SBEACH High-Frequency Storm Erosion Model Study for Palm Beach County

Final Report

by

S. Y. Wang and M. Manausa

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Table of Contents

List of Figures

List of Tables

1. **Background**

High-Frequency storm tide studies have been conducted by the Beaches and Shores Resource Center (BSRC) for 14 of the 24 CCCL studied counties since 2009. Hydrographs with return intervals of 15 and 25 years were developed for the application of dune erosion models and are available through the FDEP website at: http://www.dep.state.fl.us/beaches/publications/tech-rpt.htm 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) has contracted with the BSRC to conduct the model calibration and application on a county by county basis. At present, SBEACH model studies have been completed for seven counties: Walton , Okaloosa, Brevard, St. Johns, Volusia and Indian River by Leadon and Nguyen (2009 and 2010), and Sarasota by Wang and Manausa (2013). As a result, the SBEACH model for high-frequency storm event is currently 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, 1991; Larson, Kraus and Brynes 1990).

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 Palm Beach 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 Palm Beach 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 parts of Palm Beach County were surveyed before and after Hurricane Frances of 2004 and Hurricane Katrina 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 Palm Beach County are listed in Table 1. Hurricanes Frances of 2004 and Katrina of 2005 (highlighted) are the only storms among these 35 storms with some pre- and post-storm surveys for calibration purposes. The BSRC 2-D Storm Surge Model generated storm tide hydrographs which were then used as part of SBEACH inputs for each storm.

Table 1 Summary of Historical Storms Affecting Palm Beach County

No.	Date	Name	Type*
1	8/2/1901		L
2	9/9/1903		L
3	10/8/1906		E
4	6/26/1909		L
5	8/28/1909		L
6	9/24/1909		E
7	10/14/1924		E
8	7/22/1926		L
9	8/3/1928		L
10	9/6/1928		L
11	8/31/1933		L
12	8/7/1939		L
13	10/31/1946		L
14	9/4/1947		L
15	10/9/1947		E
16	9/18/1948		E
17	8/23/1949		L
18	2/2/1952		E
19	8/28/1953		E
20	10/17/1959	JUDITH	E
21	8/20/1964	CLEO	L
22	10/8/1964	ISBELL	E
23	10/4/1974		A
24	8/25/1979	DAVID	L
25	9/25/1984	ISIDORE	L
26	8/21/1988	CHRIS	A
27	8/22/1995	JERRY	L
28	10/22/1998	MITCH	E
29	9/19/1999	HARVEY	E
30	10/12/1999	IRENE	E
31	8/25/2004	FRANCES	L
32	9/2/2004	IVAN	L
33	9/13/2004	JEANNE	L
34	8/23/2005	KATRINA	L
35	10/15/2005	WILMA	E

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

On September 1st, Hurricane Frances passed through the Turks and Calicos Islands and advanced into the Bahamas with maximum winds near 140 mph. Frances weakened for the next two days as it passed over the central Bahama Islands on 2-3 September with winds of 115 – 125 mph (Category 3). It weakened to a Category 2 hurricane with winds of 98 - 104 mph when it passed over the northwestern Bahamas on 3 - 4 September. Frances made landfall over the southern end of Hutchinson Island, Florida at 0430 UTC, 5 September, as a Category 2 hurricane with winds of 104 mph.

Frances gradually weakened as it slowly moved west-northwestward across the Florida Peninsula, becoming a tropical storm just before emerging into the northeastern Gulf of Mexico near New Port Richey early on 6 September. Frances did not strengthen over the Gulf, with maximum sustained winds remaining at 58 – 63 mph with a pressure near 982 mb. It moved northwestward and made a final landfall east of the St. Marks River at 1800 UTC, 6 September (Beven II, 2004).

Almost one year after Frances, Katrina made its first landfall in the United States as a Category 1 hurricane, with maximum sustained winds of 70 knots, near the border of Miami-Dade County and Broward County at approximately 2230 UTC 25 August. The convective pattern of Katrina as it crossed southern Florida was rather asymmetric due to northerly wind shear, which placed the strongest winds and heaviest rains south and east of the center in Miami-Dade County. Katrina continued west-southwestward overnight and spent only about six hours over land, mostly over the water-laden Everglades.

Once back over water, Katrina quickly regained hurricane status at 0600 UTC with maximum sustained winds of 65 knots. Katrina embarked upon two periods of rapid intensification between 26 and 28 August. Katrina strengthened from a low-end Category 3 hurricane to a Category 5 in less than 12 h, reaching an intensity of 145 kt by 1200 UTC 28 August. Katrina attained its peak intensity of 150 kt at 1800 UTC 28 August about 170 n mi southeast of the mouth of the Mississippi River.

Katrina turned northward, toward the northern Gulf coast, around the ridge over Florida early on 29 August. The hurricane then made landfall, at the upper end of Category 3 intensity with estimated maximum sustained winds of 110 kt, near Buras, Louisiana at 1110 UTC 29 August. Katrina continued northward and made its final landfall near the mouth of the Pearl River at the Louisiana/Mississippi border, still as a Category 3 hurricane with an estimated intensity of 105 kt (Knabb, et al, 2005). Storm tracks plotted with data from the National Hurricane Center is shown in Figure 1 for both hurricanes.

2.1.a Storm Tide Data for Hurricane Frances

For the purpose of model calibration, the measured storm tide and wave data generated by Hurricanes Frances are essential. Measured water elevation data was available from a National Ocean Service (NOS) tide gage located at Lake Worth Pier, Palm Beach County. Two qualified High Water Marks (HWM) were surveyed by FEMA (2005) in the north Palm Beach County area.

The BSRC 2-D Storm Surge Model has been verified throughout the CCCL studies and various storm events and has been proven to be an accurate and reliable model (Dean, Chiu and

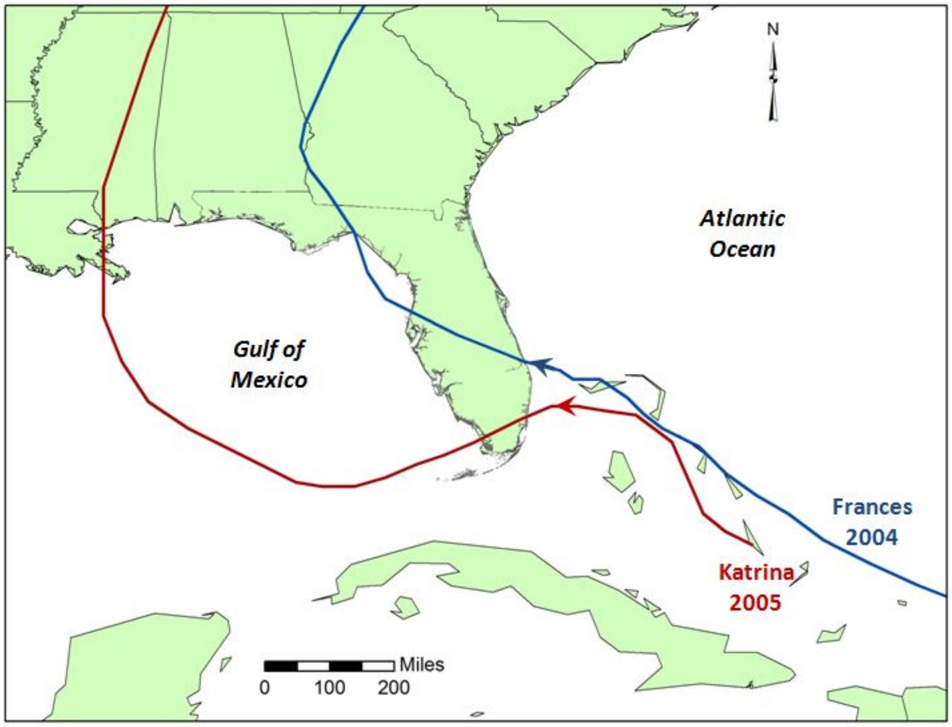

Figure 1: Hurricane Tracks in the study area

Wang, 1988). The 2-D Storm Surge Model was run using Palm Beach County bathymetry data and Hurricane Frances storm data to generate six storm tides in Palm Beach County (Figure 2). The Lake Worth Pier tide gage (8722670) is located about 750 feet offshore at a water depth of 13 ft. (NAVD), the water level with only partial or no wave setup was recorded during Frances. A method developed by Dean (1996) which was used to calculate the wave setup due to wave break at the Panama City Beach for Hurricane Opal was similarly applied to the Lake Worth Pier, with a resultant peak storm tide of 6.3 feet. The 2-D Storm Surge Model demonstrated its accuracy in storm tide calculations, therefore the 2-D grid systems and associated hydrological data of Palm Beach County from the CCCL study were used to generate storm tide data from Hurricane Frances in the north Boca Raton area, where the pre- and post- Frances survey profiles were available. Hurricane track, pressure deficit, and radius to the maximum wind of Frances 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 the six profile locations to be used for calibration (Figure 6).

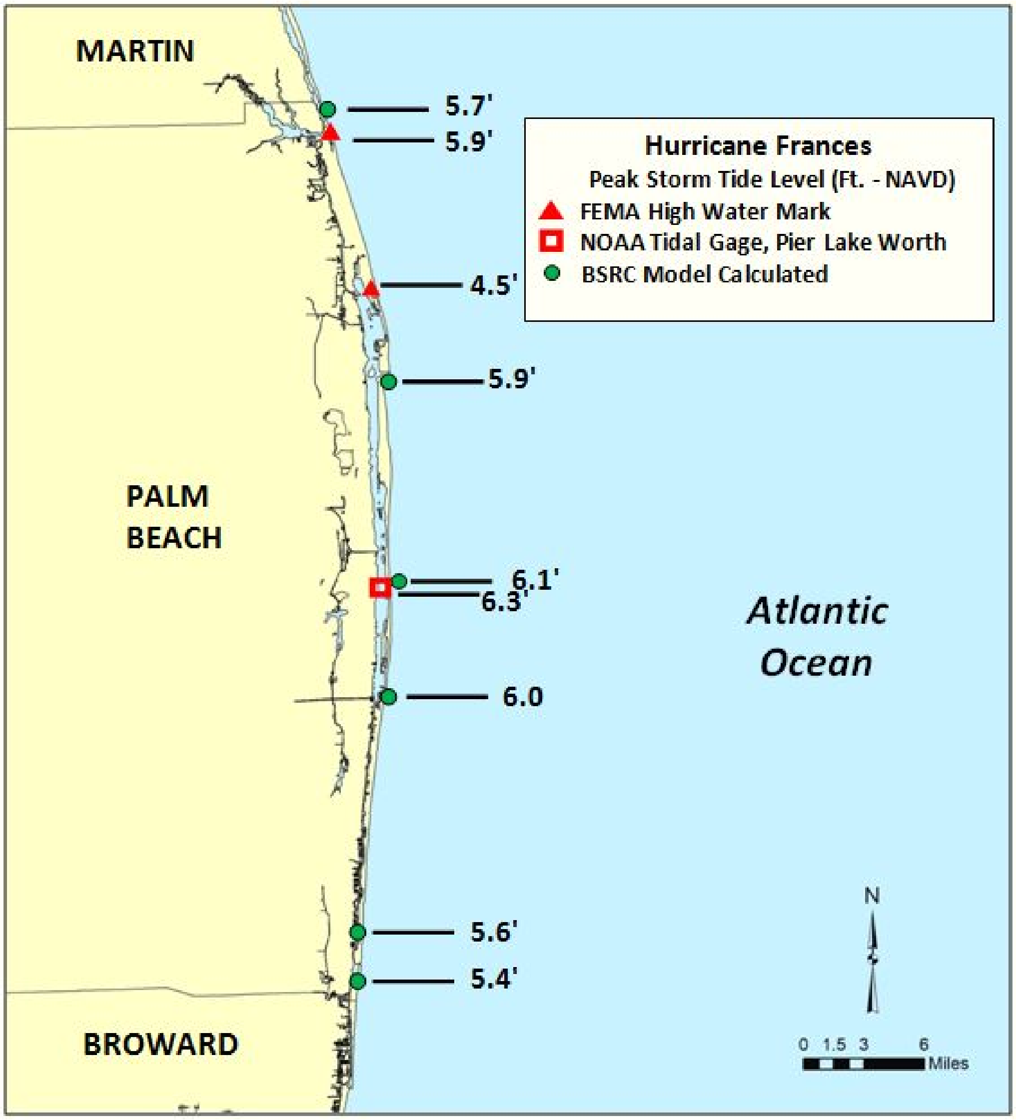

Figure 2: Peak storm tide level along the shoreline for Hurricane Frances

2.1.b Storm Tide Data for Hurricane Katrina

The only available measured water elevation data during Hurricane Katrina near Palm Beach County area was from the National Ocean Service (NOS) tide gage located at Virginia Key, Dade County. The 2-D Storm Surge Model was run using Hurricane Katrina storm data to generate a storm tide for Virginia Key. Figure 3 shows the comparison between model calculated and measured storm tides. The model calculated storm tide generally agreed well with the measured one. The 2-D grid systems and associated hydrological data of Palm Beach County from the CCCL study were used to generate storm tide data from Hurricane Katrina for the four profile locations near the south end of Palm Beach County (Figure 6).

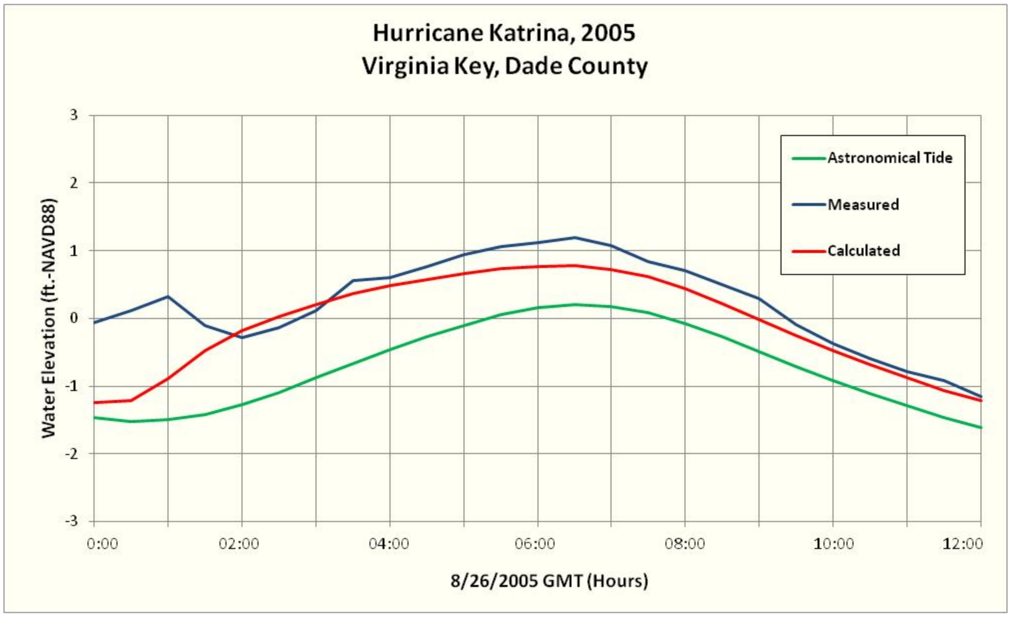

Figure 3: Comparison between measured and calculated storm tides in Virginia Key

2.1.c Wind and Wave Data for Hurricanes Frances

No wave data was recorded near the study area during Hurricane Frances in 2004. WIS stations from 63457 through 63464 which are 12 miles offshore of Palm Beach County, only provided hindcast wave data from 1980 to 1999. The Lake Worth Pier tide gage (8722670) did not record wave data during Hurricane Frances. However, the wind speed and direction data were available from the National Hurricane Center (Beven II, 2004). The significant deep water wave height, H_s, and dominant period, T_p can be calculated 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 4 shows the resulting wave data generated by applying the measured wind speed to these equations for Hurricane Frances in 2004.

