SBEACH High-Frequency Storm Erosion Model Study for Lee County

Part I

By

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Part I

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1. Background

High-Frequency storm tide studies have been conducted by the Beaches and Shores Resource Center (BSRC) and the Division of Water Resource Management (DWRM) for 16 of the 24 CCCL studied counties since 2009. Hydrographs with return intervals of 15- and 25-year were developed for the application of dune erosion models. Due to increased usage of SBEACH (Storm-Induced BEAch CHange) by coastal engineers for coastal projects in Florida, the Bureau of Beaches and Coastal Systems (BBCS) of Florida Department of Environmental Protection (FDEP) contracted with the BSRC to conduct the model calibration and application on a county by county basis. A total of eight counties: Walton, Okaloosa, Brevard, St. Johns, Volusia and Indian River by Leadon and Nguyen (2009 and 2010), Sarasota and Palm Beach by Wang and Manausa (2013), were completed. The current SBEACH study for Lee County is conducted by the Engineering, Hydrology and Geology Program (EHG) of the DWRM. At present, the SBEACH model, Version 4.03, for high-frequency storm event is used in verification for armoring project and shore/dune protection project permit application.

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 some 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 the similar storm conditions. This requires detailed pre- and post-storm beach profile surveys that represent a storm's effects upon 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 Lee 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 Lee County resulted in a limited data set with sufficient completeness and quality for model calibration. It is found that a set of beach profiles in part of Lee County were surveyed before and after Hurricane Charley of 2005. The model calibration became possible with the help of BSRC's 2-D surge model to make up for the lack of measured storm tides on the open coast.

2.1 Storm Data

Tropical storms and hurricanes since 1900 that passed within a 50 mile radius from the center of Lee County with a pressure deficit larger than 0.3 in. Hg are listed in Table 1. Hurricane Charley of 2004 is the only storm among these 23 storms with sufficient pre- and post-storm surveys for calibration purposes. The BSRC 2-D Storm Surge Model generated storm tide hydrographs which were then used as input for SBEACH.

Table 1 Summary of Historical Storms Affecting Lee County

No.	Date	Name	Type*
1	10/9/1910		L
2	11/27/1925		L
3	9/11/1926		E
4	8/7/1928		A
5	8/26/1932		E
6	8/29/1935		A
7	10/3/1941		E
8	10/12/1944		L
9	9/4/1947		E
10	9/28/1951	HOW	L
11	8/28/1953		L
12	10/7/1953	HAZEL	L
13	10/17/1959	JUDITH	L
14	8/29/1960	DONNA	A
15	6/4/1966	ALMA	A
16	6/1/1968	ABBY	L
17	10/1/1969	JENNY	L
18	10/9/1990	MARCO	A
19	11/8/1994	GORDON	L
20	10/22/1998	MITCH	L
21	9/19/1999	HARVEY	L
22	8/9/2004	CHARLEY	L
23	7/22/2010	BONNIE	E

* L: Landfalling; E: Exiting; A: Alongshore

Hurricane Charley reached Category 2 status around 1500 UTC 12 August, just after passing northeast of Grand Cayman. After Charley crossed western Cuba with a maximum wind near 120 mph, the hurricane passed over the Dry Tortugas around 1200 UTC 13 August with maximum winds around 110 mph. It then turned north-northeastward and accelerated toward the southwest coast of Florida (Figure 1).

By 1400 UTC 13 August, the maximum wind had increased to near 127 mph. Just three hours later, Charley's maximum wind had increased to Category 4 strength of 144 mph. Since the eye shrank considerably in the 12 hours before landfall in Florida, these extreme winds were confined to a very small area – within only about 6 n. mi. of the center. Moving north-northeastward at around 21 mph, Charley made landfall on the southwest coast of Florida near Cayo Costa, just north of Captiva, around 1945 UTC 13 August with maximum sustained winds near 150 mph.

Charley's eye passed over Punta Gorda at about 2045 UTC, and the eyewall struck that city and nearby Port Charlotte with devastating results (Figure 2). Continuing north-northeastward at a slightly faster forward speed, the hurricane traversed the central Florida peninsula, resulting in a swath of destruction across the state (Pash et al., 2005).

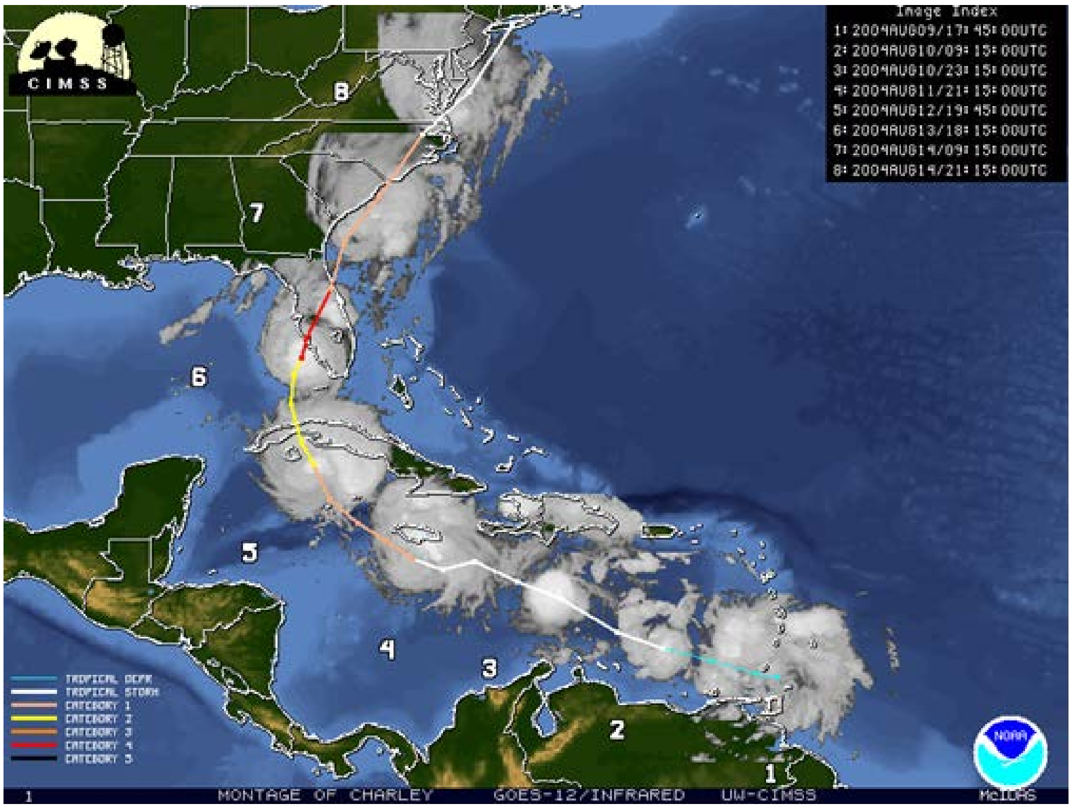

Figure 1. Hurricane Charley track, 9-14 August 2004. (Source: CIMSS, UW-Madison).

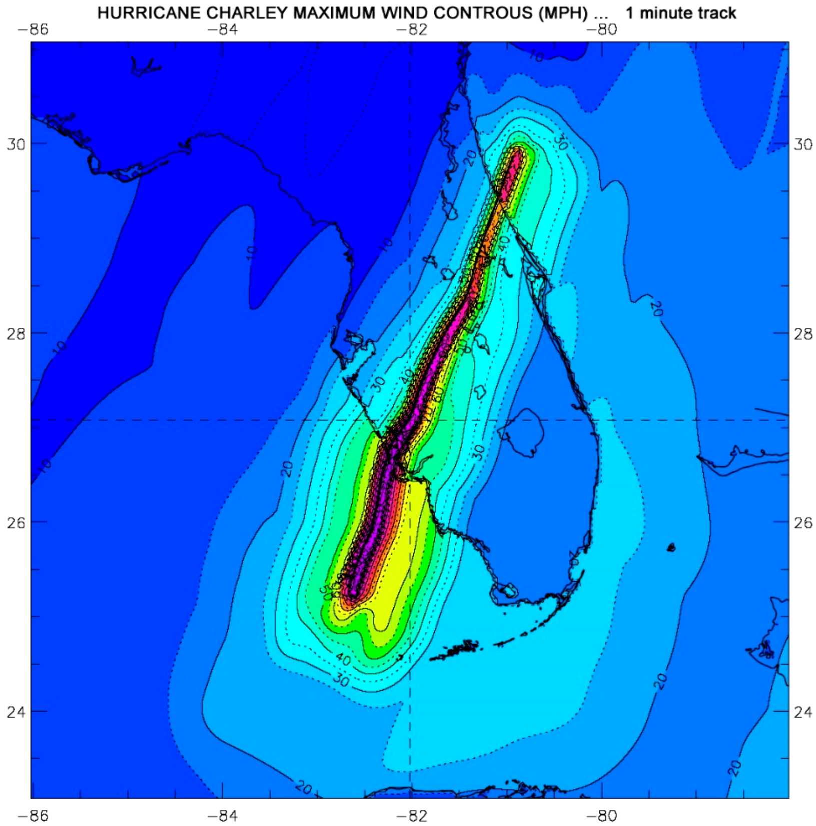

Figure 2. Surface Wind Fields Associated with Hurricane Charley at landfall.

2.1a Storm Tide Data

For the purpose of model calibration, the measured storm tide and wave data generated by Hurricanes Charley are essential. The URS Group, Inc. was contracted by the Federal Emergency Management Agency (FEMA) to collect and survey Coastal High Water Marks (CHWMs) in the Charley Impacted areas. A total of 39 CHWMs were surveyed in Lee County (FEMA, 2004). For the purpose of Storm Surge calibration, only the interior High Water Mark (HWM) data from beach areas were selected to evaluate the storm tide associated with Hurricane Charley. Two inside HWM observations are available from FEMA's report for Ft. Myers and Ft. Myers Beach. Another two inside HWM data were surveyed by Ralph Clark (BBCS, 2004) on North Captiva Island and Captiva Island. Table 2 lists these 4 HWM data and their location descriptions.

