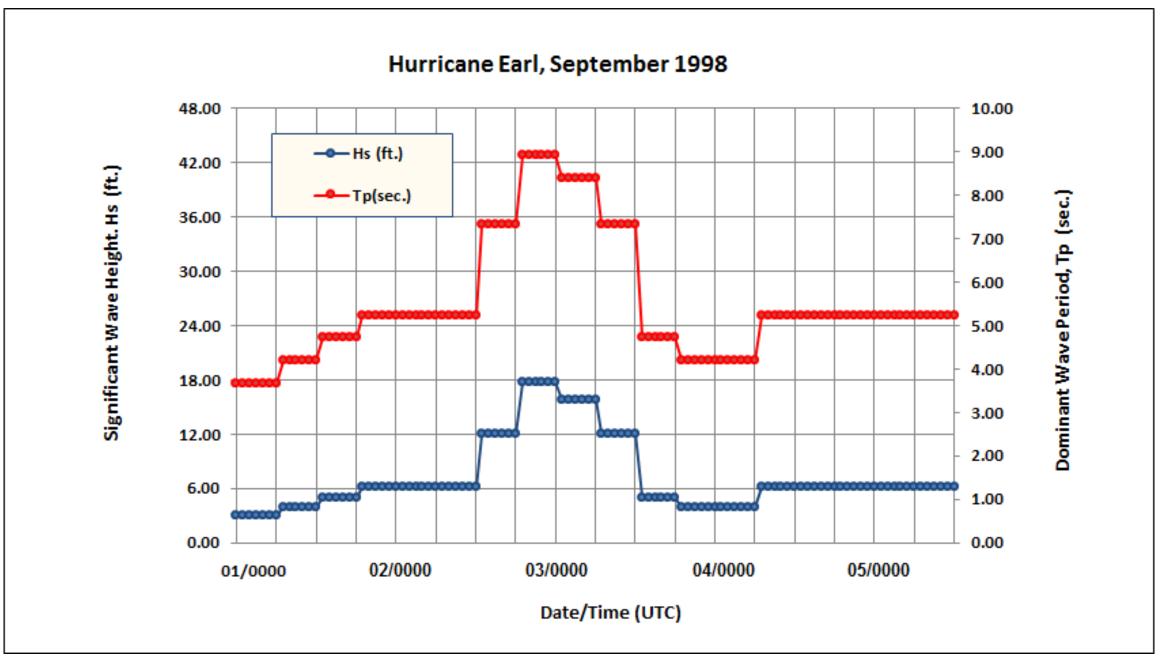

Figure 5: *Best estimated wave conditions for Hurricane Earl, 1998.*

2.1c Hydrographic Survey Data

DEP conducted pre- and post-Earl surveys for Gulf County in March 1997 and September 1998, respectively. A total of 14 selected profiles from R-73 to R-100 (segment 1) and 16 selected profiles from R-129 to R-145 (segment 2) were selected for the model calibration, all of which were located at the windward side of Hurricane Earl and show consistent erosion. The map in Figure 6 shows the location of the profiles selected for the SBEACH model calibration and the peak storm tide calculated with the 2-D Storm Surge Model.

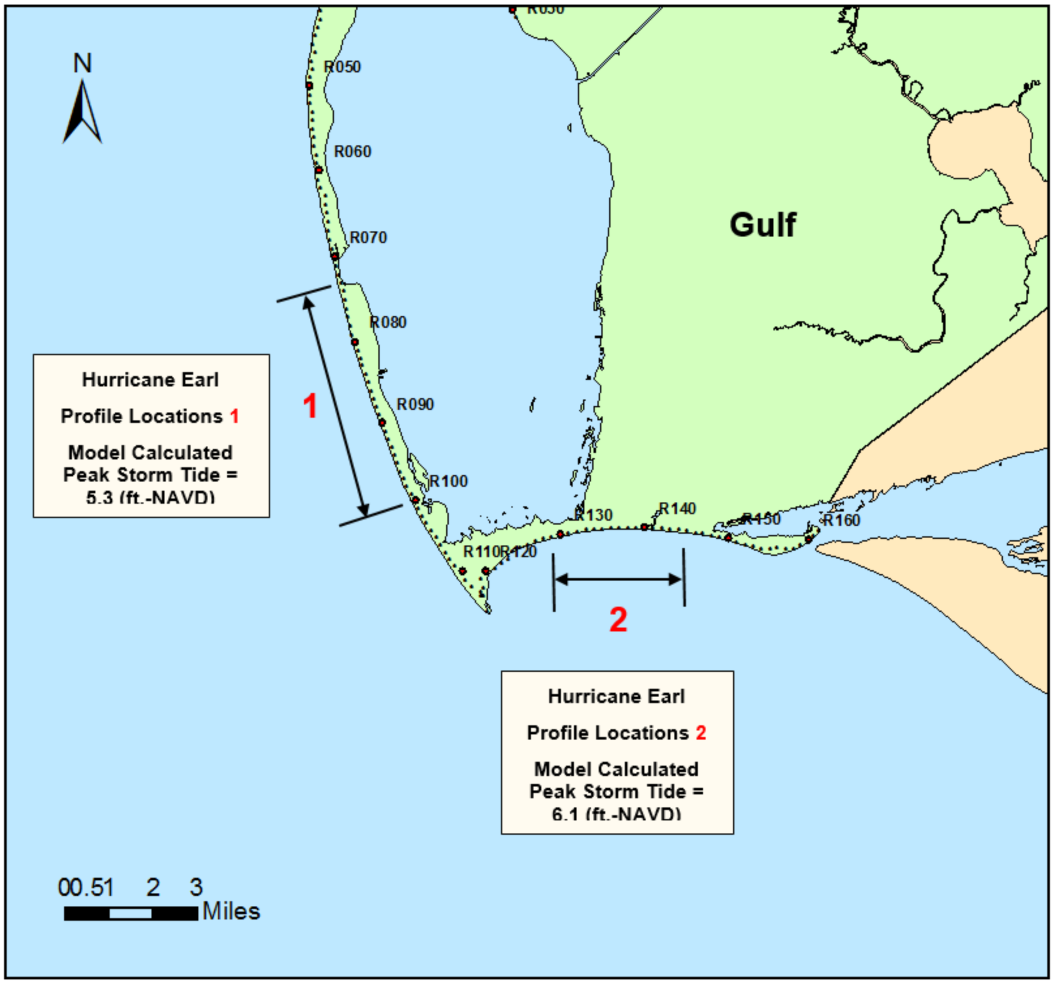

Figure 6: *Locations of Profiles and the Calculated Peak Storm Tide Used in SBEACH Calibration.*

2.2 Model Input Parameters

The SBEACH model's primary input information includes profile, storm and sediment data. Profile data are selected based on the segment of shoreline being modeled. Mean grain size of the beach material is one of the primary sediment data required. Other inputs include model parameters such as grid size, time step, and the transport rate coefficient.

The beach profiles were represented in the model using a constant grid scheme with grid cell spacing of five feet to generate a detailed result. Each reach was approximately 3,000 feet long and had about 600 cells of five feet across, well below the 1,000-cell limit allowed by the SBEACH model. Sediment data was obtained from the beach sediment survey in the Florida's Northwest Coast (Daniel et al, 2011). For the model calibration areas, R-73 to R-100 and R-129 to R-145 of Gulf County, the average mean grain sizes were 0.262 mm and 0.243 mm, respectively.

The default values for SBEACH are shown in Table 2. A series of model runs were conducted within the range of recommended values to achieve the best fit between measured and SBEACH calculated erosion profiles.

***Table 2**. Listing of SBEACH Input Parameters*

Parameters	Unit	Default Value	Range of Recommended Values
Transport rate coefficient, K	m^4 /N	1.75 e^{-006}	0.25 e^{-006} - 2.5 e^{-006}
Overwash transport parameter		0.005	0.002 - 0.008
Coefficient for slope dependent term, ε	m^2/s	0.002	0.001 - 0.005
Transport rate decay coeff. multiplier, λ	m^{-1}	0.5	0.1 - 0.5
Landward surf zone depth	ft.	1.0	0.5 - 1.6
Effective grain size (mean D_{50})	mm	0.35	0.15 – 1.0
Maximum slope prior to avalanching	degree	45	15 - 90 deg.
Water temperature	degree, C	20	0 - 40

2.3 Model Calibration Results

The sensitivity evaluation resulted in initially setting most of the model input parameters at or near the default values as described above. Wind speed and direction, available as options during the model input, were not included due to the insignificant effect in the model results. For each SBEACH run, the hydrographs without wave setup generated from the 2-D Storm Surge Model for county profiles two and four were applied, the SBEACH model then calculated and added the wave setup internally to reach the desired final water level. The hydrographs were then adjusted for the 30 selected profiles, such that the peak water elevation output from SBEACH agreed with the peak storm tide values calculated by the 2-D Storm Surge Model for Hurricane Earl.

The average measured versus the SBEACH calculated erosion distance for contours from 0 to 15 feet above NAVD 88 of the 30 profiles were used as the principle basis for determining the calibration parameters setting. A wave height of 10 feet and wave period of seven seconds, which are the average values from the Earl data as shown in Figure 5, were selected for model parameters. Starting with the default values, a series of values for each calibration parameter were tested. The transport rate coefficient, K, the transport rate decay coefficient, the coefficient for slope dependent term, ε, and the maximum slope prior to avalanching were found to be significant to the calibration results, so they were adjusted individually until reasonable agreement with the measured erosions were achieved.

The final parameter values summarized in Table 3 were determined as those providing the best presentation of measured erosions for the 30 selected profiles. Figures 7 and 8 show comparisons of average contour recessions between the measured and SBEACH model computed for Hurricane Earl based on the final model parameters described above. The SBEACH model predicted erosions with the calibrated parameters were agreed well with the measured ones, especially for contours between two and five feet, which were impacted the most by the given five- and six-foot storm tides. Plots of pre-storm, post-storm, and SBEACH model predicted profiles with the final calibration parameters for each of the 30 profiles are presented in Appendix A.

Table 3. *SBEACH Model Calibration Parameters for Gulf County*

Parameters	**Unit**	**Values**
Transport rate coefficient, *K*	m^4 /N	2.5 e^{-006}
Overwash transport parameter		0.005
Coefficient for slope dependent term, ε	m^2/s	0.005
Transport rate decay coeff. multiplier, λ	m^{-1}	0.5
Landward surf zone depth	ft.	1.0
Effective grain size (mean D_{50})	mm	0.262 (R-73-100), 0.243 (R-129-145)
Maximum slope prior to avalanching	degree	45
Water temperature	degree, C	27
Wave Input Conditions		
Wave Height, H	ft.	10
Wave Period, Tp	Sec.	7
Wave Direction, α	degree	0 (shore-normal)

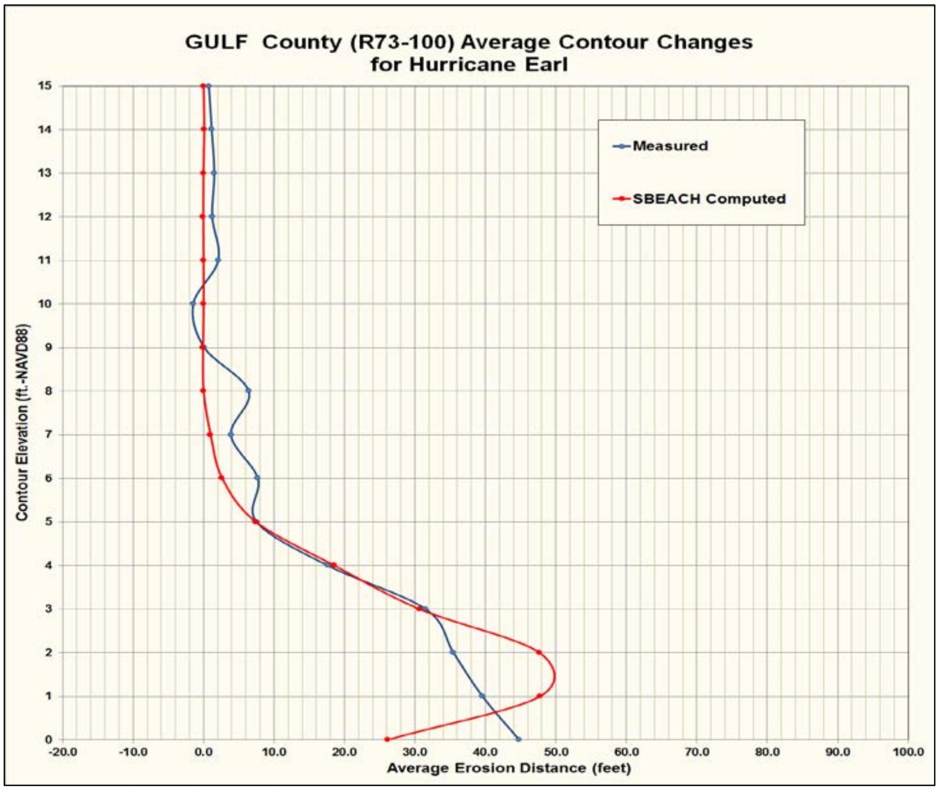

Figure 7: *Comparisons of Average Contour Changes Between Measured and SBEACH Model Computed for Hurricanes Earl.*

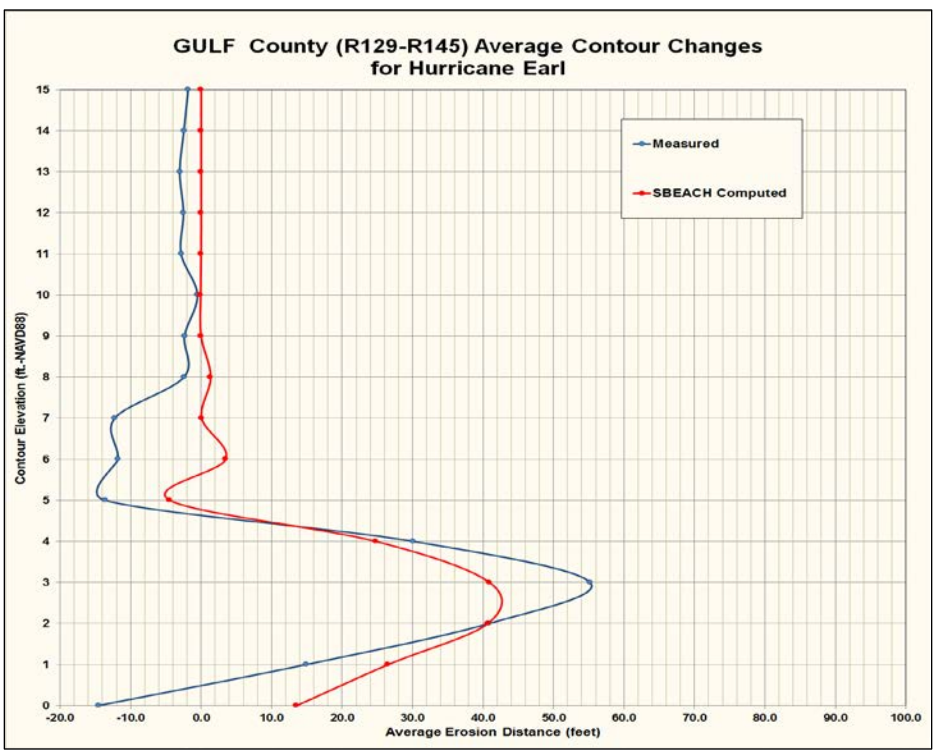

Figure 8: *Comparisons of Average Contour Changes Between Measured and SBEACH Model Computed for Hurricanes Earl.*

3. Gulf County SBEACH Application

3.1 Model Configuration

Configuration of the SBEACH model in Gulf County for high-frequency storm erosion will be primarily based on the model calibration results, as shown in Table 3 of the previous section. Countywide sediment data was obtained from the beach sediment survey in the Florida's Northwest Coast and Keys (Daniel et al, 2011). Figure 9 presents the mean grain size distribution throughout Gulf County. The wave height was set as 10 ft., which was averaged from the wave heights applied in the other counties for a typical high frequency storm, as listed in Table 4. A 10-foot wave height with a 10-second wave period were chosen as reasonable approximations for a generic high-frequency storm that would impact this area. Gulf County storm tides developed by Wang (2015) for 15- and 25-year storms are shown in Table 5.

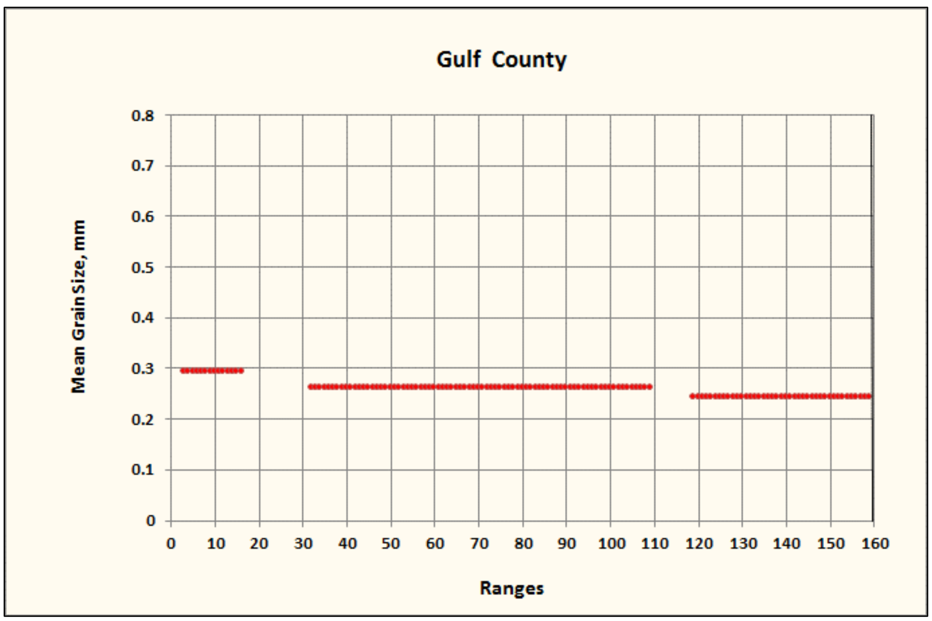

Figure 9: *Sediment Data Distributions in Gulf County.*

Table 4. *Wave Heights Used in Florida Counties for SBEACH Applications*

County	Wave Height (ft.)	Reference
Brevard	12	Leadon and Nguyen, 2010
Indian River	12	Leadon and Nguyen, 2010
Palm Beach	15	Wang and Manausa, 2013
Pensacola Beach, Escambia	10	Olson Associates, 2014
St. Johns	10	Leadon and Nguyen, 2010
Sarasota	7	Wang and Manausa, 2013
Volusia	10	Leadon and Nguyen, 2010
Walton	10	Leadon and Nguyen, 2009

Table 5. *High-frequency Storm Tides Level* (ft.-NAVD) for Gulf County*

Ranges	15-year Return Period	25-year Return Period
R-1 to R-31, R-93 to R-115	4.6	6.0
R-32 to R-92	4.0	5.2
R-116 to R-159	5.8	7.3

* *Includes contributions of: wind stress, barometric pressure, dynamic wave set up and astronomical tide.*

As mentioned in the Model Calibration Results (Section 2.3), only the hydrographs without wave setup were applied since the SBEACH model calculated and added the wave setup internally to reach the final water level. The final model output water levels did not always agree with the desired 15- or 25-year storm tides at first run; therefore, the input hydrographs were then adjusted so the resultant SBEACH model peak water levels were equivalent to the predicated storm tides for each profile. Recommended Reach and Storm input values to be used in 15- and 25-year storm erosion calculations by SBEACH are listed in Appendix B. Time series values for the adjusted hydrographs without wave setup for each reach are shown in Figures 10 and 11 and are tabulated in Appendix C.

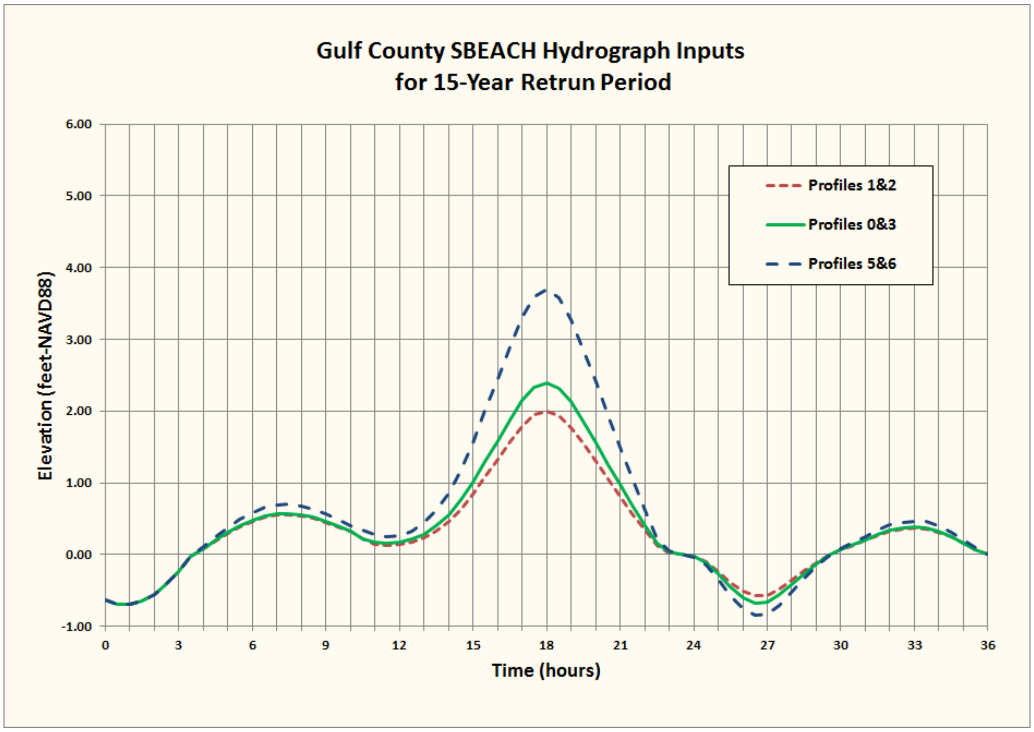

Figure 10: *15-year Hydrographs for Gulf County Profiles in SBEACH Application.*

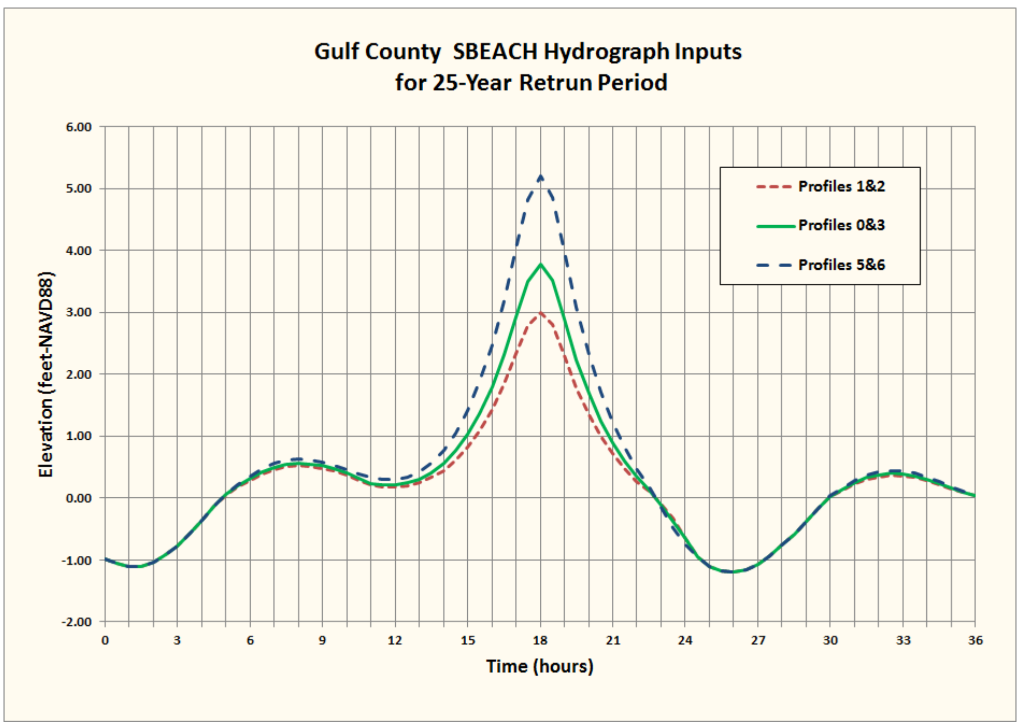

Figure 11: *25-year Hydrographs for Gulf County Profiles in SBEACH Application.*

3.2 Model Application and Results

Representative plots of surveyed profiles and their associated eroded profiles generated from SBEACH for the 15- and 25-year return periods for Gulf County are provided in Appendix D. The most updated profiles available for Gulf County at present for SBEACH application are listed in Table 6.

Table 6. *Profiles Used in SBEACH Application for Gulf County*

Range	Beach Profile Date	Offshore Profile Date
1-61	Sept. 2008	Sept. 2008
62-110	Aug. 2014	Aug. 2014
121-155	Sept. - Oct. 2008	Sept. - Oct. 2008

The plots in Appendix D are shown in the NAVD88 vertical datum. The map in Figure 12 below depicts the DEP profile range locations along the Gulf County shoreline.