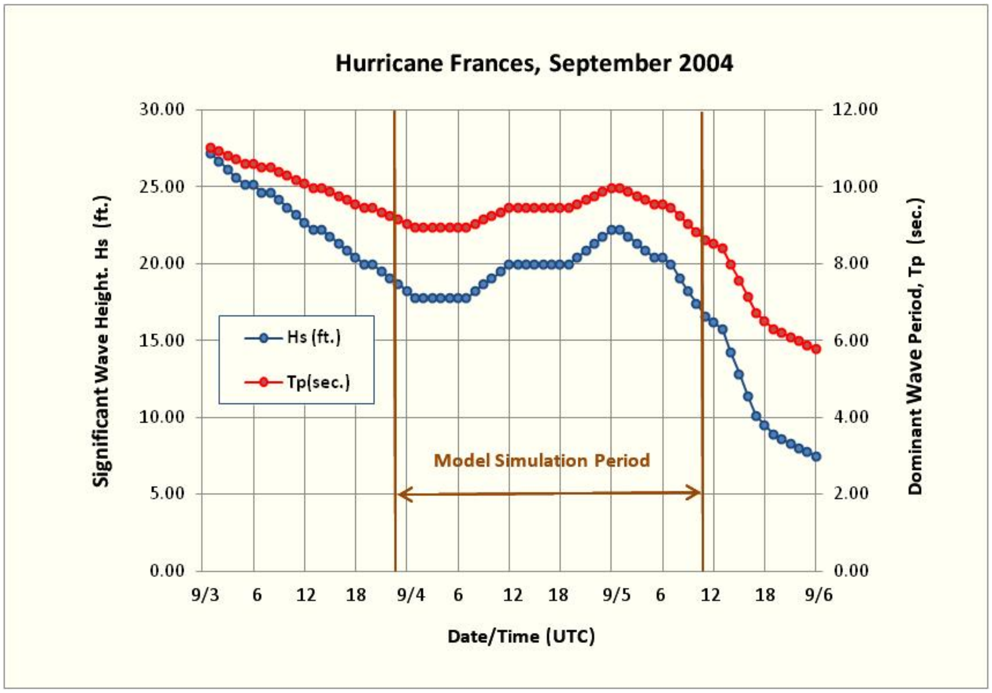

Figure 4: Best estimated wave conditions for Hurricane Frances, 2004

2.1.d Wind and Wave Data for Hurricanes Katrina

No wave data was recorded in the study area during Hurricane Katrina in 2005. WIS stations 63467 through 63472 which are 12 miles offshore of Broward County, only provided hindcast wave data from 1980 to 1999. The Virginia Key tide gage (8723214) did not record wave data during Hurricane Katrina. However, by applying the wind speed and direction data from the National Hurricane Center (Knabb, et al, 2005), the significant deep water wave height, H_s, and dominant period, T_p can be calculated by empirical equations as shown in the previous section for Hurricane Katrina. Figure 5 shows the resulting wave data by applying wind speed to these equations for Hurricane Katrina in 2005.

2.1.e Hydrographic Survey Data for Hurricane Frances

Coastal Planning & Engineering, Inc. (CPE) was contracted by the City of Boca Raton to provide a Post-Frances survey in September 2004 for the Central Boca Raton Beach Nourishment Project (CPE, 2005). Data for the beach profile and hydrographic surveys are available through the FDEP website (Reference 4). The Central Boca Raton Beach Nourishment Project started in February and ended in March 2004. A total of 0.7 million cubic yards of sand were put on the 1.5 miles of beach from R-216 to R-222. Shoreline change analysis before and after Frances for the beach nourishment project area showed an average of 82 foot recession in less than six months post nourishment (Reference 3). The unusually large recession was due to the freshly nourished beach having received no chance for stabilization before erosion was caused by Hurricanes Frances.

Therefore, the Central Boca Raton Beach profiles could not be used for SBEACH model calibration.

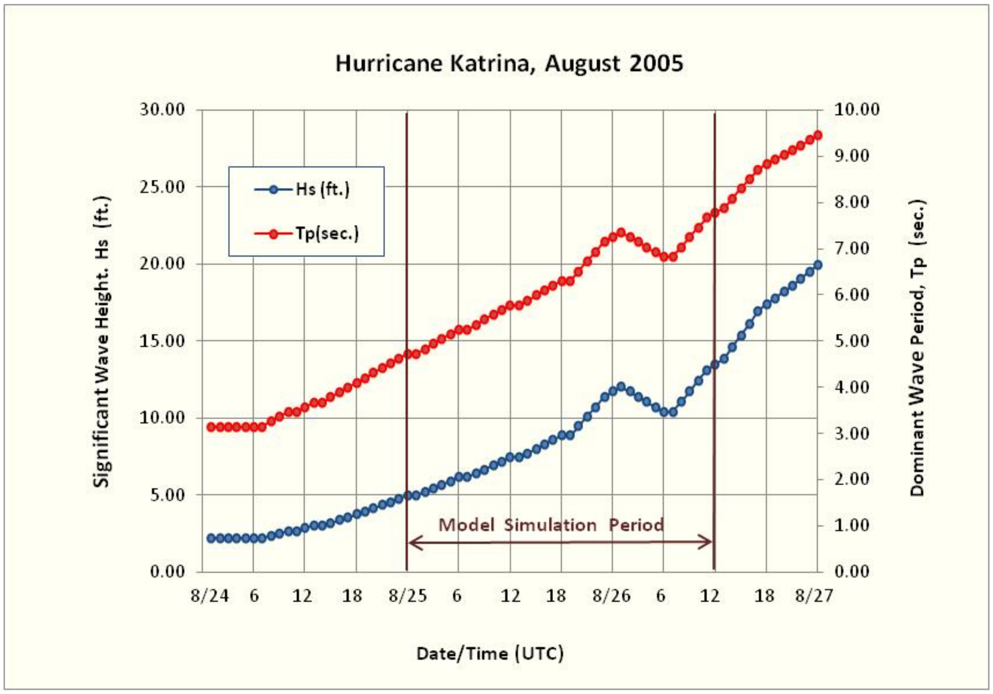

Figure 5: Best estimated wave conditions for Hurricane Katrina, 2005

In addition to the Central Boca Raton Beach Nourishment Project area, CPE also surveyed the north and south portions of Boca Raton from R-204 to R-215, and R-223 to R-227, respectively. After a visual inspection, R-204 to R-209 were selected as pre-storm (April 2004) and post-storm (September 2004) profiles for model calibration, because these profiles seem to show no effects of recent beach fill activities. 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 is also indicated relative to the profile locations.

2.1.f Hydrographic Survey Data for Hurricane Katrina

CPE conducted Pre-and Post-Katrina surveys in May 2005 and February 2006, respectively. Data for the beach profile and hydrographic surveys are available through FDEP website (Reference 3). From February to March 2006, 0.36 million cubic yards of sand were put on the Central Boca Raton Beach from R-216 to R-222 to replace the beach sand lost during the 2004 and 2005 hurricane seasons. For the same reason as addressed in the previous section for Hurricane Frances, the Central Boca Raton Beach profiles were not considered as good candidates for SBEACH model calibration.

The four profiles, R-224 to R-227, located at the southern boundary of Palm Beach County apparently were not affected by the beach fill activities, were therefore selected as pre-storm (May

2005) and post-storm (February 2006) profiles for model calibration. The map in Figure 6 shows the location of the profiles selected for model calibration. The storm tide calculated with the 2-D storm surge model are also indicated relative to the profile locations.

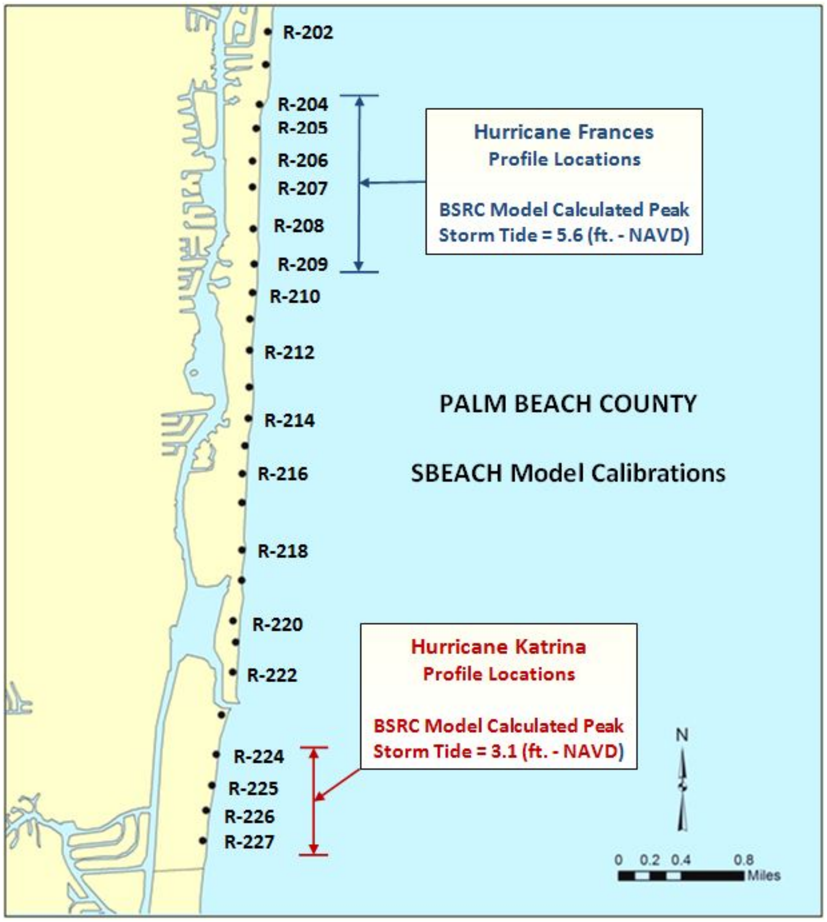

Figure 6: Locations of profiles and storm tides used in SBEACH calibrations

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. Median 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. The reaches ranged from 2,100 to 3,025 feet in length composed of 420 to 605 cells of 5 feet each, well below the 1,000 cell limit allowed by the SBEACH model. Sediment data were obtained from six beach nourishment projects from 1995 to 2002, USACE sampled native beach sand in North and South Palm Beach County (USACE, 1987) and the sediment distribution analysis for every nine ranges in Palm Beach County by Charles, Malarka and Dean (1994). Figure 7 summarizes the three above mentioned sediment data analyses. An average mean grain size of 0.34 mm was selected for county wide model applications. Other than the sediment size, seven more parameters were tested individually by using default values and within the range of model recommended values as shown in Table 2.

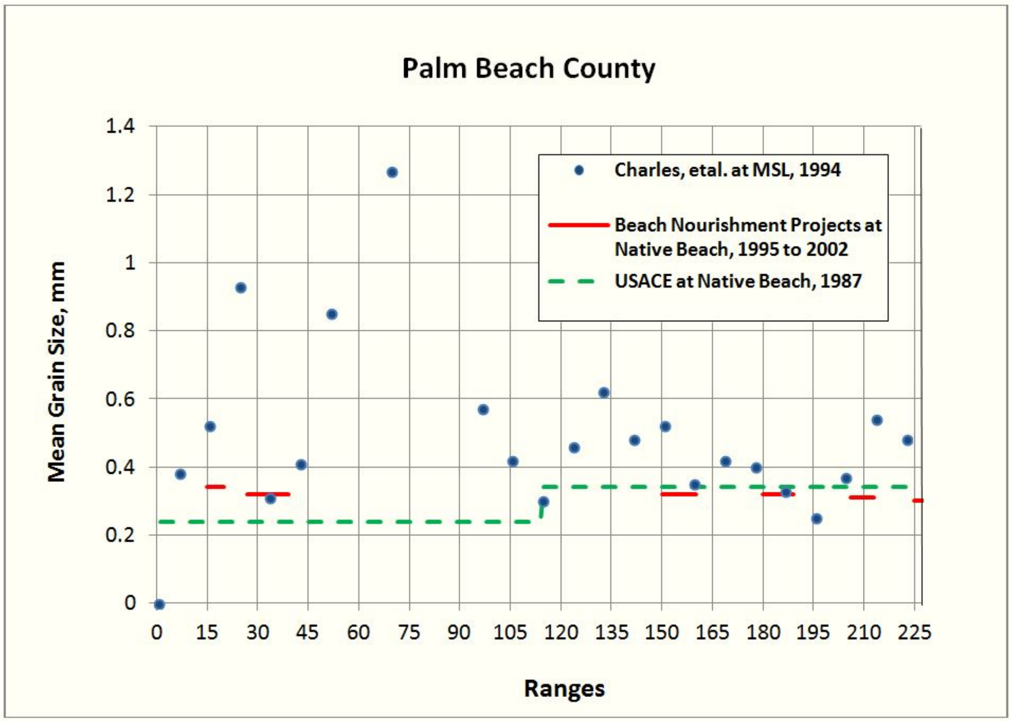

Figure 7: Measured sediment sizes in Palm Beach County

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 test, 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. It was noted the maximum water elevation values from SBEACH output at each of the calibration profiles showed significantly lower peak storm tide elevations than values generated by the 2-D storm surge model (Leadon and Nguyen, 2010). Therefore, the hydrographs input from the initial calibration work were adjusted a sufficient amount, so the peak water elevation output from SBEACH were very similar to the peak storm tide values from Hurricanes Frances and Katrina. The final adjusted hydrographs for Hurricanes Frances and Katrina are shown in Figures 8 and 9.

