

SBEACH Calibration and Erosion Analysis for Walton County and Okaloosa County, Florida

Prepared by

Mark E. Leadon, P.E. and Nhan T. Nguyen

Beaches and Shores Resource Center
Florida State University

May 2009



Prepared for

Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Beaches and Coastal Systems

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FOREWORD

The Florida Department of Environmental Protection's (FDEP) Bureau of Beaches and Coastal Systems (BBCS) is responsible for programs for the protection and management of beaches and coastal systems of the State of Florida. This responsibility includes evaluation of coastal processes through the use of analytical and numerical models. Modeling evaluations to simulate and predict beach and dune erosion of coastal areas resulting from episodic coastal storms are integral to the BBCS coastal management and oversight activities.

This report summarizes work performed to provide estimates of beach and dune erosion for Walton County and Okaloosa County resulting from high-frequency storm events through the use of the SBEACH model. The report describes model calibration work performed during initial phases of the overall work in order to apply model input appropriate for use in the Florida Panhandle study region.

The work performed and described in this report was conducted under specific task order contained and described in a contract (BS-025) between the BBCS and the Florida State University (FSU) Beach and Shores Resource Center (BSRC). The SBEACH model was purchased as part of the Coastal Engineering Design and Evaluation System (CEDAS) from Veri-Tech, Inc.

The SBEACH model is distributed through Veri-Tech, Inc. based on a version of the SBEACH model prepared by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, USA. SBEACH (Storm-induced BEACH CHange) simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels. As conveyed by Veri-Tech, Dr. Magnus Larson of the University of Lund is the principal author of the SBEACH model.

The SBEACH model work performed and described in this report included no modifications/revisions to the model code. It is noted that no multiplier factors were applied to model results as additional work outside operation of the SBEACH model as part of the calibration work performed. SBEACH was operated according to the Veri-tech version interface.

The model evaluation work and report preparation was performed by Mark Leadon, P.E., Program Director of the BSRC, and Nhan Nguyen, Research Engineer, of the BSRC. Contract task oversight for performance and completion of this work for the BBCS was conducted by Robert Brantly, P.E., and Subarna Malakar.

EXECUTIVE SUMMARY

Beach and dune erosion simulation for the Panhandle coastal region of Florida was performed through use of the SBEACH numerical model. The SBEACH model simulation included beach and dune erosion estimates for high-frequency storm events for Walton and Okaloosa counties. Initial work included model calibration using measured topographic/bathymetric survey, storm tide, wave and weather data.

Sufficient survey data with available storm tide measurements from within Walton and Okaloosa counties associated with coastal storms impacting these counties necessary for model calibration work could not be found at the time of this work. However, model calibration data applicable to Walton and Okaloosa counties was found for nearby Panama City Beach in Bay County. Sufficient pre- and post-storm ground survey and storm tide data measurements, as well as concurrent wave data, from Hurricane Opal in 1995 and Hurricane Ivan in 2004 were compiled and evaluated for model calibration.

Storm tide data for model input for Opal and Ivan was obtained from an NOS tide gage located on Panama City Beach pier at R40. Wave data for SBEACH model input for Ivan was obtained through wave transformation of deep-water NDBC buoy data. Wave data for Opal was compiled through wave transformation of nearshore USACE-WIS wave hindcast data.

Model input parameters for sediment grain size and water temperature were obtained for the Panama City Beach pier location for the Opal and Ivan time periods. As a result of sensitivity testing of sediment transport model input parameters, it was found that most of these parameter values should remain at the recommended default values. However, adjustment of the sediment transport parameter (K) and the coefficient for slope dependent term (ϵ) produced better model calibration results. These two parameters were adjusted to the upper limits of the recommended range of values which resulted in closer agreement of model-computed erosion with measured erosion from Opal and Ivan.

The adjustments of K and ϵ resulted in very good model calibration for Hurricane Ivan. Despite the adjustments of the K and ϵ values, it was found that SBEACH significantly under-predicted erosion for Hurricane Opal in comparison with the measured erosion, particularly for dune recession in upper contour elevations above approximately the 10 foot elevation. It is apparent that application of multiplier factors to the model-computed erosion would be needed in order to obtain good dune erosion calibration for Hurricane Opal. Use of such multipliers is beyond the intent and scope of this study.