To verify those surveyed HWM data and to provide the un-surveyed area with the predicted storm tides, the 2-D Storm Surge Model was employed to calculate the total storm tide, i.e. surge generated from barometric pressure and wind stress plus dynamic wave setup and astronomical tide. The 2-D grid systems and associated hydrological data of Lee County from the high-frequency storm tide study (Wang, 2012) were used to cover the study area. Hurricane track, pressure deficit, radius to the maximum wind (RMW) of Charley for the last 26 hours before and 10 hours after landfall were input to the 2-D storm Surge Model. The Model then ran and calculated the total storm tide for 15 locations in Lee County. Figure 3 displays the results of model calculated total storm tides and the surveyed HWM.

Table 2 High Water Marks data in Lee County during Hurricane Charley

Location	Peak Surge (ft.-NAVD)	Lat.(N)	Lon.(W)	HWM Object
Ft. Myers Beach	8.2	26.45062	81.94958	Mud line of interior wall
Ft. Myers	3.6	26.48764	82.01187	Mud line of interior wall
North Captiva Island, South End	7.8	N/A	N/A	Water line of interior wall
Captiva Island, North End	5.8 ~ 6.8	N/A	N/A	Water line of interior wall

Figure 3 shows that the BSRC Model calculated Total Storm Tide by Hurricane Charley agrees closely with the surveyed HWM. The BSRC Model results can then be used to show that the Total Tide Values for Various Return Periods in the CCCL study for Lee County are validated to provide a storm tide return period for the HWM during Hurricane Charley.

A total of 15 storm tides in 6 profile transact lines from the CCCL studies for Lee County were selected to generate return periods of 15, 25 and 50 years. Figure 4 depicts a comparison between the model calculated storm tide for Charley and the CCCL's total storm tide for various return periods (Wang, 2012). It shows that Hurricane Charley generated a storm tide ranging between 15 and 50 years return period for most of the Lee County area. The storm tides with a high return periods in Lee County, especially in the greatly impacted Captiva Island and Sanibel Island areas, was mainly attributed to two factors: a fast moving hurricane and a narrow RMW. Hurricane Charley moved quickly at about 25 mph before and after landfall with a narrow RMW of 6.9 miles, which caused a lower storm tide than might be expected from a slower moving and larger hurricane.

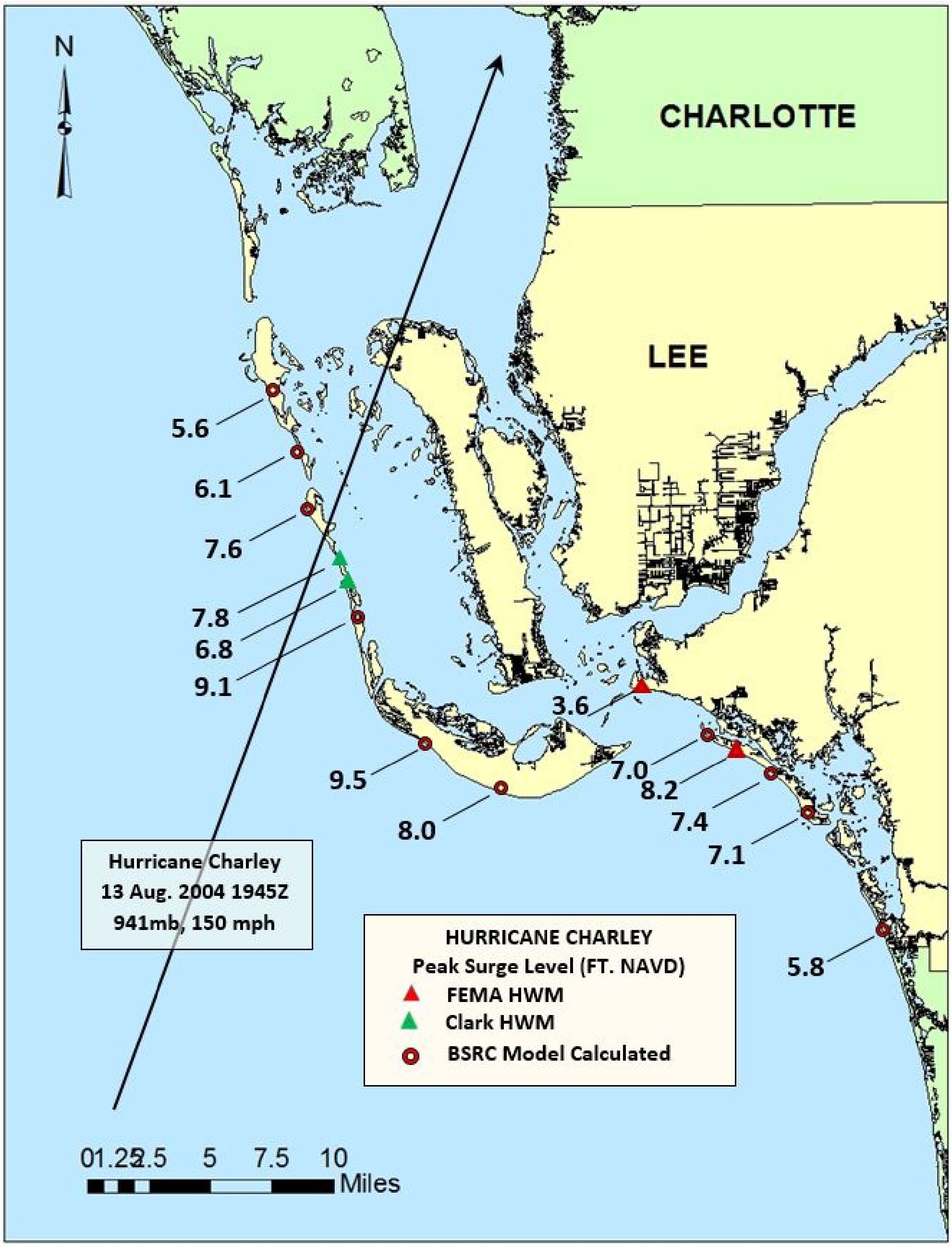

Figure 3. Peak Surge Levels in Lee County for Hurricane Charley.

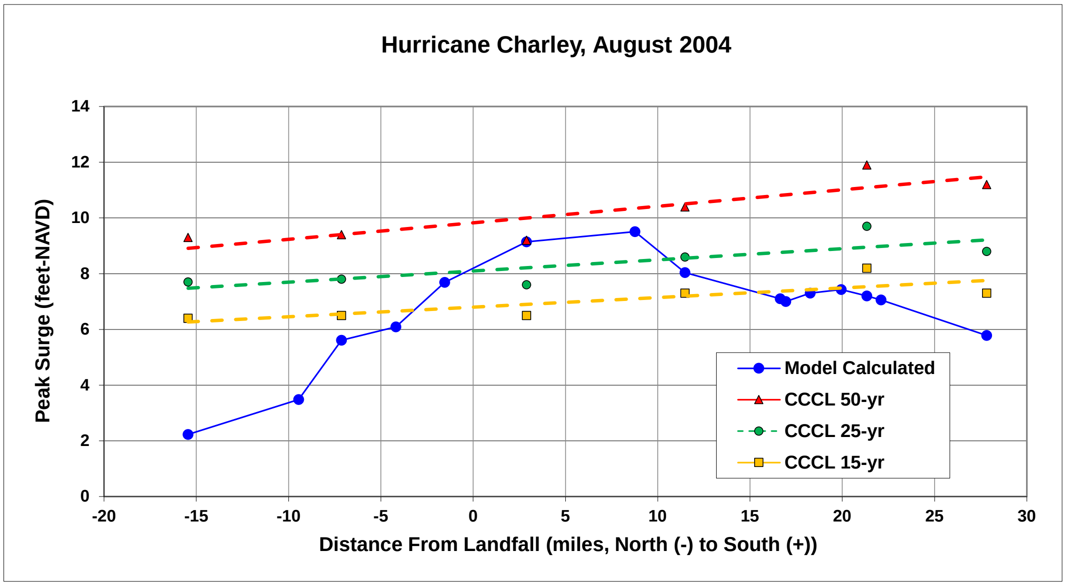

Figure 4. Hurricane Charley Storm Tide Return Period.

2.1b Wind and Wave Data

No wave data was recorded in the study area during Hurricane Charley in 2004. However, since the wind speed and direction data were available from the National Hurricane Center (Pasch et al., 2011), 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 its 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.

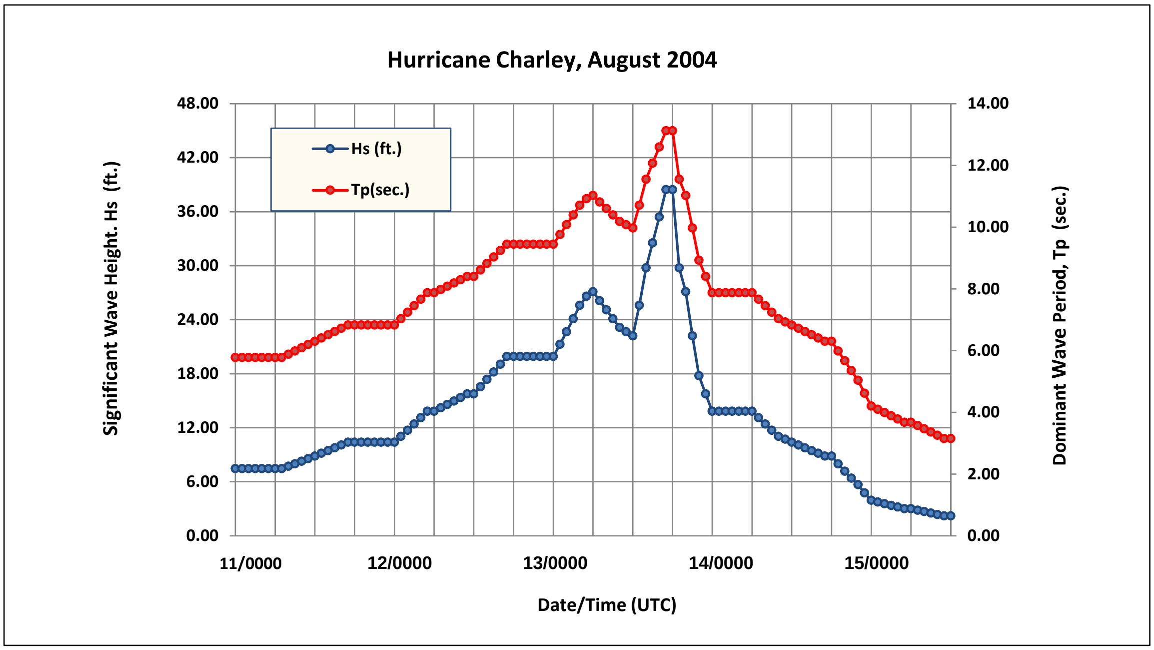

Figure 5: Best estimated wave conditions for Hurricane Charley, 2004.