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

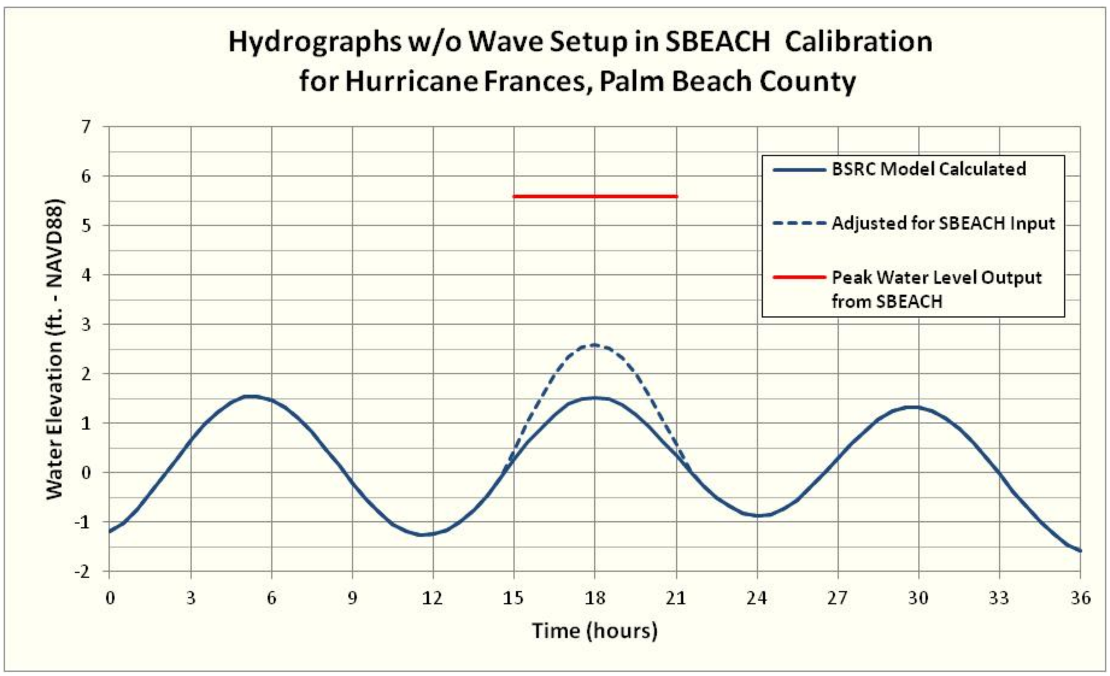

Figure 8: Adjusted hydrographs in SBEACH Model input for Hurricane Frances

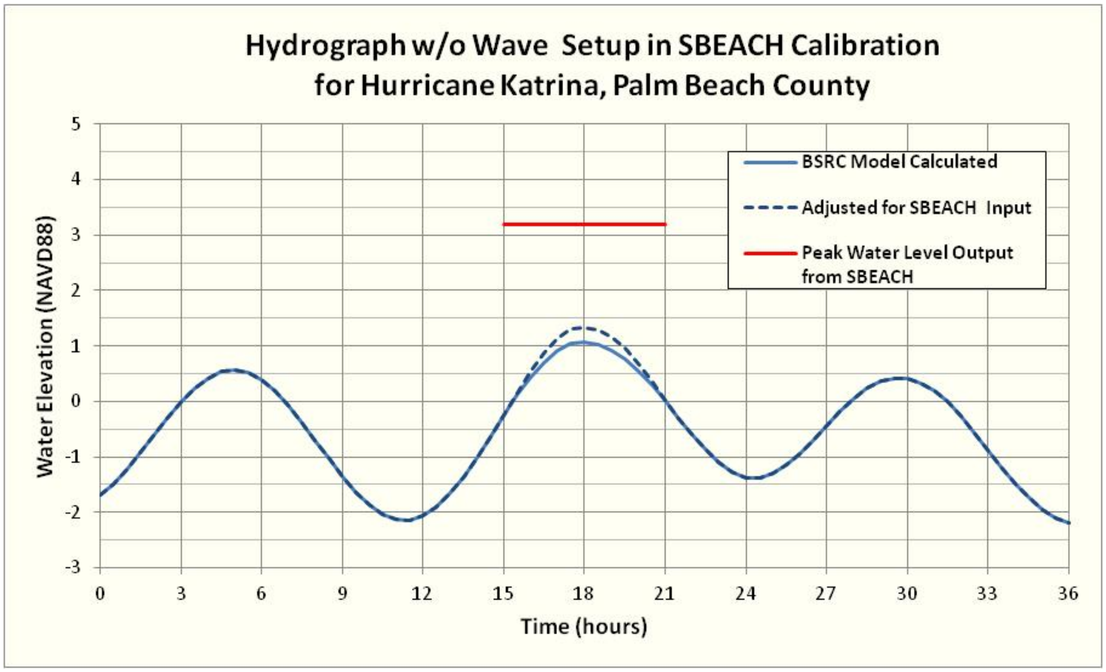

Figure 9: Adjusted Hydrographs in SBEACH Model Input for Hurricane Katrina

The 5.6 feet storm tide for the 6 selected profiles in the Boca Raton area for Hurricane Frances is equivalent to a return intervals of 15 to 20 years (BSRC, 2011). It is noted that the 3.2 feet storm tide in the 4 selected profiles for Hurricanes Katrina is equivalent to a return intervals of only 5 years, so the calibration results from Hurricane Katrina can be considered as a supplement to the calibration results from Hurricane Frances.

The average measured erosion distance for contours from 0 to 9 feet above NAVD 88 of the selected profiles were used as the principle basis for determining the calibration parameters setting. The estimated variable wave heights and periods (Figures 4 and 5) were first tested in the model calibration. For the purpose of simpler county wide application of SBEACH, a constant wave height and period will be used. Different constant wave heights and periods were later tested to find the best matchup to the measured ones. It was found that 15 feet wave height and 9 seconds wave period, 10 feet wave height and 7.5 seconds wave period matched well with the calibration results from the estimated wave conditions for Hurricanes Frances and Katrina, respectively.

Hard bottoms (HB) in Palm Beach County consist of artificial reefs, wormrock, macroalgae, sponges, stony corals. octocorals and other organisms exist near both nearshore and offshore. The algorithm developed for HB features in SBEACH (Larson and Kraus, 1998) is applicable to HB appearing on the dune, foreshore, and surf zoon, but not in the far offshore, beyond the influence of breaking waves. Available HB measurements data for Palm beach County are listed in Appendix A. Since HB data were not available for the calibration profiles from R-204 to R-227, calibration of SBEACH for HB area was not performed. Instead, the recommended default value of scour attenuation coefficient for HB area was applied in this study.

Starting with the default values, a series of values for each calibration parameter were tested. Several of the parameters were insensitive during the tests as mentioned above. The final parameter values were determined as those that provided the best approximation to the measured erosion distances. The final parameter values resulting from the model calibration are summarized in Table 3.

Figures 10 and 11show comparisons of average contour recessions between the measured and SBEACH model computed for Hurricanes Frances and Katrina based on the final model parameters described above. Average erosions distances for the contours between 4 and 7 feet for model predicted with constant waves were 13 and 2 feet less than the measured ones for Frances and Katrina, respectively. In both cases, the transport rate coefficient, *K,* was set to the maximum allowed by the model in order to achieve more erosion. The SBEACH generated post-storm profiles mostly under predicted or matched well the erosion distances than the measured ones except for R-204 and R-227, which are located at the ends of the selected profiles area. Plots of pre-storm, post-storm, and SBEACH model predicted profiles with the final calibration parameters for each of the selected profiles are presented in the Appendices B1 and B2.

Table 3 Recommended SBEACH Model Parameters for Palm Beach County

Parameters	**Unit**	**Recommended Values for HF Storm for Palm Beach County**
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	0.002
Transport rate decay coeff. multiplier, λ	m^{-1}	0.5
Landward surf zone depth	ft.	1.0
Effective grain size (mean D_{50})	mm	0.34
Maximum slope prior to avalanching	degree	17 & 45
Water temperature	degree, C	27
Wave Height, H	ft.	15
Wave Period, Tp	Sec.	9
Wave Direction, α	degree	0 (shore-normal)

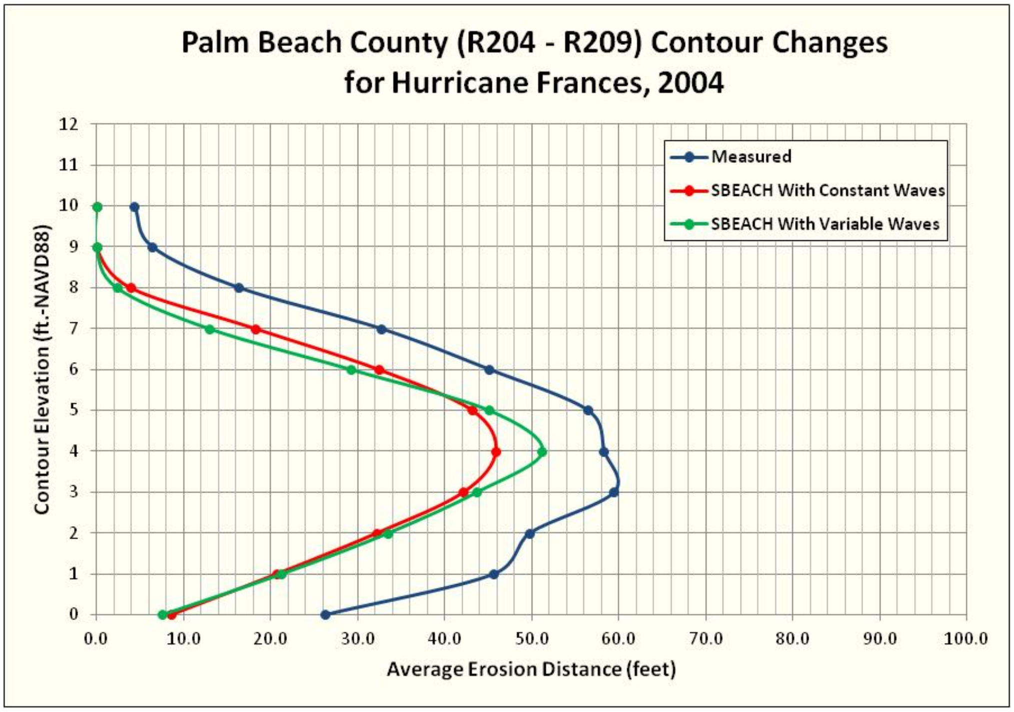

Figure 10: Comparisons of average contour recessions between measured and SBEACH model computed for Hurricanes Frances

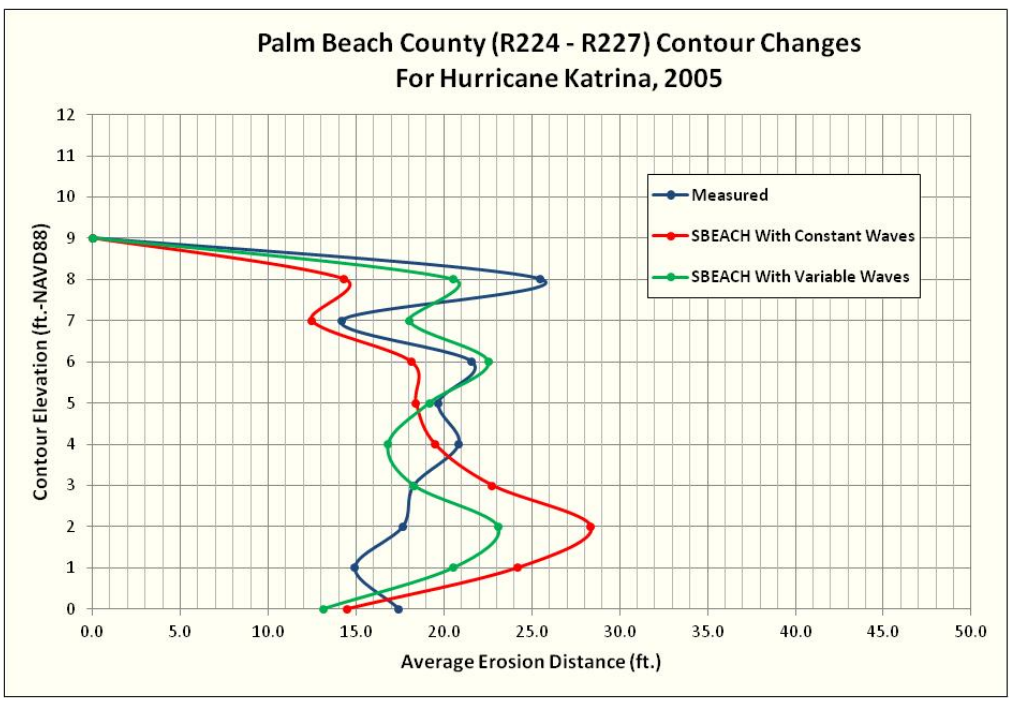

Figure 11: Comparisons of average contour recessions between measured and SBEACH model computed for Hurricanes Katrina

3. Palm Beach County SBEACH Application

3.1 Model Configuration

Application of SBEACH model in Palm Beach County for high-frequency storm erosion was based on the model calibration results, as shown in Table 3 of the previous section. Palm Beach County storm tides and hydrographs developed by BSRC (2011) for 15- and 25-year storms are shown in Table 4 and Figure 12.

Table 4 High-Frequency Storm Tides (ft.-NAVD) for Palm Beach County

Return Period (years)	Profile 1 (R-1 to R-60)	Profile 2 (R-61 to R-125)	Profile 3 (R-126 to R-185)	Profile 4 (R-186 to R-227)
25	6.9	6.7	6.4	6.3
15	5.8	5.7	5.4	5.2

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

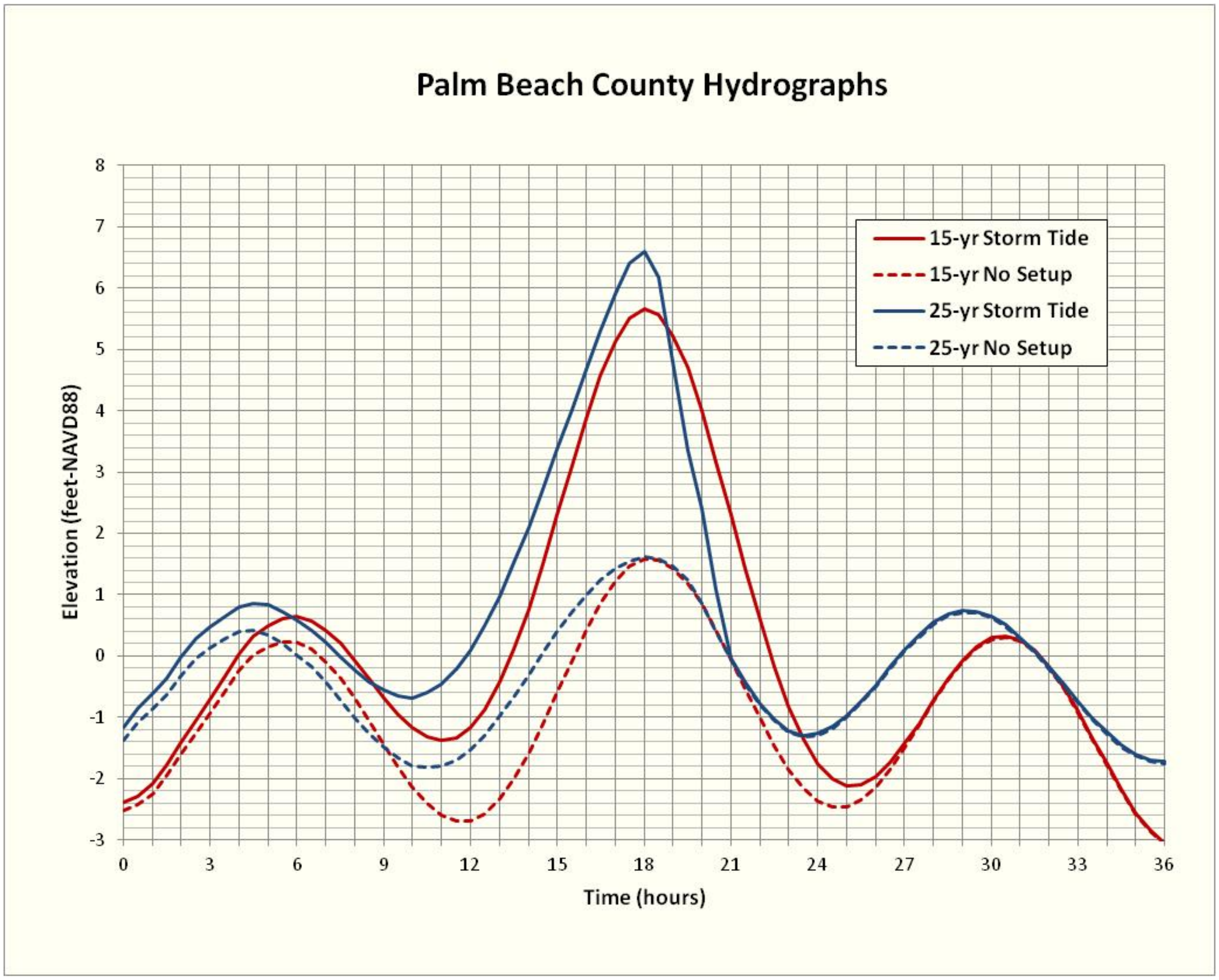

Figure 12: Hydrographs of 15- and 25-year for Palm Beach County

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. If the final model output water level did not agree with the desired 15- or 25-year storm tides, 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 original and adjusted hydrographs are shown in Figures 13 and 14 and are tabulated in Appendix D.