In review of the model calibration results, a significant difference is noted between Ivan and Opal within Panama City Beach. The measured storm tide and the transformed wave heights were higher for Opal than for Ivan. Opal was more characteristic of a lower-frequency storm and resulted in greater dune erosion than Ivan. The lower storm tide and wave conditions associated with Ivan are more characteristic of a higher-frequency storm. The favorable calibration results for Ivan are considered to be sufficient basis for use in high-frequency storm erosion analyses in Walton and Okaloosa counties.

SBEACH Calibration and Erosion Analysis for Walton County and Okaloosa County, Florida

1.0 Background

Coastal resource protection and management responsibilities of the FDEP Bureau of Beaches and Coastal Systems necessitates use of dune erosion modeling to assist in prediction of beach and dune erosion associated with coastal storms. The FDEP's CCCL erosion model by Dean and Chiu (1984, 2002) has been used extensively, particularly in 100-year storm erosion prediction for establishment of coastal construction control lines. The CCCLa erosion model by Dean and Malakar (1995) has been used extensively by the FDEP in prediction of high-frequency storm erosion.

A beach and dune erosion model developed through the U. S. Army Corps of Engineers (USACE) and used extensively by the USACE and coastal engineering consultants in Florida is the SBEACH (Storm-induced BEAch CHange) model. A detailed description of the model will not be provided herein. Detailed information on the SBEACH model can be found in SBEACH Reports 1, 2, and 3 (Larson and Kraus 1989a; Larson, Kraus, and Byrnes 1990; and Rosati, Wise, Kraus, and Larson 1993) which are available through the USACE Coastal & Hydraulics Laboratory website at: <http://chl.erdc.usace.army.mil/>

As a result of the on-going use of the SBEACH model in Florida, particularly by the USACE, the FDEP-BBCS contracted with the FSU-BSRC to conduct investigations using SBEACH. The contracted SBEACH work included specific application of SBEACH to estimate beach and dune erosion for 15 and 25 year storm events in Walton County and Okaloosa County. Description of SBEACH model calibration and model application and results for Walton County and Okaloosa County are described below.

2.0 Model Calibration

Review of available data for calibration of the SBEACH model for Walton and Okaloosa counties resulted in limited data of sufficient completeness and quality for calibration purposes. The available measured topographic and bathymetric survey data for pre- and post-storm comparison is limited and no known direct storm tide hydrograph data measurements coincident with the survey data is available for these counties.

Survey data for Walton and Okaloosa counties from recent storm activity, including Hurricane Ivan in 2004 and Hurricane Dennis in 2005, is not sufficiently complete for calibration purposes. Survey data before and after Hurricane Opal in 1995 is sufficient in coverage and quality in Walton and Okaloosa counties for model calibration work. However, there are no known storm tide hydrograph data measurements available along the Gulf coast within these counties associated with Opal.

Fortunately, survey data and storm tide data sufficient for model calibration can be found from nearby Panama City Beach in Bay County. This data, combined with measured

storm wave data, for Hurricane Ivan and for Hurricane Opal provided necessary information for SBEACH model input for use in model calibration work. Details about this data, how it was used in calibration work, and the model calibration results are discussed below.

2.1 Measured Storm Data

The FDEP-BBCS has compiled pre- and post-storm beach and offshore profiles along FDEP range lines for a number of storms in Bay County, including Opal, Ivan, and Dennis. Survey data collected for Opal was prior to the Panama City Beaches beach restoration project. Data for Ivan and Dennis was collected after the beach restoration project was constructed and obtained as part of project monitoring for the project. For reference purposes, an illustrative map depicting the storm tracks for Opal, Ivan, and Dennis is shown in Figure 1 below.