2.1c Hydrographic Survey Data

CPE conducted Pre-and Post-Charley surveys for Captiva Island in March 2004 and August 2004, respectively. Data for the beach profile and hydrographic surveys from R-83 to R-120 of Lee County are available through the FDEP website (Reference 4). A total of 8 profiles from R-85 to R-92, all of which are located at the windward side of Hurricane Charley and showed consistent erosion were selected for the model calibration. The map in Figure 6 shows the location of the profiles selected for the SBEACH model calibration and the storm tide calculated with the 2-D storm surge model.

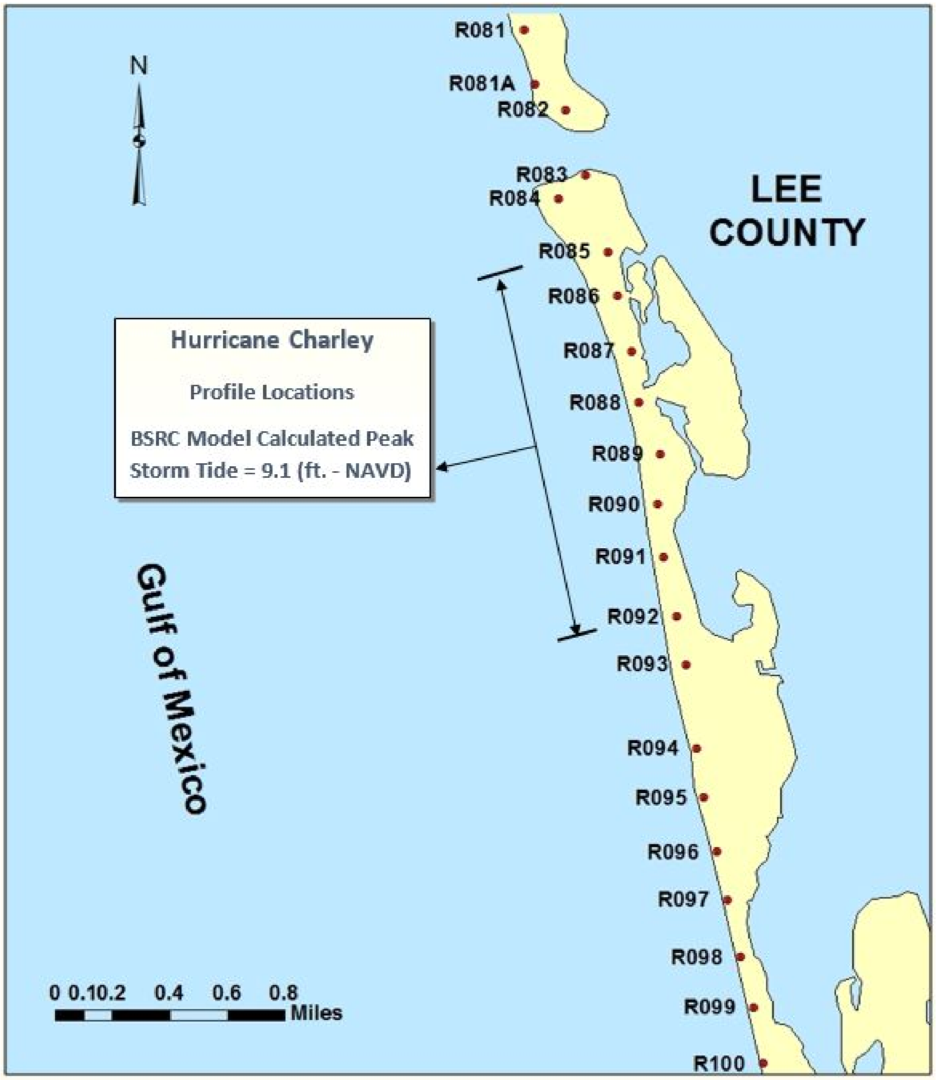

Figure 6: Locations of profiles and the calculated storm tide used in SBEACH calibration.

2.2 Model Input Parameters

The SBEACH model's primary input includes profile, storm and sediment data. Profile data are prepared according to its locations on a "reach" of shoreline. Mean grain size of the beach material is one of the primary sediment data required. Other input includes model parameters such as grid size, time step, and the transport rate coefficient.

The beach profiles, called a reach in the SBEACH model, were represented in the model using a constant grid scheme with grid cell spacing of 5 feet in order to generate a detailed result. Each reach was approximately 3,400 feet long and had about 680 cells of 5 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 southwest coast and keys (Daniel et al, 2010). For the model calibration area, R-85 to R-92 of Captiva Island, the beach sediment was shell beds intermingled with quartz sands and the resulting mean grain size was 0.536 mm.

The average eroded beach slope measured from the 8 selected August 2004 (post-storm) surveyed profiles was found to be very mild and below 5 degrees. The maximum slope prior to avalanching is the maximum slope angle, ranging from 15 to 90 degrees that the profiles is allowed to achieve in SBEACH. Different angles were tested during the calibration and erosion results were not sensitive to this parameter. It was due to the fact that SBEACH calculated erosion slopes did not reach the minimum angle of 15 degrees for any of the post-storm survey profiles. Other parameters tested in the model calibration were the landward surf zone depth, water temperature, and the transport decay factor. The default values are shown in Table 3.

Table 3 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 its insignificant effect in the model results. For each SBEACH run, only the hydrographs without wave setup were entered since the SBEACH model calculated and added the wave setup internally to reach the desired final water level. The hydrographs without wave setup were then adjusted for each of the 8 selected profiles, so the peak water elevation output from SBEACH were in agreement with the peak storm tide values calculated by the 2-D storm surge model for Hurricane Charley.

For the purpose of area wide application of the SBEACH model in Lee County, the 8 selected profiles represented the windward area impacted by Hurricane Charley. The storm tide level of 9.1 feet (NAVD) calculated for the 8 profiles is equivalent to a return intervals between 30 and 50 years (Wang, 2012), which is considered a high frequency storm event. The average measured versus the SBEACH calculated erosion distance for contours from 0 to 7 feet above NAVD 88 of the 8 profiles were used as the principle basis for determining the calibration parameters setting.

Since Lee County consists mainly of low level beaches and barrier islands, the overwash transport parameter was scrutinized during model calibration. The overwash algorithm in the SBEACH model was improved by the incorporation of more advanced hydrodynamics and sediment transport considerations. The model was validated at Ocean City, and at Assateague Island, MD, the former representing a location with a protective dune typical of shore protection projects and the latter location representing a low and wide barrier island in a nature condition (Larson, Wise and Kraus, 2004).

Since a constant wave height and period will be used for the purpose of practical county wide application of SBEACH, different constant wave heights and periods were tested to generate a comparison between the model calculated erosion profiles and the measured post-storm profiles. It was found that a constant deep water wave with 15 foot wave height and 10 second wave period matched well with the calculated results from the measured ones.

Starting with the default values, a series of values for each calibration parameter were tested. Some of the parameters were insensitive during the tests as mentioned above. The overwash parameter, the coefficient for slope dependent term, ε, and the transport rate coefficient, K, were found to be very significant to the calibration results, so they were adjusted individually until reasonable agreement with the measured erosions were achieved.

The final parameter values were determined as those providing the best presentation of measured erosions for the 8 selected profiles. The final parameter values resulting from the model calibration are summarized in Table 4. Figure 7 shows comparisons of average contour recessions between measured and SBEACH model computed for Hurricane Charley based on the final model parameters described above. Plots of pre-storm, post-storm, and SBEACH model predicted profiles with the final calibration parameters for each of the 8 profiles are presented in Appendix B.

Table 4 SBEACH Model Calibration Parameters for Lee County

Parameters	Unit	Values
Transport rate coefficient, *K*	m^4 /N	0.5 e^{-006}
Overwash transport parameter		0.002
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	0.536
Maximum slope prior to avalanching	degree	15
Water temperature	degree, C	28
Suggested Wave Input Conditions		
Wave Height, H	ft.	15
Wave Period, Tp	Sec.	10
Wave Direction, α	degree	0 (shore-normal)

The 8 calibration profiles were used as inputs to the SBEACH model in order to compare erosion differences that were due to the parameter sensibility. Average erosion distances above 0 foot NAVD88 at each foot contour were compared between the model predicted and measured so the best SBEACH model parameters could be achieved.

Differences of average erosions between model predicted with constant waves and pre- and post-storm measured were within 7 feet at all contours. The SBEACH model predicted erosions with the calibrated parameters (Table 4) came to a close agreement with the measured ones, especially for contours between 3 and 6 feet of the 8 selected profiles.