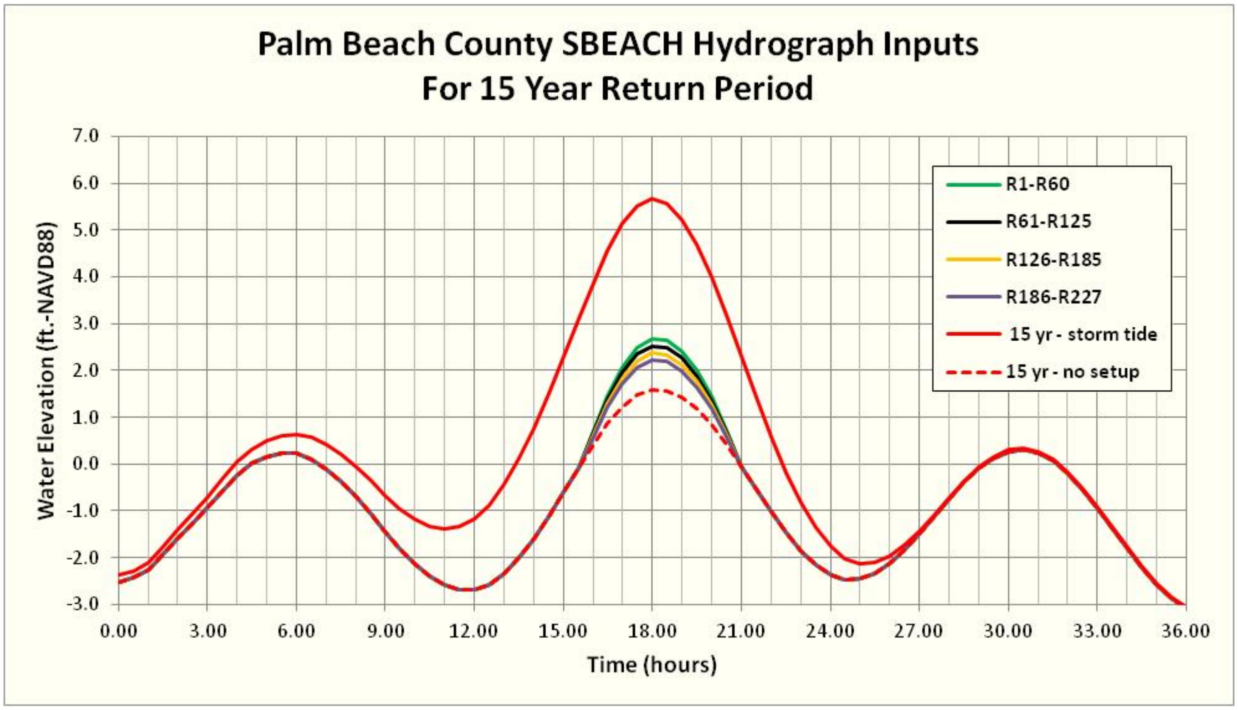

Figure 13: 15-year hydrographs for Palm Beach County profiles in SBEACH application

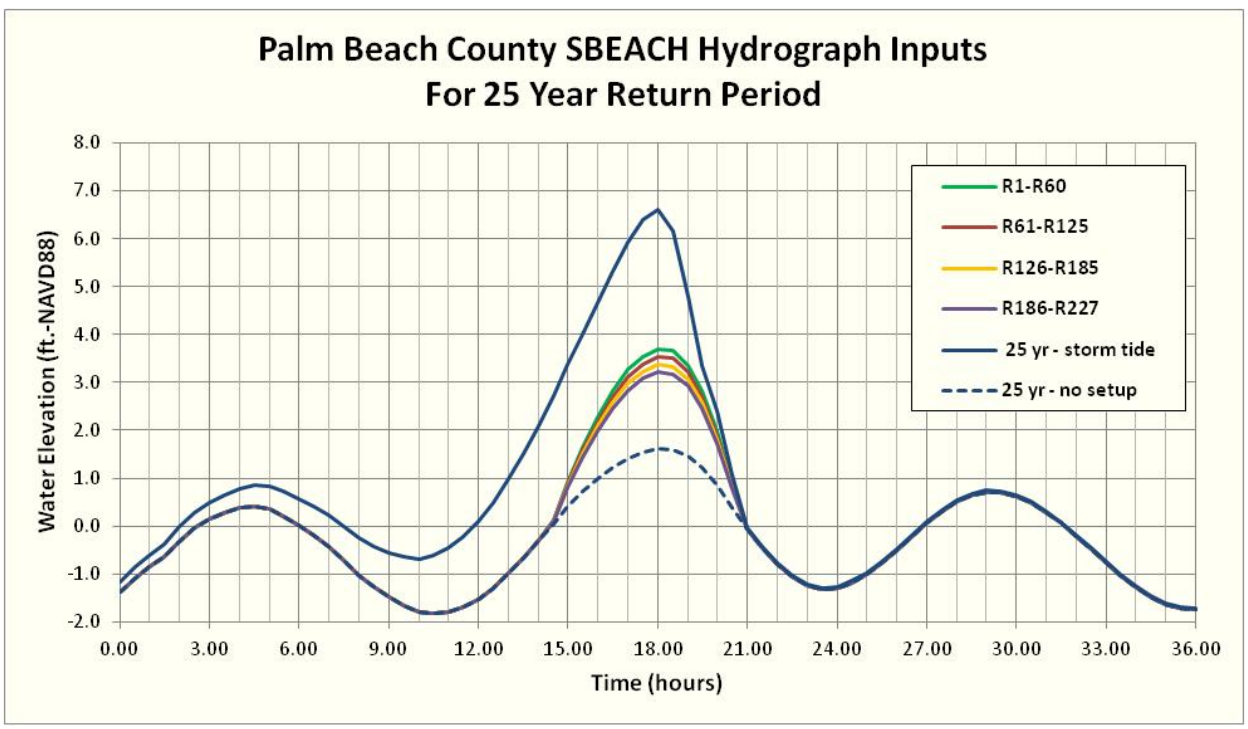

Figure 14: 25-year hydrographs for Palm Beach County profiles in SBEACH application

3.2 Model Application and Results

The survey profiles used as the input profiles in SBEACH are listed in Table 5. Tables showing the horizontal eroded distances between the initial profile and the eroded profiles for specific elevation interval for 15- and 25-year storms are listed in Appendix E. Plots of the initial profile and the associated eroded profiles generated from SBEACH for the 15- and 25-year return periods for 227 range location profiles of Palm Beach County are provided in Appendix F. The plots in Appendix F are shown in the NAVD88 vertical datum. All the profiles in Palm Beach County were run as sandy beaches, including those profiles with sea wall and rock armoring, as shown in Table 6. Although there is no calibration data available at present time, it is recommended to pay additional attention to profiles with sea wall and rock armoring for the future SBEACH model application. The Maximum slope prior to avalanching of 17 degrees was used for the calibrated areas from R-186 to R-227. However, it is recommended to use the default value of 45 degrees for the remaining areas to avoid over prediction of erosion for the higher than 10 foot contours. The map in Figure 15 below depicts the FDEP profile range locations along the Palm Beach County shoreline.

Table 5 Profiles Used in SBEACH Application for Palm Beach County

Ranges	**Survey Dates**
1-8	May - Aug. 2012
9	Aug. 2006
10-12	May 2010
13-45	May - Aug. 2012
46-59	Oct. - Nov. 2010
60-71	May - Aug. 2012
72	Oct. - Nov. 2010
73-134	Sept. - Nov. 2011
135-164	May - Aug. 2012
165-174	Sept. - Oct. 2010
175-192	Nov. 2008
193-199	Sept. - Oct. 2010
200-227	June 2012

Table 6 Sea Wall and Rock Armoring Locations in Palm Beach County

Sea Wall	Rock Armoring
R-8	R-9
R-21	R-111 - R-116
R-68*	R-136
R-71	R-138 - R-139
R-73	R-153
R-74*	R-180*
R-78 - R-94	
R-95*	
R-97 - R-106	
R-109	
R-110*	
R-120	
R-124* - R-126*	
R-127 - R-128	
R-134*	
R-135	
R-140 - R-146	
R-152	
R-154	
R-168	
R-171 - R-179	
R-189	
R-190*	
R-192	
R-193*	
R-194	
R-195* - R-196*	
R-200	
R-204	
R-218 - R-219	
R-221	
R-225*	
R-226 - R-227	

* Partial Sea Wall or Rock Armoring

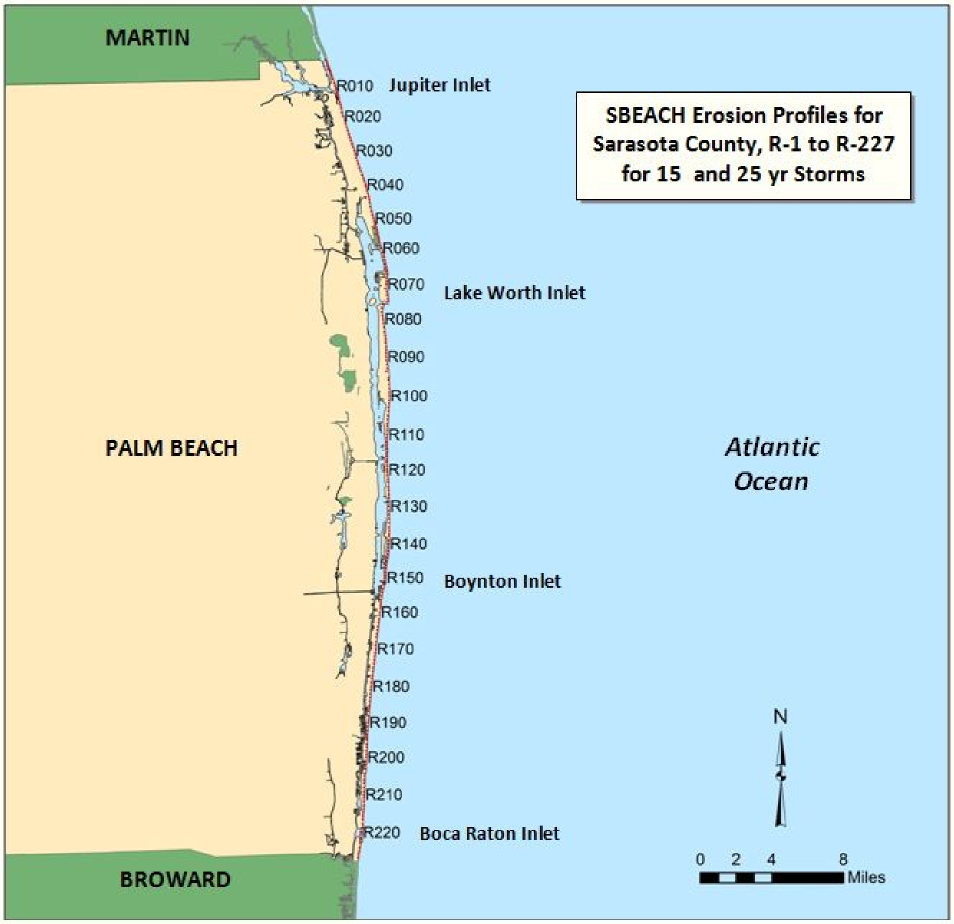

Figure 15: FDEP profile range locations along the Palm Beach County shoreline

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1. Beven II, J. L., “Tropical Cyclone Report, Hurricane Frances, 25 August - 8 September, 2004", Tropical Prediction Center, National Hurricane Center, December 2004.

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16. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Hurricane Center, "Hurricane Best Track Files (HURDAT), 1851 – 2011", http://www.nhc.noaa.gov/data/hurdat/tracks1851to2010_atl_reanal.txt.