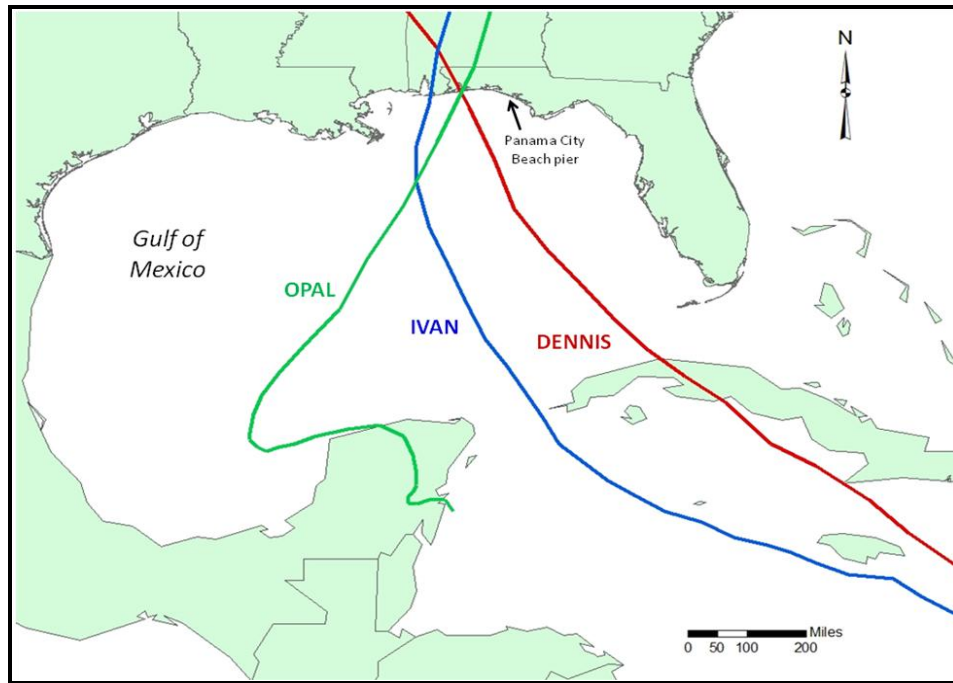


Figure 1. Map depicting storm tracks for Hurricanes Opal, Ivan, and Dennis

The National Ocean Survey (NOS) of the National Oceanographic and Atmospheric Administration (NOAA) maintained a tide gage and weather station for many years on the Panama City Beach public pier located adjacent to FDEP range R40. The relative location of the Panama City Beach pier to the storm tracks of Opal, Ivan, and Dennis across the Gulf of Mexico is shown in Figure 1.

The location map in Figure 2 shows the proximity of the pier and tide gage to the adjacent shorelines of Walton and Okaloosa counties. The aerial photo (April 2004; pre-Ivan) shown in Figure 3 depicts the location of the NOS tide gage on the pier and near proximity of the pier and tide gage to FDEP range location at R40.