Figure 12: *DEP Profile Range Locations Along the Gulf County Shoreline.*

References

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10. Wang, S. Y. and Manausa, M., “SBEACH High-Frequency Storm Erosion Model Study for Sarasota County, Final Report”, Beaches and Shores Resource Center, Florida State University, March 2013.

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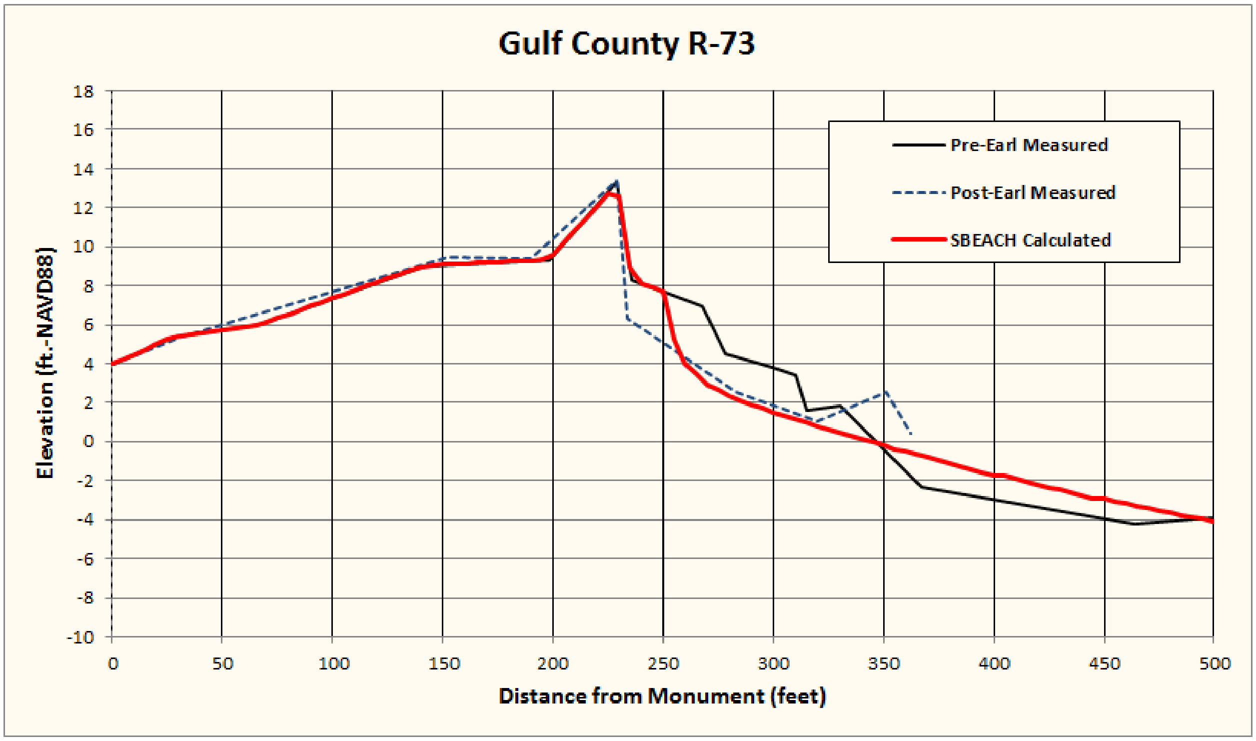
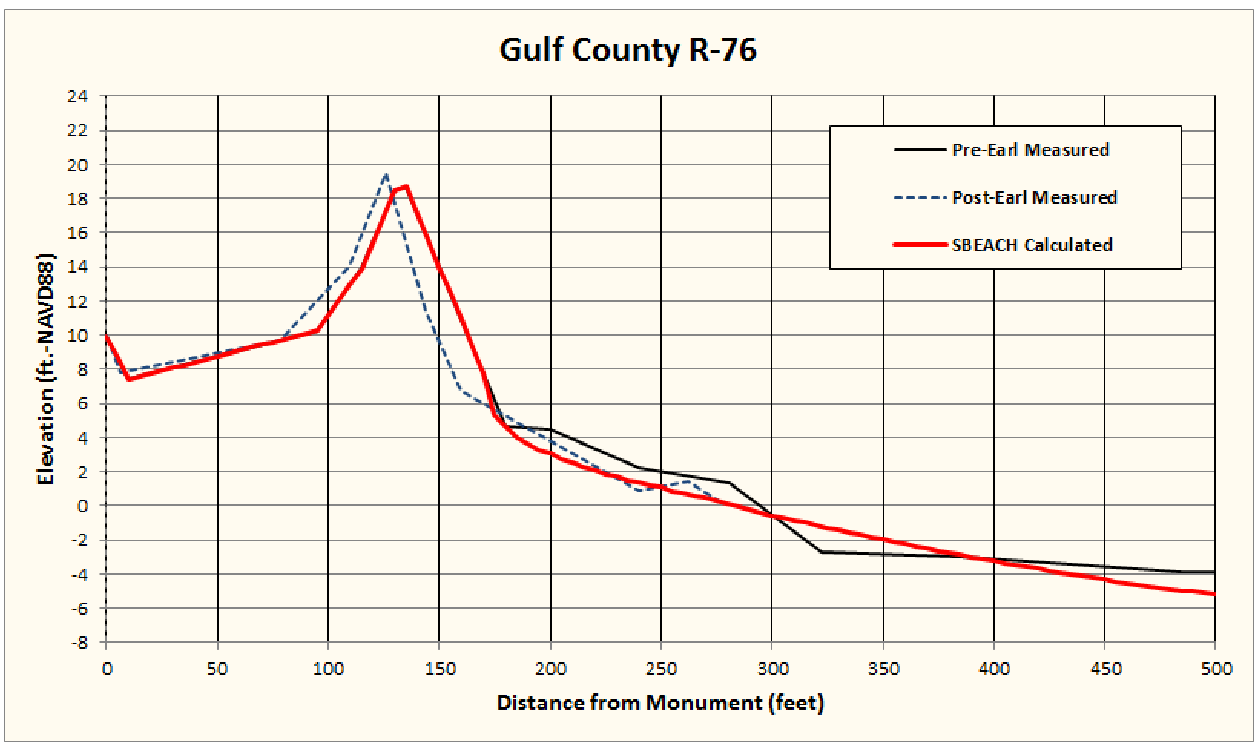
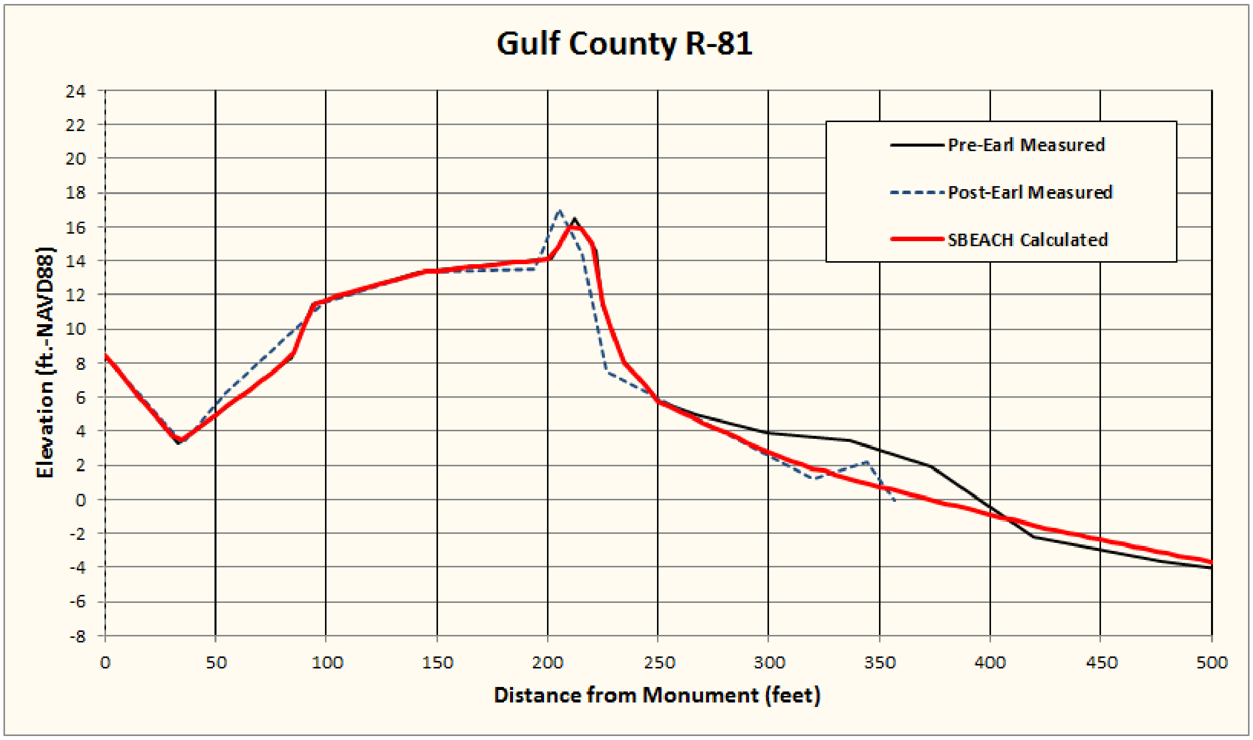
14. Wang, S. Y., “SBEACH High-Frequency Storm Erosion Model Study for Bay County”, Engineering, Hydrology & Geology Program, Division of Water Resource Management, Florida Department of Environmental Protection, June 2017.

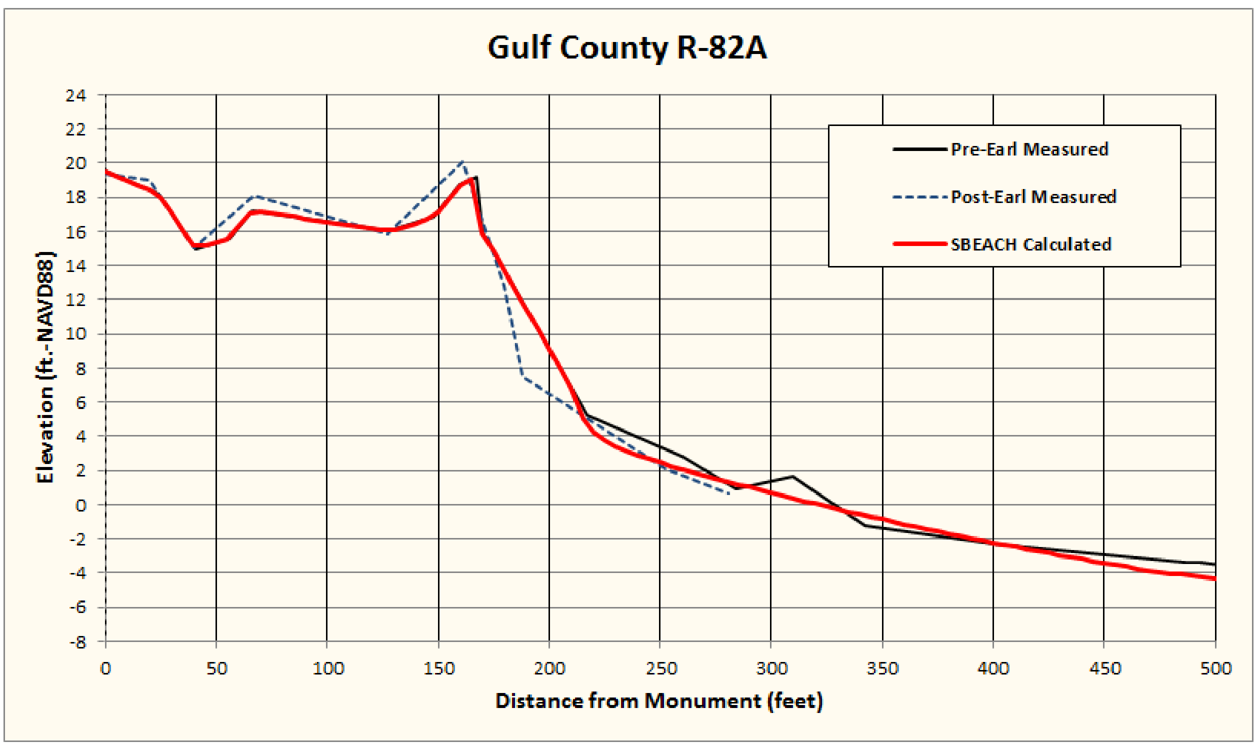
Appendix A

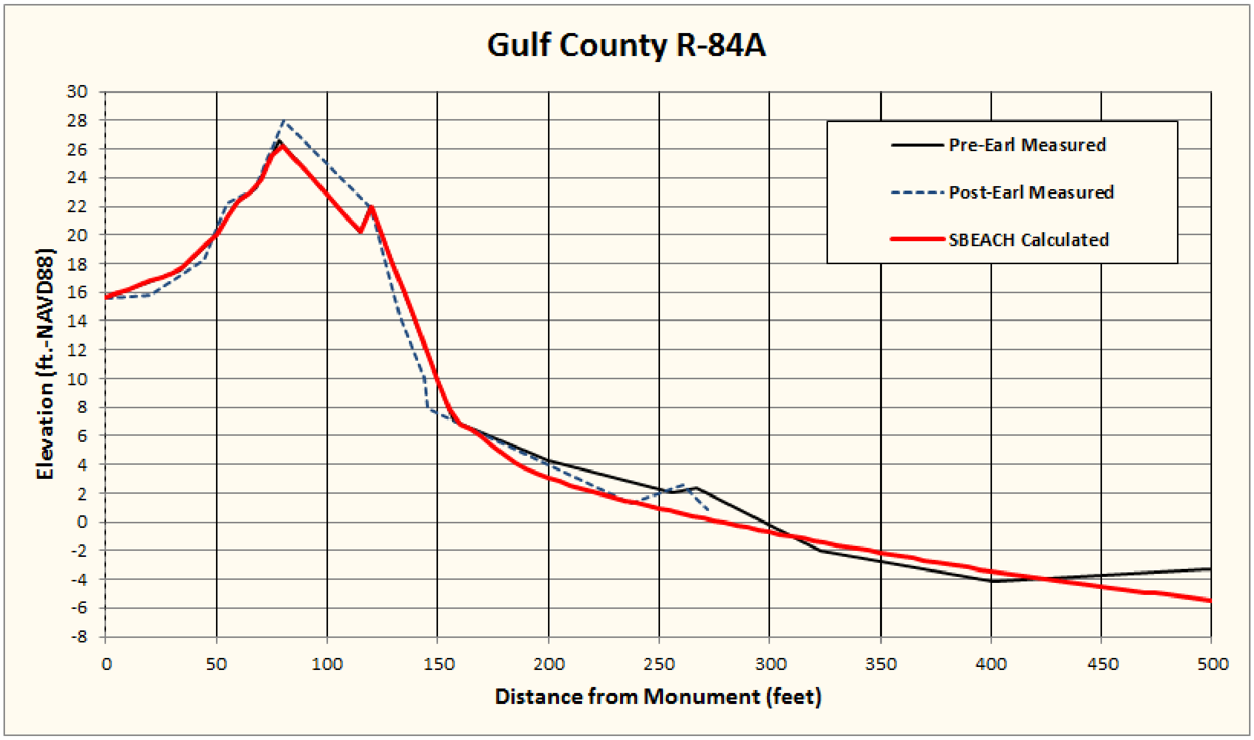
SBEACH Calibration Profiles for Gulf County

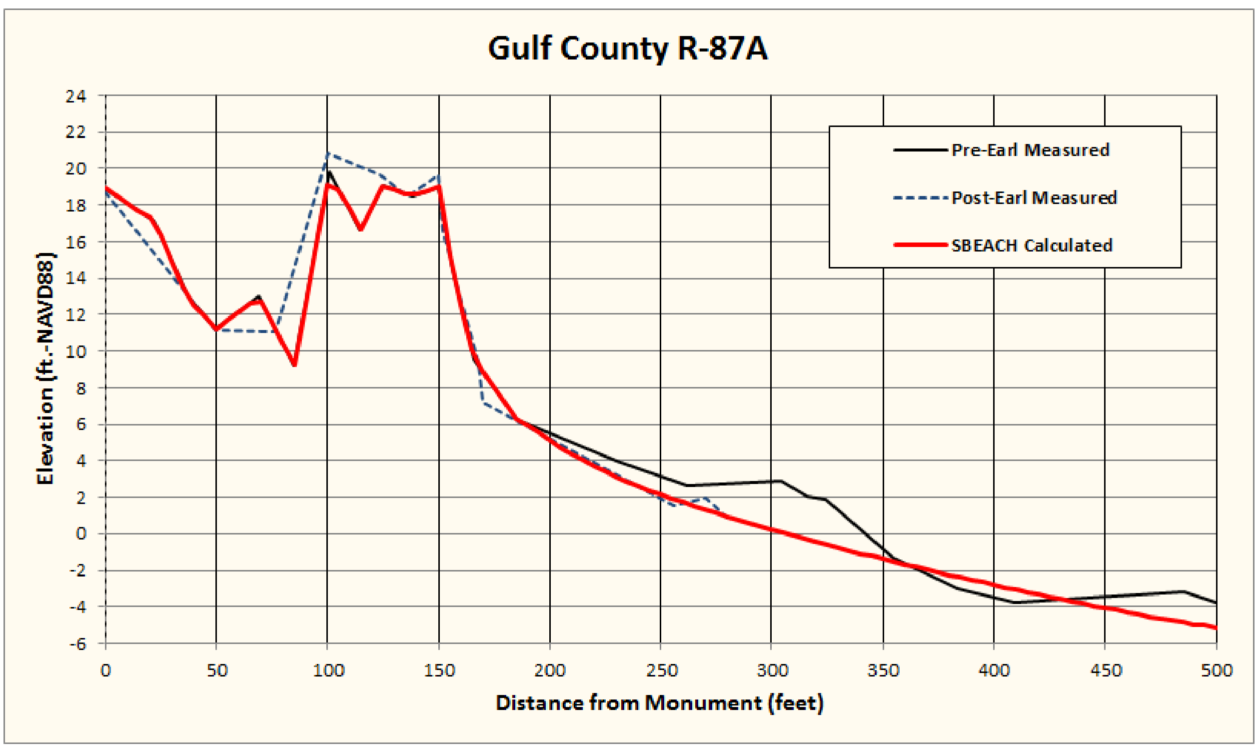





Gulf County R-81
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
400
450
500


Gulf County R-82A
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
400
450
500


Gulf County R-84A
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
400
450
500


Gulf County R-87A
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
24
22
20
18
16
14
12
10
8
6
4
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150
200
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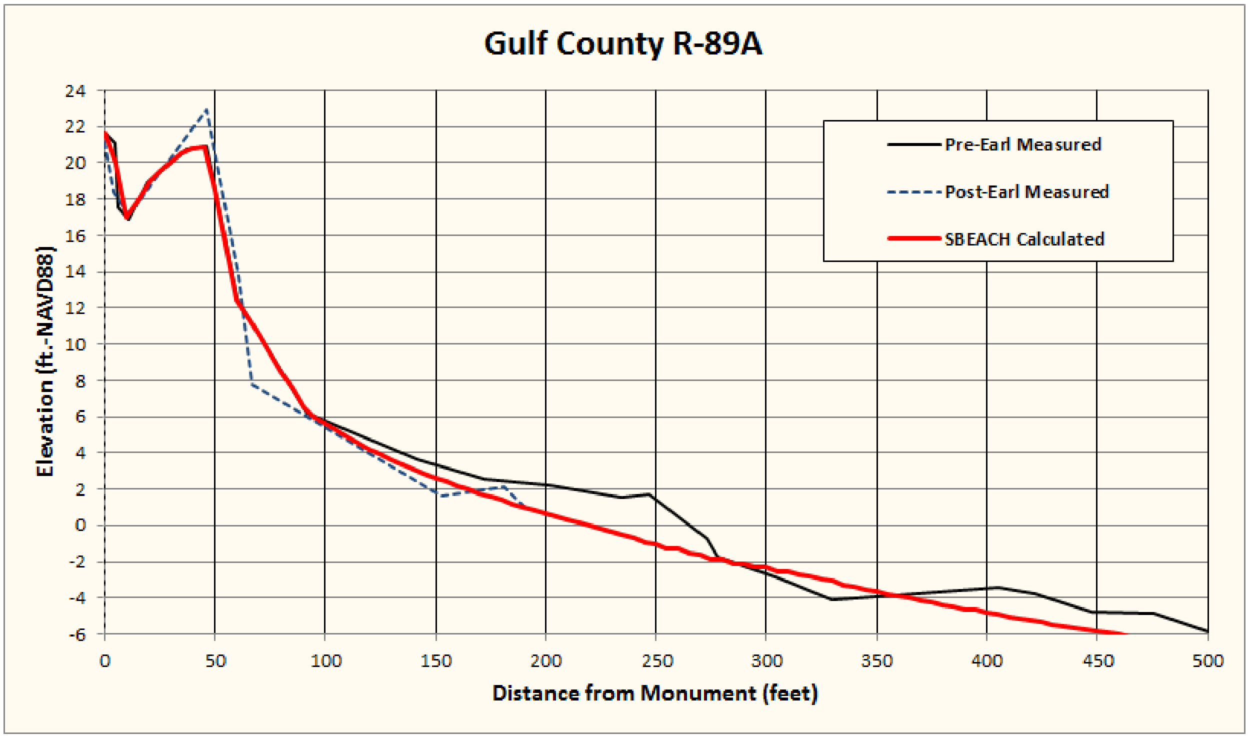
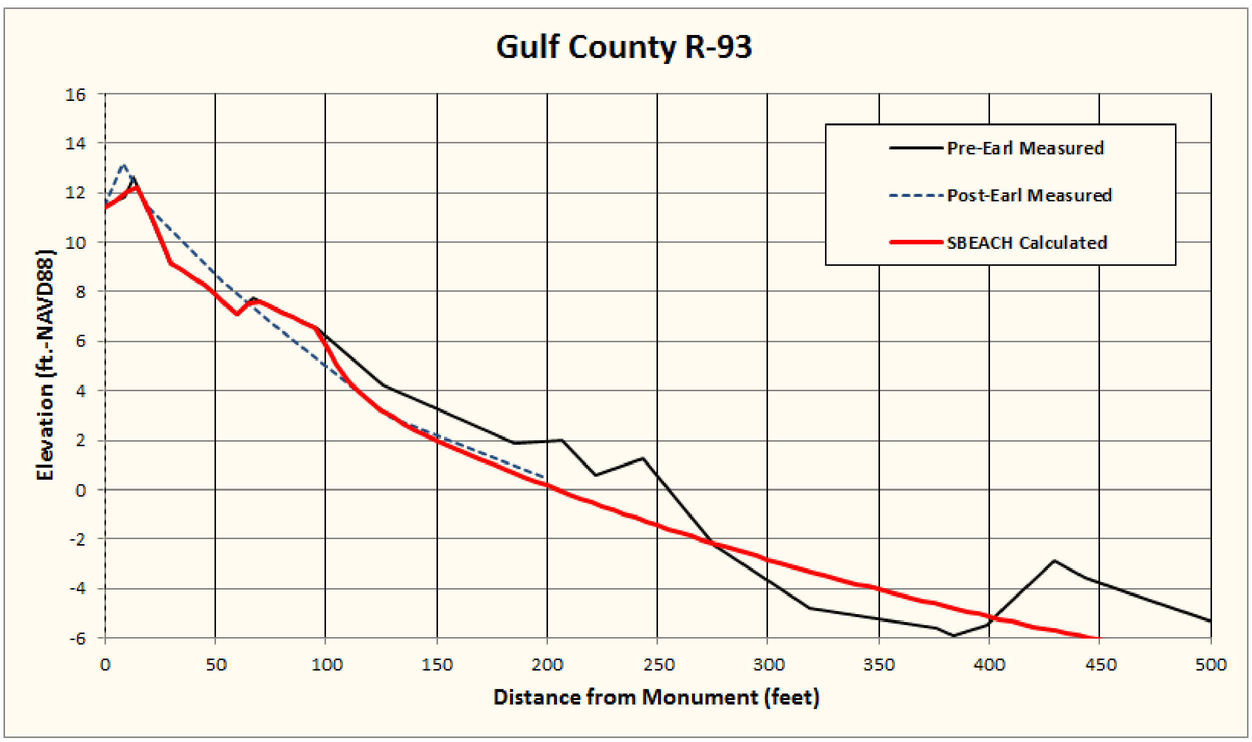
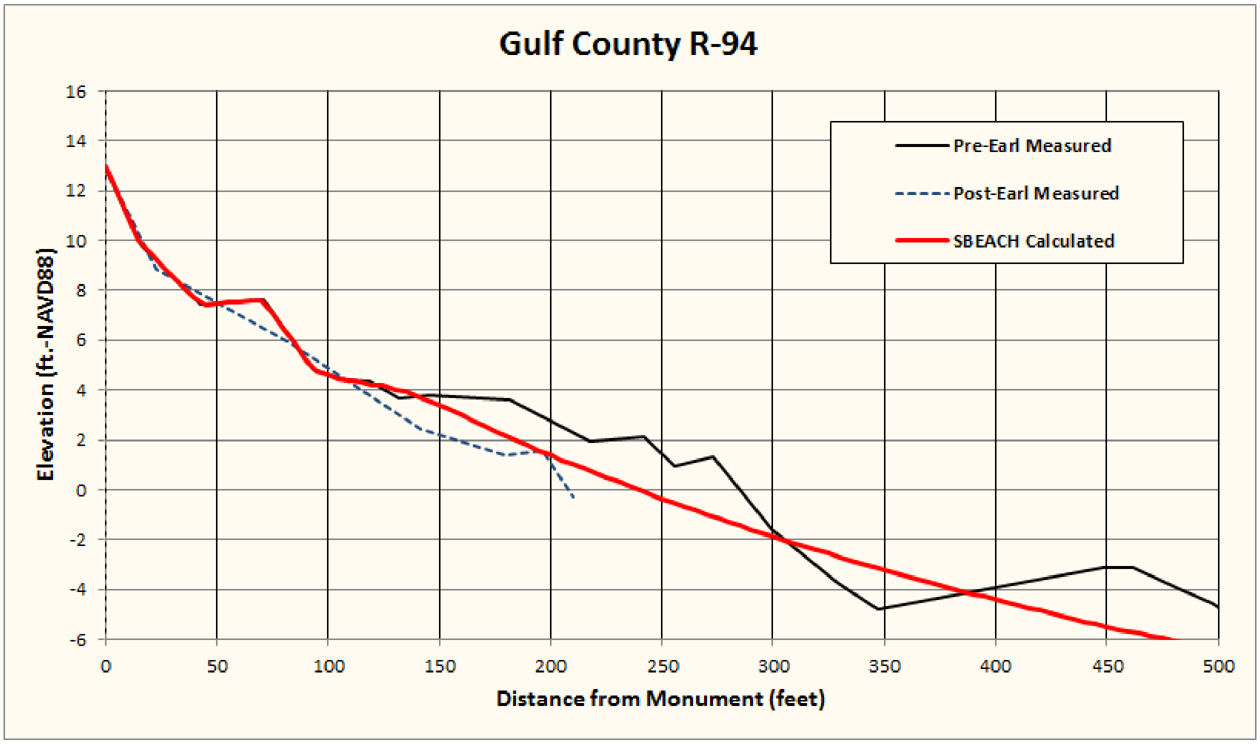