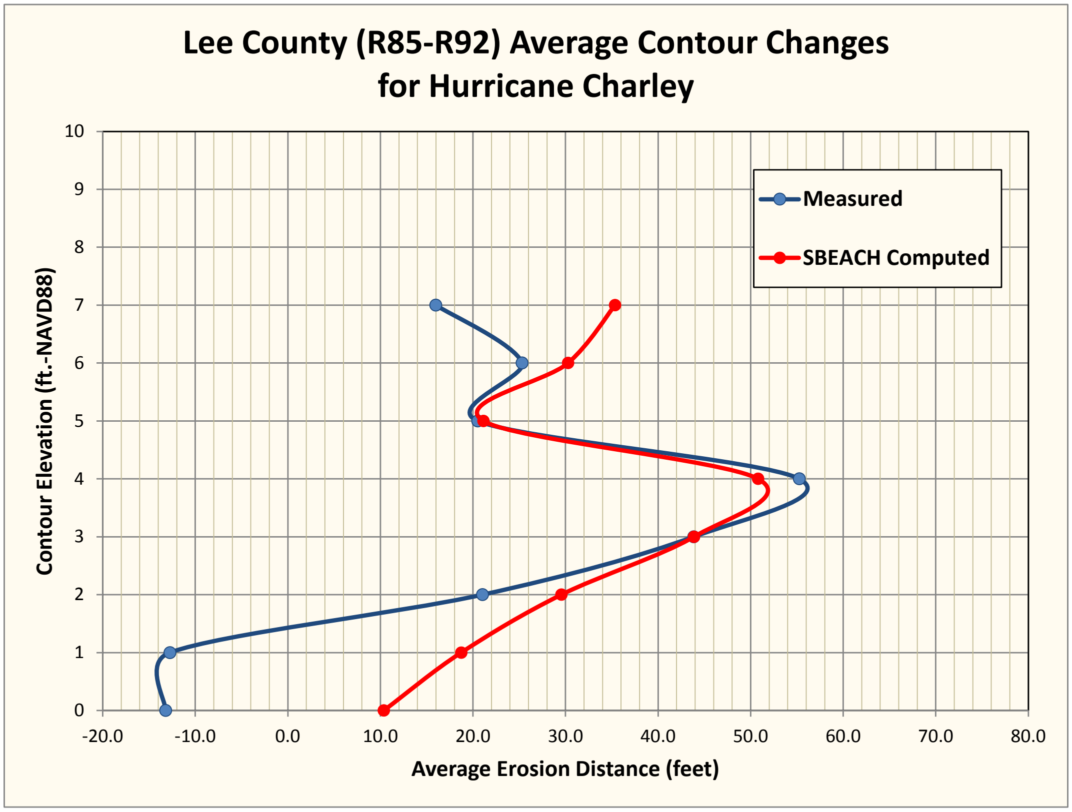

Figure 7: Comparisons of average contour changes between measured and SBEACH model computed for Hurricanes Charley.

3. Lee County SBEACH Application

3.1 Model Configuration

Application of the SBEACH model in Lee County for high-frequency storm erosion will be based on the model calibration results, as shown in Table 4 of the previous section, except for sediment size and wave height. Sediment data was obtained from the beach sediment survey in the Florida's southwest coast and Keys (Daniel et al, 2010). Figure 8 presents the mean grain size distribution throughout Lee County. The wave height of 15 ft. used in model calibration was considered above average for county wide application, since it was derived from the strong and yet narrow wind field of Hurricane Charley as shown in Figures 2 and 5. Therefore, it was determined to use a wave height of 10 ft., which was averaged from the wave heights applied in the other counties for a typical high frequency storm, as listed in Table 5. A change of the wave height and period combined with the adjustable input hydrograph will not affect the desired 15- and 25-year storm tide levels generated by SBEACH. Lee County storm tides developed by Wang (2012) for 15- and 25-year storms are shown in Table 6.

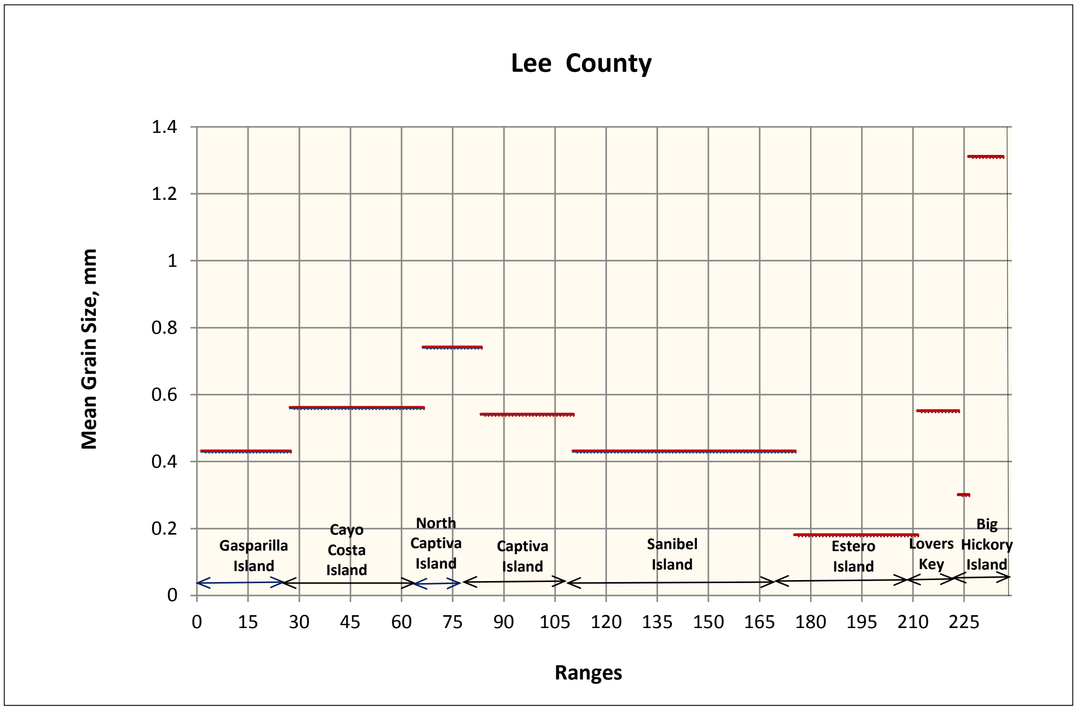

Figure 8: Sediment data distributions in Lee County.

Table 5 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 6 High-Frequency Storm Tides Level* (ft.-NAVD) for Lee County

Ranges	15-year Return Period	25-year Return Period
R-1 to R-26A	6.4	7.7
R-27 to R-82	6.5	7.8
R-83 to R-130	6.5	7.6
R-131 to R-174	7.3	8.6
R-175 to R-210	8.2	9.7
R-211 to R-239	7.3	8.8

* 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 C. Time series values for the adjusted hydrographs without wave setup for each reach are shown in Figures 9 and 10 and are tabulated in Appendix C.

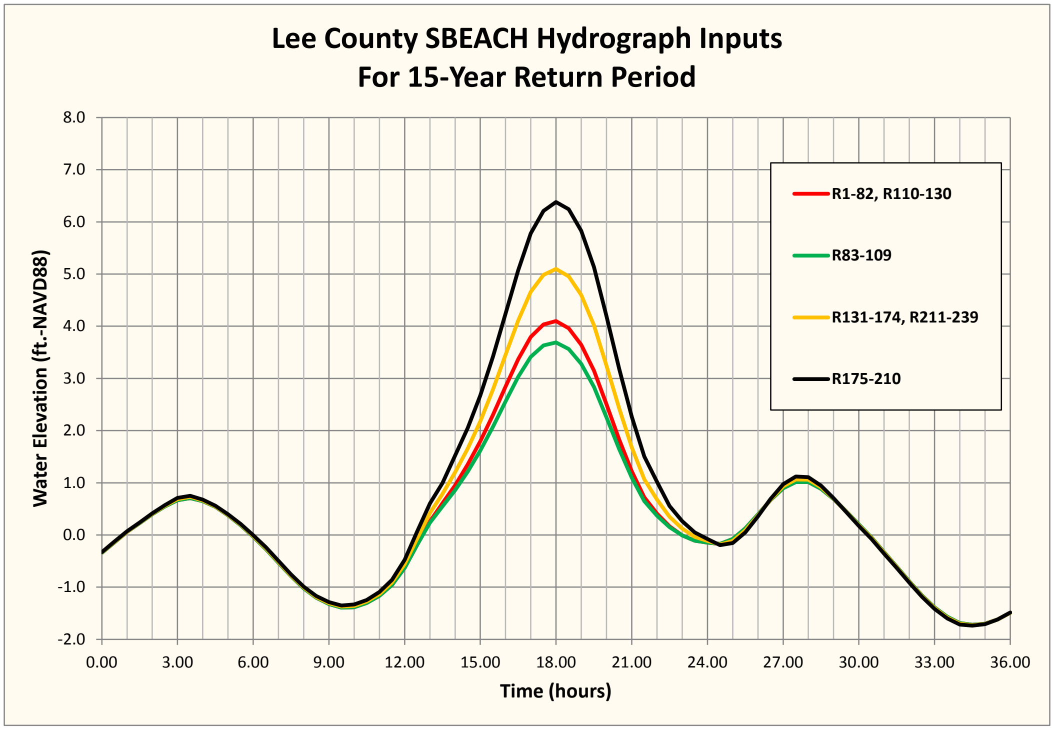

Figure 9: 15-year hydrographs for Lee County profiles in SBEACH application.

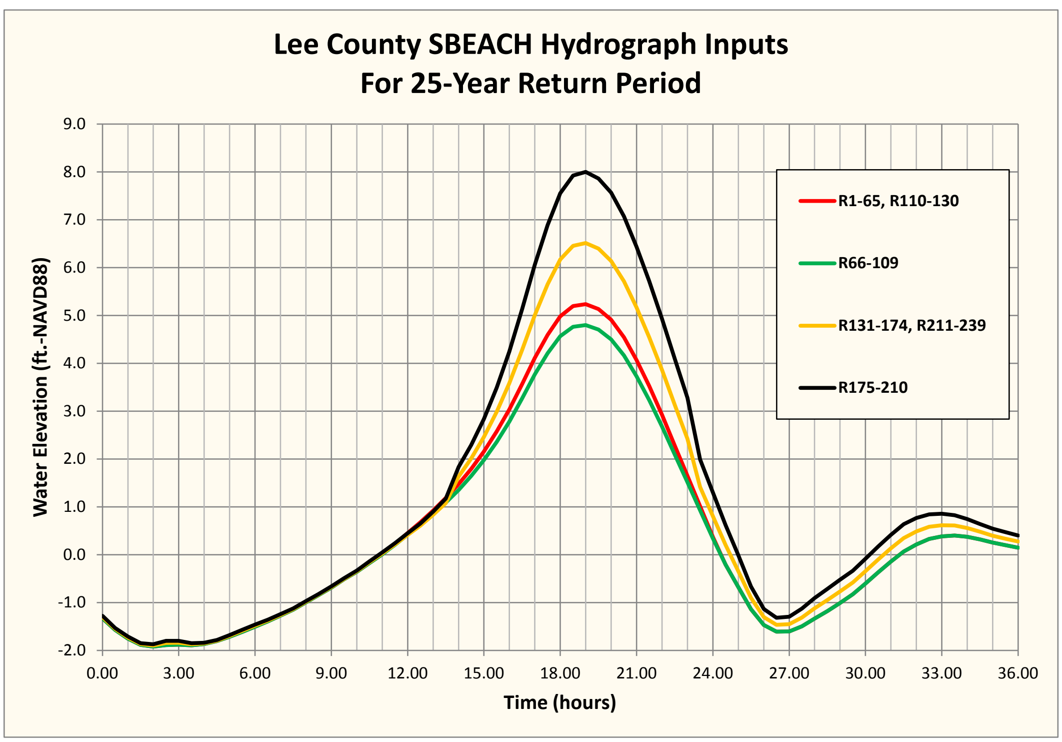

Figure 10: 25-year hydrographs for Lee County profiles in SBEACH application.