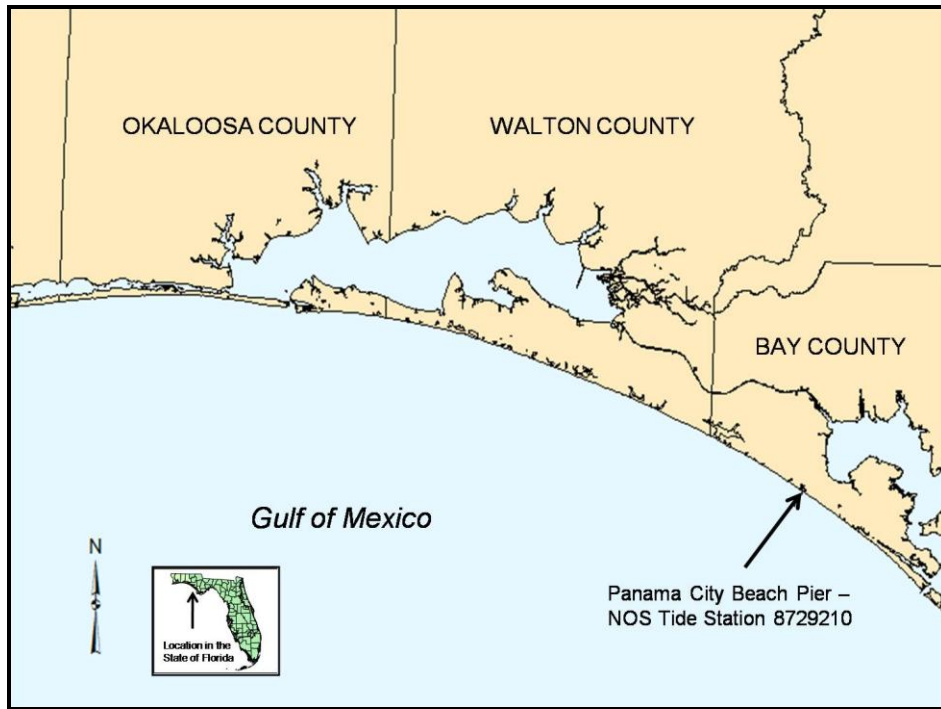


Figure 2. Map depicting proximity of NOS tide gage to WL and OK counties

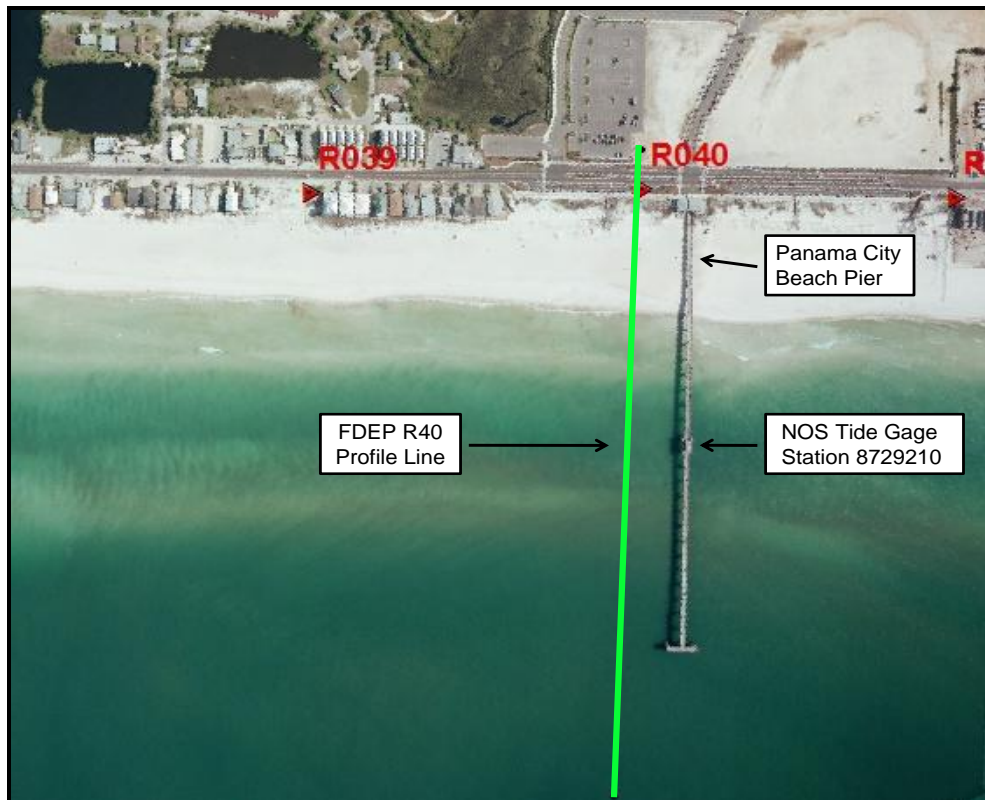


Figure 3. Pre-Ivan aerial photo depicting location of NOS tide gage and R40 profile line

The pier and tide gage are located approximately 150 feet east of R40. Pre- and post-Ivan survey data obtained along the profile line at R40 shown in Figure 3 was used in much of the initial SBEACH testing along with other adjacent profile data for the model calibration work, discussed further below.

The NOS tide gage on the Panama City Beach pier was taken off-line in January 2008 during the time of pier re-construction. Storm tide data was acquired from this gage for Opal, Ivan, and Dennis. A comparative graphical schematic of the storm tide data for all three of these storms is shown in Figure 4. Ivan and Opal were chosen for the SBEACH calibration analysis to provide a wider range of storm tide conditions in the analysis.