Gulf County R-89A
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated


Gulf County R-93
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated


Gulf County R-94
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
16
14
12
10
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100
150
200
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400
450
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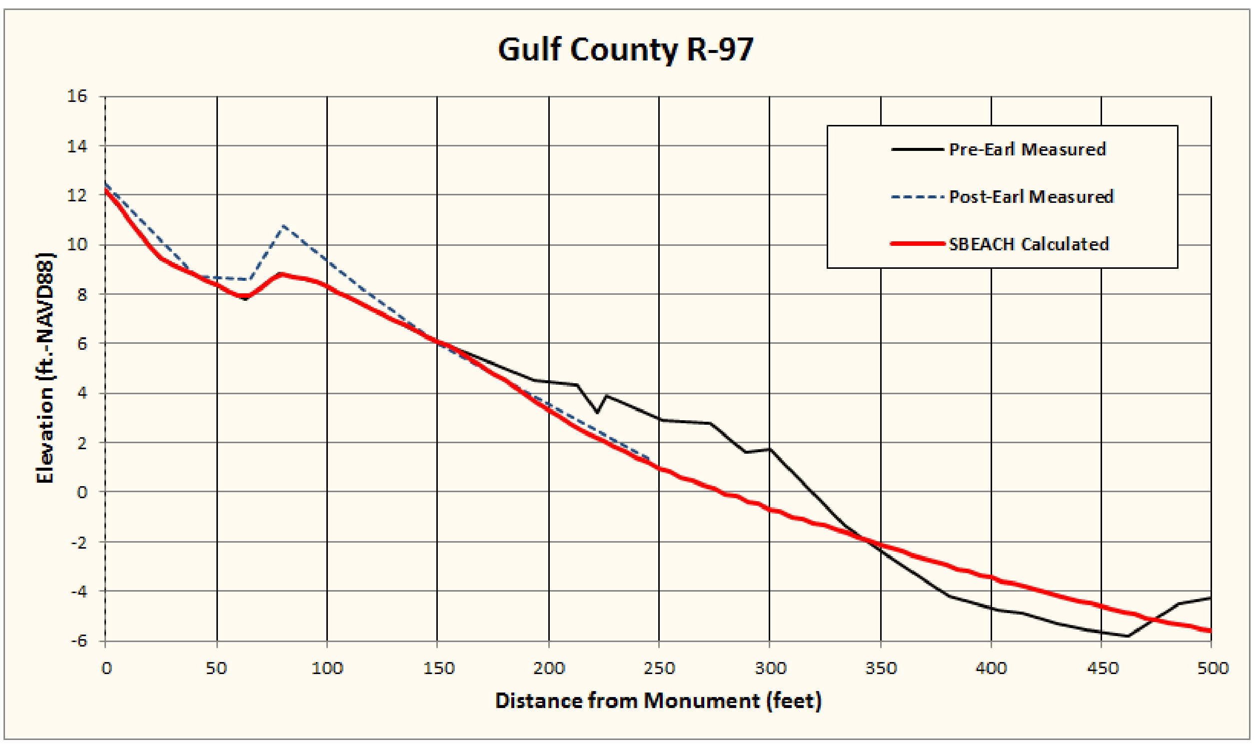
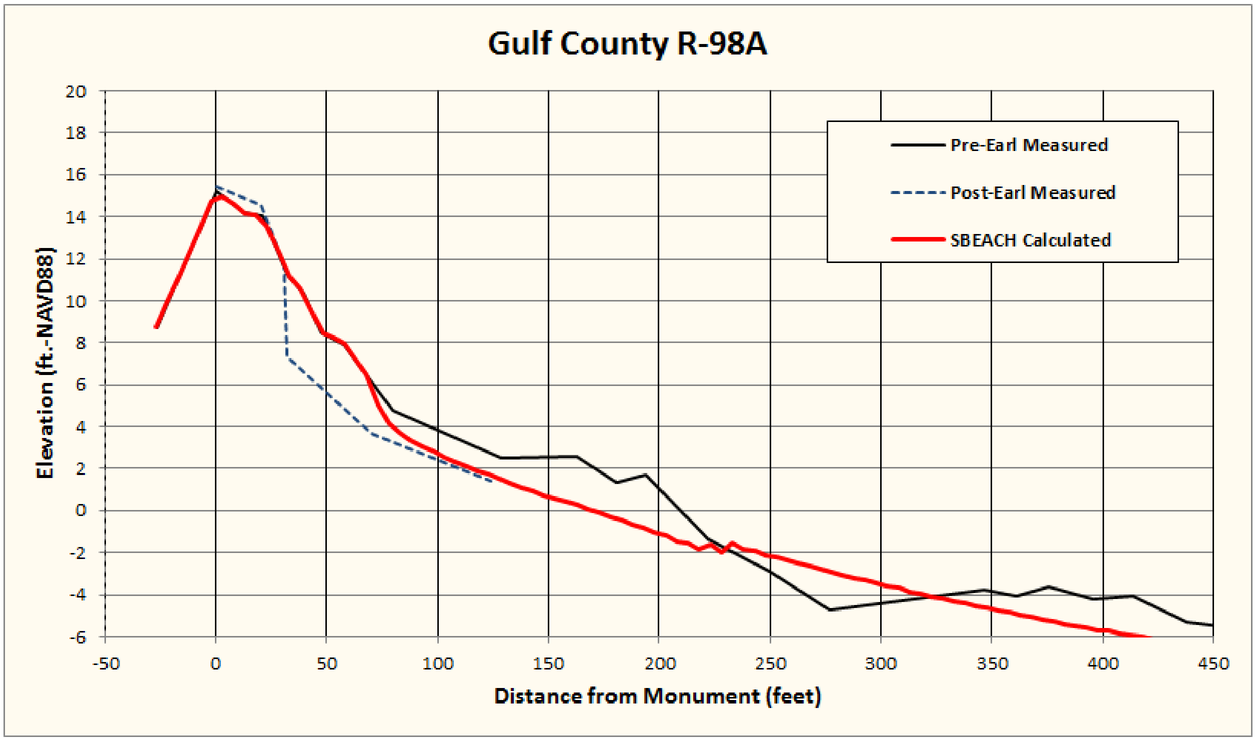
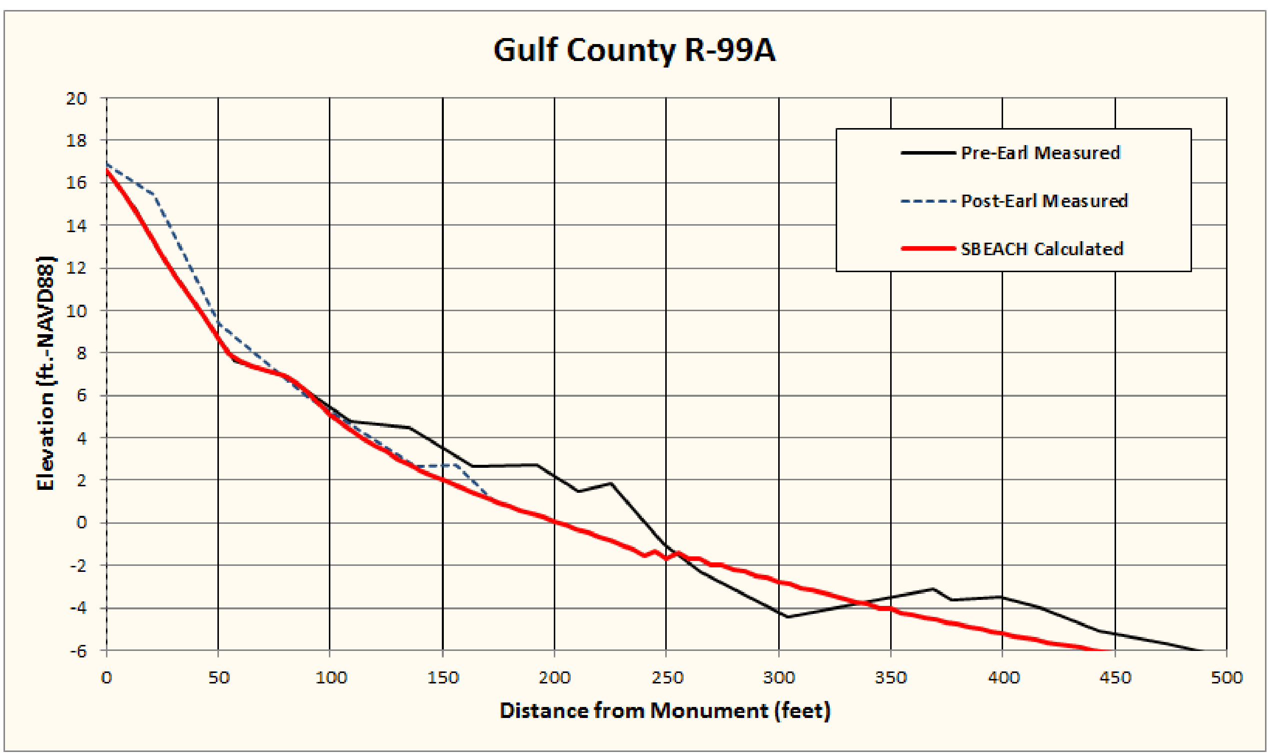
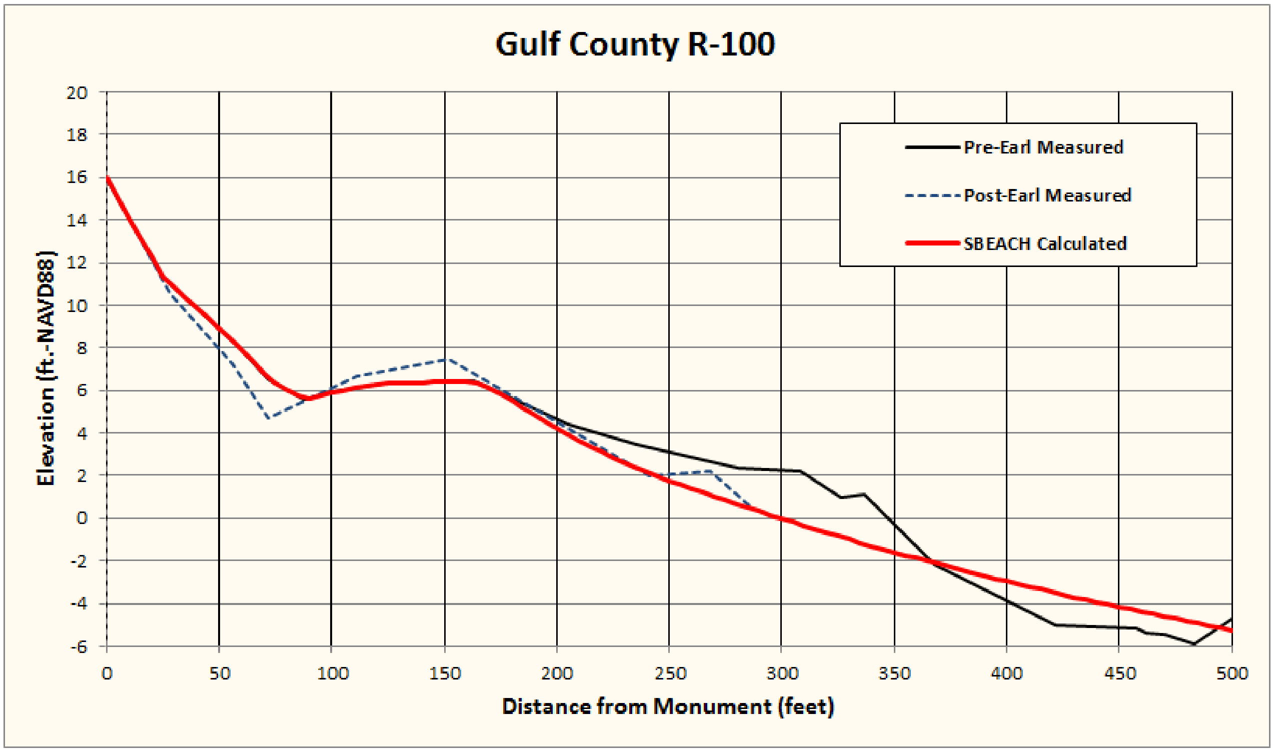
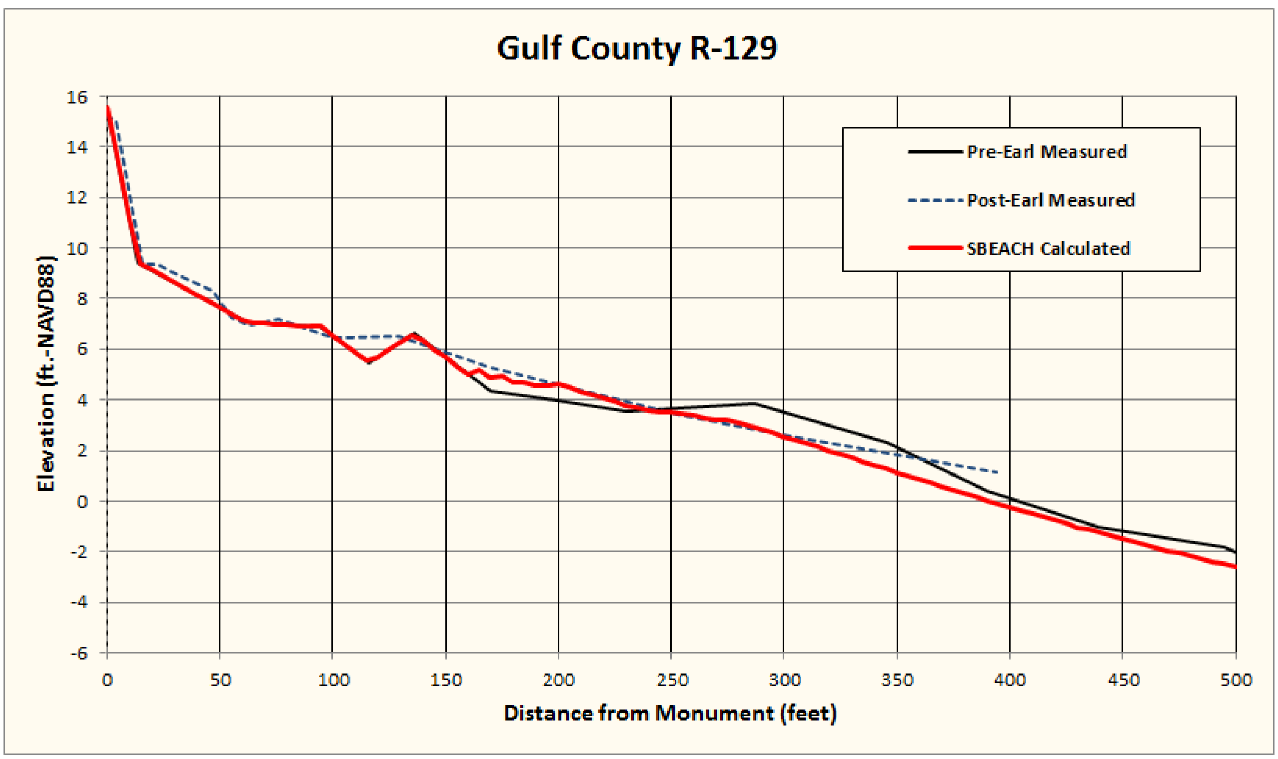
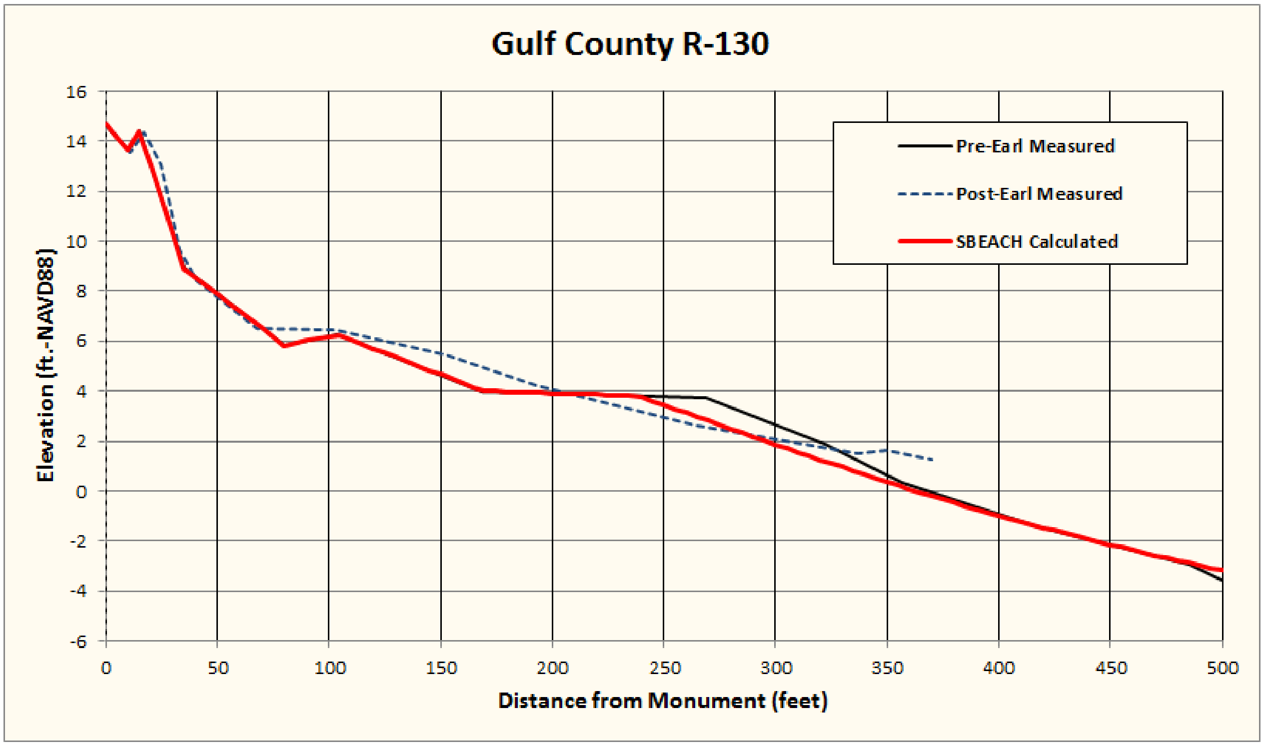