3.2 Model Application and Results

Plots of the surveyed profiles and their associated eroded profiles generated from SBEACH for the 15- and 25-year return periods for Lee County are provided in Appendix D. Profiles at R-26A to R-28 and R-82 to R-84 were not included due to the inlet configuration and SBEACH could not produce reasonable eroded profiles. Another 2 profiles at R-78 and R-222 were not considered due to insufficient upland data. The most updated profiles available for Lee County in SBEACH application are listed in Table 7.

Table 7 Profiles Used in SBEACH Application for Lee County

Range	Beach Profile Date	Offshore Profile Date
1-6	July 2009	April 2010
7-9	Aug. 2010	Aug. 2010
10-26	May 2013	May 2013
27-34	Aug. 2010	Aug. 2010
35-82	Oct. 2004	Oct. 2004
83-123	Aug. 2012	Aug. 2012
124-125	Oct. 2011	Oct. 2011
126	July 2009	April 2010
127	July 2009	Sep. 2005
128-156	July 2009	April 2010
157	July 2009	Sep. 2005
158-174	July 2009	April 2010
175-186	April 2013	April 2013
187-201	March 2010	March 2010
202-204	July 2009	April 2010
205-222	March 2010	March 2010
223-225	Nov. 2013	Nov. 2013
226-235	March 2010	March 2010
236-239	July 2009	April 2010

The plots in Appendix D are shown in the NAVD88 vertical datum. The map in Figure 11 below depicts the FDEP profile range locations along the Lee County shoreline.

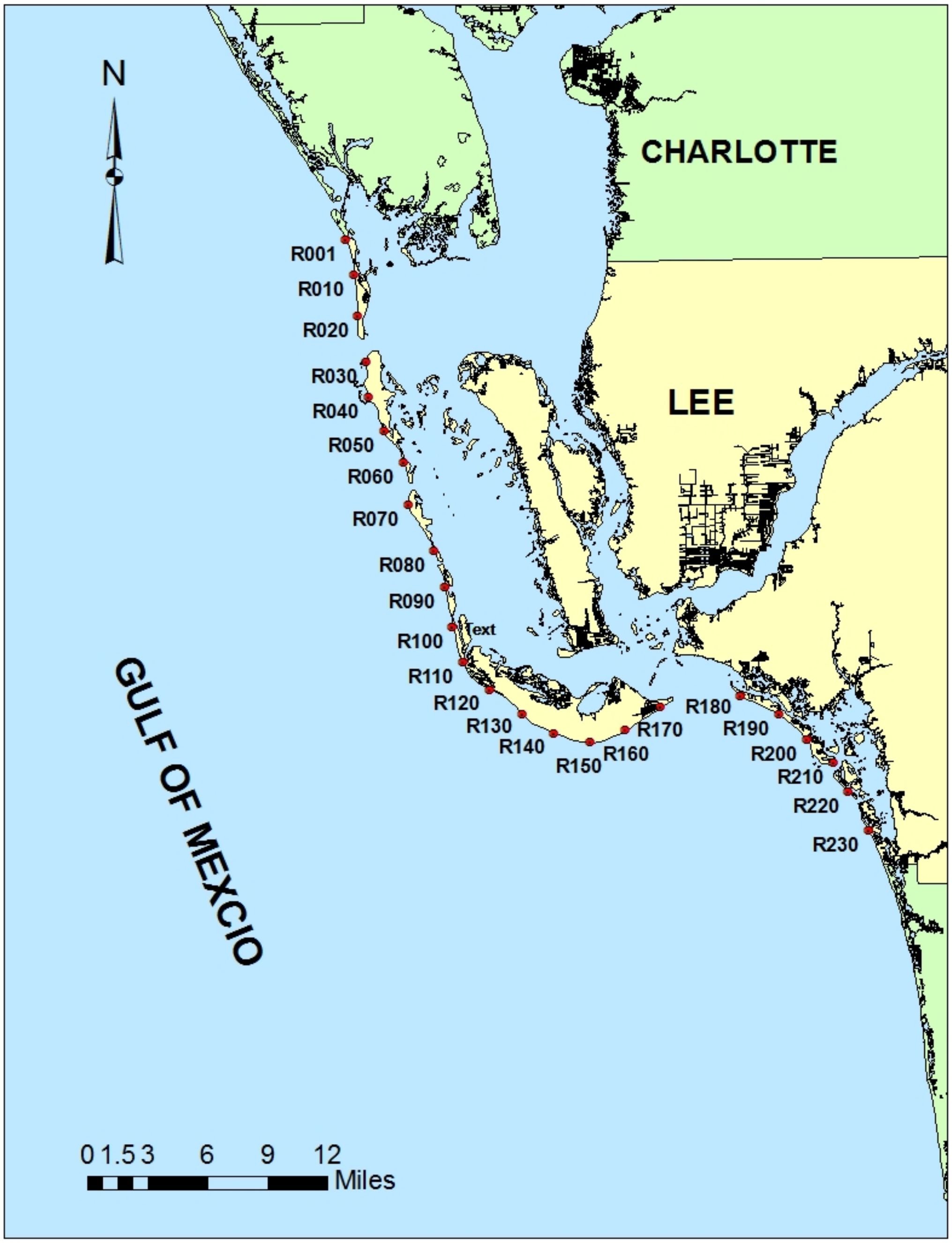

Figure 11: FDEP profile range locations along the Lee County shoreline.