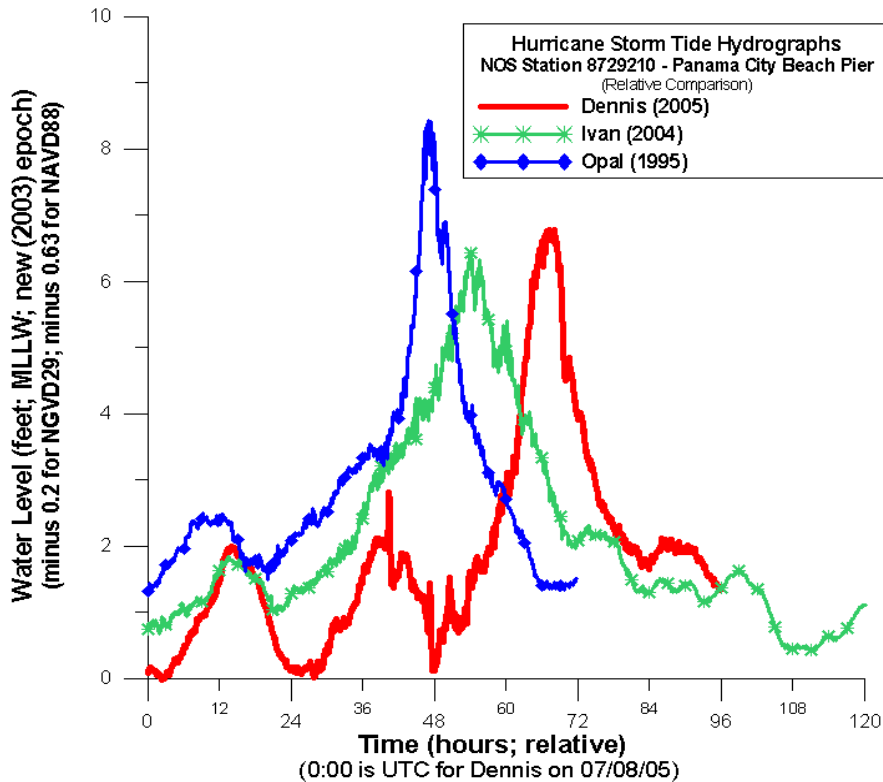


Figure 4. Relative comparison plot of measured storm tide for Opal, Ivan, and Dennis

Wave data measurements from a NOAA National Data Buoy Center (NDBC) deep water buoy south of Panama City Beach (Station 42039) were obtained for Hurricane Ivan and for Hurricane Dennis. Wave hindcast data compiled by the USACE Coastal and Hydraulics Laboratory (CHL) Wave Information Study (WIS) program offshore of Panama City Beach are available for Hurricane Opal.

WIS hindcast data from Station 183 which is the station nearest to the Panama City Beach pier was used. Wave data from the 42039 buoy is also available for Dennis, but not for Opal. Wave hindcast data is not yet available from the CHL website for Ivan nor Dennis. A map depicting the locations of the NDBC station 42039 and the WIS station 183 is provided in Figure 5 below.