Gulf County R-97
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

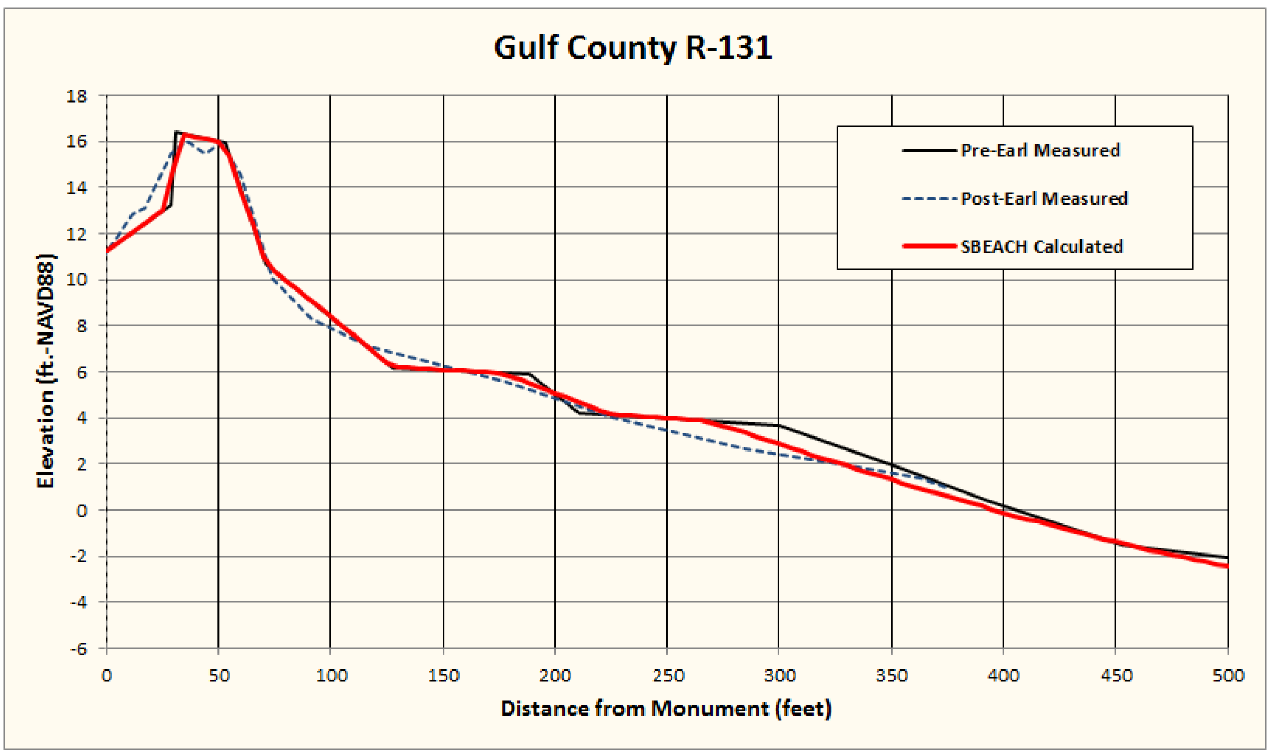

Gulf County R-98A
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450

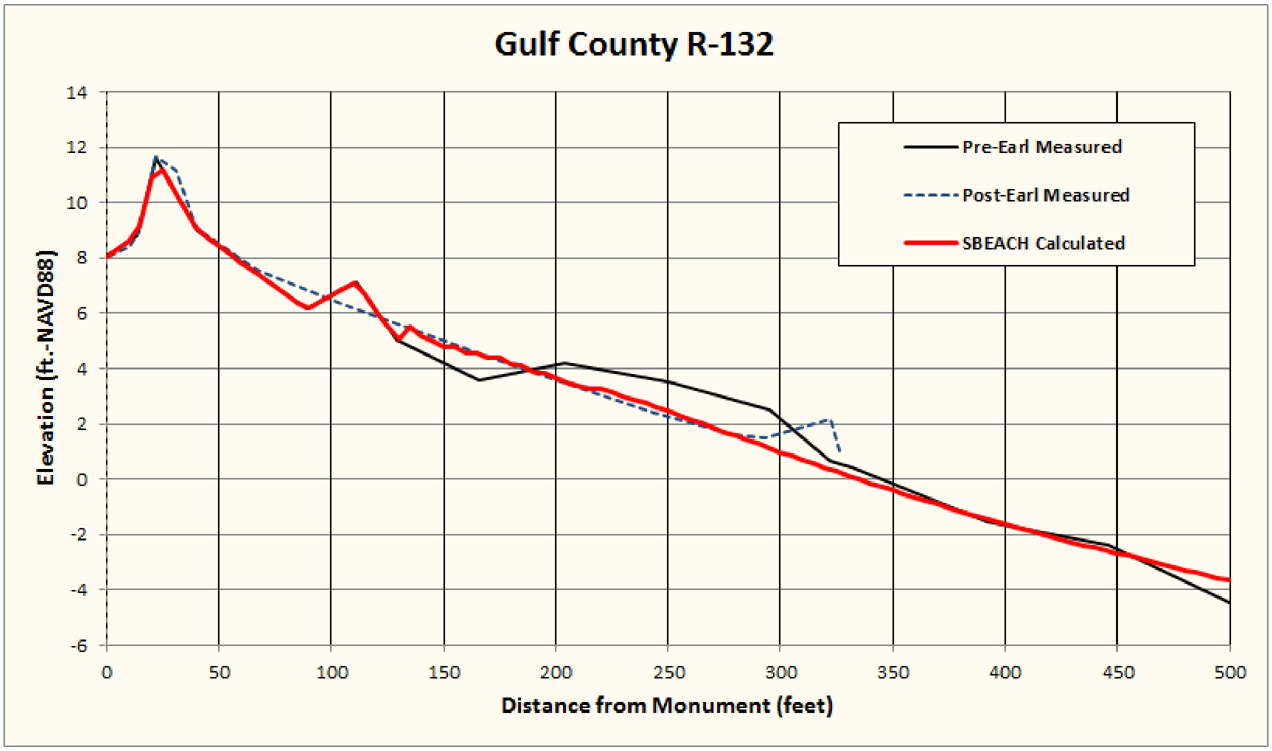

Gulf County R-99A
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

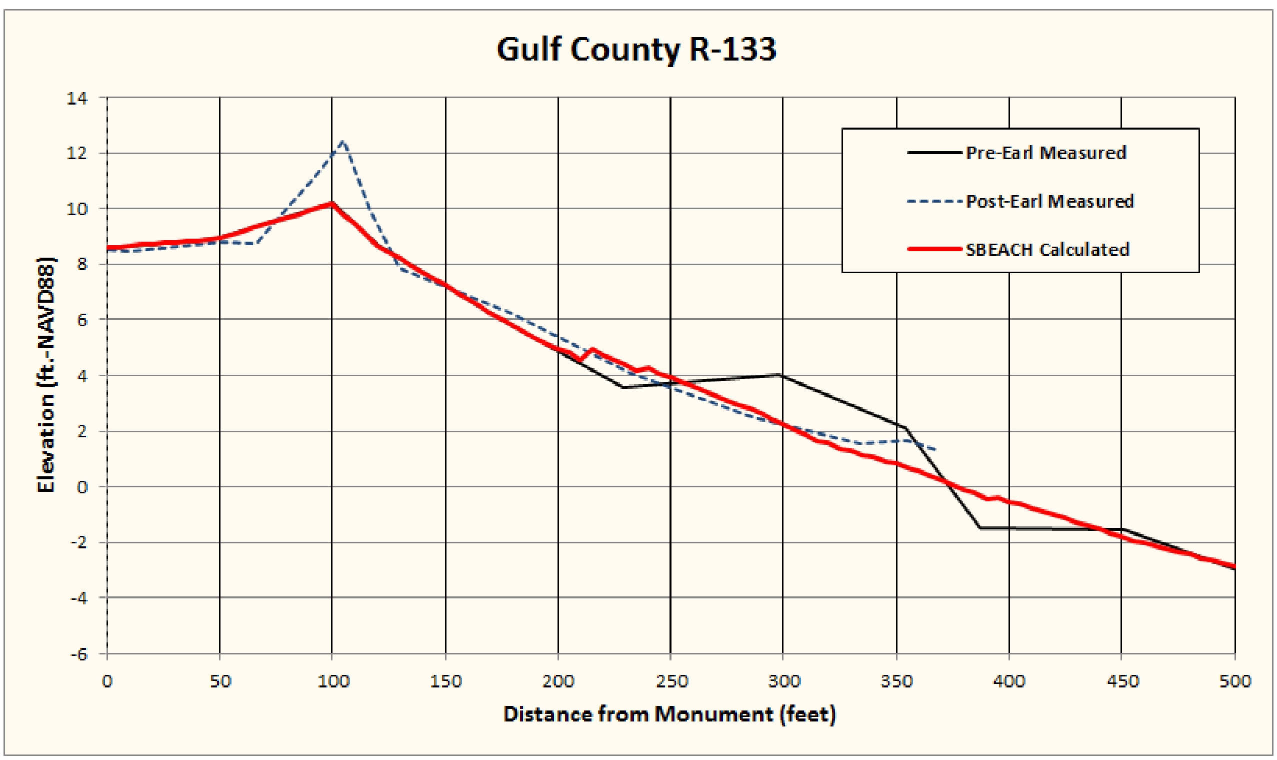

Gulf County R-100
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

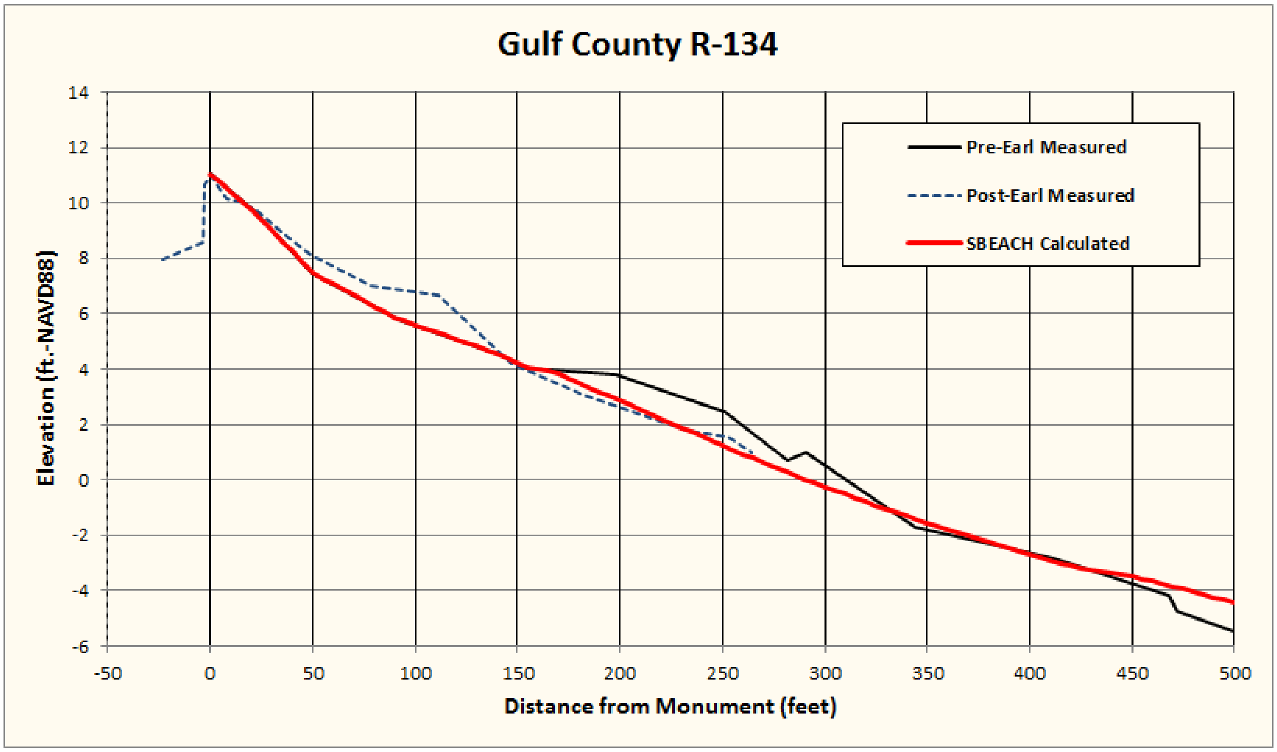

Gulf County R-129
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

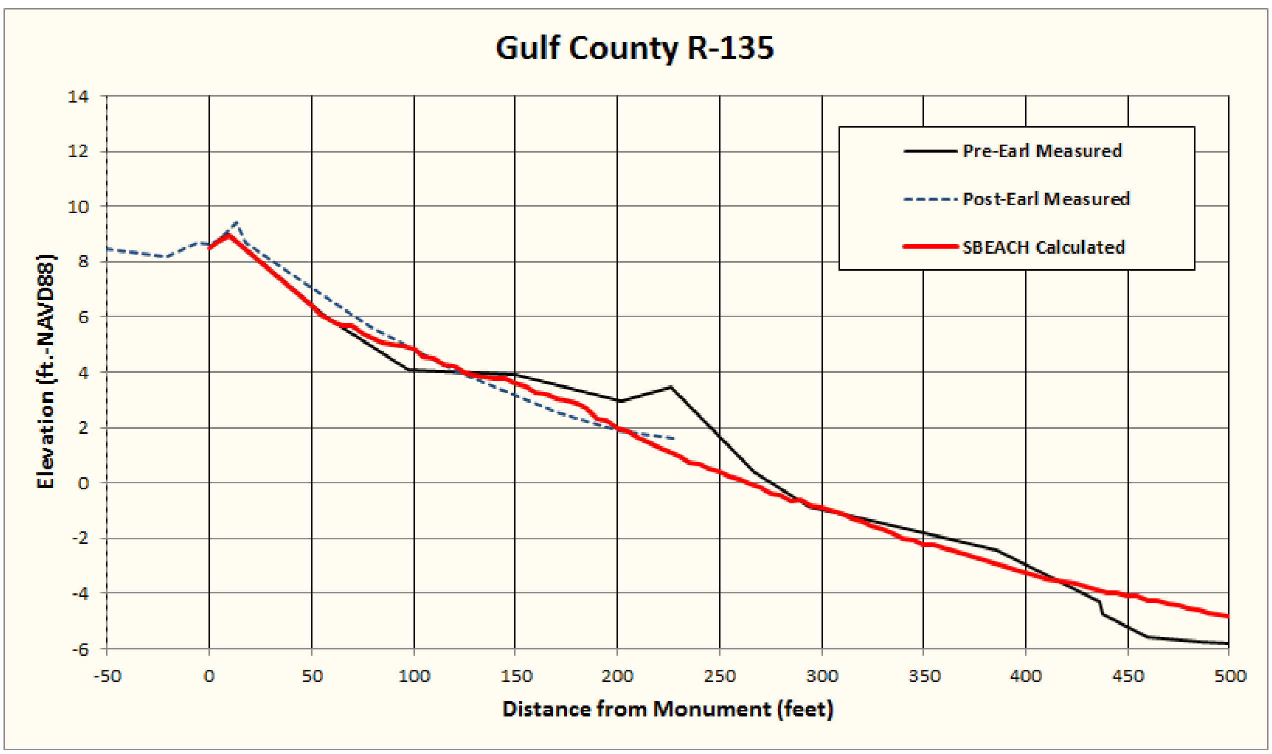

Gulf County R-130
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

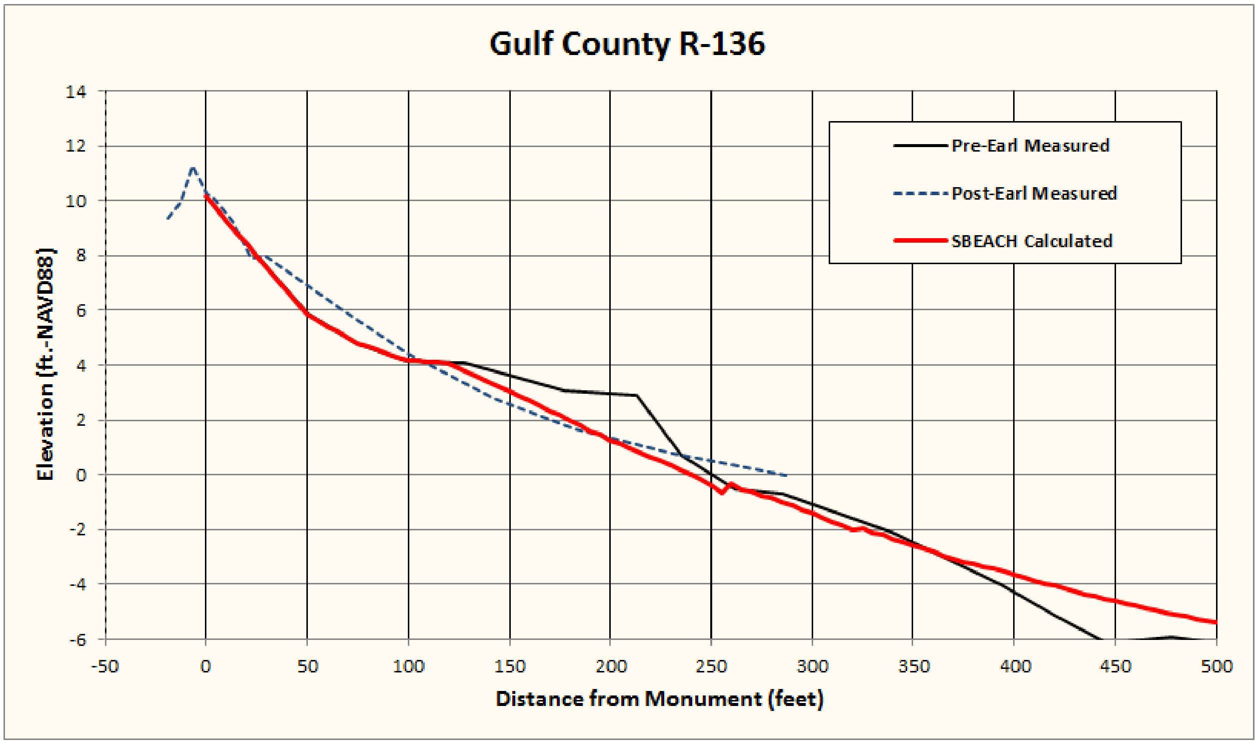

Gulf County R-131
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

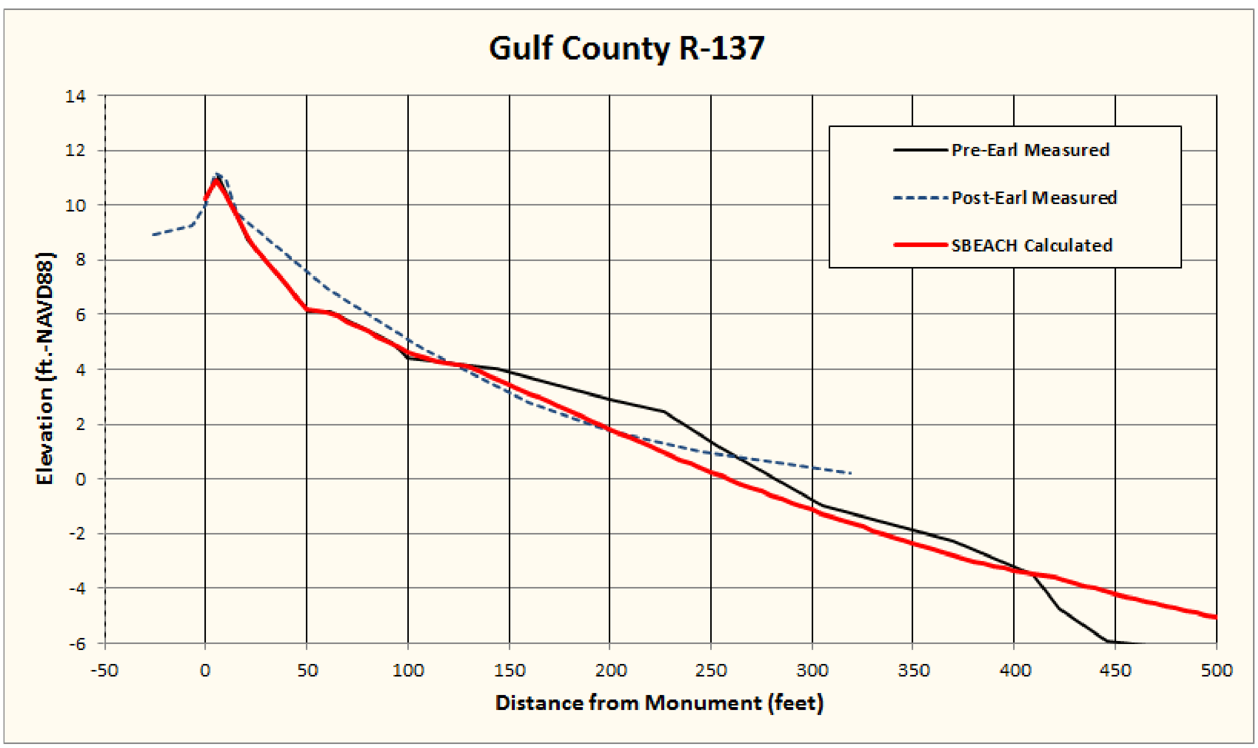

Gulf County R-132
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

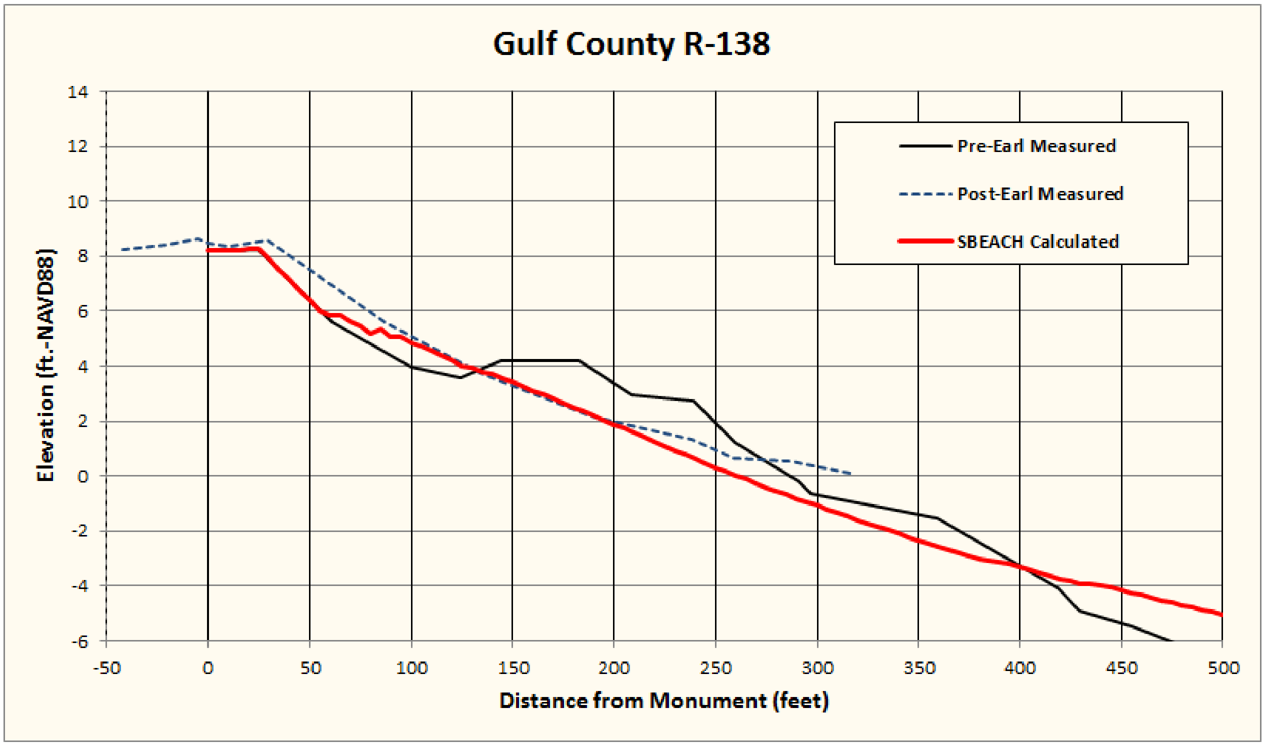

Gulf County R-133
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

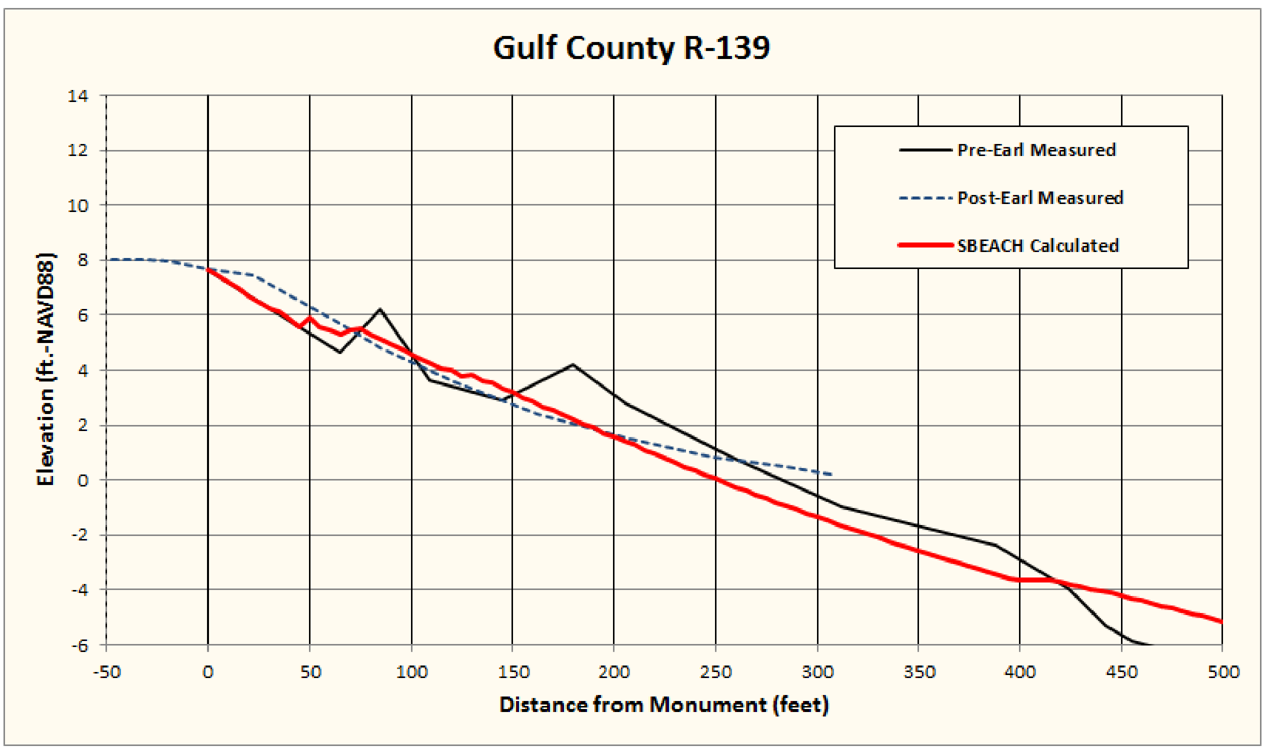

Gulf County R-134
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450
500

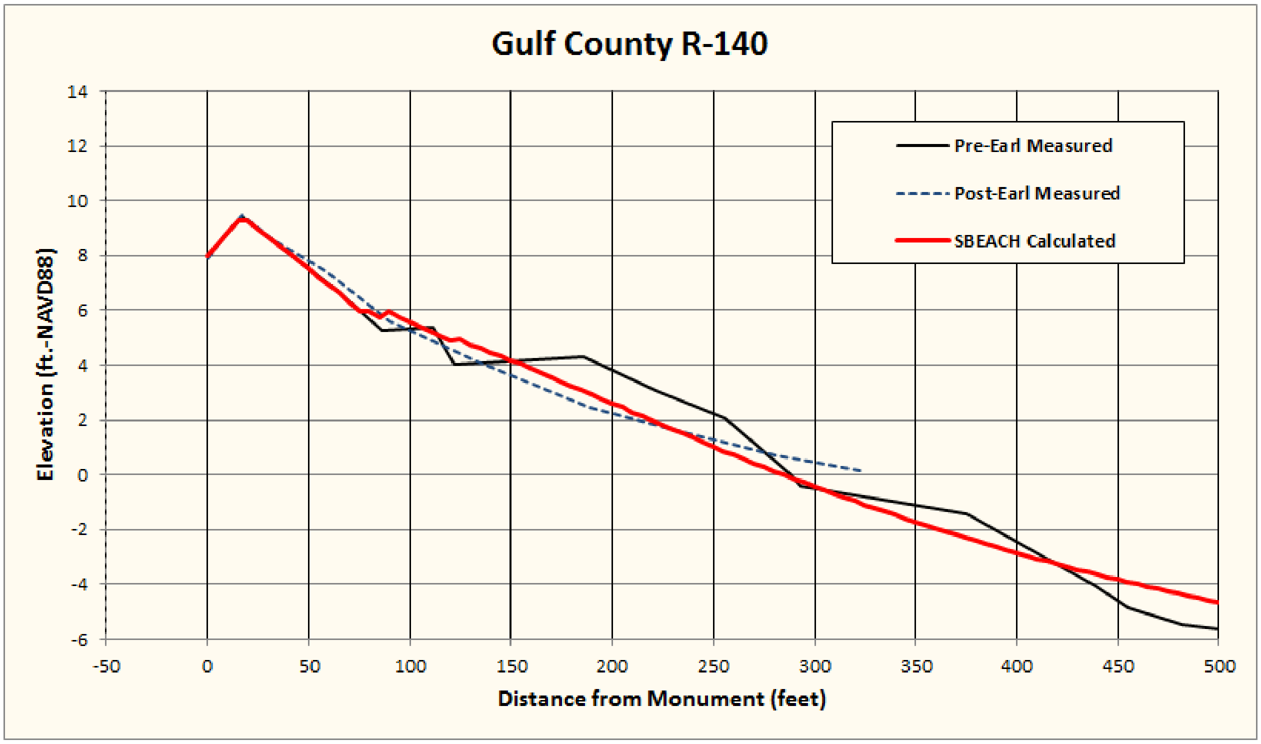

Gulf County R-135
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450
500

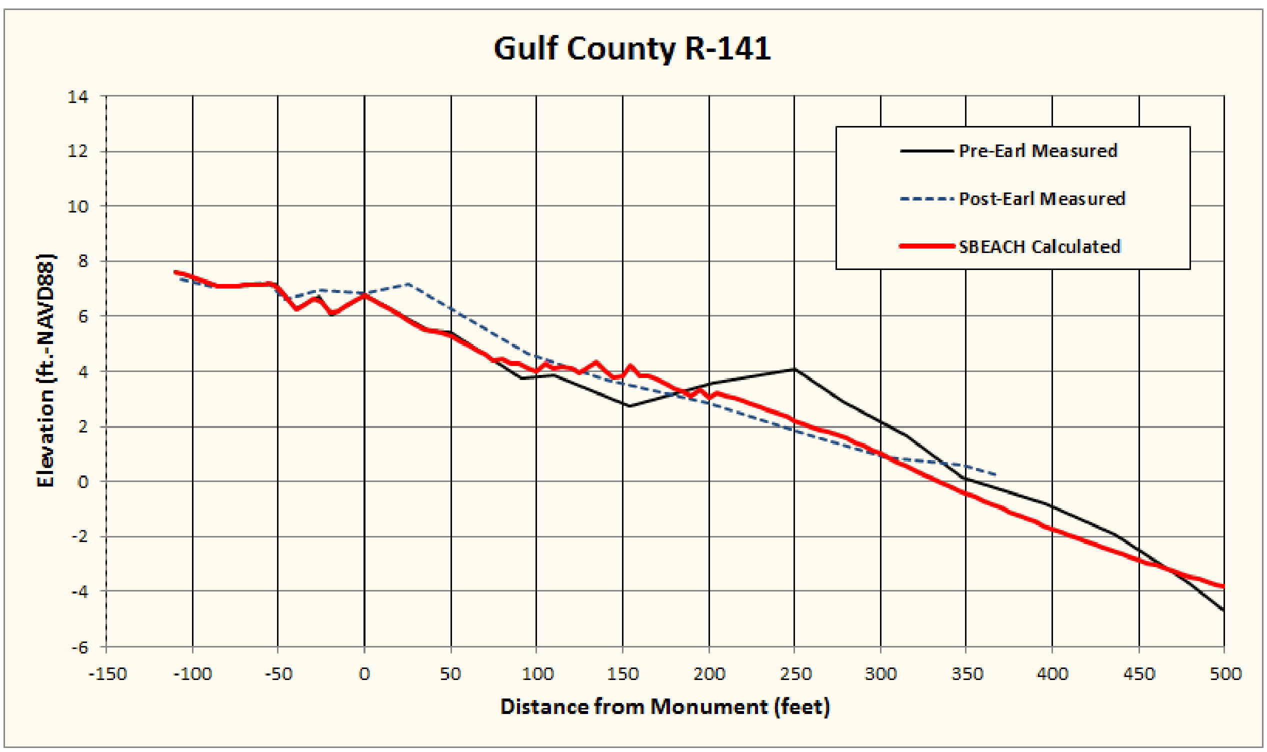

Gulf County R-136
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)