APPENDIX A

Hard Bottom Measurement data for Palm Beach County

Palm Beach County Hard Bottom Offshore Distance (ft.) from Monuments

Range	Start	End	Start	End	Start	End
R-70	665	780				
R-78	765	870				
R-80	190	370				
R-81	145	350	500	645		
R-82	100	430				
R-83	145	470				
R-84	90	420				
R-85	110	370				
R-86	160	420				
R-87	136	365				
R-88	215	460				
R-89	430	820				
R-90	520	680	790	935	1150	1260
R-91	580	630	690	740	800	1055
R-92	720	1095	1235	1450	1555	1760
R-93	840	925	1000	1200	1360	1485
R-94	900	1040	1245	1470		
R-95	1100	1350				
R-96	1175	1270	1335	1450	1520	1725
R-97	880	1090				
R-98	920	1190	1315	1505		
R-99	850	1180				
R-100	980	1200				
R-101	810	900	970	1120		
R-102	65	125	400	595	705	1080
R-103	645	1205				
R-104	960	1275				
R-109	235	415				
R-110	290	390				
R-111	120	165	260	430		
R-112	125	165	265	470		
R-113	170	210	320	555		
R-114	130	190	280	505		
R-115	155	220	350	445		
R-116	160	195				
R-117	120	190				
R-118	150	215				
R-119	90	180				
R-120	155	180				
R-121	155	225				
R-122	125	165				

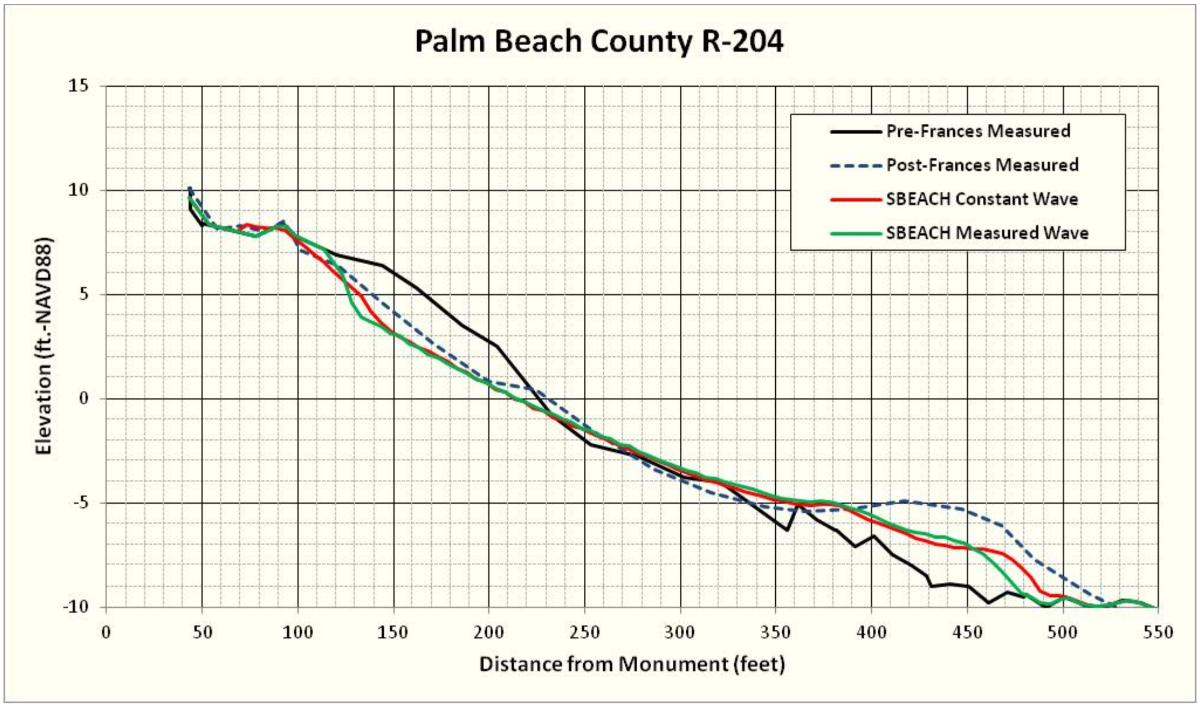
R-123	120	160				
R-130	160	200				
T-131	150	190	220	260		
R-132	180	340	450	570		
R-133	140	290	330	555		
R-134	350	565				
R-135	560	690				
R-136	490	520	760	950		
R-137	210	250	400	655		
R-138	112	157				
R-139	150	550				
R-140	180	220	280	550		
R-141	140	500				
R-142	140	190	256	480		
R-143	105	525				
T-144	175	495				
R-145	160	415				
R-146	410	725				
T-152	200	460				
R-153	310	590				
R-156	420	520				

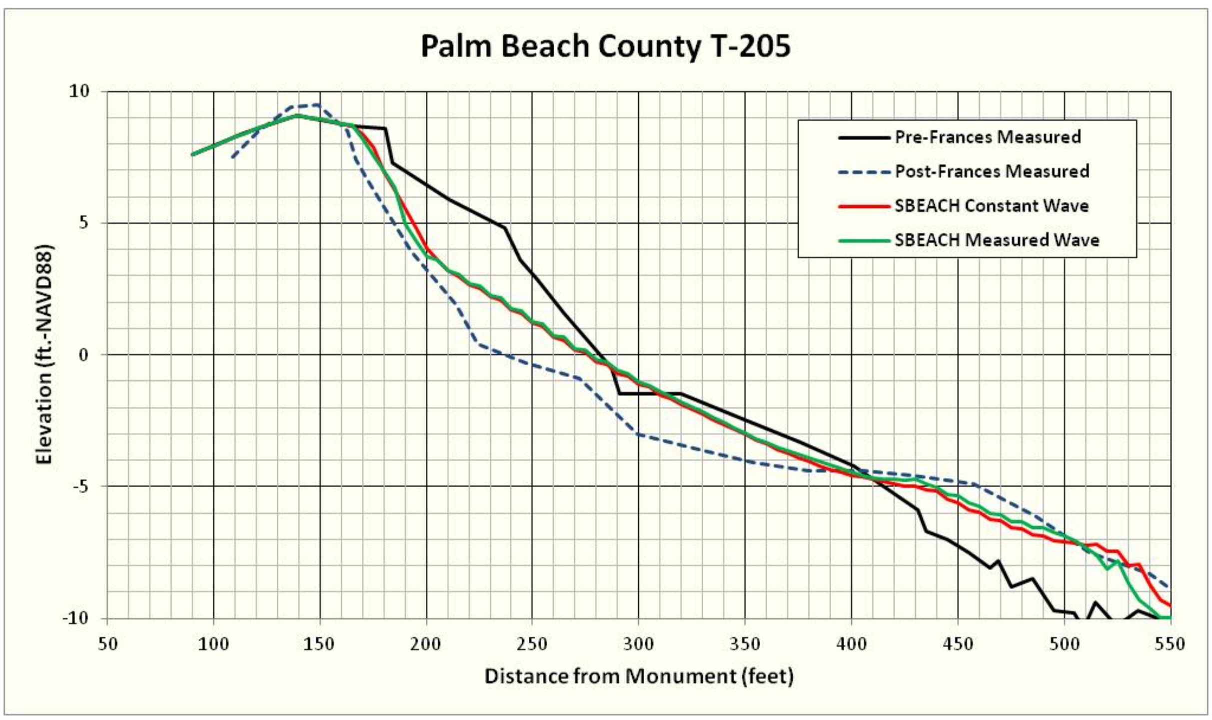
Resource:

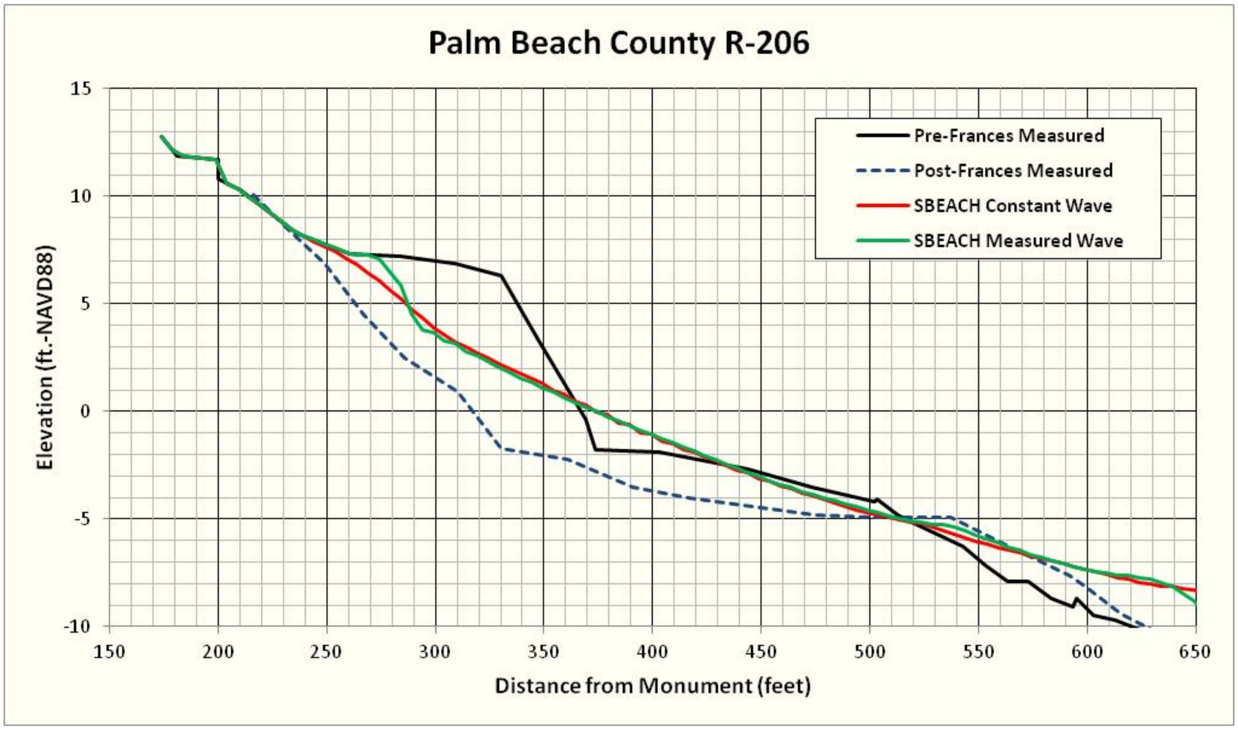
Florida DEP Bureau of Beaches and Coastal Systems, Palm Beach Island Beach Management Agreement (BMA) Pilot Project Website.
FDEP Beaches Management

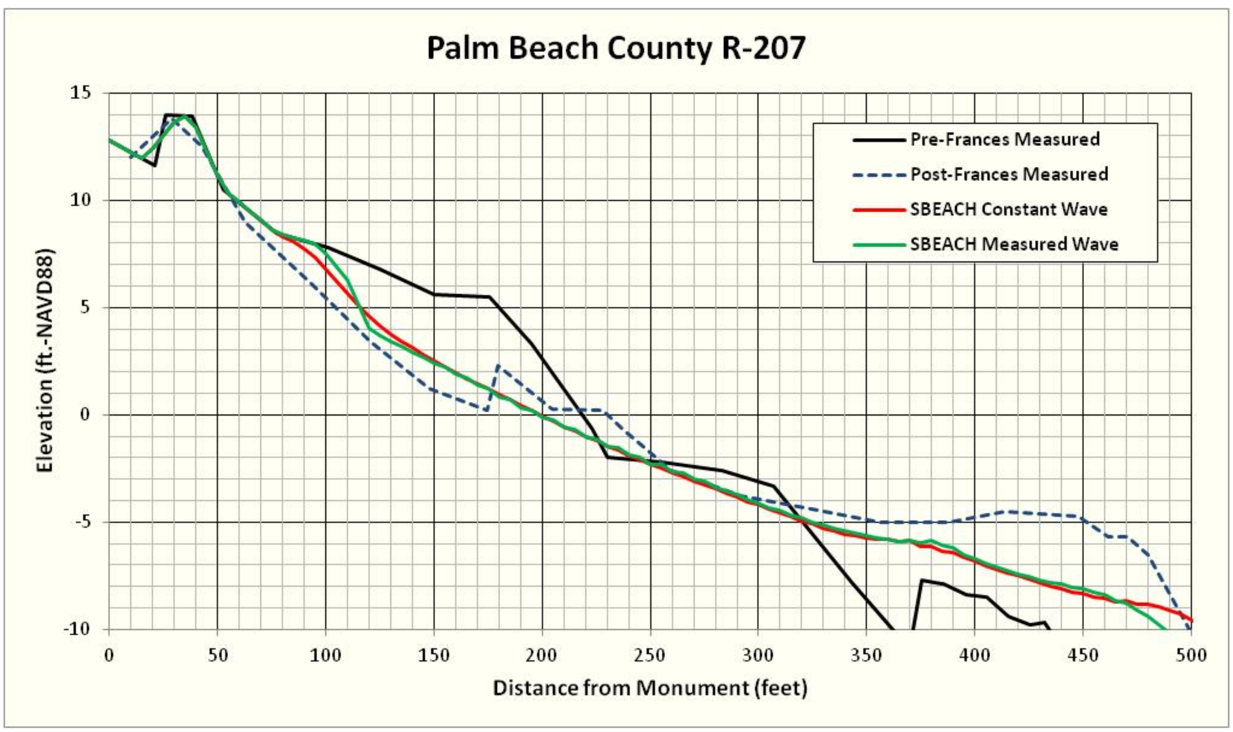
APPENDIX B1

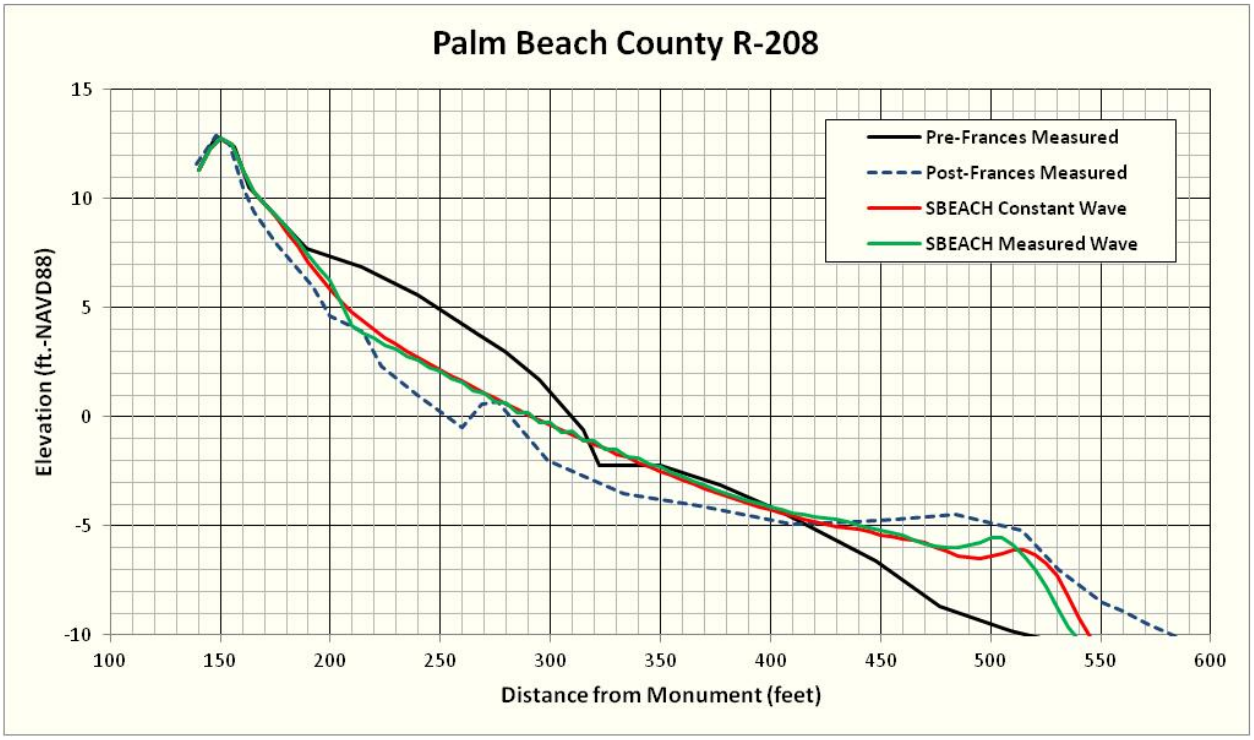
SBEACH Calibration Profiles for Hurricane Frances