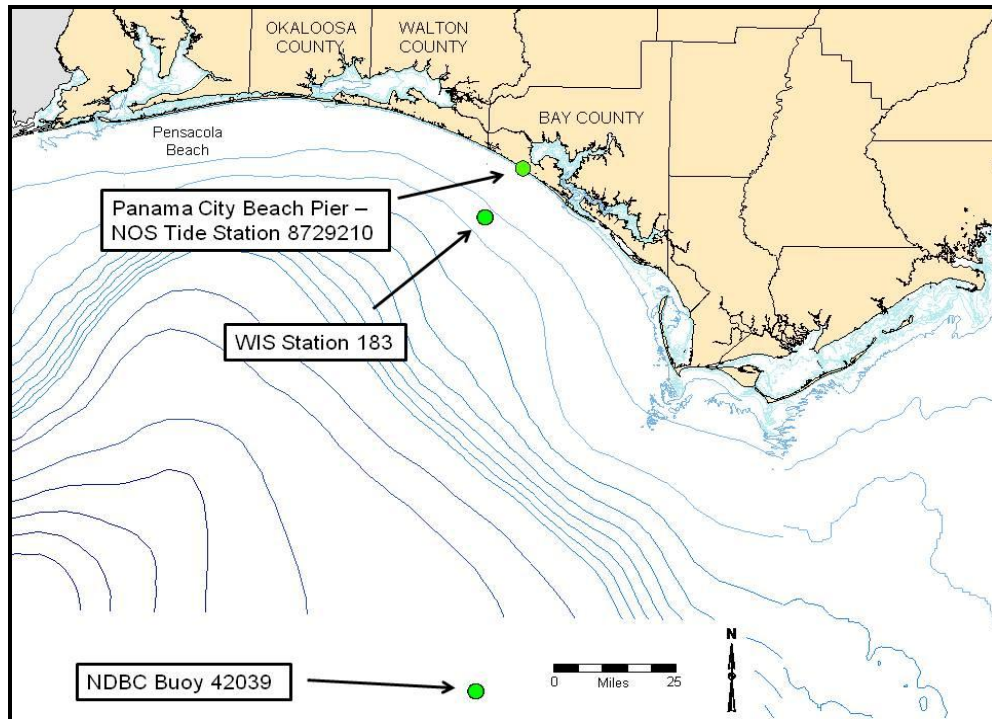


Figure 5 . Map depicting locations of NDBC buoy 42039 and WIS station 183

2.1.a Hydrographic Survey Data

Topographic/bathymetric ground survey data was compiled for the three hurricanes described above, Opal, Ivan, and Dennis, which have associated storm tide and wave data concurrently available. Survey data along FDEP range lines within relatively close proximity to the pier, which is close to R40, was reviewed for acceptability for use in the calibration work.

Selected profile survey data for Ivan between R30 and R50T from June 2004 (pre-storm) and October 2004 (post-storm) were evaluated in the SBEACH calibration work. A total of 19 profiles within this coastal segment were evaluated for Ivan. Selected profile survey data for Opal from April 1995 (pre-storm) and October 1995 (post-storm) between R3 and R51 were evaluated. A total of 25 profiles were evaluated within this coastal segment for Opal. The map in Figure 6 shows the general location of the evaluated coastal segment with respect to Panama City Beach, St. Andrews Inlet, and the Walton County boundary line.

Selected profile survey data for Dennis within the Panama City Beach shoreline area from October 2004 (pre-storm) and July 2005 (post-storm) were evaluated in the SBEACH calibration work. Results of initial evaluation concluded that additional calibration work to include Dennis was not justified for a couple of reasons. First, Dennis' peak storm tide elevation was between the two storms already being evaluated, Opal and Ivan. Secondly, pre- and post-Dennis survey data was unacceptably affected by

Hurricane Ivan the prior year and by post-Ivan beach restoration activities within the study area.