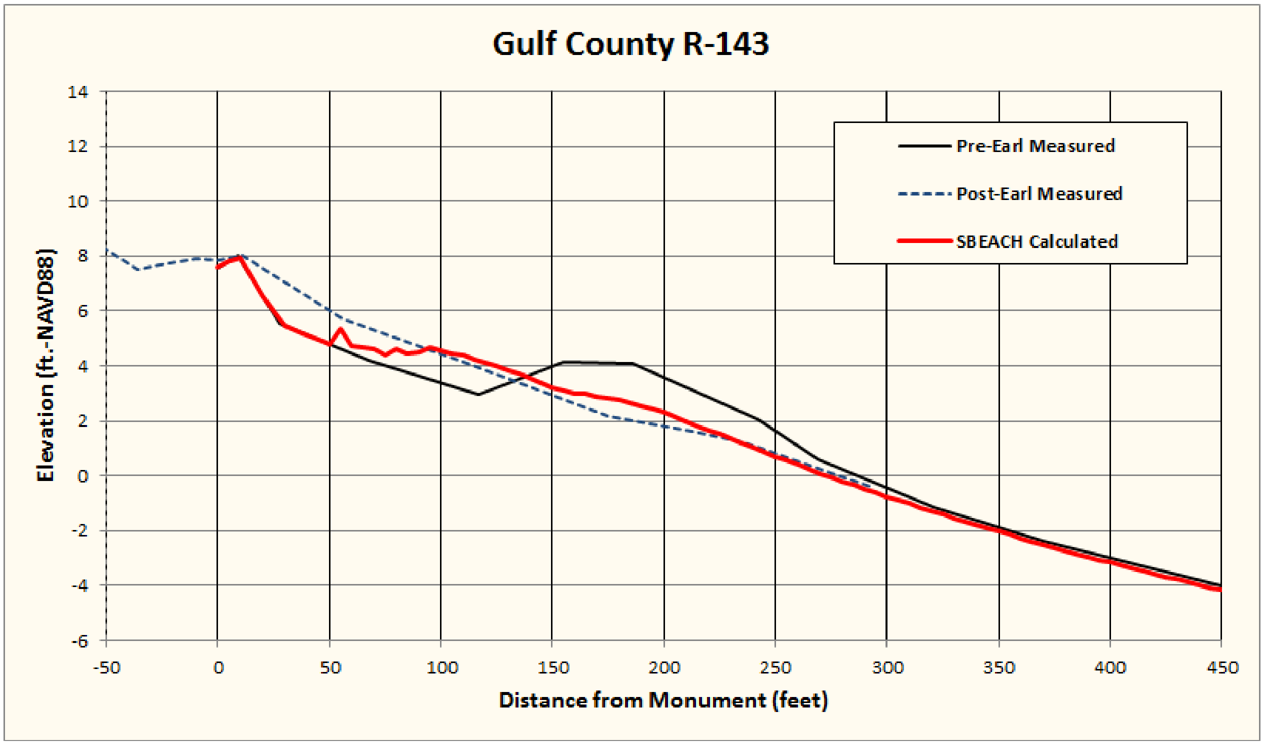

Gulf County R-137
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)

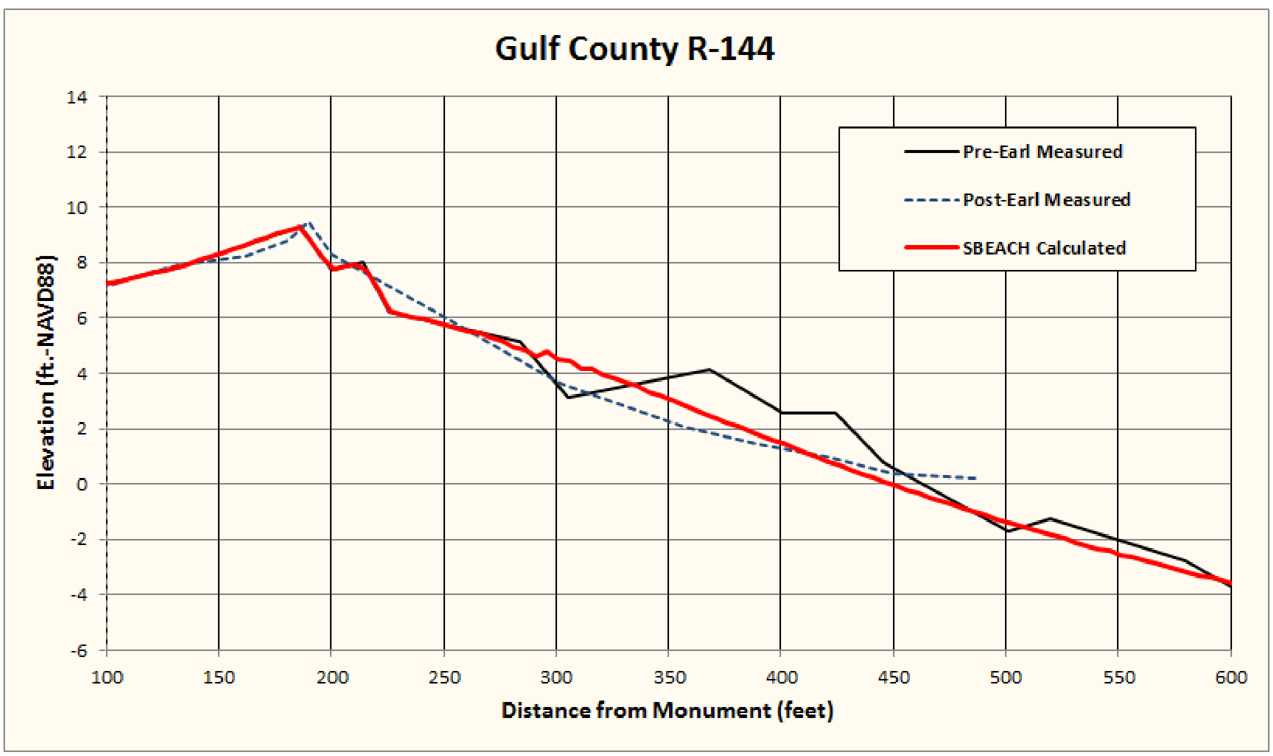

Gulf County R-138
Elevation (ft.-NAVD88)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated

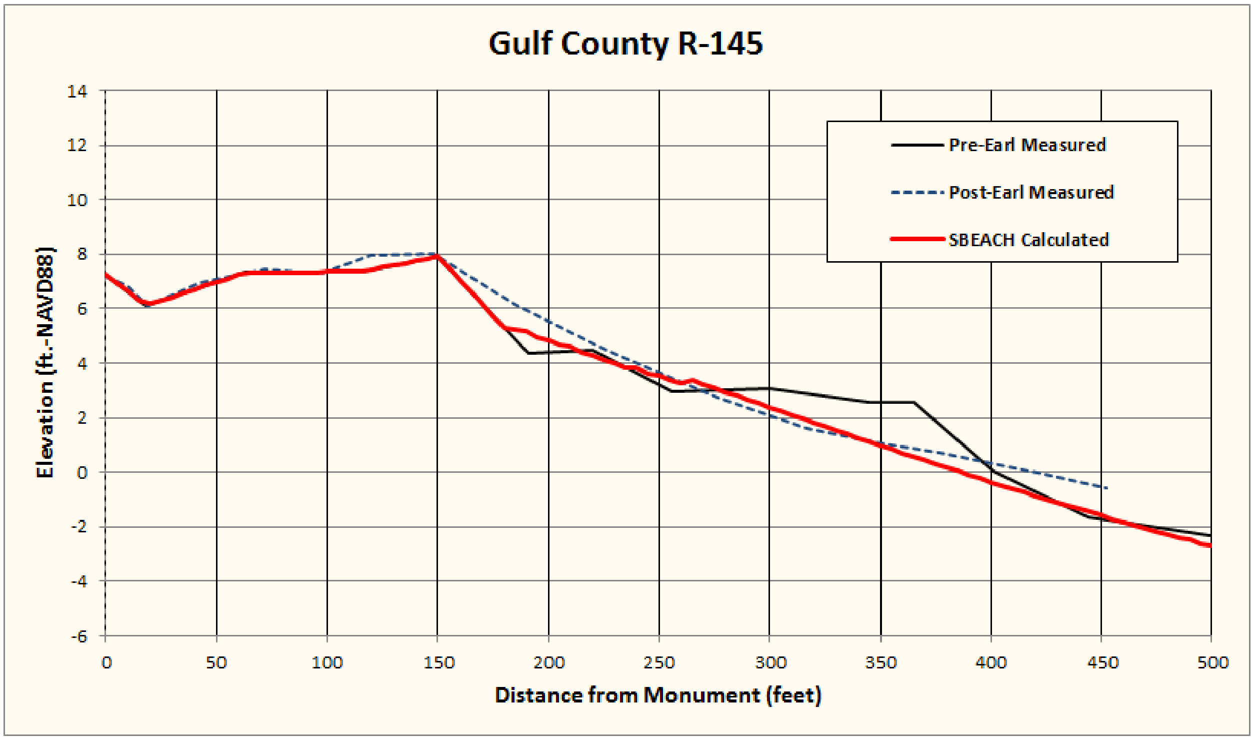

Gulf County R-139
Elevation (ft.-NAVD88)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated


Gulf County R-140
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)


Gulf County R-141
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
14
12
10
8
6
4
2
0
-2
-4
-6
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)


Gulf County R-143
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
-50
0
50
100
150
200
250
300
350
400
450


Gulf County R-144
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
100
150
200
250
300
350
400
450
500
550
600


Gulf County R-145
Pre-Earl Measured
Post-Earl Measured
SBEACH Calculated
Elevation (ft.-NAVD88)
Distance from Monument (feet)
14
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
450
500

Appendix B

Recommended SBEACH Input Values

Final SBEACH Input Settings – for 15- and 25-year storm erosions in Gulf County.

For all Storm Tide Hydrographs – Use 15- and 25-year hydrographs without wave setup adjusted proportionally to peak elevation shown for each range location segment shown below; storm duration for all cases is 36 hrs. All elevations listed below are in NAVD88 vertical datum. All wave input depth values were set as deep water with no wave randomization. All storm time steps were set at 5 minutes. Water temperature is set at 27 degrees. Grid cell width is five feet.

Range Segments	**R1 – R31, R93 – R115**	**R32 – R92**	**R116 – R162**
Transport Rate Coefficient, *K*	2.5 e^{-006}	2.5 e^{-006}	2.5 e^{-006}
Overwash Transport Parameter	0.005	0.005	0.005
Coefficient for Slope Dependent Term, ε	0.005	0.005	0.005
Transport Rate Decay Coeff. M ultiplier, λ	0.1	0.1	0.1
Landward Surf Zone Depth (ft.)	1.0	1.0	1.0
Maximum Slope Prior to Avalanching	45	45	45
Constant Wave Height (ft.)	10	10	10
Constant Wave Period (sec.)	10	10	10
15-year Hydrograph Peak Elevation (ft.)	4.6	4.0	5.8
25-year Hydrograph Peak Elevation (ft.)	6.0	5.2	7.3

Range	**Mean Grain Size (mm)**
1 - 16	0.293
32 - 109	0.262
119 - 159	0.243

Appendix C

Adjusted 15- and 25-year Hydrograph Tables for Gulf County

Gulf County - Adjusted 15-year Hydrograph (ft.-NAVD) for SBEACH

Time (hour)	R1 – R31, R93 – R115	R32 – R92	R116 – R162
0.00	-0.64	-0.64	-0.64
0.50	-0.69	-0.69	-0.69
1.00	-0.70	-0.70	-0.70
1.50	-0.65	-0.65	-0.65
2.00	-0.55	-0.55	-0.55
2.50	-0.40	-0.40	-0.40
3.00	-0.23	-0.23	-0.23
3.50	-0.03	-0.03	-0.03
4.00	0.09	0.09	0.11
4.50	0.20	0.19	0.24
5.00	0.31	0.30	0.38
5.50	0.41	0.39	0.49
6.00	0.48	0.47	0.59
6.50	0.54	0.52	0.65
7.00	0.57	0.55	0.69
7.50	0.57	0.56	0.70
8.00	0.56	0.54	0.68
8.50	0.52	0.50	0.63
9.00	0.46	0.45	0.56
9.50	0.41	0.39	0.49
10.00	0.33	0.32	0.40
10.50	0.22	0.21	0.33
11.00	0.18	0.15	0.28
11.50	0.16	0.14	0.25
12.00	0.17	0.14	0.26
12.50	0.21	0.18	0.33
13.00	0.29	0.24	0.44
13.50	0.39	0.33	0.61
14.00	0.55	0.46	0.85
14.50	0.76	0.63	1.17
15.00	1.01	0.85	1.56
15.50	1.30	1.09	2.01
16.00	1.59	1.32	2.45
16.50	1.88	1.57	2.90
17.00	2.14	1.79	3.31
17.50	2.33	1.95	3.60
18.00	2.40	2.00	3.70
18.50	2.32	1.94	3.58

Time (hour)	R1 – R31, R93 – R115	R32 – R92	R116 – R162
19.00	2.13	1.78	3.28
19.50	1.86	1.55	2.87
20.00	1.56	1.30	2.40
20.50	1.26	1.05	1.94
21.00	0.97	0.81	1.50
21.50	0.69	0.58	1.06
22.00	0.40	0.33	0.62
22.50	0.16	0.12	0.22
23.00	0.03	0.03	0.04
23.50	0.00	0.00	0.00
24.00	-0.03	-0.03	-0.04
24.50	-0.11	-0.10	-0.14
25.00	-0.27	-0.23	-0.34
25.50	-0.45	-0.39	-0.57
26.00	-0.60	-0.52	-0.76
26.50	-0.67	-0.58	-0.85
27.00	-0.66	-0.56	-0.83
27.50	-0.56	-0.48	-0.71
28.00	-0.42	-0.36	-0.53
28.50	-0.26	-0.22	-0.33
29.00	-0.13	-0.11	-0.16
29.50	-0.01	-0.01	-0.02
30.00	0.06	0.06	0.08
30.50	0.14	0.13	0.17
31.00	0.21	0.20	0.26
31.50	0.28	0.27	0.34
32.00	0.34	0.33	0.41
32.50	0.37	0.36	0.45
33.00	0.38	0.37	0.46
33.50	0.37	0.36	0.46
34.00	0.33	0.32	0.40
34.50	0.25	0.24	0.31
35.00	0.16	0.16	0.20
35.50	0.07	0.07	0.09
36.00	0.01	0.01	0.01

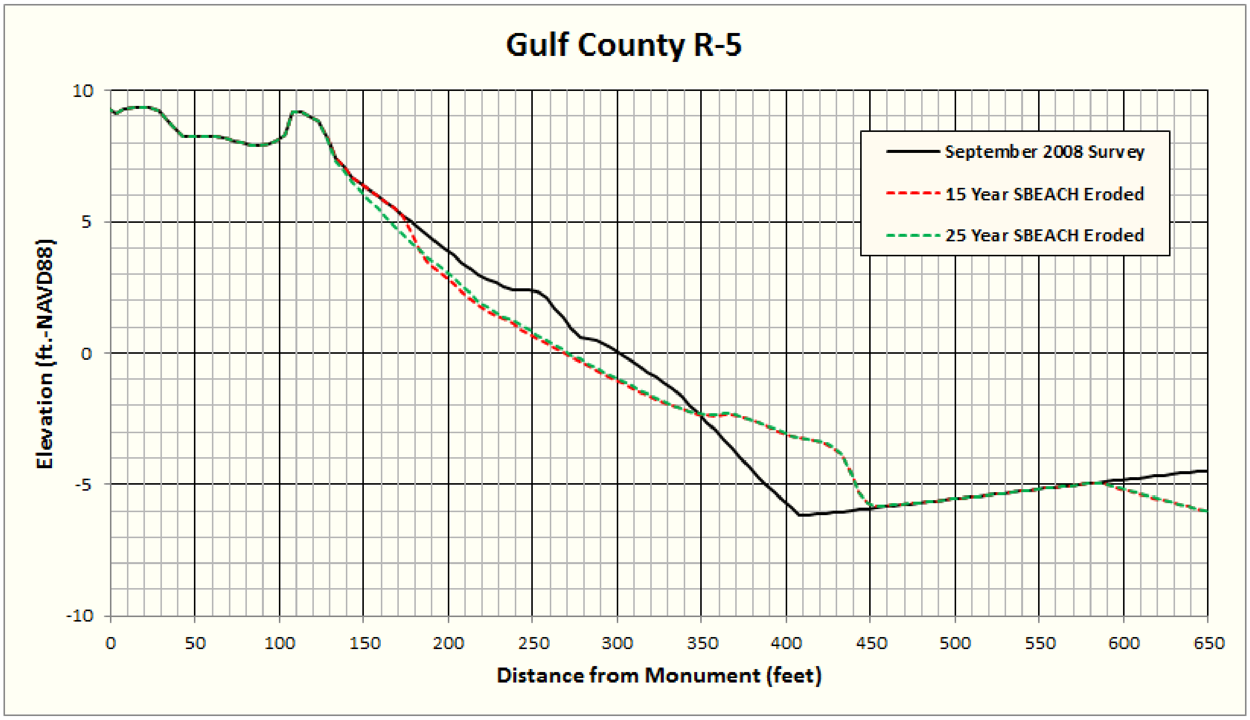
Gulf County - Adjusted 25-year Hydrograph (ft.-NAVD) for SBEACH

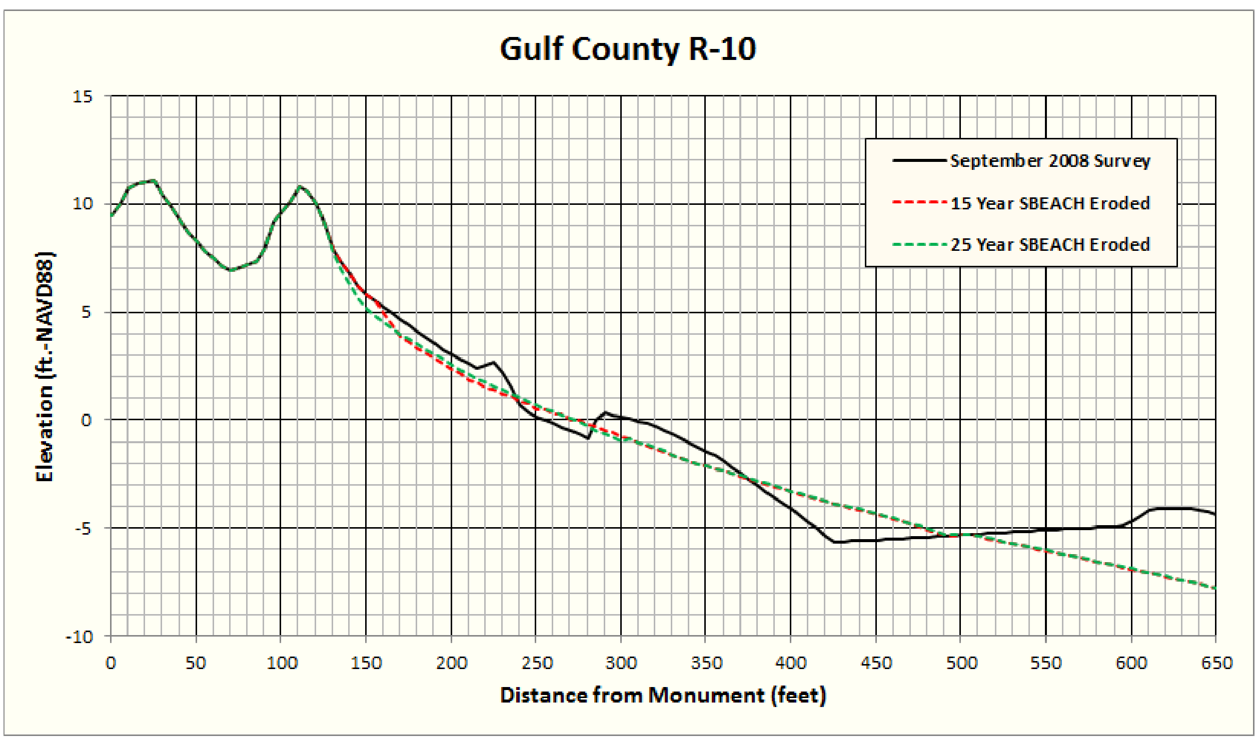
Time (hour)	R1 – R31, R93 – R115	R32 – R92	R116 – R162
0.00	-0.98	-0.98	-0.98
0.50	-1.06	-1.06	-1.06
1.00	-1.11	-1.11	-1.11
1.50	-1.10	-1.10	-1.10
2.00	-1.04	-1.04	-1.04
2.50	-0.92	-0.92	-0.92
3.00	-0.77	-0.77	-0.77
3.50	-0.58	-0.58	-0.58
4.00	-0.36	-0.36	-0.36
4.50	-0.14	-0.14	-0.14
5.00	0.05	0.05	0.06
5.50	0.19	0.18	0.21
6.00	0.32	0.29	0.36
6.50	0.42	0.39	0.47
7.00	0.50	0.46	0.56
7.50	0.55	0.50	0.61
8.00	0.56	0.52	0.63
8.50	0.55	0.51	0.62
9.00	0.52	0.48	0.58
9.50	0.47	0.43	0.53
10.00	0.41	0.37	0.45
10.50	0.31	0.29	0.39
11.00	0.24	0.22	0.33
11.50	0.22	0.18	0.30
12.00	0.22	0.18	0.30
12.50	0.25	0.20	0.34
13.00	0.31	0.25	0.42
13.50	0.41	0.33	0.57
14.00	0.56	0.45	0.77
14.50	0.76	0.61	1.05
15.00	1.03	0.82	1.41
15.50	1.37	1.09	1.88
16.00	1.79	1.42	2.47
16.50	2.32	1.84	3.19
17.00	2.93	2.33	4.03
17.50	3.50	2.78	4.82
18.00	3.78	3.00	5.20
18.50	3.52	2.80	4.85
19.00	2.90	2.30	3.99
19.50	2.24	1.78	3.08
20.00	1.68	1.34	2.32
20.50	1.25	0.99	1.71
21.00	0.89	0.71	1.23