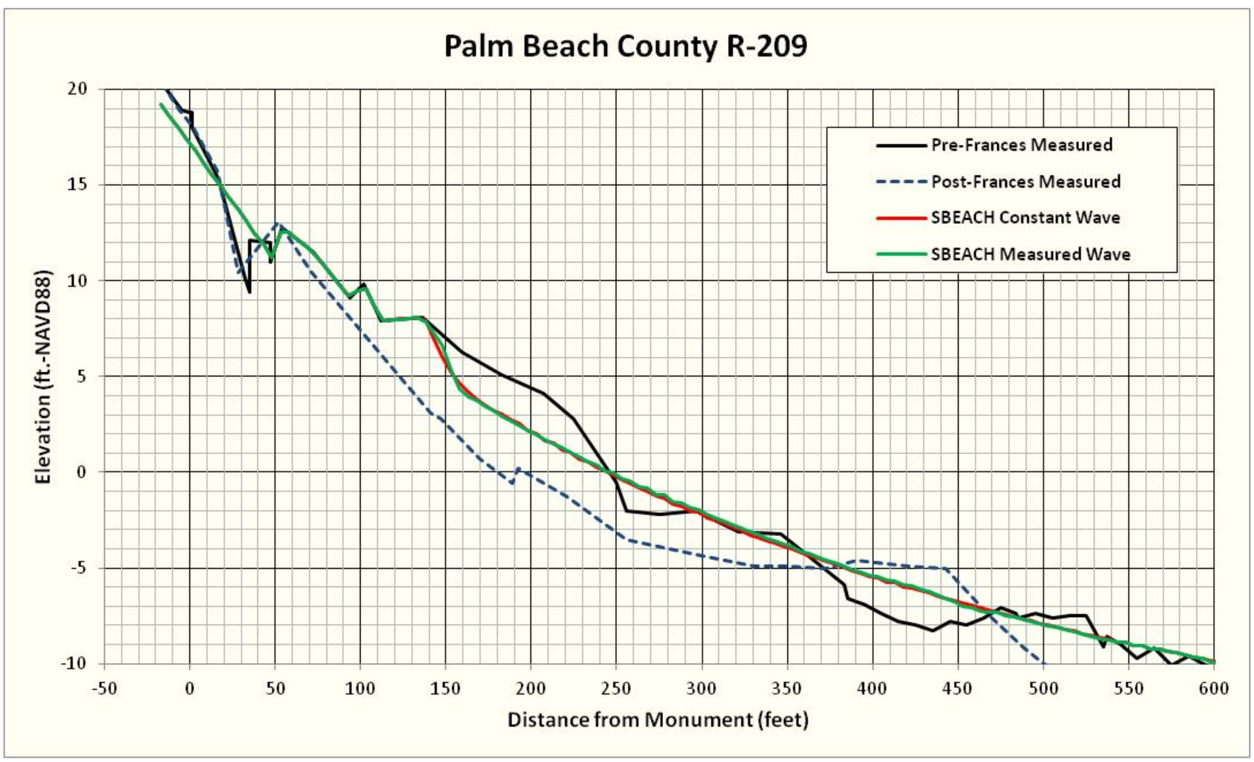

Palm Beach County R-204
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
550


Palm Beach County T-205
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
Distance from Monument (feet)
10
5
0
-5
-10
50
100
150
200
250
300
350
400
450
500
550


Palm Beach County R-206
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
150
200
250
300
350
400
450
500
550
600
650
Distance from Monument (feet)

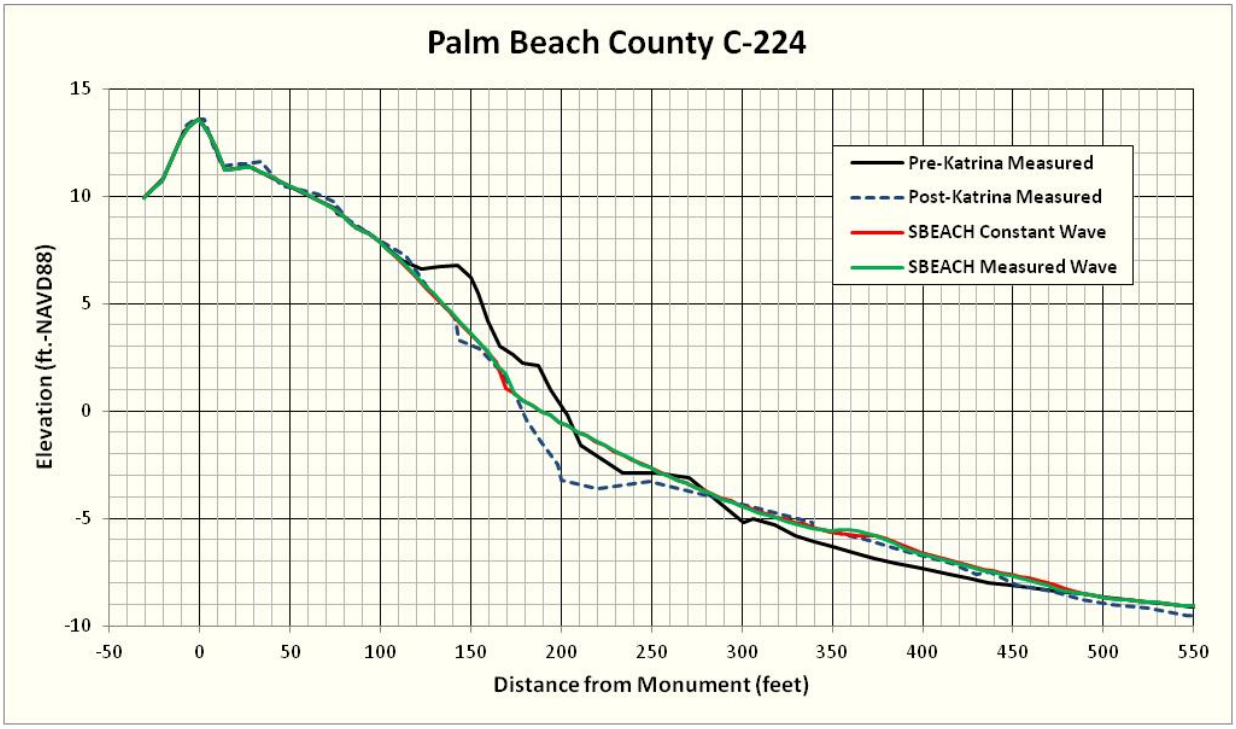

Palm Beach County R-207
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
500
Distance from Monument (feet)

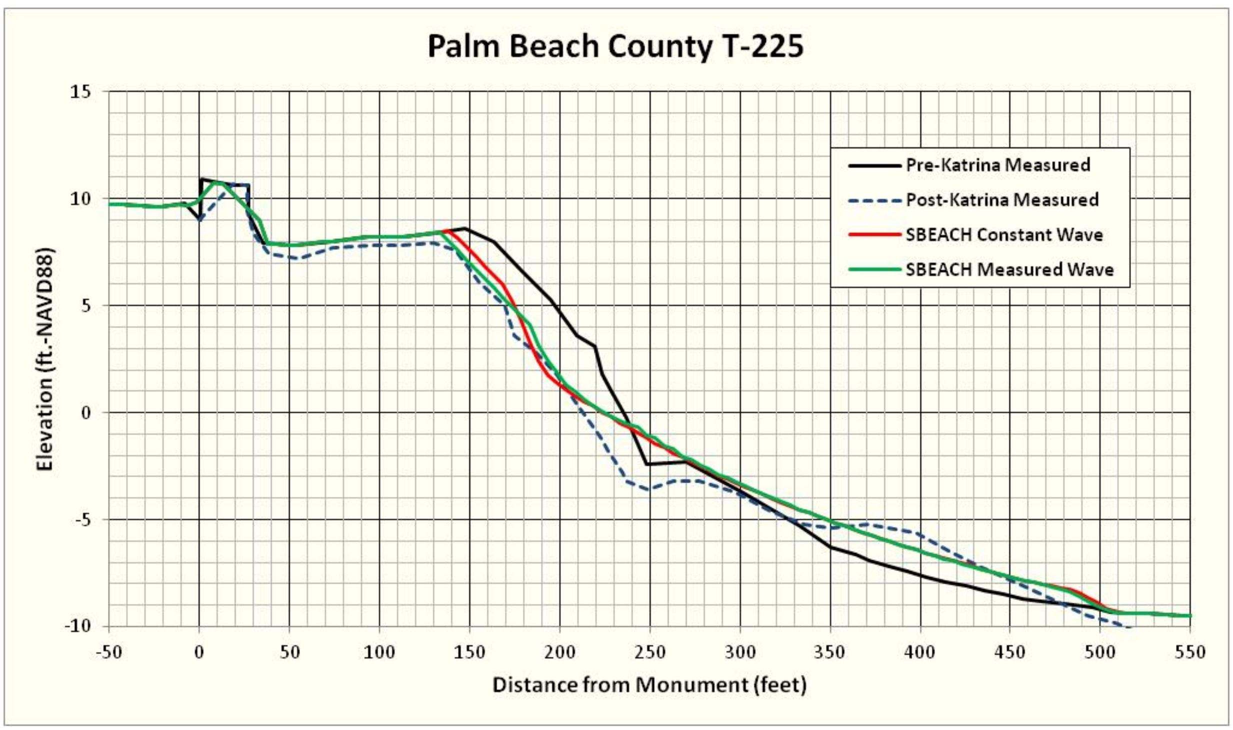

Palm Beach County R-208
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
Distance from Monument (feet)
15
10
5
0
-5
-10
100
150
200
250
300
350
400
450
500
550
600

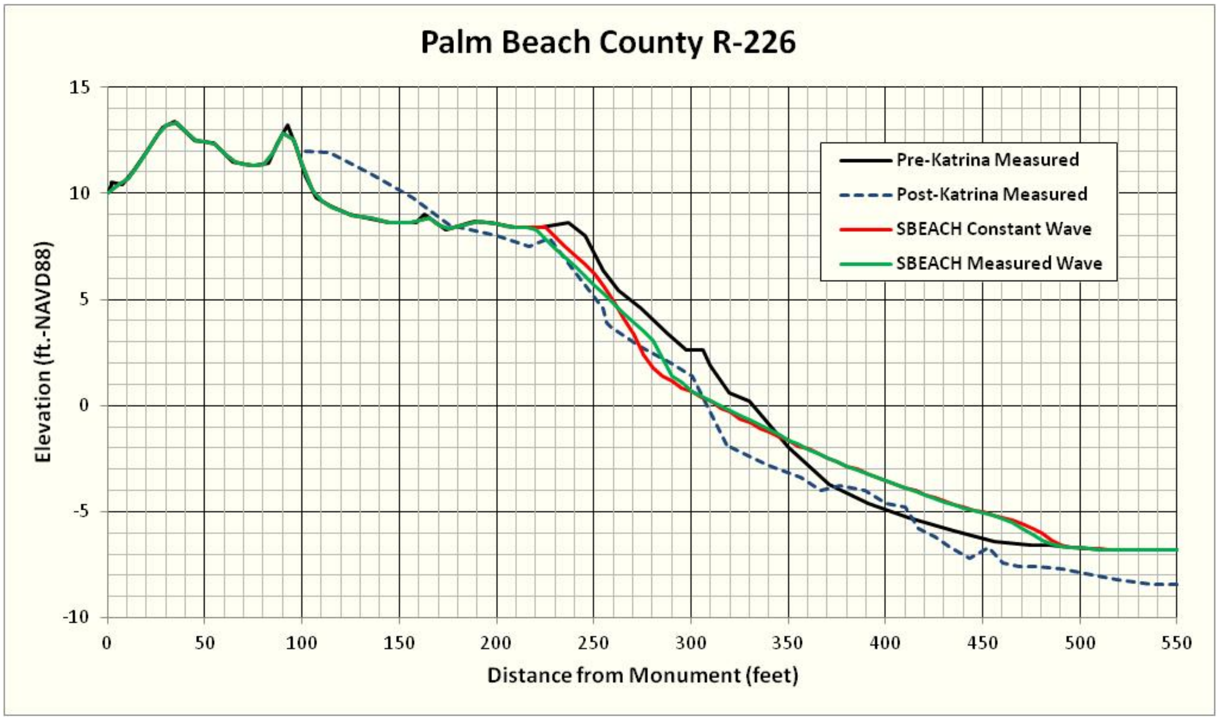

Palm Beach County R-209
Pre-Frances Measured
Post-Frances Measured
SBEACH Constant Wave
SBEACH Measured Wave
Elevation (ft.-NAVD88)
Distance from Monument (feet)
20
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
300
350
400
450
500
550
600

APPENDIX B2

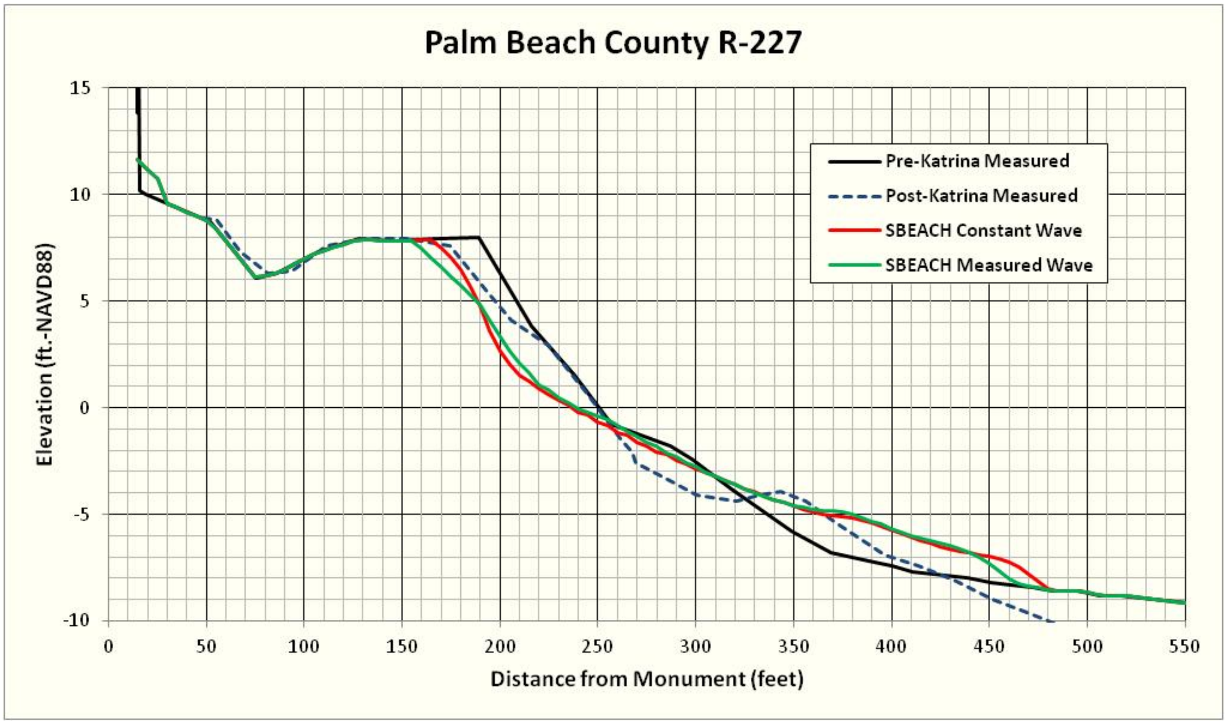
SBEACH Calibration Profiles for Hurricane Katrina


Palm Beach County C-224
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
300
350
400
450
500
550
Distance from Monument (feet)
Pre-Katrina Measured
Post-Katrina Measured
SBEACH Constant Wave
SBEACH Measured Wave


Palm Beach County T-225
Elevation (ft.-NAVD88)
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
300
350
400
450
500
550
Distance from Monument (feet)
Pre-Katrina Measured
Post-Katrina Measured
SBEACH Constant Wave
SBEACH Measured Wave



Palm Beach County R-226
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Katrina Measured
Post-Katrina Measured
SBEACH Constant Wave
SBEACH Measured Wave



Palm Beach County R-227
Elevation (ft.-NAVD88)
Distance from Monument (feet)
Pre-Katrina Measured
Post-Katrina Measured
SBEACH Constant Wave
SBEACH Measured Wave

APPENDIX C

Recommended SBEACH Input Values for Palm Beach County

Final SBEACH Input Settings – for 15- and 25-year storm erosions in Palm Beach 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 hours. 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 degrees. Grid cell width is 5 feet.