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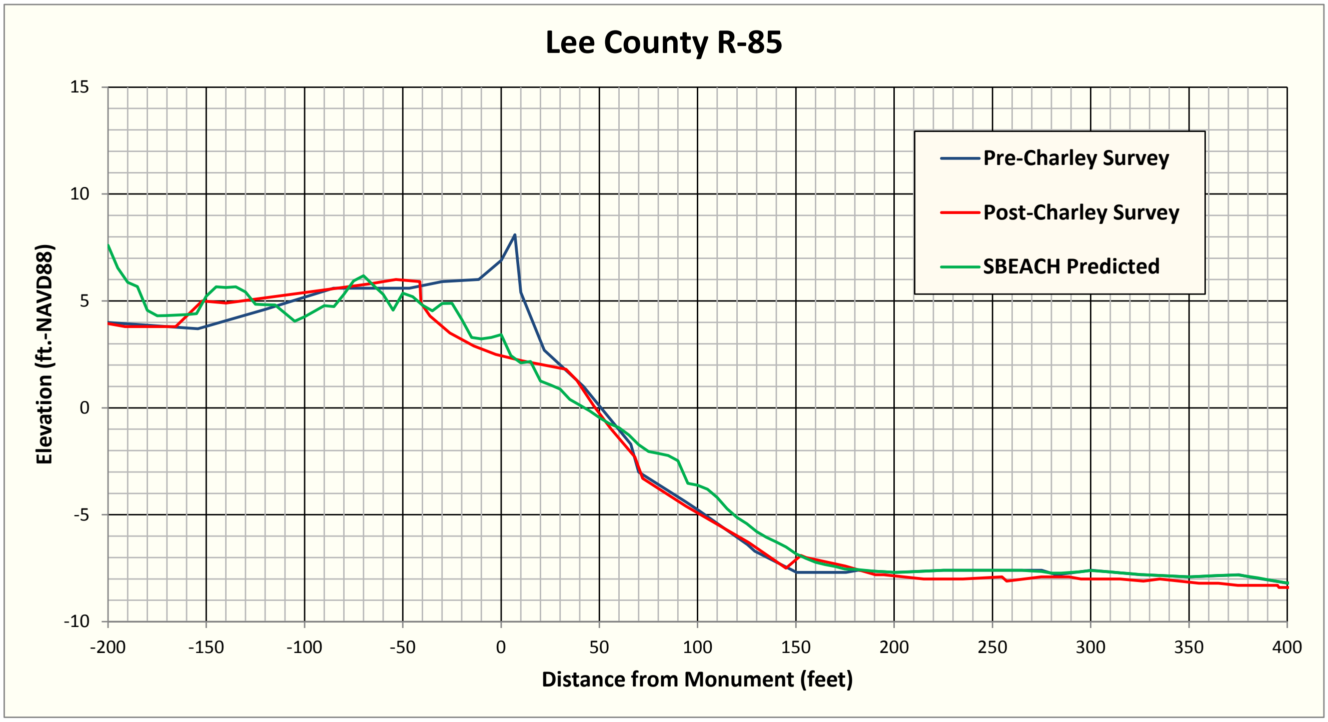
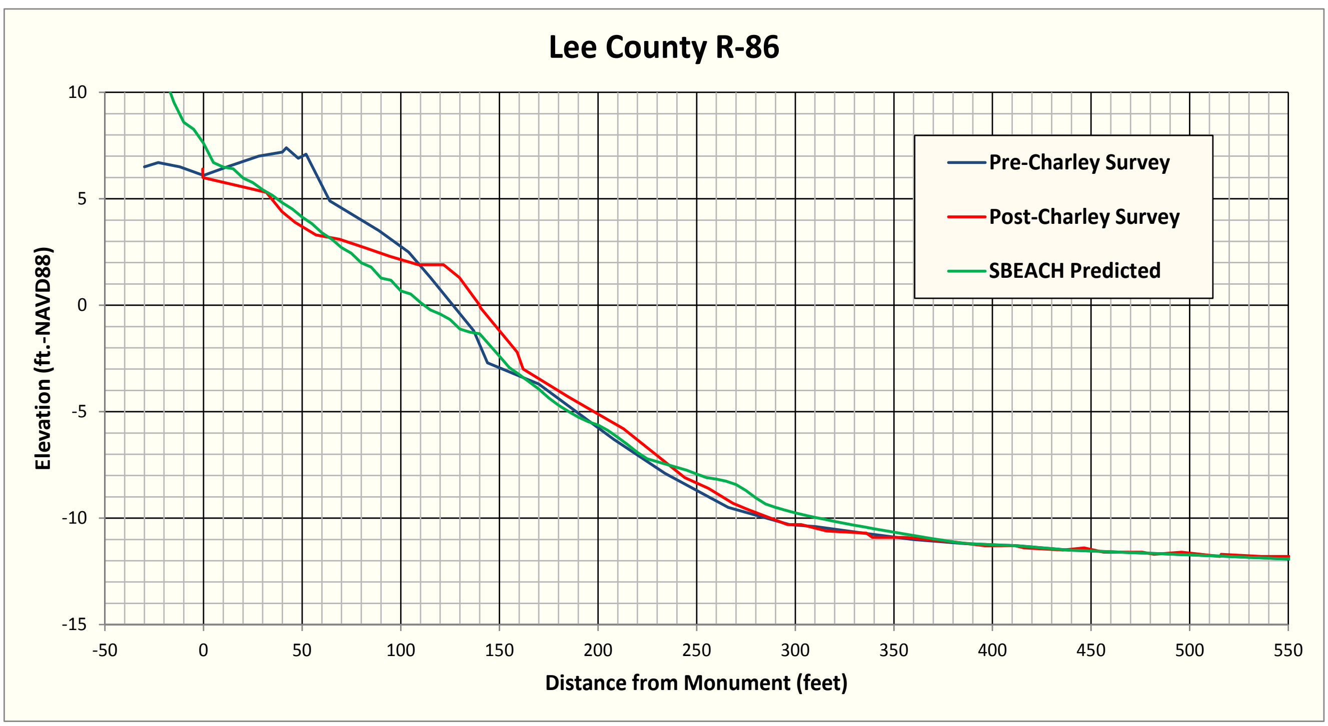
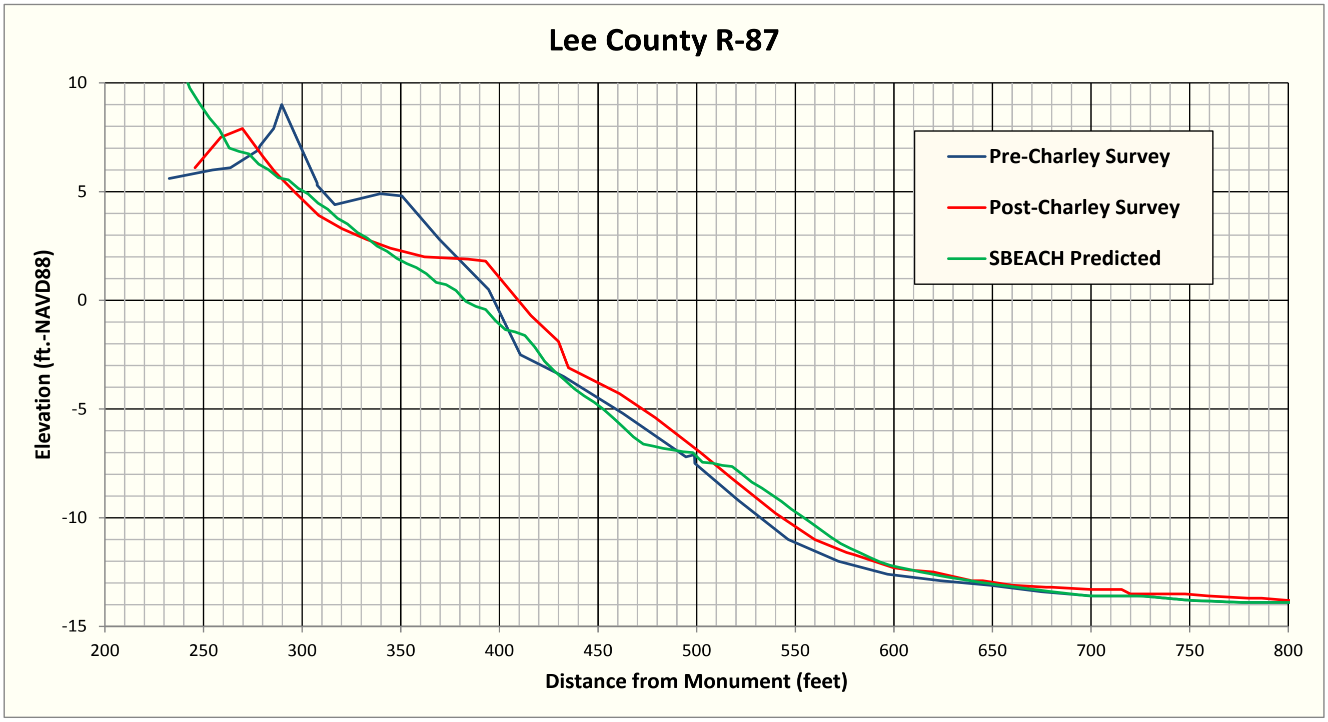
APPENDIX A

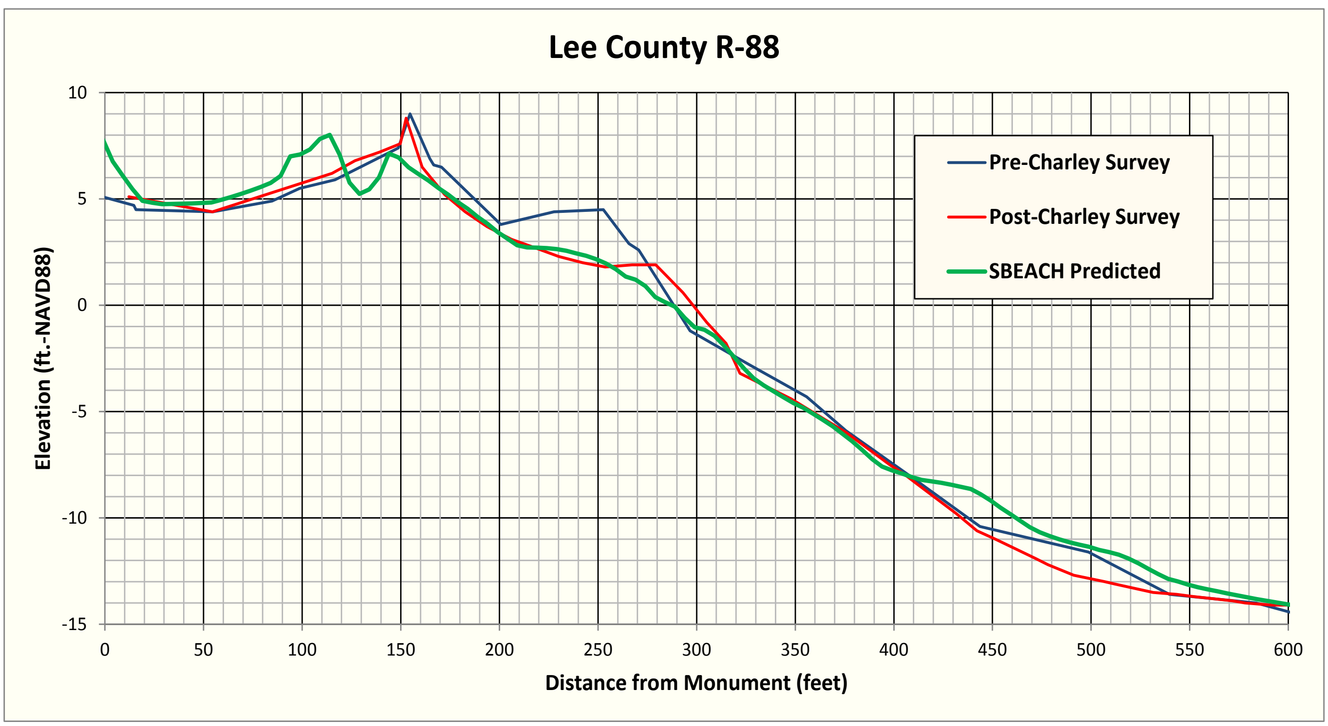
SBEACH Calibration Profiles for Lee County


Lee County R-85
15
10
5
0
-5
-10
Elevation (ft.-NAVD88)
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
Distance from Monument (feet)
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted

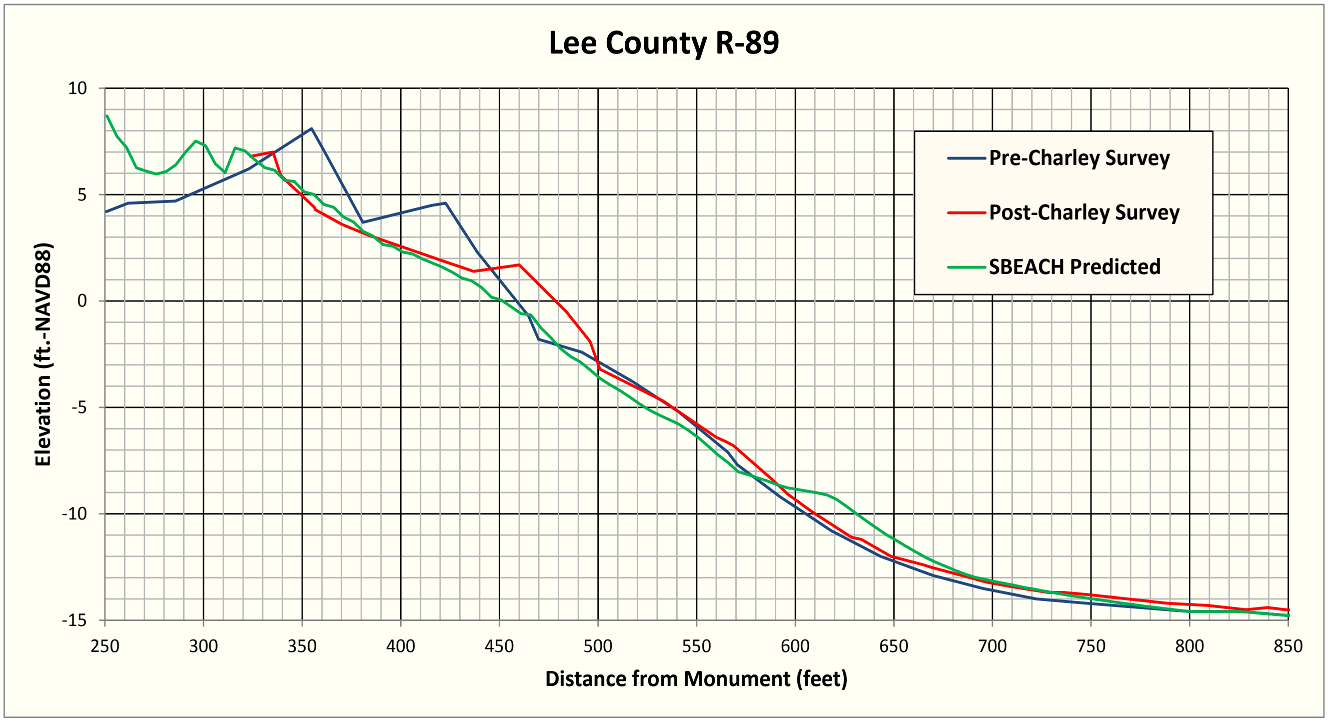

Lee County R-86
10
5
0
-5
-10
-15
Elevation (ft.-NAVD88)
-50
0
50
100
150
200
250
300
350
400
450
500
550
Distance from Monument (feet)
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted