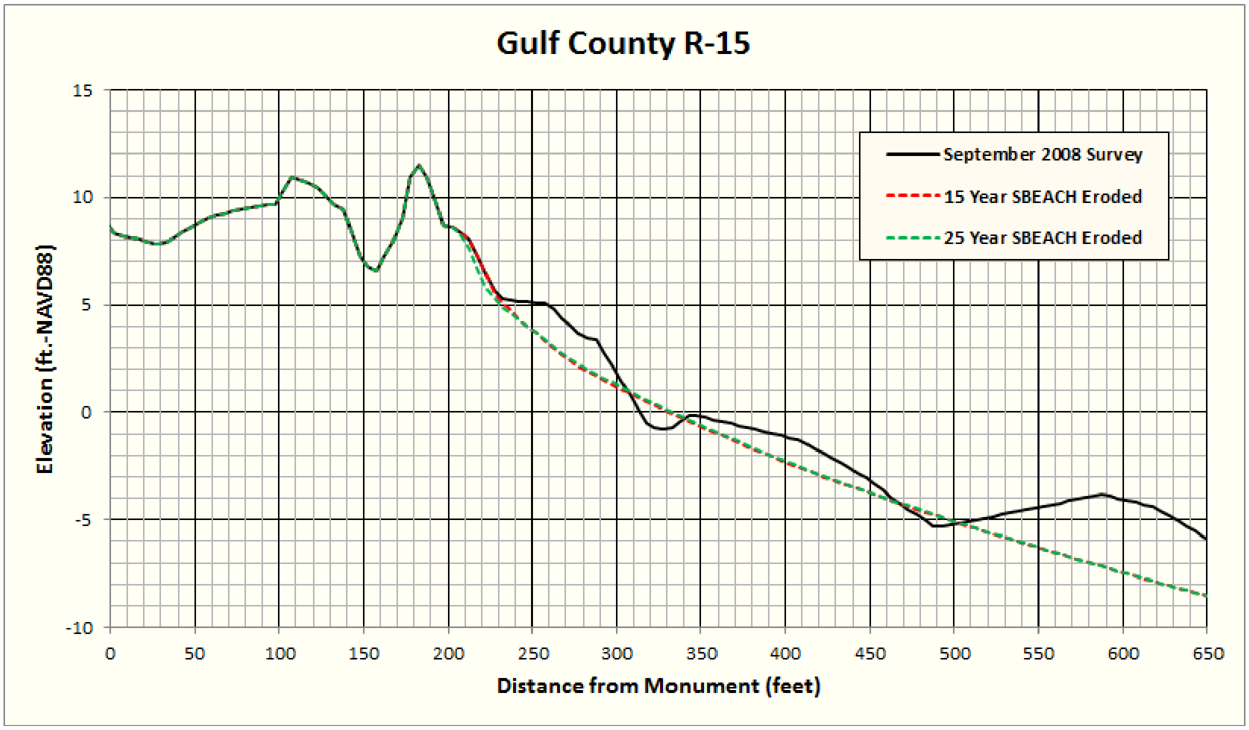
Time (hour)	**R1 – R31, R93 – R115**	**R32 – R92**	**R116 – R162**
21.50	0.59	0.47	0.82
22.00	0.35	0.28	0.48
22.50	0.13	0.10	0.18
23.00	-0.11	-0.10	-0.14
23.50	-0.38	-0.33	-0.47
24.00	-0.63	-0.63	-0.74
24.50	-0.95	-0.95	-0.95
25.00	-1.10	-1.10	-1.10
25.50	-1.18	-1.18	-1.18
26.00	-1.20	-1.20	-1.20
26.50	-1.16	-1.16	-1.16
27.00	-1.07	-1.07	-1.07
27.50	-0.93	-0.93	-0.93
28.00	-0.76	-0.76	-0.76
28.50	-0.58	-0.58	-0.58
29.00	-0.37	-0.37	-0.37
29.50	-0.16	-0.16	-0.16
30.00	0.03	0.03	0.04
30.50	0.15	0.13	0.16
31.00	0.25	0.23	0.28
31.50	0.33	0.30	0.37
32.00	0.37	0.34	0.42
32.50	0.40	0.37	0.45
33.00	0.39	0.36	0.44
33.50	0.36	0.33	0.41
34.00	0.30	0.28	0.34
34.50	0.24	0.22	0.27
35.00	0.16	0.15	0.19
35.50	0.10	0.09	0.11
36.00	0.04	0.04	0.04

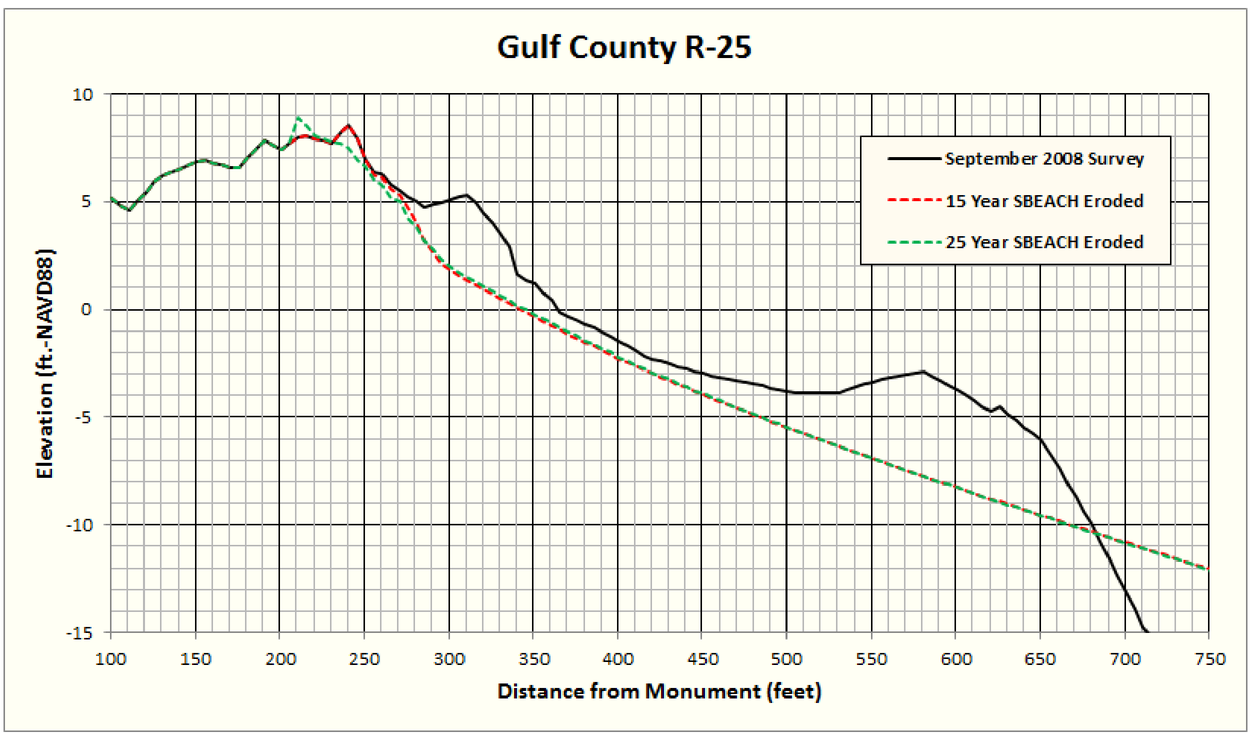
Appendix D

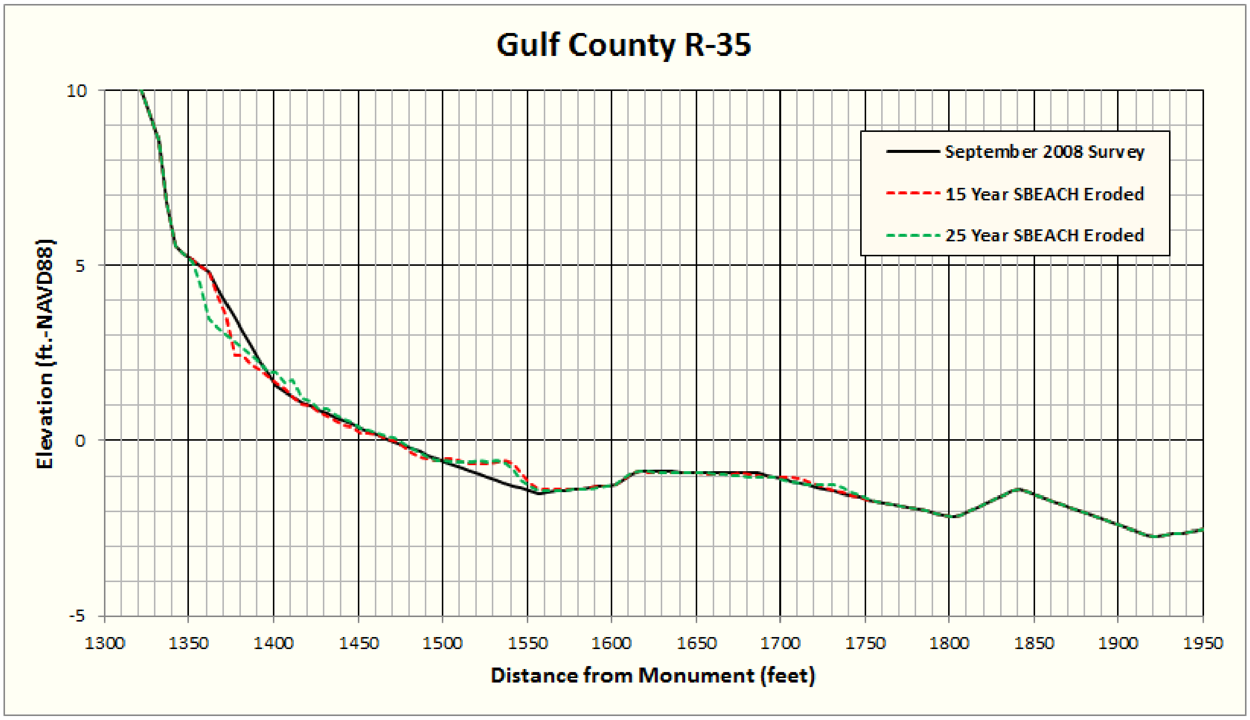
Gulf County SBEACH 15- and 25-year Storm Erosion Profiles

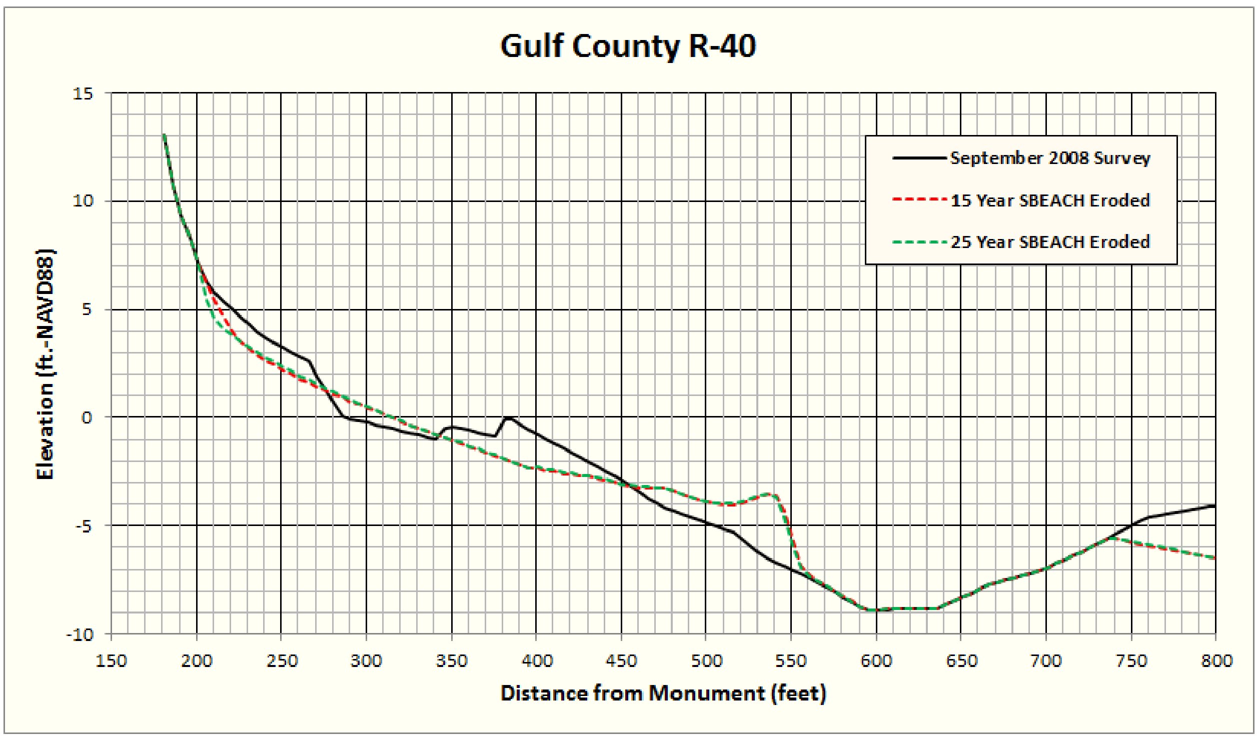


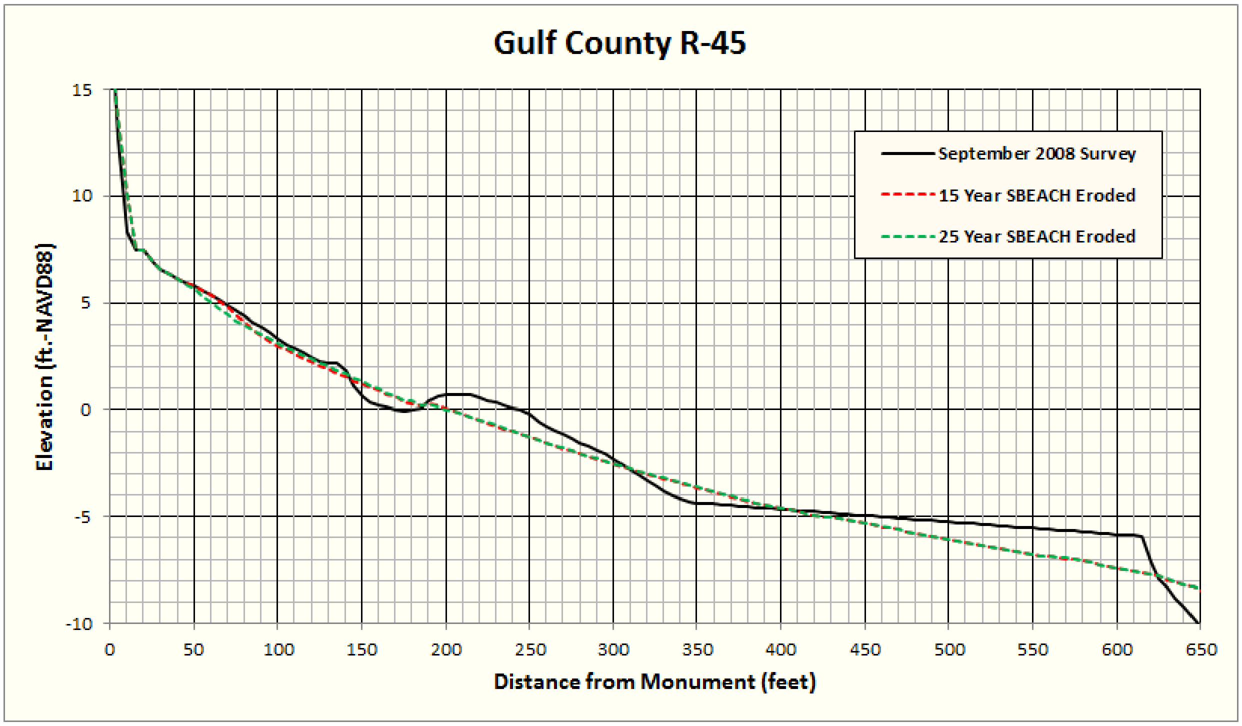


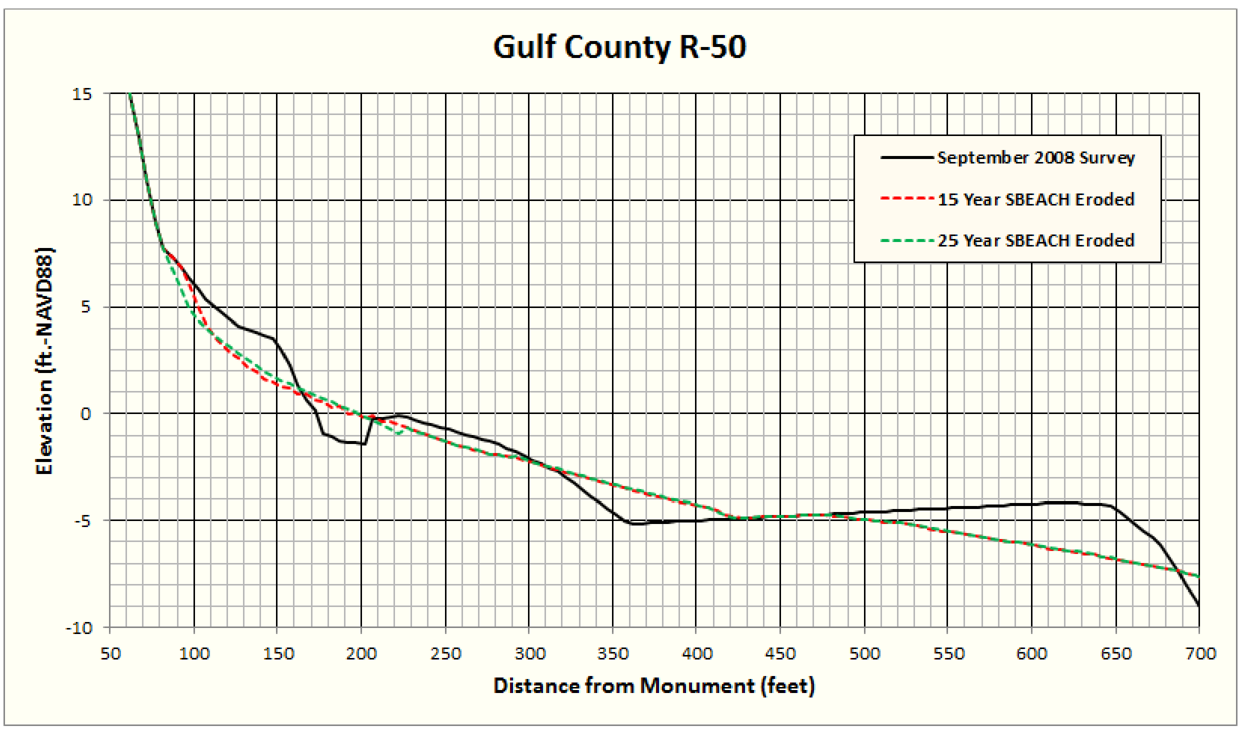

Gulf County R-15
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650

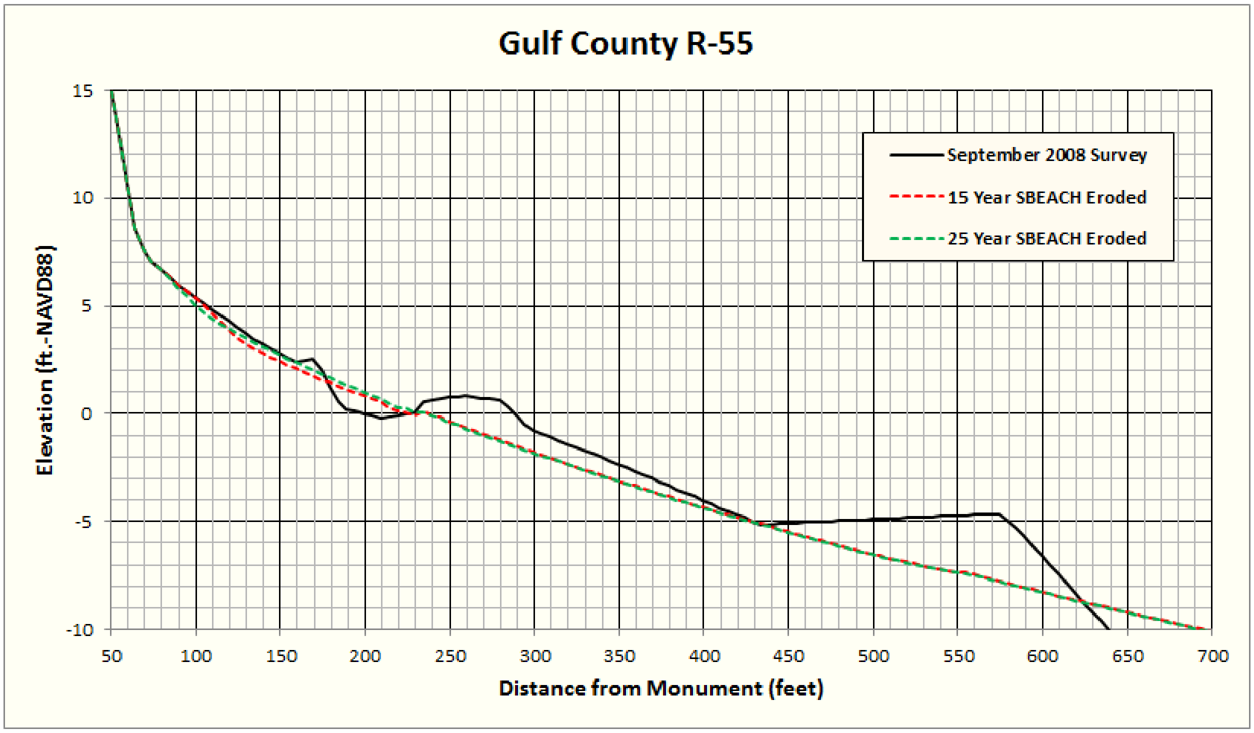

Gulf County R-25
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
100
150
200
250
300
350
400
450
500
550
600
650
700
750

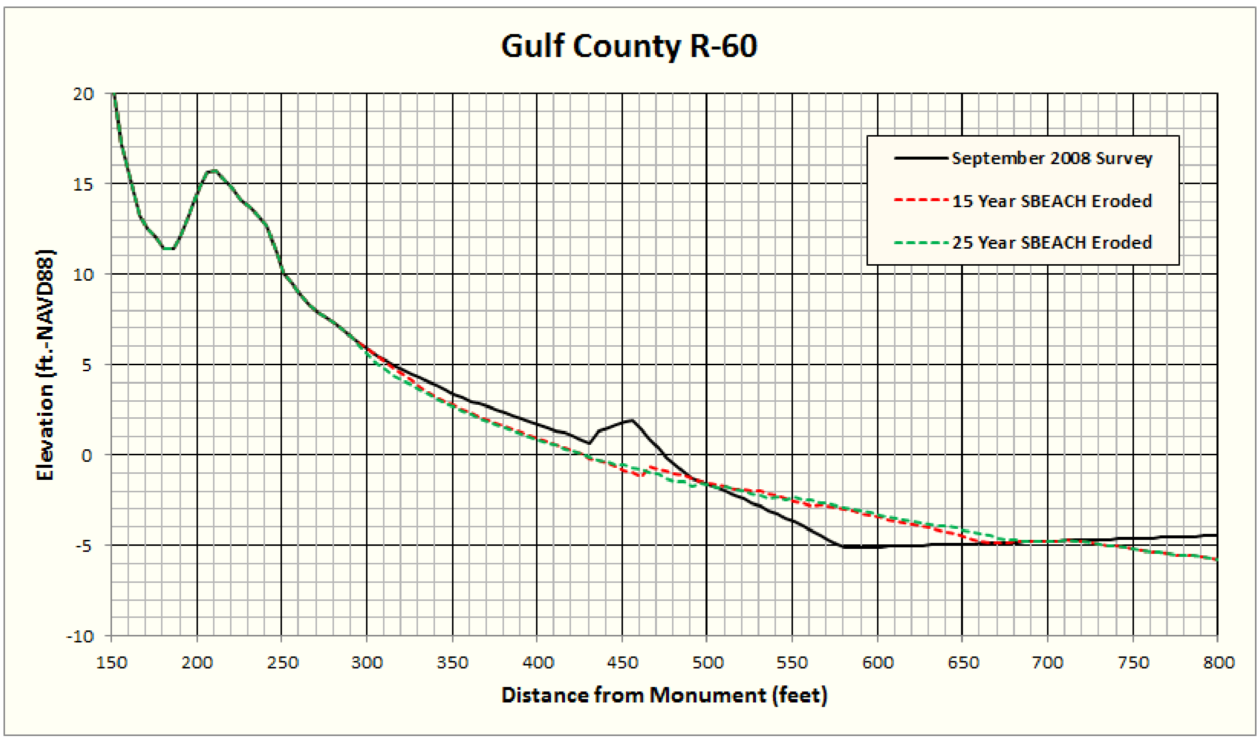

Gulf County R-35
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
10
5
0
-5
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
Distance from Monument (feet)