Final SBEACH Input Values for Range Segments

Input Parameters	**R1 - R60**	**R61 - R125**	**R126 - R185**	**R186 - R227**
Transport Rate Coefficient, *K*	2.5 e^{-006}	2.5 e^{-006}	2.5 e^{-006}	2.5 e^{-006}
Overwash Transport Parameter	0.005	0.005	0.005	0.005
Coefficient for Slope Dependent Term, ε	0.002	0.002	0.002	0.002
Transport Rate Decay Coeff. M ultiplier, λ	0.5	0.5	0.5	0.5
Landward Surf Zone Depth (ft.)	1.0	1.0	1.0	1.0
Maximum Slope Prior to Avalanching	45	45	45	17
Constant Wave Height (ft.)	15	15	15	15
Constant Wave Period (sec.)	9	9	9	9
Grain Size (mm)	0.34	0.34	0.34	0.34
Adjusted 15-year Hydrograph Peak Elevation (ft.)	5.8	5.7	5.4	5.2
Adjusted 25-year Hydrograph Peak Elevation (ft.)	6.9	6.7	6.4	6.3

APPENDIX D

Adjusted 15- and 25-year Hydrograph Tables for Palm beach County

Palm Beach County - Adjusted 15-year Storm Surge Elevation Hydrograph Time Series Values for SBEACH (ft. - NAVD)

Time Steps (hr.)	R1 - R60	R61 - R125	R126 - R185	R186 - R227
0.00	-2.52	-2.52	-2.52	-2.52
0.50	-2.43	-2.43	-2.43	-2.43
1.00	-2.25	-2.25	-2.25	-2.25
1.50	-1.95	-1.95	-1.95	-1.95
2.00	-1.60	-1.60	-1.60	-1.60
2.50	-1.27	-1.27	-1.27	-1.27
3.00	-0.94	-0.94	-0.94	-0.94
3.50	-0.58	-0.58	-0.58	-0.58
4.00	-0.24	-0.24	-0.24	-0.24
4.50	0.01	0.01	0.01	0.01
5.00	0.15	0.15	0.15	0.15
5.50	0.23	0.23	0.23	0.23
6.00	0.22	0.22	0.22	0.22
6.50	0.11	0.11	0.11	0.11
7.00	-0.10	-0.10	-0.10	-0.10
7.50	-0.37	-0.37	-0.37	-0.37
8.00	-0.69	-0.69	-0.69	-0.69
8.50	-1.06	-1.06	-1.06	-1.06
9.00	-1.45	-1.45	-1.45	-1.45
9.50	-1.82	-1.82	-1.82	-1.82
10.00	-2.14	-2.14	-2.14	-2.14
10.50	-2.40	-2.40	-2.40	-2.40
11.00	-2.59	-2.59	-2.59	-2.59
11.50	-2.69	-2.69	-2.69	-2.69
12.00	-2.69	-2.69	-2.69	-2.69
12.50	-2.57	-2.57	-2.57	-2.57
13.00	-2.33	-2.33	-2.33	-2.33
13.50	-2.00	-2.00	-2.00	-2.00
14.00	-1.59	-1.59	-1.59	-1.59
14.50	-1.11	-1.11	-1.11	-1.11
15.00	-0.60	-0.60	-0.60	-0.60
15.50	-0.08	-0.08	-0.08	-0.08
16.00	0.71	0.67	0.63	0.59
16.50	1.46	1.38	1.29	1.20
17.00	2.07	1.95	1.83	1.71
17.50	2.50	2.35	2.21	2.06
18.00	2.69	2.53	2.37	2.21
18.50	2.65	2.50	2.34	2.18
19.00	2.41	2.27	2.13	1.99
19.50	2.01	1.89	1.77	1.65

Time Steps (hr.)	R1 - R60	R61 - R125	R126 - R185	R186 - R227
20.00	1.45	1.36	1.28	1.19
20.50	0.71	0.67	0.63	0.59
21.00	-0.05	-0.05	-0.05	-0.05
21.50	-0.53	-0.53	-0.53	-0.53
22.00	-1.02	-1.02	-1.02	-1.02
22.50	-1.47	-1.47	-1.47	-1.47
23.00	-1.86	-1.86	-1.86	-1.86
23.50	-2.16	-2.16	-2.16	-2.16
24.00	-2.37	-2.37	-2.37	-2.37
24.50	-2.47	-2.47	-2.47	-2.47
25.00	-2.46	-2.46	-2.46	-2.46
25.50	-2.35	-2.35	-2.35	-2.35
26.00	-2.13	-2.13	-2.13	-2.13
26.50	-1.85	-1.85	-1.85	-1.85
27.00	-1.50	-1.50	-1.50	-1.50
27.50	-1.13	-1.13	-1.13	-1.13
28.00	-0.74	-0.74	-0.74	-0.74
28.50	-0.39	-0.39	-0.39	-0.39
29.00	-0.09	-0.09	-0.09	-0.09
29.50	0.13	0.13	0.13	0.13
30.00	0.27	0.27	0.27	0.27
30.50	0.31	0.31	0.31	0.31
31.00	0.24	0.24	0.24	0.24
31.50	0.07	0.07	0.07	0.07
32.00	-0.19	-0.19	-0.19	-0.19
32.50	-0.53	-0.53	-0.53	-0.53
33.00	-0.93	-0.93	-0.93	-0.93
33.50	-1.36	-1.36	-1.36	-1.36
34.00	-1.79	-1.79	-1.79	-1.79
34.50	-2.20	-2.20	-2.20	-2.20
35.00	-2.57	-2.57	-2.57	-2.57
35.50	-2.87	-2.87	-2.87	-2.87
36.00	-3.08	-3.08	-3.08	-3.08

Palm Beach County - Adjusted 25-year Storm Surge Elevation Hydrograph Time Series Values for SBEACH (ft. - NAVD)

Time Steps (hr.)	R1 - R60	R61 - R125	R126 - R185	R186 - R227
0.00	-1.38	-1.38	-1.38	-1.38
0.50	-1.09	-1.09	-1.09	-1.09
1.00	-0.86	-0.86	-0.86	-0.86
1.50	-0.64	-0.64	-0.64	-0.64
2.00	-0.32	-0.32	-0.32	-0.32
2.50	-0.04	-0.04	-0.04	-0.04
3.00	0.14	0.14	0.14	0.14
3.50	0.28	0.28	0.28	0.28
4.00	0.39	0.39	0.39	0.39
4.50	0.42	0.42	0.42	0.42
5.00	0.35	0.35	0.35	0.35
5.50	0.20	0.20	0.20	0.20
6.00	0.02	0.02	0.02	0.02
6.50	-0.18	-0.18	-0.18	-0.18
7.00	-0.43	-0.43	-0.43	-0.43
7.50	-0.73	-0.73	-0.73	-0.73
8.00	-1.02	-1.02	-1.02	-1.02
8.50	-1.27	-1.27	-1.27	-1.27
9.00	-1.49	-1.49	-1.49	-1.49
9.50	-1.66	-1.66	-1.66	-1.66
10.00	-1.79	-1.79	-1.79	-1.79
10.50	-1.82	-1.82	-1.82	-1.82
11.00	-1.80	-1.80	-1.80	-1.80
11.50	-1.69	-1.69	-1.69	-1.69
12.00	-1.52	-1.52	-1.52	-1.52
12.50	-1.29	-1.29	-1.29	-1.29
13.00	-0.98	-0.98	-0.98	-0.98
13.50	-0.66	-0.66	-0.66	-0.66
14.00	-0.30	-0.30	-0.30	-0.30
14.50	0.12	0.11	0.11	0.10
15.00	0.92	0.88	0.84	0.80
15.50	1.66	1.58	1.51	1.44
16.00	2.28	2.18	2.08	1.98
16.50	2.83	2.71	2.58	2.46
17.00	3.27	3.12	2.98	2.84
17.50	3.54	3.39	3.23	3.08
18.00	3.70	3.54	3.38	3.22
18.50	3.66	3.50	3.34	3.18
19.00	3.36	3.21	3.07	2.92
19.50	2.83	2.71	2.58	2.46

Time Steps (hr.)	R1 - R60	R61 - R125	R126 - R185	R186 - R227
20.00	1.98	1.89	1.81	1.72
20.50	0.90	0.86	0.82	0.78
21.00	-0.06	-0.06	-0.06	-0.06
21.50	-0.45	-0.45	-0.45	-0.45
22.00	-0.80	-0.80	-0.80	-0.80
22.50	-1.05	-1.05	-1.05	-1.05
23.00	-1.25	-1.25	-1.25	-1.25
23.50	-1.31	-1.31	-1.31	-1.31
24.00	-1.29	-1.29	-1.29	-1.29
24.50	-1.18	-1.18	-1.18	-1.18
25.00	-1.00	-1.00	-1.00	-1.00
25.50	-0.76	-0.76	-0.76	-0.76
26.00	-0.50	-0.50	-0.50	-0.50
26.50	-0.21	-0.21	-0.21	-0.21
27.00	0.07	0.07	0.07	0.07
27.50	0.31	0.31	0.31	0.31
28.00	0.52	0.52	0.52	0.52
28.50	0.66	0.66	0.66	0.66
29.00	0.71	0.71	0.71	0.71
29.50	0.70	0.70	0.70	0.70
30.00	0.62	0.62	0.62	0.62
30.50	0.48	0.48	0.48	0.48
31.00	0.29	0.29	0.29	0.29
31.50	0.06	0.06	0.06	0.06
32.00	-0.21	-0.21	-0.21	-0.21
32.50	-0.49	-0.49	-0.49	-0.49
33.00	-0.77	-0.77	-0.77	-0.77
33.50	-1.04	-1.04	-1.04	-1.04
34.00	-1.28	-1.28	-1.28	-1.28
34.50	-1.48	-1.48	-1.48	-1.48
35.00	-1.63	-1.63	-1.63	-1.63
35.50	-1.71	-1.71	-1.71	-1.71
36.00	-1.75	-1.75	-1.75	-1.75

APPENDIX E

15- and 25-year Horizontal Erosion Distances for Palm Beach County

MHW = 0.55 ft. (NAVD)

+ : Erosion

- : Accretion

15-year Horizontal Erosion Distances at Contours (ft. – NAVD)

Range	MHW	5'	7'	9'
R1	7	25.2	14.4	6.6
R2	7.1	34.4	16.7	0.3
R3	6.4	56	86.2	-0.7
R4	7.2	46.6	42.9	3.2
R5	19.4	55.9	10.6	3
R6	-8	26.8	10.9	0.6
R7	7.3	41.6	37.8	0
R8	5	29.3	18.7	14.3
R9	33.8	52.2	41.9	11
R10	29.5			
R11	32.1	29	32	30.7
R12	21	65.6	73.5	
R13	24.7	36.5	29.6	0
R14	21.5	49.2	19.4	8.3
R15	9.1	27.5	20.7	17.3
R16	8.4	27.4	21.1	18.9
R17	15.9	23.9	24.4	21.6
T18	16.1	12.6	18.3	21.5
T19	23.5	35.4	9.8	0
R20	19	37.5	32.5	25.1
R21	10.4	40.9	28.5	11.5
T22	22	33.2	32.6	16.5
T23	36.1	49.9	53.2	7.5
T24	36.5	39.8	17.4	1.6
T25	28.8	47.6	56.9	0.4
R26	10.2	49.2	-34.1	0
T27	15.9	21.3	23.3	1.8
R28	2.1	31.9	31.5	27.1
R29	4.8	29.6	37.1	40.2
R30	14.8	37	43.3	41
R31	8.7	43.8	22.8	0.1
T32	13.5	27.7	26.4	0
R33	22.9	27.6	1.5	0
R34	24.6	34	13.5	0
R35	7.5	43.5	17.1	0
R36	4.7	32.3	21.5	0
R37	13.5	41.2	52	5.8
R38	13.4	28.6	31.1	-17.7
R39	7.3	50.6	34.4	0
R40	7.5	47	33.8	4.8
R41	7.1	25.8	22.7	4.2

Range	MHW	5'	7'	9'
R42	6.9	26.5	5.9	2.3
R43	-2.3	43.6	23.6	13.3
R44	15.6	39.9	31.3	16.2
R45	3.4	13.7	9.6	5.4
R46	27.5	8.6	9.1	6.3
R47	0.8	14.3	15.8	10.8
R48	27.7	19	24.3	9.9
R49	26.3	15.6	22.4	0.9
R50	17.9	26.2	22.1	0
R51	29.1	27.8	23.9	5.6
R52	38.6	25.5	24.9	9.2
R53	28.5	13.4	17.7	0.8
R54	23.4	10.9	16.6	9.1
R55	23	13.4	13.2	0
R56	29.5	15.8	16	14.1
T57	28.1	9.6	24.7	0.3
R58	21.5	11.9	29.2	0.1
R59	7.2	21.9	28.6	0
R60	29.2	20.1	22.1	22.1
R61	31.1	21.4	12.2	8
R62	29.9	24.4	16.6	8.2
R63	32.2	24.1	20.6	8.1
R64	41.8	45.7	13.2	5.6
R65	36.2	48.2	22.2	11.8
R66	27.6	47.7	22.6	19
R67	35.6	23.9	1.1	0
R68	14.6	45	0	0
R69	13	60.4	-5.5	0
R70	6.7	45.9	21.9	0
R71	18.1	32	13.1	0
R72	5.8	28.9	29.4	0.2
R73	26.9	58.2	10.3	5.7
R74	29	58.7	3.9	0
R75	42.5	77.9		
R76	15.1	57.8		
R77	-0.6	44.5	19.5	0
R78	62.5	41.7	33.4	27.1
R79	37.8	74.2	20.2	0
R80	31.6	6.7	6.2	0
R81	15.6	43.3	18.8	6.3
R82	5.5	35.6		
R83	16.3	45.4	10.7	6.1
R84	-7.9	28.8	23.9	25.1

Range	MHW	5'	7'	9'
R85	4.4	23.2	20.7	22.5
R86	6.2	43.6	19.9	13.5
R87	-17	9.4	15	16.3
R88	4.6	28.3	17.1	12.2
R89	22.1	22.9	12.7	10.1
R90	12.8	22.6	6	6.8
R91	29.1	38.8	33.9	14.2
R92	29.6	50.9	17.4	18.7
R93	50.1	15.4	14	15.1
R94	42.5	63.3	10.7	4.8
R95	38.6	24.9	16.3	12.1
R96	39	87.9	12	-75.3
R97	14.4	9.9	23.2	0
R98	-3.7	29.8	24.3	1.3
R99	-2	28.3	16.1	0
R100	16	54.9	-3.8	-6.4
R101	21.3	11.2	17.4	16.2
R102	12.6	10.9	16.5	18.1
R103	20.9	44.6	24.2	5.3
R104	6.7	17.6	0.3	0
R105	27.2	11.1	6.2	-1.7
R106	21.3	81.8	0.1	0
R107	20.8	8.9	3.2	0.2
R108	8.9	72.1	1.5	0
R109	6.6	1.6	3.2	0.1
R110	-0.9	8.8	3.9	0.8
R111	-5.4	1.4	4.1	3.4
R112	-11.4	20.1	20.8	20.9
R113	-14.5	11	10.1	10.2
R114	-10.4	23.7	13.6	8.8
R115	6.3	16.8	13	12.8
R116	5.6	31.2	12.3	10.2
R117	17.7	33.7	21.8	9.3
R118	24.4	34.5	19	10
R119	0	27.2	17	10
R120	0	43.1	10.3	2.8
R121	0	20	0	0
R122	0	29.5	9.3	0.4
R123	31.4	65.1	8.5	2.9
T124	30.3	65.5	5.7	0.5
T125	22.6	7.4	3.2	0
R126	17.6	3.7	6.8	0
R127	17	-2.3	5	0