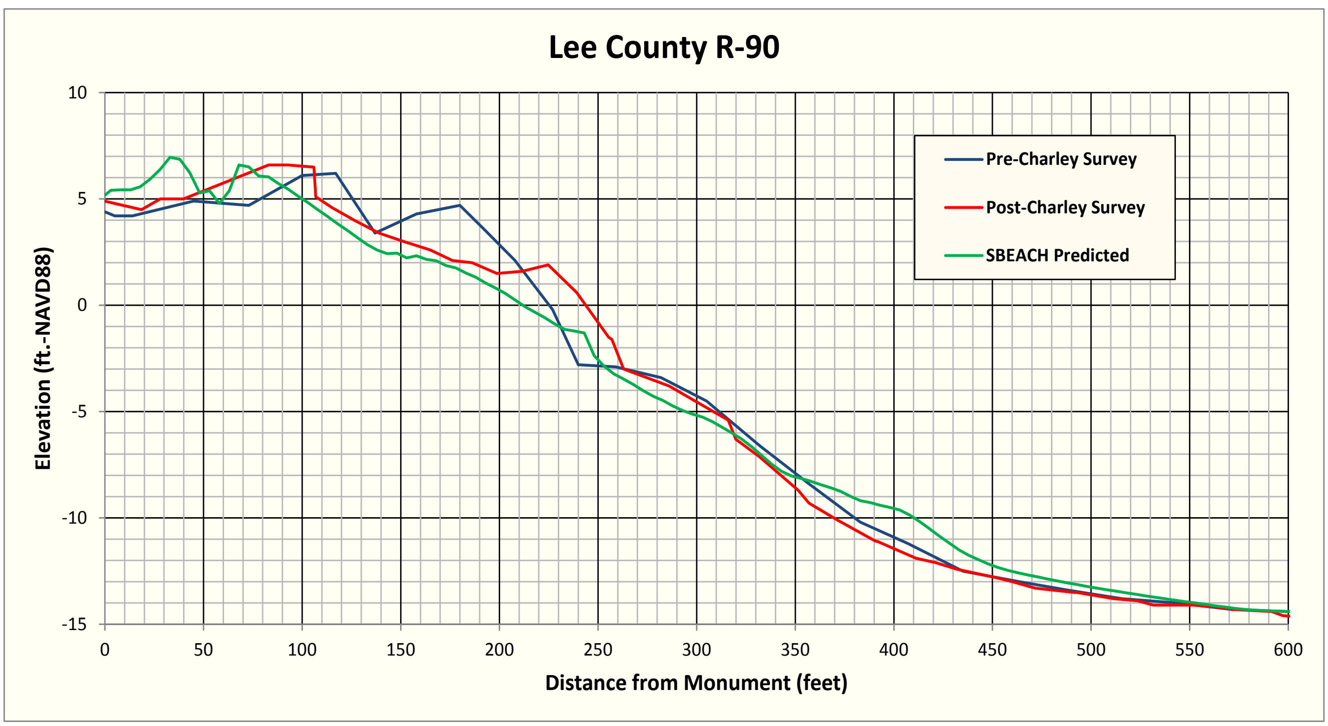
Lee County R-87
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
10
5
0
-5
-10
-15
200
250
300
350
400
450
500
550
600
650
700
750
800



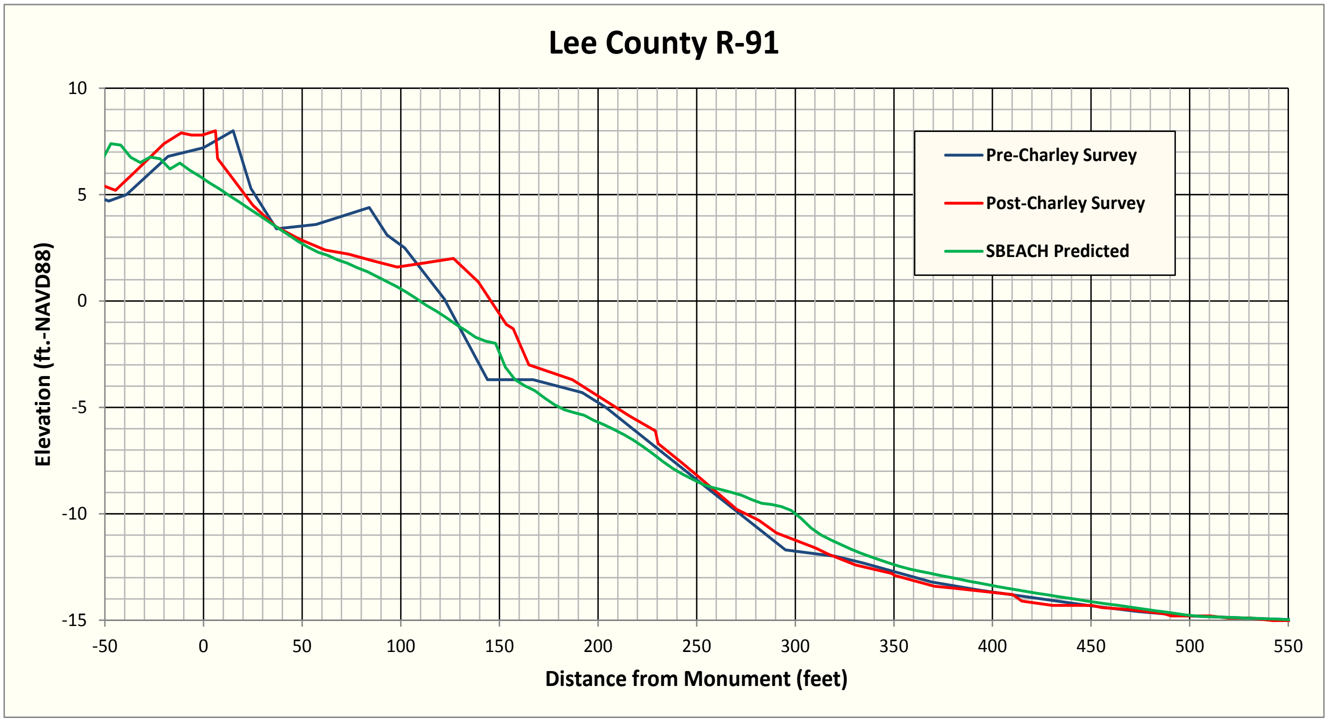
Lee County R-88
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600

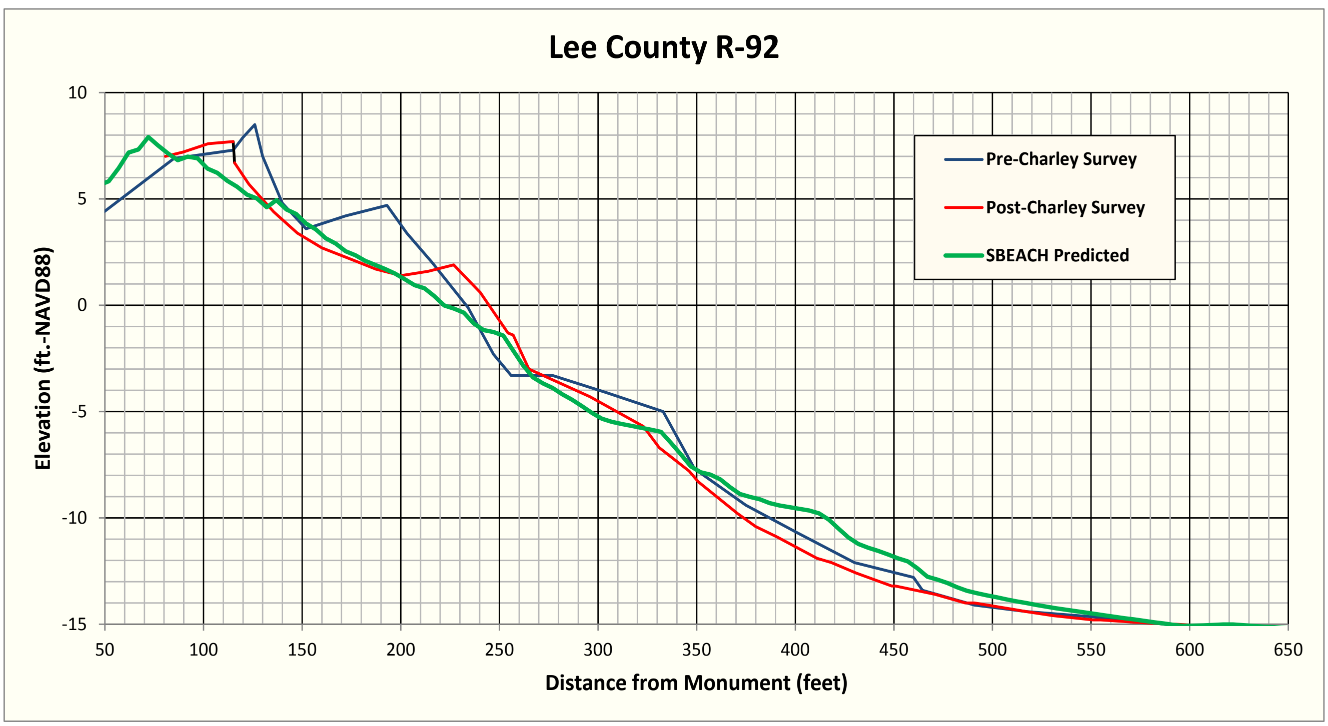


Lee County R-89
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-15
250
300
350
400
450
500
550
600
650
700
750
800
850
Distance from Monument (feet)



Lee County R-90
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
Elevation (ft.-NAVD88)
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400
450
500
550
600
Distance from Monument (feet)


Lee County R-91
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
-50
0
50
100
150
200
250
300
350
400
450
500
550


Lee County R-92
Pre-Charley Survey
Post-Charley Survey
SBEACH Predicted
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
-15
50
100
150
200
250
300
350
400
450
500
550
600
650

APPENDIX B

Recommended SBEACH Input Values

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

For all Storm Tide Hydrographs - Use BSRC-generated 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 28 deg. Grid cell width is 5 feet.