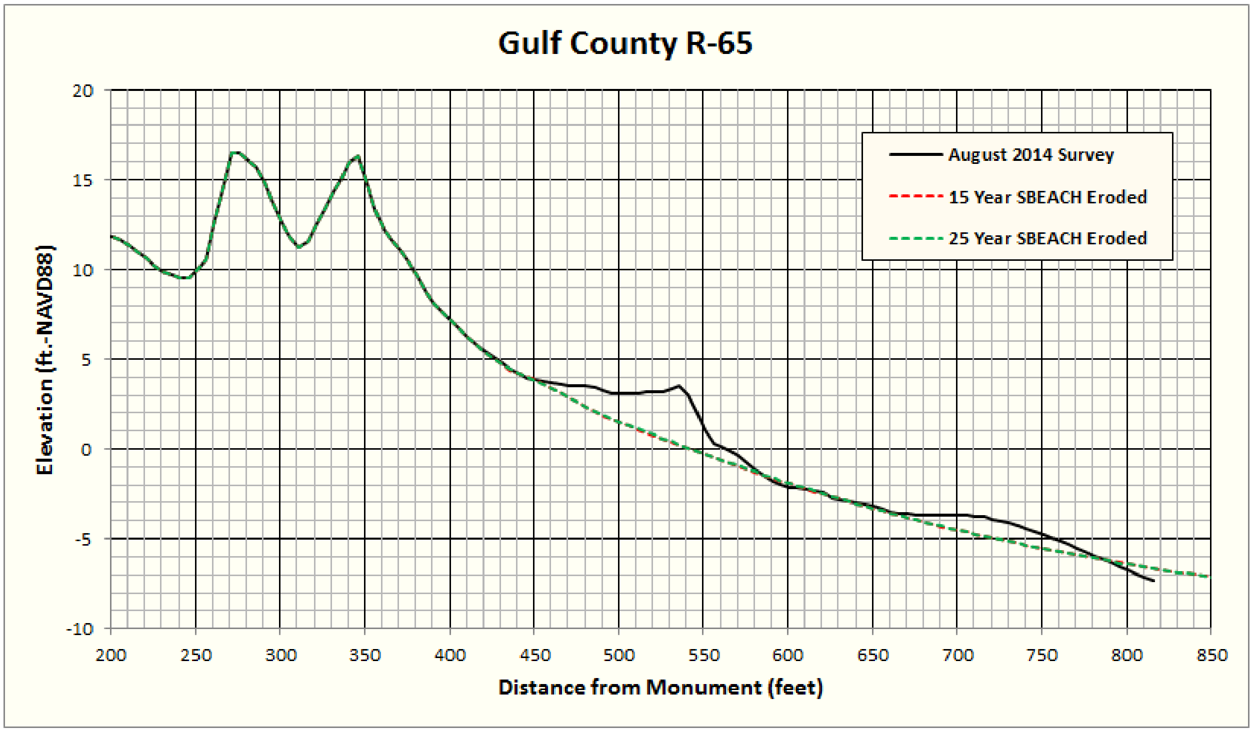

Gulf County R-40
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance from Monument (feet)

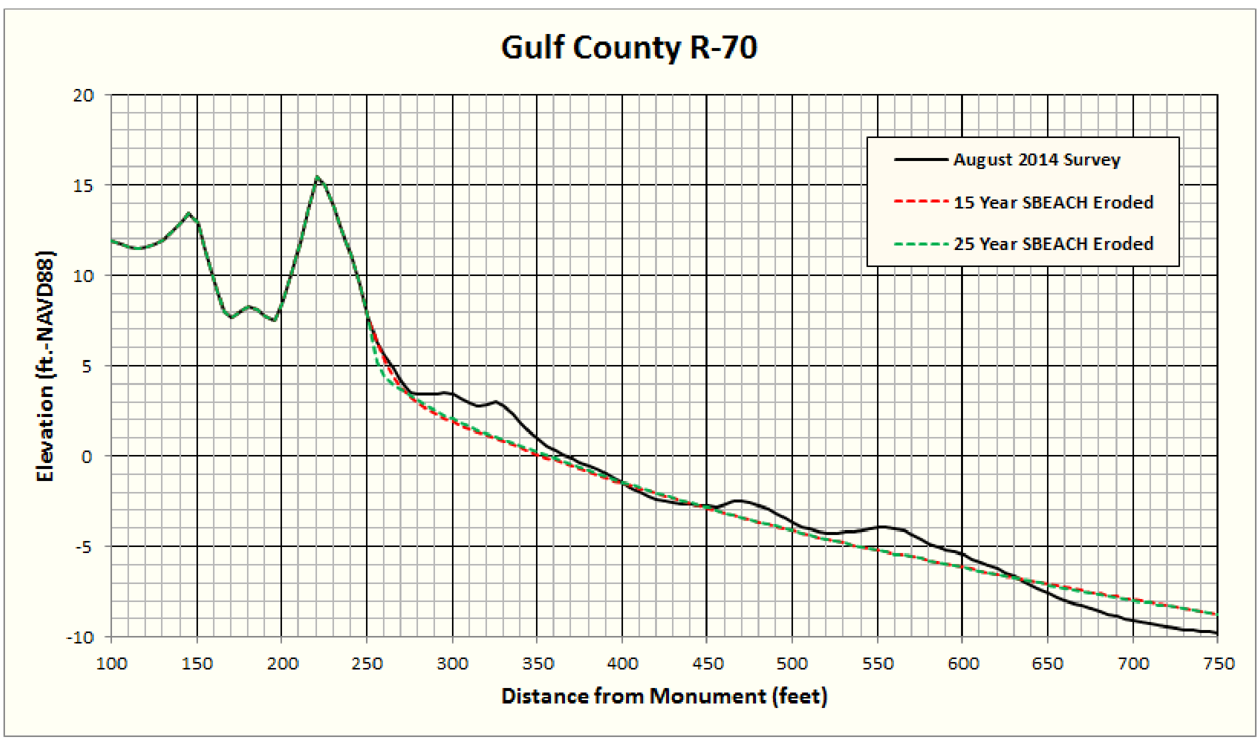

Gulf County R-45
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance from Monument (feet)

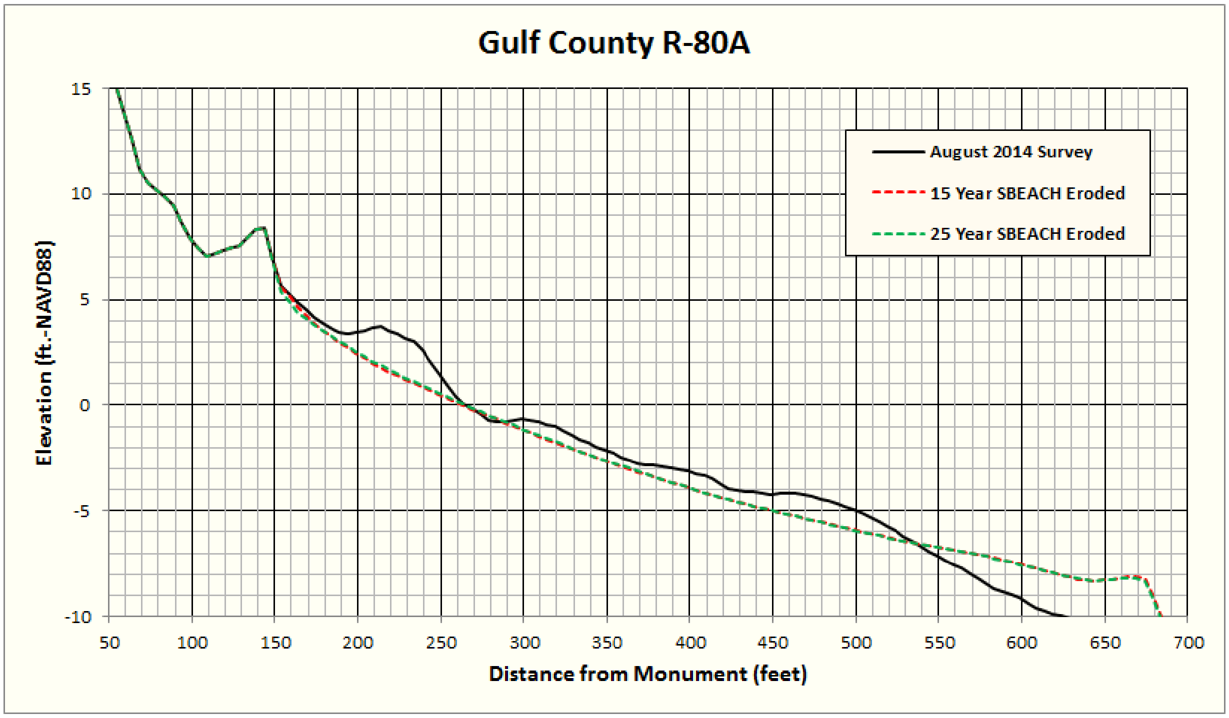

Gulf County R-50
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Distance from Monument (feet)

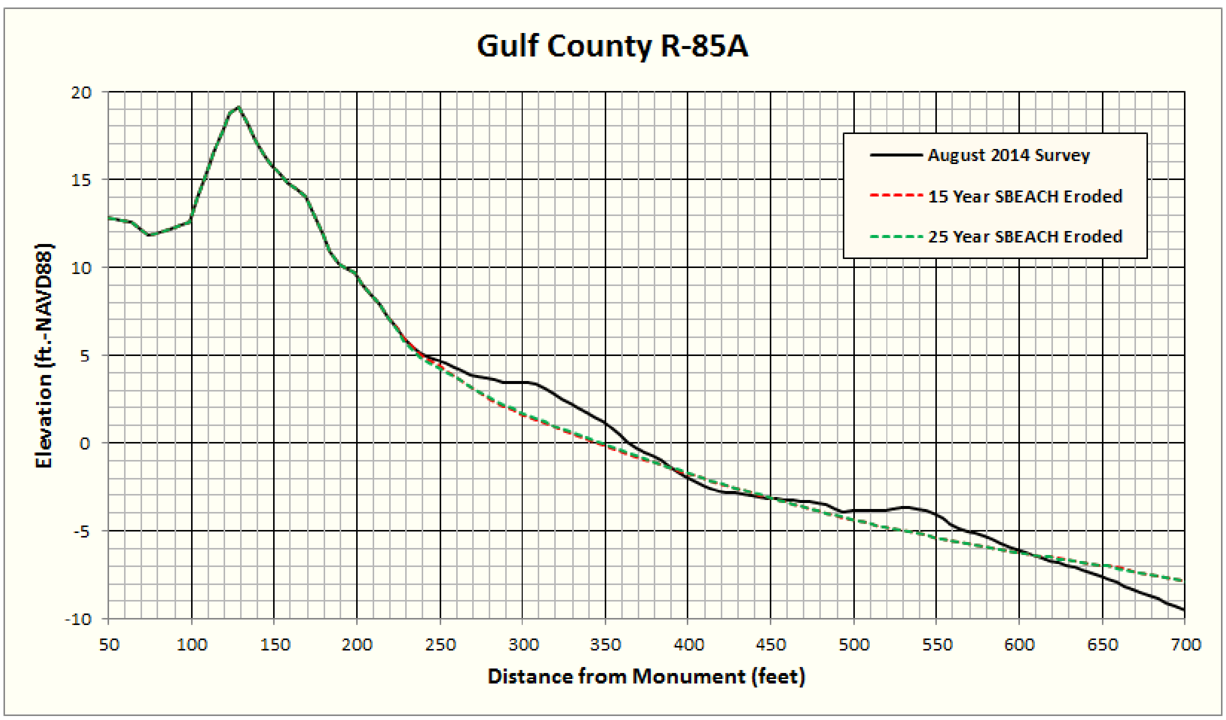

Gulf County R-55
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550
600
650
700

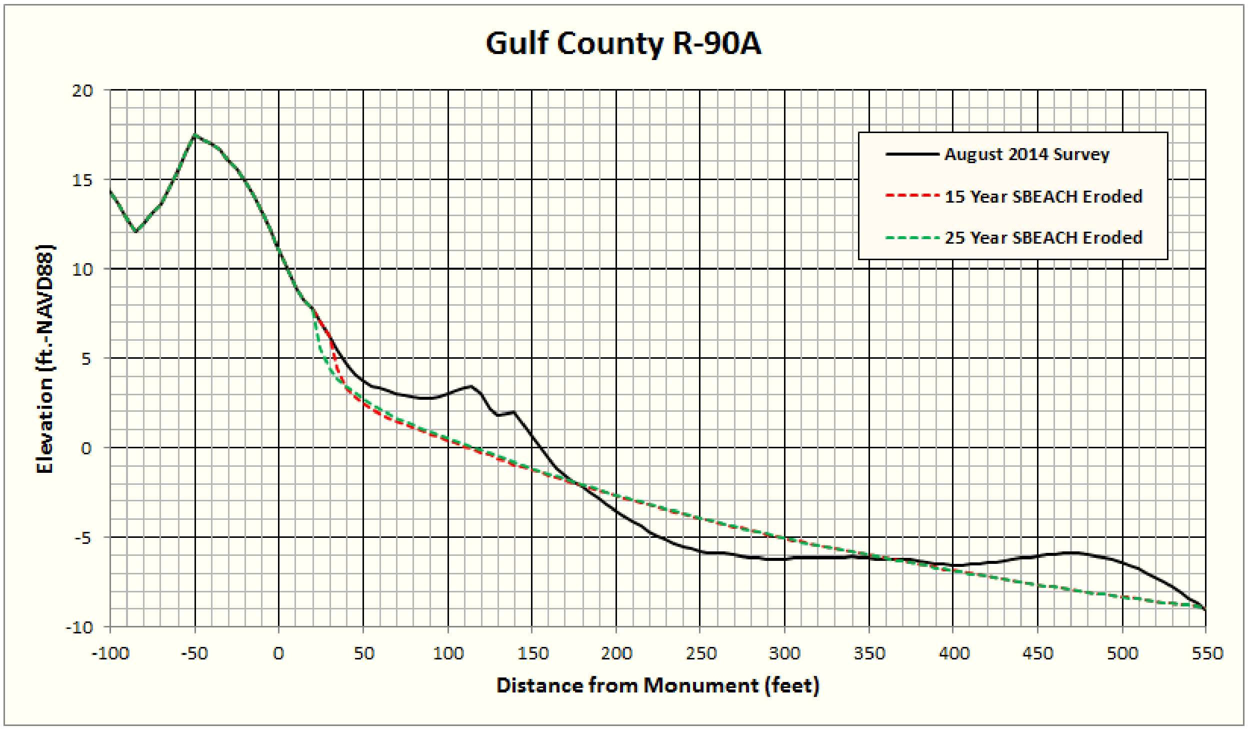

Gulf County R-60
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
150
200
250
300
350
400
450
500
550
600
650
700
750
800

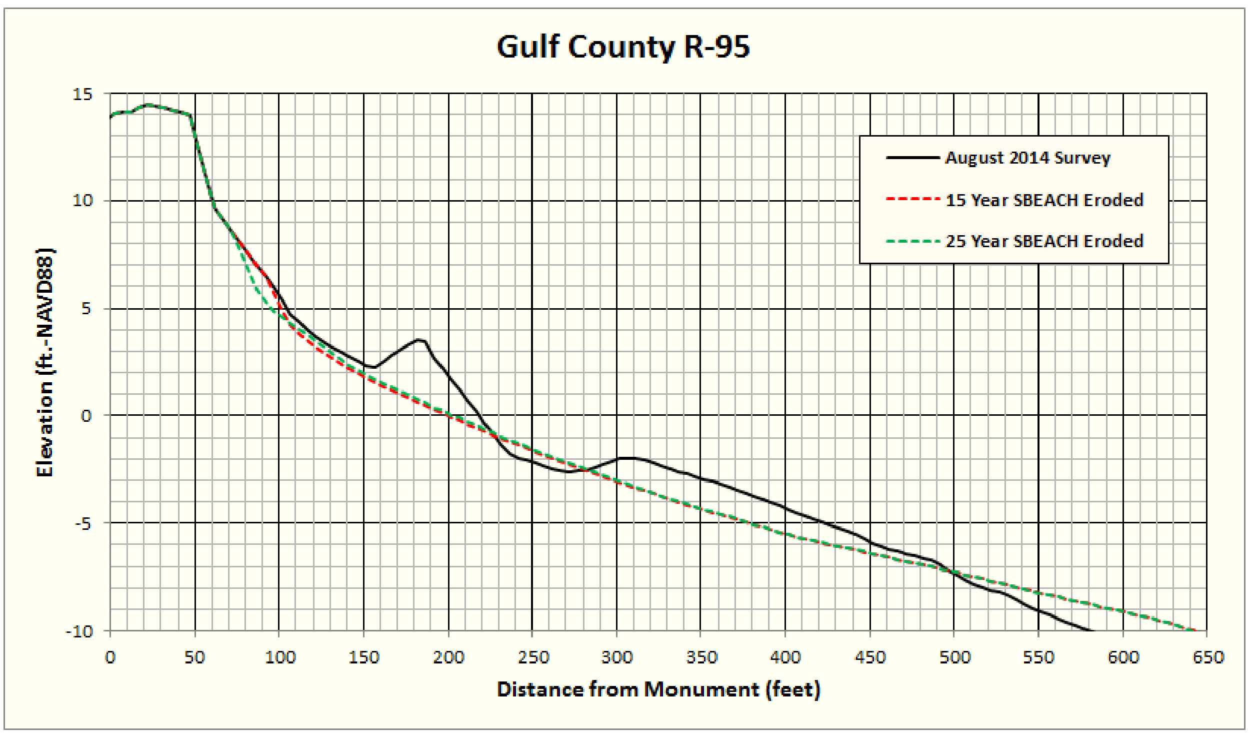

Gulf County R-65
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
200
250
300
350
400
450
500
550
600
650
700
750
800
850

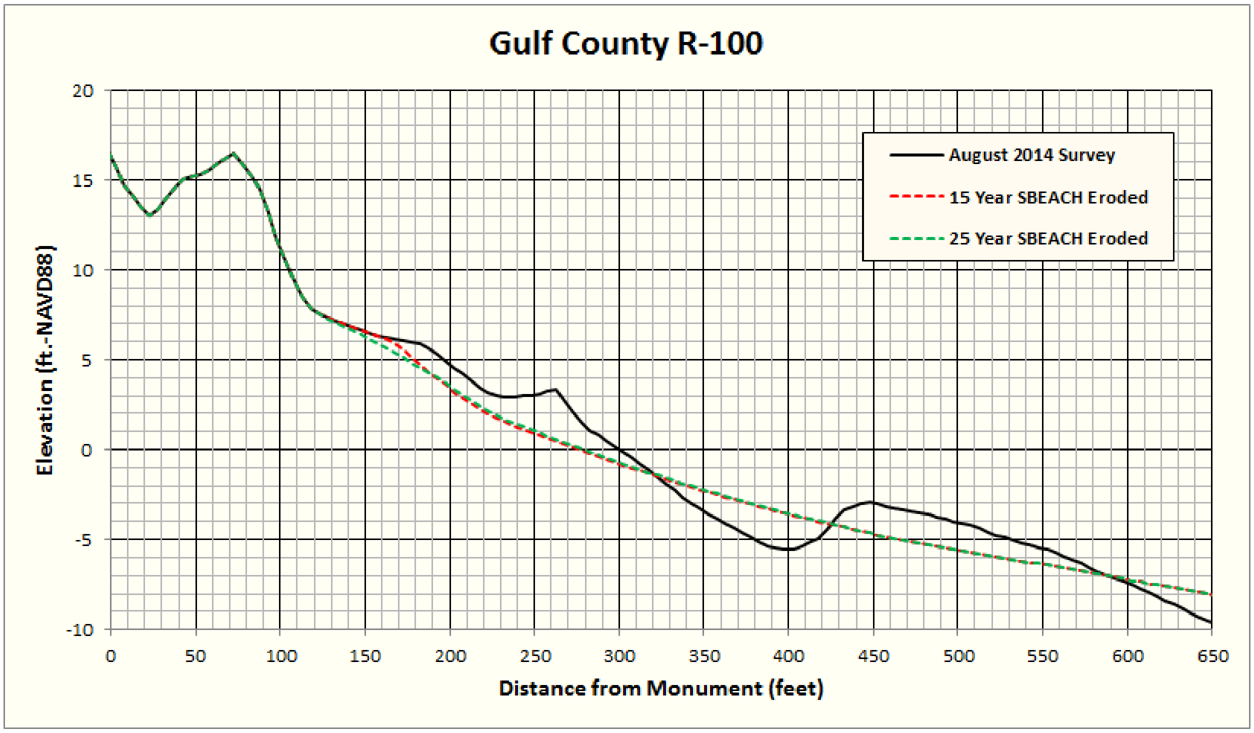

Gulf County R-70
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
100
150
200
250
300
350
400
450
500
550
600
650
700
750

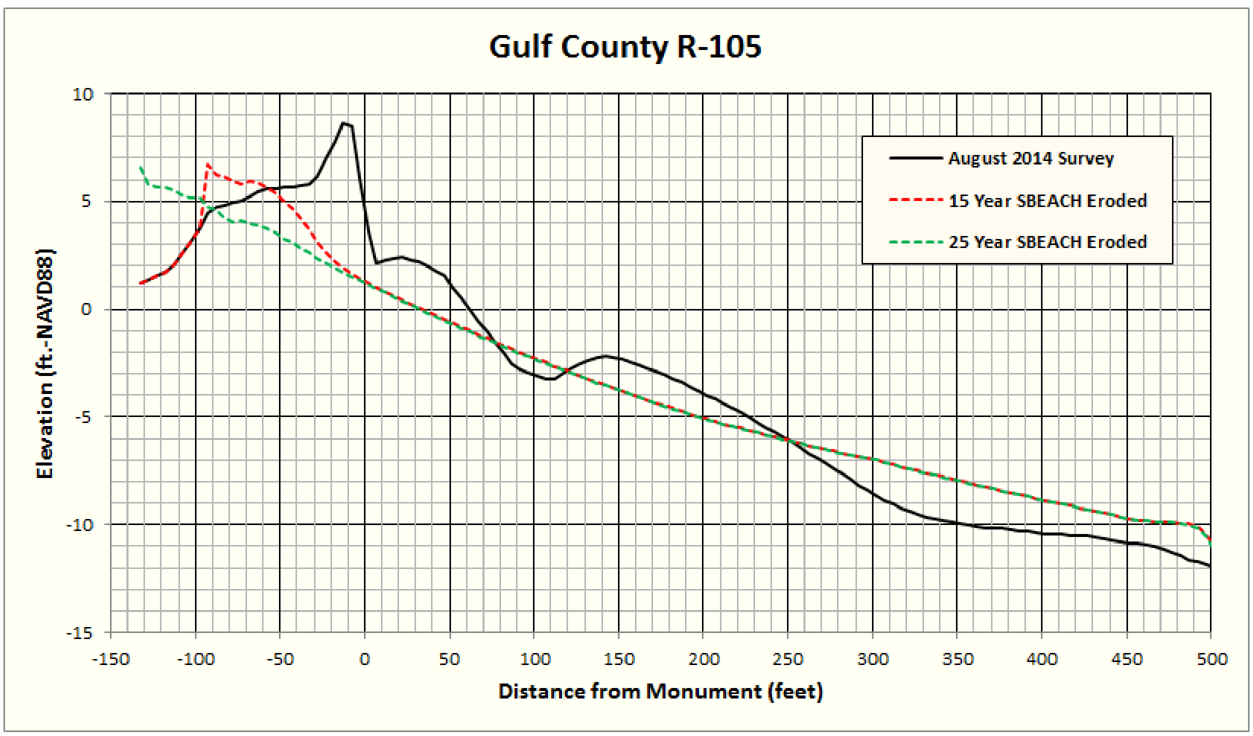

Gulf County R-80A
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550
600
650
700

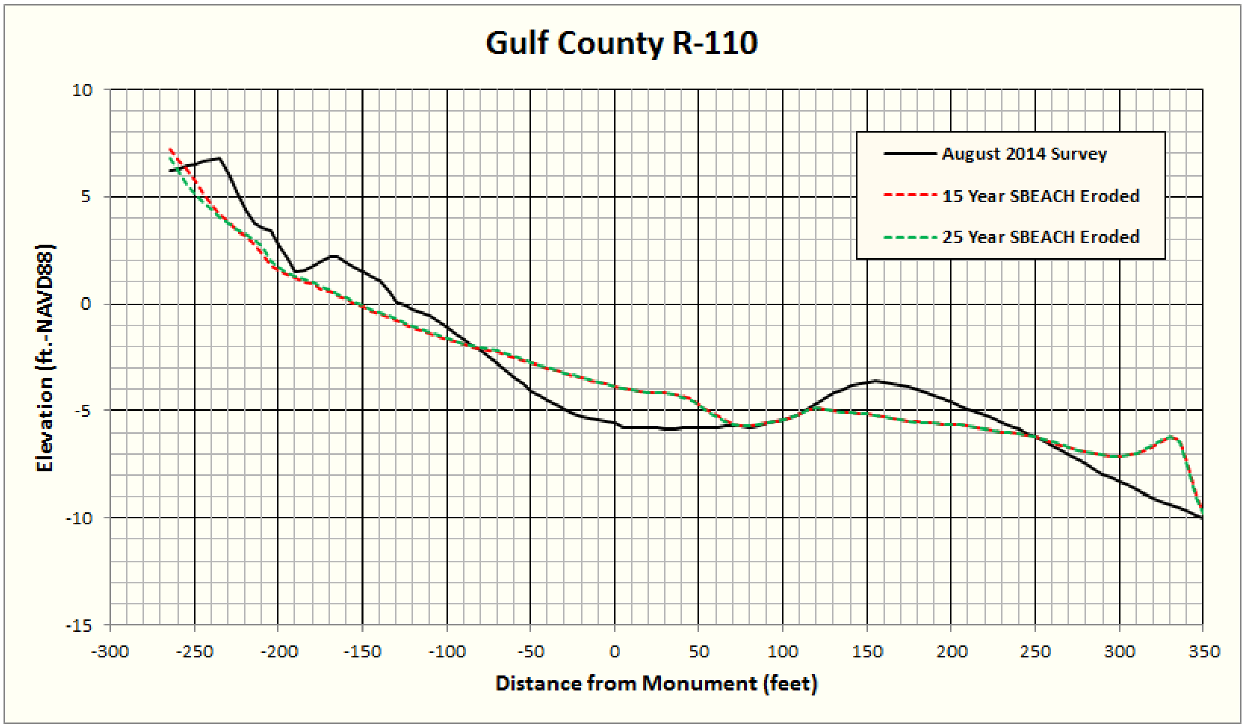

Gulf County R-85A
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550
600
650
700