Range	MHW	5'	7'	9'
R128	17.6	44.3	58.2	0.1
R129	8	40.3	3.2	0.2
R130	-2.4	15.8	24.1	29.4
T131	12.8	24.6	16.2	12
R132	-8.8	17.8	16.3	15.9
R133	18.1	37.8	13.4	6.9
R134	17.5	40.5	13.4	0.7
R135	11.9	19.6	12.3	1.7
R136	1.7	29.4	-0.4	1.4
R137	2.6	16.3	7.7	9.3
R138	4.3	18.3		
R139	-2.2	21.1	13.2	14.8
R140	1.5	21.7	14.5	15.5
R141	18.7			
R142	4.3			
R143	19.5			
T144	19.4			
R145	6.2	36.8	23.5	-0.5
R146	2.6	38.4	0.5	0
R147	4.3	31.5	3.9	0
R148	9.1	43.9	10.7	0.1
R149	10	30.2	13.6	0.7
R150	6.3	28.3	10.4	3.6
R151	3.6	26.9	27	18
T152	32.2	25.6	6.7	6.8
R153	36.4	19.3	11.9	0
R154	13	29.3	15	0
R155	22	15.8	20.2	5.9
R156	1.3	14.6	15.2	15.2
R157	12.4	19.6	13.7	2.4
R158	12.6	17.7	12.9	10.5
R159	8.4	25.8	13.8	2.9
R160	22.9	17.4	7.8	0.2
R161	31.1	15	7.8	0.5
T162	22.3	24.9	17.5	1.5
R163	21.4	20.6	19.2	0.2
R164	14.3	23.3	2.5	0
R165	4.7	33.7	14.2	0
R166	6.6	34.6	26.7	1.5
R167	3.6	33.3	19.8	1.2
T168	1.6	37.4	24.2	6.8
R169	10.8	36.8	29.1	12.7
R170	12.3			

Range	MHW	5'	7'	9'
R171	-3.4	30		
R172	4.9			
R173	7.8	36.1	24.9	7.3
R174	-1.3	30.8	20.8	8
R175	-3	31.2	36.2	33.7
R176	-9.1	32.5	32.1	0
R177	-4.8	29.9	16.4	0
R178	12	38.6	34.4	0
R179	6.1	38.3	17.6	0
R180	18	38.7	39.4	0
R181	15	30.7	0.8	0
R182	6.6	30.2	8.4	0
R183	25.1	13.8	30.1	0
R184	-6.9	30.1	31	2.8
R185	13.6	32.7	27.1	0
R186	7.2	16.9	16.9	
R187	9.4	13.4	0.9	
R188	-0.6	33.3	8.9	
R189	21.8	8.3	-2	7.2
R190	-5.9	34.1	1.7	0
R191	9.5	14.9	0	0
R192	-19.1	40.7	0	
R193	6.4	26.7	9	0
R194	0.5	30	22.3	6.5
R195	8.7	34.6	21.5	1
R196	-5.9	30.1	18.7	5.9
R197	5.4	34.3	17.1	5.5
R198	-5.9	29.6	22.4	8.2
R199	-4.5	29.1	27.2	10.4
R200	12.1	11	6.9	
R201	1.8	31.5		
R202	14.4	9.3	3.3	
T203	7.6	22.4	15.2	
R204	17.1	16.8	5.7	
T205	3.6	15.5	1.5	0
R206	1.8	26.6	41.3	
R207	6	31.1	45	
R208	6	21.1	28.7	
R209	4.4	12.9	20	
R210	-0.3	15.2	11.8	
T211	2.4	27	39.4	
R212	9.2	1.4	11.6	
T213	-9.5	8.9	-16.7	-29.6

Range	MHW	5'	7'	9'
R214	3.1	28.6	19.2	7.8
T215	9.7	29.6	3.2	
R216	10.1	19.6	0	
R217	7.5	24.4	23	
R218	4.2	22	17.4	0
R219	20.5	9.4	8.2	9.2
R220	4.8	35.6	9.3	
R221	6	28.6	33.6	
R222	12.1	26.5	36	0.8
H222	11.1	55.1	20.7	0
R223	30.6	1.7		
C224	-2.2	20.2	27.5	3.9
T225	-12.1	28.2	26.2	
R226	-3.9	8.2	10.6	
R227	4.1	19.4	31.3	27

25-year Horizontal Erosion Distances at Contours (ft. – NAVD)

Range	MHW	5'	7'	9'
R1	2	26.2	20.7	14.6
R2	5.9	35.8	21.6	6.9
R3	6.9	59.7	90.6	0.1
R4	6.4	51.7	50.9	11
R5	18.8	57.7	15.7	10.4
R6	-11.6	25	19.7	11.6
R7	5.1	42.7	47.1	9.7
R8	-4.6	33.9	26.1	20.7
R9	32.3	56.6	49.7	26.9
R10	32.4			
R11	28.7	29.4	38.2	40.2
R12	20.2	72.7		
R13	28.9	47	44.2	-28.7
R14	16	55.1	27.9	16
R15	4.3	30.7	27	25.5
R16	4.9	31.2	29.1	27.1
R17	12.2	26.2	29.9	29.1
T18	15.7	14.6	26	31
T19	20.7	39.5	24.7	1.8
R20	13.3	37.8	42.9	39.9
R21	8.1	41.1	35.9	20.2
T22	23.3	40.3	40.1	23.1
T23	37.7	56.8	60.9	12.3
T24	38.7	46	23.4	4.3
T25	31.8	52.9	58.9	1.5
R26	14	56.9	-28.8	-6.2
T27	16.5	24.3	30.6	11
R28	0.8	34.6	40.7	43.3
R29	2.7	33.7	45.2	51.8
R30	14.5	42.5	52.6	51.5
R31	4.1	46.3	35.6	14.5
T32	13.9	34.4	50.2	-62.8
R33	24.3	30.4	6.3	-39.5
R34	21.9	27.6	44.5	0.2
R35	-0.5	41.9	40.4	-36.8
R36	2.3	32.9	30.2	0.3
R37	14.4	47	60.8	10.5
R38	13.7	33.5	39.2	-6.8
R39	9.1	55.6	41.7	0.1
R40	7.3	50.5	38.8	11.6
R41	4.2	31.7	29.7	9.1

Range	MHW	5'	7'	9'
R42	9.2	29.2	6	5.1
R43	-5.5	48.9	30.2	18.7
R44	11.5	43.9	41.1	21.7
R45	-2.4	12.2	16.3	11
R46	27.5	7.9	17.9	15.1
R47	-3.2	16.4	25	20.1
R48	28.1	21.6	31.5	18.4
R49	25	16.6	28.3	4.6
R50	13.9	29	32.8	13.4
R51	25.5	28.7	31.9	17.8
R52	38.5	30.5	32.2	16.1
R53	25.3	13.3	30	11
R54	20.4	10.6	24.9	26.4
R55	20	18.3	22.6	7.4
R56	27.6	15.8	23.2	30.7
T57	30	13.8	31.5	1.3
R58	21.8	15.6	37.6	1.6
R59	7.9	26.4	35.7	4.1
R60	30.9	24	29.6	34.5
R61	28.4	23.7	16.8	12.8
R62	29.3	28.2	23.4	14.2
R63	29.1	29	26.9	14.1
R64	40.2	48.2	18.2	10.5
R65	33.7	53	28.4	18.9
R66	25.2	54	31	26.9
R67	37.6	30.9	-1.8	2.4
R68	18.2	36.6	-3.8	0
R69	10.4	42.7	0.9	0
R70	5	47.9	31.5	6.8
R71	19.5	36.6	22.4	2.4
R72	2.2	30.2	37.8	10.1
R73	25.5	59.7	19.1	19.9
R74	28	61	13.4	9.6
R75	44	69.5		
R76	21.2	80.1		
R77	3.4	52.2	26.6	-99.4
R78	64.7	51.3	47	43.1
R79	42.4	81.3	27.3	3.7
R80	26.2	10.8	15.2	6
R81	12.5	45.8	24.4	13.4
R82	6.5			
R83	12.5	47.5	21.6	24.1
R84	-12.6	30.8	29.9	33.1

Range	MHW	5'	7'	9'
R85	3.2	24.2	26.5	29.2
R86	3.7	46.8	31.2	27.8
R87	-22.2	12.6	19.6	21.7
R88	-2.1	28.7	25.8	21.8
R89	16.3	21.9	18.5	18.9
R90	5.3	23.9	10.5	13.9
R91	26.5	41.6	40.7	20.2
R92	27.6	56.7	24.7	27.2
R93	50.6	21.8	21.8	27.7
R94	41.9	68.9	17.1	11.3
R95	36.5	28	24	23.4
R96	43.1	97.2	22.7	-46.7
R97	16.8	14.3	30.6	0.8
R98	-4.7	31.3	30.7	10.6
R99	-5.6	32.6	29.1	2.1
R100	12.8	60.6	6	0.3
R101	16.1	12.6	20.6	21.4
R102	3.4	10.1	20.9	28.8
R103	18.9	47.8	30.3	14.4
R104	16.1	7.9	7.7	0
R105	27	10.6	16.2	4.2
R106	25.4	68.5	8.7	0.1
R107	23.6	5.1	4.6	10.8
R108	13.3	62.7	4.9	1.5
R109	9.8	5.7	8.7	1
R110	-2.4	9.5	10.5	6.5
R111	-9.3	0	8.5	9.5
R112	-18	20.7	28.3	27.7
R113	-23.6	9.5	15.6	16.5
R114	-17.2	21.2	20.9	15.4
R115	2.7	17.6	17.2	18.2
R116	-3.3	30	19.9	17.9
R117	15	38.1	30.5	17.6
R118	24.8	36.2	28.1	20.1
R119	0	26.9	21.1	15.6
R120	0	46	17.9	8.2
R121	0	39.2	18.6	7.3
R122	0	30.3	9.7	0.5
R123	35.2	71.7	15.8	8.2
T124	31.6	70.3	11.2	5.4
T125	25.7	6.7	8.1	3
R126	16.4	7.1	17.6	0.3
R127	19.8	2	12.5	0.2

Range	MHW	5'	7'	9'
R128	16.7	50.6	65.6	1.4
R129	6.4	45.5	7.2	1.8
R130	-4.5	23.6	31	35.3
T131	7.7	29.6	22	19.1
R132	-14.8	18.8	20.6	21
R133	13	39.2	18.5	14
R134	13.7	43.7	23.1	9.1
R135	10.9	23.9	17.8	5.9
R136	-2.1	30.3	4.9	6.1
R137	-2.6	17.1	14.5	15.1
R138	8.6			
R139	-9.5	24.5	21.6	24.3
R140	-3.6	22.2	19.6	23.2
R141	21.7			
R142	5			
R143				
T144				
R145	1.2	39.4	28	3.7
R146	2.8	38.5	5.5	0
R147	6.7	35.8	8	1.4
R148	10.8	47	15.6	7.2
R149	10.2	36.4	19.3	3.7
R150	-0.1	32.3	19.2	12.4
R151	-2.4	26.2	38	41.5
T152	34.8	30	13.7	13.2
R153	33.9	22.6	23.9	14.6
R154	12.8	34.5	27.3	7.2
R155	19	19.5	30.9	11.3
R156	-0.5	20.4	24.9	24.3
R157	9.2	22.9	22.6	11.6
R158	9.9	20	20.6	19
R159	4.9	29.2	22.2	11.1
R160	22.9	22.4	15.5	2.8
R161	29.2	13.9	16.8	15.9
T162	20.6	30.6	24.8	11.9
R163	22.2	26.7	26.2	1
R164	17	27.3	6.2	2.3
R165	2.6	38	25.2	4.7
R166	4.7	39.9	35.3	9
R167	3.8	37.6	27.6	8.1
T168	-1.4	40.3	29.7	12
R169	3	38.3	49.9	61.5
R170	15.3			

Range	MHW	5'	7'	9'
R171	0.2			
R172	7.8			
R173	3.4	37.6	39.9	45.7
R174	-7.5	30.9	37.5	37.2
R175	-7.7	33.4	47.1	51.2
R176	-14.1	34.3	44.7	0.4
R177	-7.5	32.8	28.9	0
R178	7.7	44.1	59	0
R179	3.1	42.7	46.2	0.7
R180	16.2	45.2	61.3	0
R181	16.4	32.6	9.7	0
R182	2.1	38.7	42.4	0
R183	25.2	17.2	36.4	2.5
R184	-11.1	33.7	39.2	14
R185	13	37.3	34.8	0.6
R186	7.9	21.2	29.2	
R187	10.5	17.2	5.2	
R188	-3.3	42.5	22.9	
R189	23.1	9.6	10.1	22.1
R190	-4.9	36.6	4.7	8.2
R191	10.2	24.8	4.8	3.0
R192	-17.4	42.3	0.4	
R193	5.1	34.1	20.7	2.8
R194	-6.2	36.0	32.5	11.5
R195	3.0	42.3	30.7	3.2
R196	-9.7	31.5	21.8	10.5
R197	4.1	40.5	26.3	10.4
R198	-8.9	28.6	24.2	6.8
R199	-8.4	33.7	36.3	16.5
R200	11.3	17.6	15.8	
R201	3.3			
R202	13.6	15.1	12.2	
T203	5.0	30.8	27.6	
R204	20.0	21.6	14.8	
T205	3.2	18.4	6.6	3.2
R206	1.7	33.4	50.6	
R207	7.1	35.7	57.9	
R208	6.7	23.3	44.7	
R209	1.7	22.9	39.9	
R210	-6.4	19.5	38.7	
T211	2.4	32.5	55.0	
R212	8.2	13.6	17.2	
T213	-12.9	8.6	-15.2	-25.6

Range	MHW	5'	7'	9'
R214	1.7	32.7	27.2	15.8
T215	12.4	34.8	5.5	
R216	9.6	23.6	7.4	
R217	5.2	30.0	32.3	
R218	1.0	26.5	27.9	4.6
R219	16.0	17.4	13.0	13.5
R220	1.4	39.2	32.2	
R221	5.5	34.7	51.6	
R222	12.2	30.9	43.7	5.0
H222	8.1	58.6	32.7	8.2
R223	35.3	1.8		
C224	-6.0	25.5	41.3	20.8
T225	-13.8	29.6	41.5	
R226	-4.2	17.8	20.8	
R227	1.6	32.1	37.2	28.4