Range Segments	**R1 - R130**	**R131 - R174, R211 - R239**	**R175 - R210**
Transport Rate Coefficient, *K*	0.5 e^{-006}	0.5 e^{-006}	0.5 e^{-006}
Overwash Transport Parameter	0.002	0.002	0.002
Coefficient for Slope Dependent Term, ε	0.005	0.005	0.005
Transport Rate Decay Coeff. M ultiplier, λ	0.5	0.5	0.5
Landward Surf Zone Depth (ft.)	1.0	1.0	1.0
Maximum Slope Prior to Avalanching	15	15	15
Constant Wave Height (ft.)	10	10	10
Constant Wave Period (sec.)	10	10	10
Adjusted 15-year Hydrograph Peak Elevation (ft.)	6.5	7.3	8.2
Adjusted 25-year Hydrograph Peak Elevation (ft.)	7.7	8.7	9.7

Range	Mean Grain Size (mm)
1 - 26	0.43
27 - 65	0.56
66 - 82	0.74
83 -109	0.54
110 - 174	0.43
175 - 210	0.18
211 - 222	0.55
223 - 225	0.30
226 - 239	1.00

APPENDIX C

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

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

Time (hour)	R1 - R82, R110 - R130	R83 - R109	R131 - R174, R211 - R239	R175 - R210
0.00	-0.34	-0.34	-0.33	-0.33
0.50	-0.14	-0.14	-0.13	-0.13
1.00	0.06	0.06	0.07	0.07
1.50	0.23	0.23	0.23	0.24
2.00	0.40	0.40	0.41	0.41
2.50	0.55	0.55	0.56	0.57
3.00	0.67	0.67	0.69	0.71
3.50	0.71	0.71	0.73	0.75
4.00	0.65	0.65	0.66	0.68
4.50	0.54	0.54	0.55	0.56
5.00	0.38	0.38	0.39	0.40
5.50	0.19	0.19	0.20	0.21
6.00	-0.03	-0.03	-0.02	0.00
6.50	-0.27	-0.27	-0.25	-0.24
7.00	-0.53	-0.53	-0.51	-0.50
7.50	-0.79	-0.79	-0.78	-0.76
8.00	-1.02	-1.02	-1.01	-0.99
8.50	-1.20	-1.20	-1.19	-1.17
9.00	-1.32	-1.32	-1.30	-1.29
9.50	-1.39	-1.39	-1.37	-1.35
10.00	-1.38	-1.38	-1.36	-1.33
10.50	-1.30	-1.30	-1.28	-1.24
11.00	-1.16	-1.16	-1.13	-1.09
11.50	-0.96	-0.96	-0.91	-0.86
12.00	-0.63	-0.63	-0.56	-0.47
12.50	-0.19	-0.19	-0.06	0.07
13.00	0.26	0.23	0.42	0.61
13.50	0.61	0.55	0.79	0.99
14.00	0.95	0.86	1.20	1.53
14.50	1.35	1.21	1.66	2.05
15.00	1.79	1.61	2.17	2.67
15.50	2.30	2.07	2.79	3.42
16.00	2.84	2.56	3.45	4.24
16.50	3.37	3.03	4.11	5.07
17.00	3.79	3.41	4.66	5.78
17.50	4.04	3.63	4.98	6.21
18.00	4.10	3.69	5.10	6.38
18.50	3.96	3.56	4.96	6.24
19.00	3.64	3.28	4.60	5.83
19.50	3.15	2.84	4.02	5.14

Time (hour)	**R1 - R82, R110 - R130**	**R83 - R109**	**R131 - R174, R211 - R239**	**R175 - R210**
20.00	2.50	2.25	3.24	4.19
20.50	1.83	1.64	2.42	3.18
21.00	1.22	1.10	1.68	2.27
21.50	0.72	0.65	1.07	1.51
22.00	0.41	0.37	0.68	1.02
22.50	0.17	0.15	0.35	0.55
23.00	-0.01	-0.01	0.12	0.26
23.50	-0.11	-0.11	-0.03	0.05
24.00	-0.14	-0.14	-0.11	-0.08
24.50	-0.17	-0.17	-0.18	-0.20
25.00	-0.08	-0.08	-0.11	-0.15
25.50	0.12	0.12	0.09	0.05
26.00	0.39	0.39	0.37	0.36
26.50	0.67	0.67	0.68	0.69
27.00	0.90	0.90	0.93	0.97
27.50	1.01	1.01	1.06	1.12
28.00	1.01	1.01	1.06	1.11
28.50	0.89	0.89	0.91	0.95
29.00	0.69	0.69	0.70	0.71
29.50	0.45	0.45	0.44	0.44
30.00	0.20	0.20	0.19	0.17
30.50	-0.05	-0.05	-0.06	-0.08
31.00	-0.33	-0.33	-0.34	-0.36
31.50	-0.61	-0.61	-0.62	-0.63
32.00	-0.89	-0.89	-0.90	-0.91
32.50	-1.16	-1.16	-1.17	-1.19
33.00	-1.39	-1.39	-1.40	-1.42
33.50	-1.57	-1.57	-1.58	-1.60
34.00	-1.69	-1.69	-1.70	-1.72
34.50	-1.72	-1.72	-1.73	-1.74
35.00	-1.70	-1.70	-1.70	-1.71
35.50	-1.62	-1.62	-1.62	-1.62
36.00	-1.49	-1.49	-1.49	-1.49

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

Time (hour)	R1 - R65, R110 - R130	R66 - R109	R131 - R174, R211 - R239	R175 - R210
0.00	-1.33	-1.33	-1.31	-1.28
0.50	-1.57	-1.57	-1.55	-1.53
1.00	-1.75	-1.75	-1.73	-1.71
1.50	-1.88	-1.88	-1.87	-1.85
2.00	-1.92	-1.92	-1.90	-1.87
2.50	-1.89	-1.89	-1.84	-1.80
3.00	-1.88	-1.88	-1.84	-1.80
3.50	-1.89	-1.89	-1.87	-1.85
4.00	-1.87	-1.87	-1.85	-1.84
4.50	-1.81	-1.81	-1.79	-1.78
5.00	-1.71	-1.71	-1.70	-1.68
5.50	-1.61	-1.61	-1.59	-1.57
6.00	-1.50	-1.50	-1.48	-1.46
6.50	-1.39	-1.39	-1.38	-1.36
7.00	-1.27	-1.27	-1.26	-1.24
7.50	-1.15	-1.15	-1.13	-1.12
8.00	-1.00	-1.00	-0.98	-0.97
8.50	-0.85	-0.85	-0.83	-0.82
9.00	-0.69	-0.69	-0.67	-0.66
9.50	-0.52	-0.52	-0.50	-0.49
10.00	-0.36	-0.36	-0.34	-0.33
10.50	-0.17	-0.17	-0.16	-0.14
11.00	0.01	0.01	0.03	0.05
11.50	0.23	0.21	0.21	0.24
12.00	0.46	0.42	0.42	0.45
12.50	0.68	0.62	0.61	0.65
13.00	0.92	0.85	0.84	0.90
13.50	1.19	1.09	1.08	1.17
14.00	1.48	1.35	1.63	1.84
14.50	1.79	1.64	2.01	2.29
15.00	2.16	1.98	2.46	2.84
15.50	2.57	2.36	2.99	3.49
16.00	3.03	2.78	3.58	4.24
16.50	3.57	3.27	4.28	5.13
17.00	4.11	3.77	5.01	6.06
17.50	4.59	4.21	5.65	6.89
18.00	4.98	4.56	6.17	7.55
18.50	5.19	4.76	6.45	7.92
19.00	5.23	4.80	6.51	8.00
19.50	5.13	4.71	6.39	7.86

Time (hour)	R1 - R65, R110 - R130	R66 - R109	R131 - R174, R211 - R239	R175 - R210
20.00	4.91	4.50	6.14	7.57
20.50	4.54	4.16	5.71	7.07
21.00	4.06	3.73	5.16	6.43
21.50	3.52	3.23	4.55	5.72
22.00	2.92	2.68	3.86	4.93
22.50	2.29	2.10	3.14	4.10
23.00	1.65	1.51	2.42	3.28
23.50	1.01	0.93	1.41	1.99
24.00	0.37	0.34	0.80	1.30
24.50	-0.21	-0.21	0.20	0.62
25.00	-0.68	-0.68	-0.35	-0.01
25.50	-1.14	-1.14	-0.90	-0.67
26.00	-1.47	-1.47	-1.30	-1.14
26.50	-1.61	-1.61	-1.46	-1.32
27.00	-1.60	-1.60	-1.45	-1.30
27.50	-1.49	-1.49	-1.31	-1.13
28.00	-1.34	-1.34	-1.12	-0.91
28.50	-1.18	-1.18	-0.95	-0.72
29.00	-1.01	-1.01	-0.77	-0.53
29.50	-0.83	-0.83	-0.58	-0.33
30.00	-0.60	-0.60	-0.34	-0.08
30.50	-0.37	-0.37	-0.10	0.18
31.00	-0.15	-0.15	0.13	0.42
31.50	0.07	0.07	0.35	0.64
32.00	0.21	0.21	0.49	0.77
32.50	0.33	0.33	0.59	0.85
33.00	0.38	0.38	0.62	0.85
33.50	0.40	0.40	0.61	0.82
34.00	0.38	0.38	0.56	0.74
34.50	0.32	0.32	0.48	0.64
35.00	0.25	0.25	0.40	0.54
35.50	0.20	0.20	0.34	0.47
36.00	0.15	0.15	0.27	0.40