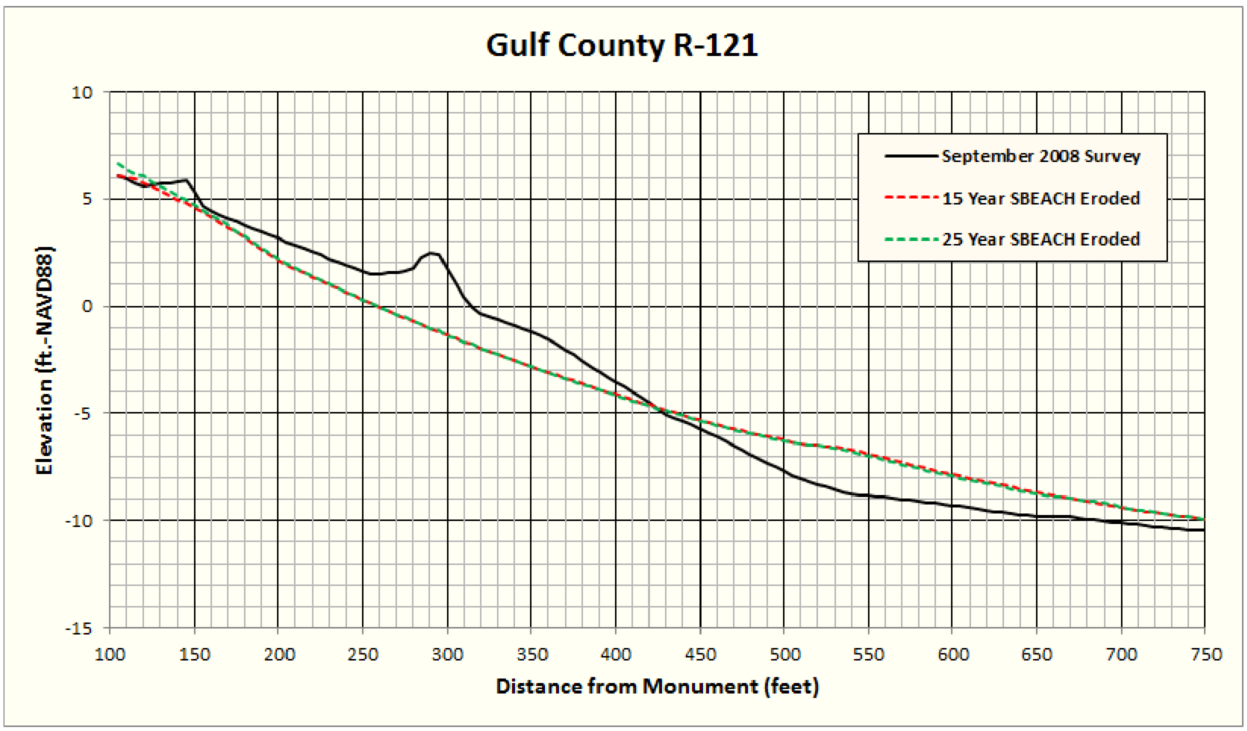

Gulf County R-90A
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550

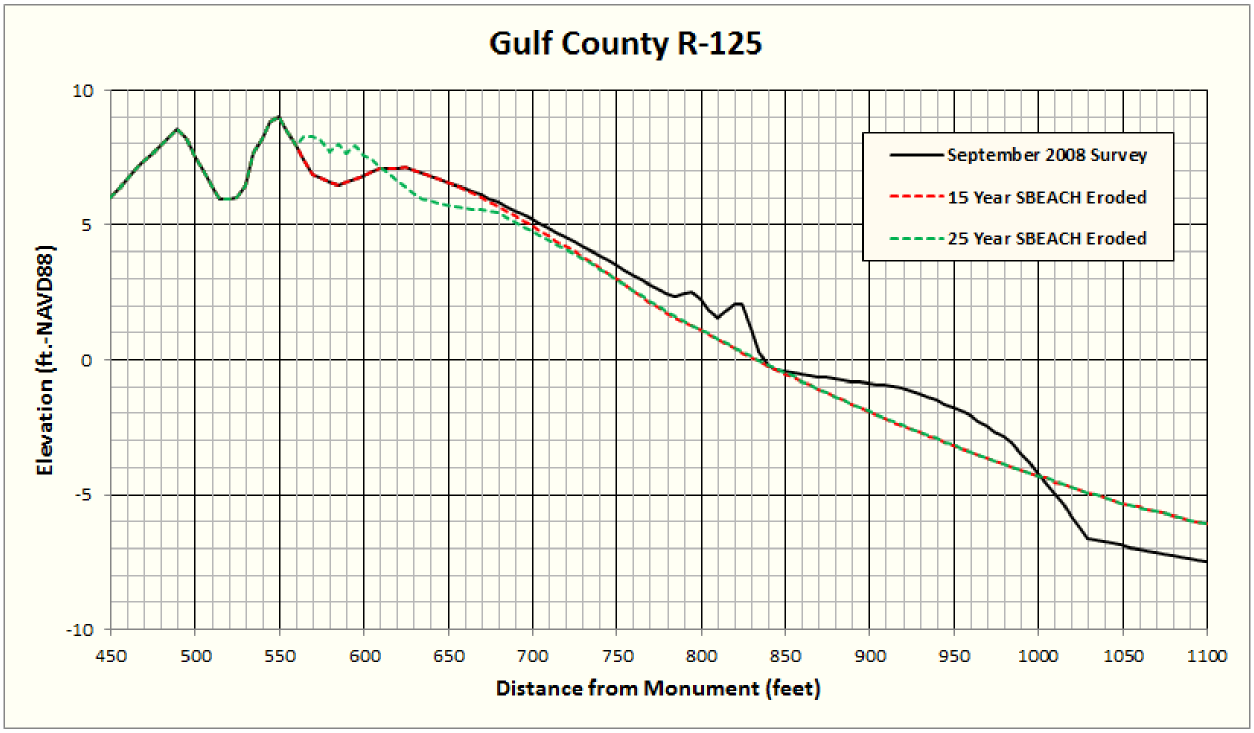

Gulf County R-95
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650

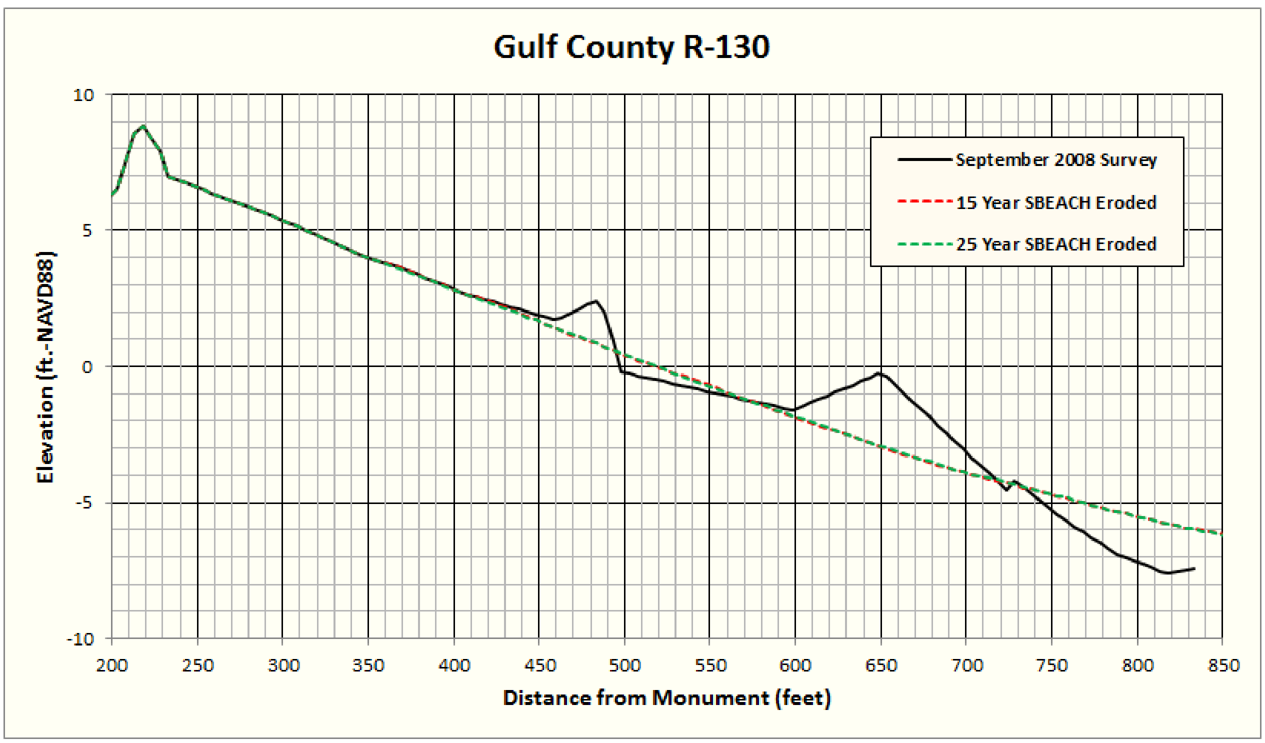

Gulf County R-100
Elevation (ft.-NAVD88)
Distance from Monument (feet)
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
20
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650

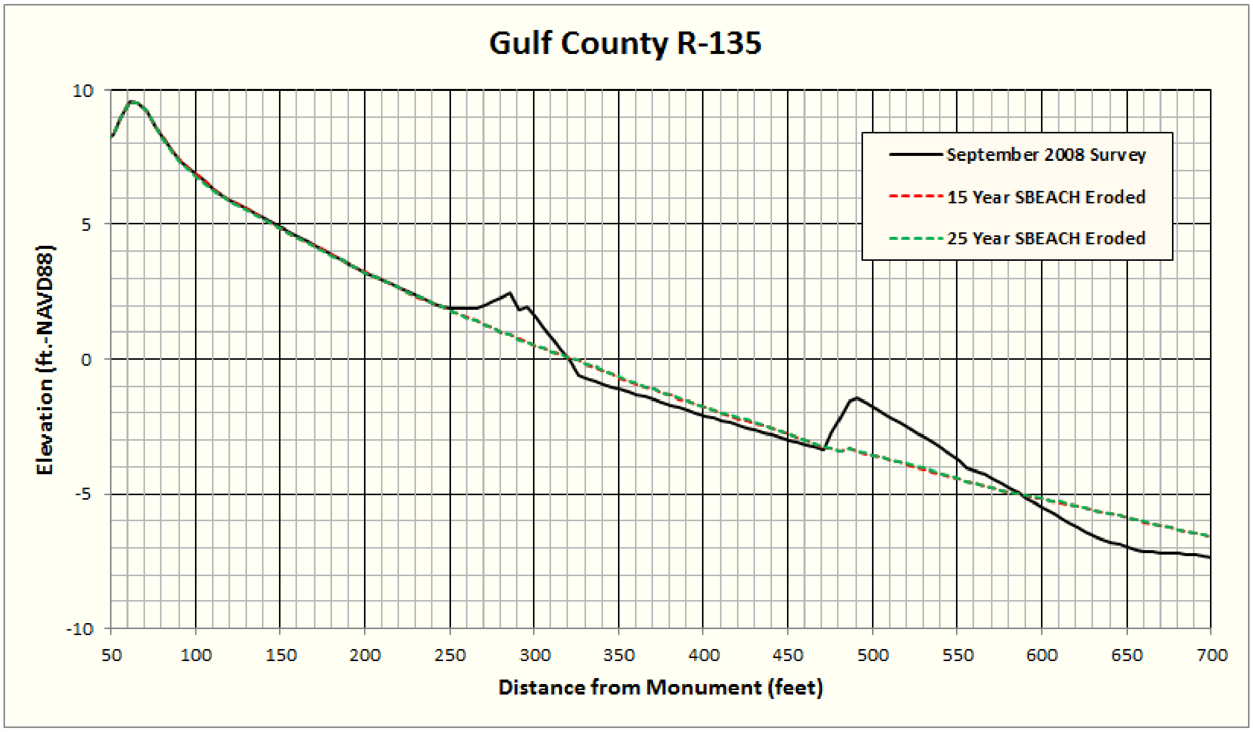

Gulf County R-105
Elevation (ft.-NAVD88)
Distance from Monument (feet)
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500

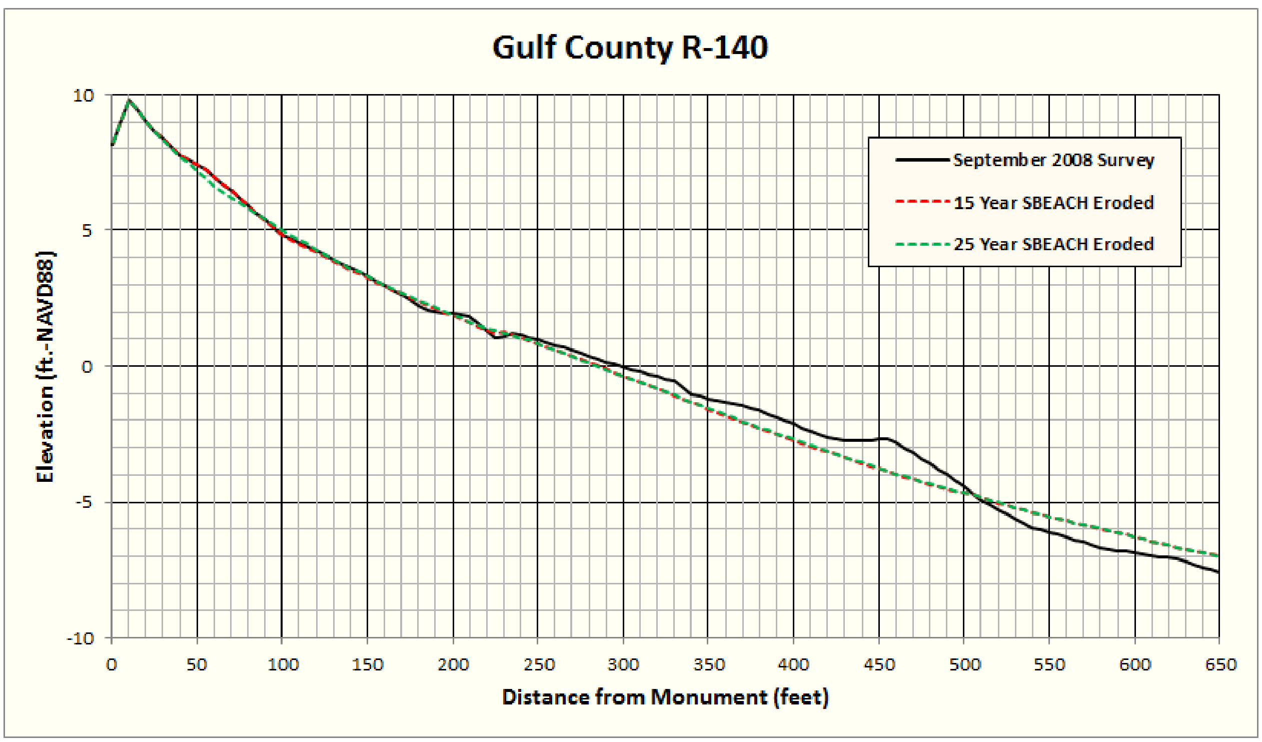

Gulf County R-110
Elevation (ft.-NAVD88)
Distance from Monument (feet)
August 2014 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
350

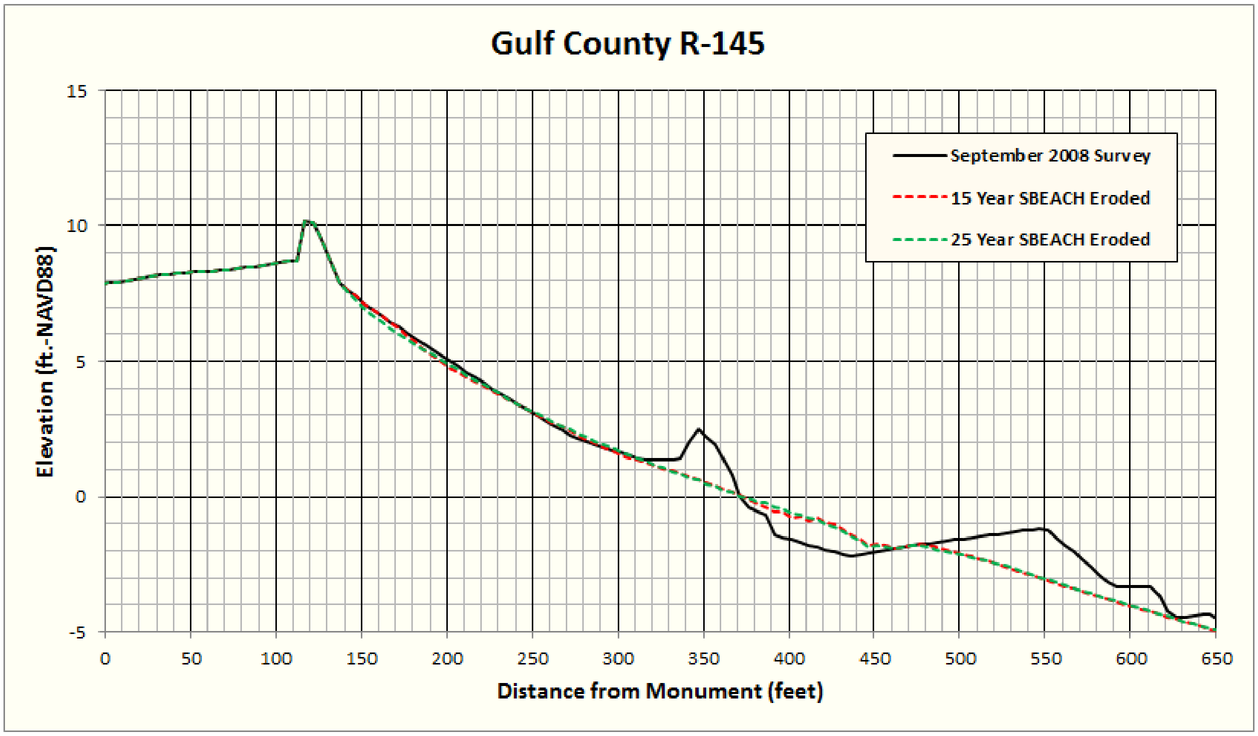

Gulf County R-121
Elevation (ft.-NAVD88)
Distance from Monument (feet)
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
10
5
0
-5
-10
-15
100
150
200
250
300
350
400
450
500
550
600
650
700
750

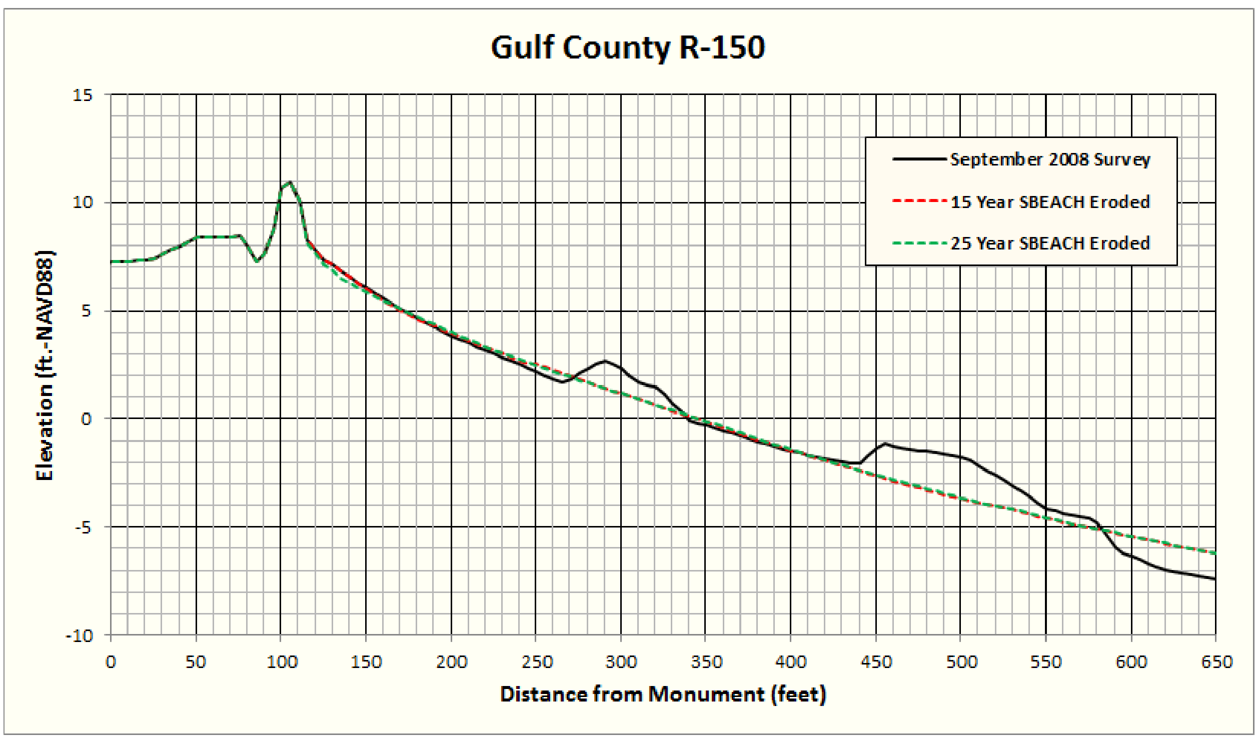

Gulf County R-125
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100

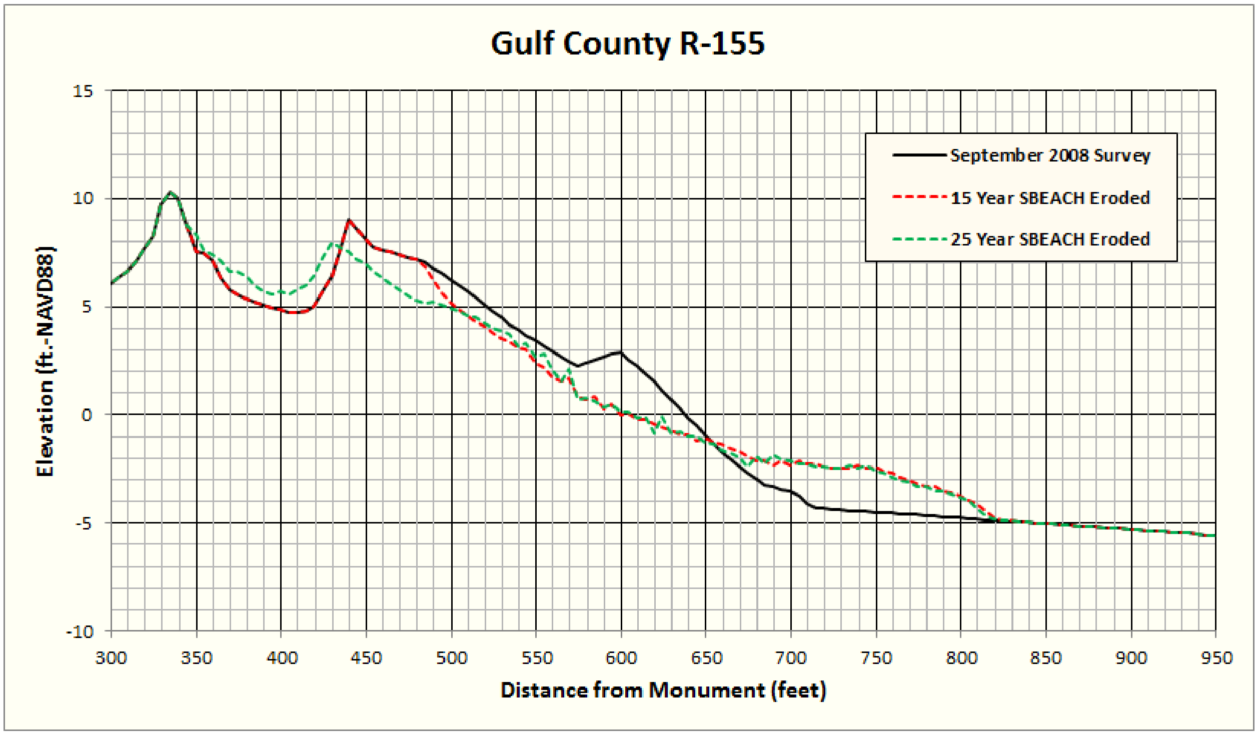

Gulf County R-130
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
200
250
300
350
400
450
500
550
600
650
700
750
800
850


Gulf County R-135
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550
600
650
700


Gulf County R-140
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650


Gulf County R-145
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance from Monument (feet)


Gulf County R-150
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance from Monument (feet)


Gulf County R-155
September 2008 Survey
15 Year SBEACH Eroded
25 Year SBEACH Eroded
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
300
350
400
450
500
550
600
650
700
750
800
850
900
950
Distance from Monument (feet)