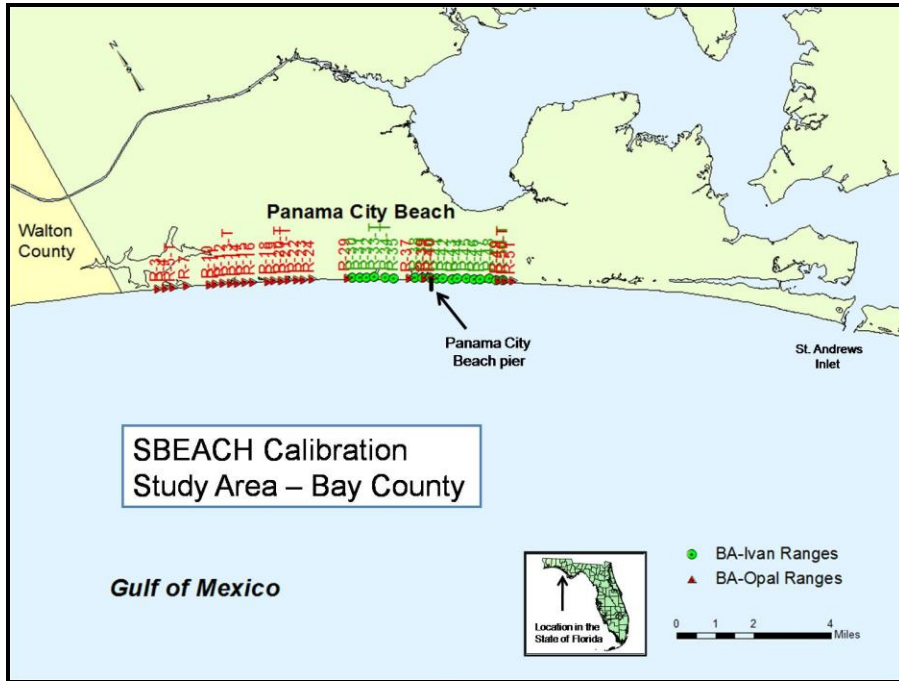


Figure 6. General vicinity map of the SBEACH calibration study area in Bay County

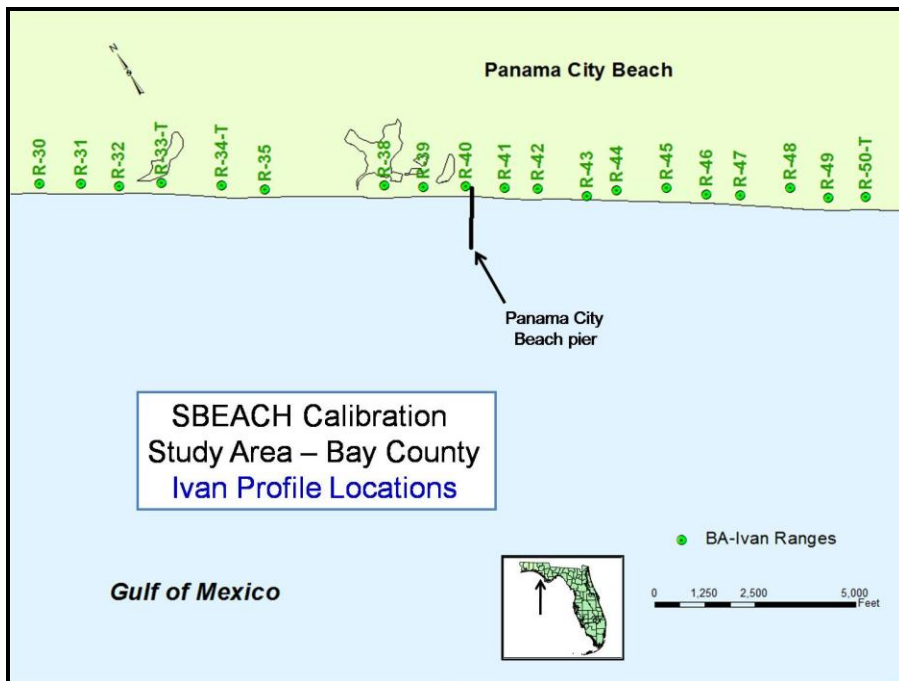


Figure 7. Map of the SBEACH calibration study area for Hurricane Ivan in Bay County

A more detailed depiction of the specific profile locations used for the SBEACH model calibration work for Ivan is shown in Figure 7 above and for Opal in Figure 8 below.



Figure 8. Map of the SBEACH calibration study area for Hurricane Opal in Bay County

Observation of the profile data sets for Ivan has shown post-storm beach recovery evident in the lower beach elevations below approximately the 5 foot contour. This is unfortunate for calibration purposes. Upper beach elevations between approximately the 5 and 10 foot contours were shown to be unaffected by beach recovery and acceptable for calibration. Profiles at R36 and R37 were discarded from the evaluation as a result of seawall effects impacting the data quality.

Profile data sets for Opal were not significantly affected by post-storm recovery. The Opal profiles show significantly greater dune erosion resulting from a storm of greater magnitude compared to Ivan and a narrower, steeper beach-dune profile prior to the beach restoration project. Effects of these differences between Ivan and Opal on the calibration results will be discussed further below.

2.1.b Storm Tide Data

The NOS tide gage Station 8729210 was located on the Panama City Beach pier approximately 830 feet seaward of R40 which is generally about 400 feet seaward of the approximate shoreline. Water depths at the gage ranged from approximately -15 feet (NAVD) (i.e., pre-Ivan) to approximately -20 feet (NAVD) (i.e., post-Ivan). The storm tide recordings for Ivan and Opal were extracted and re-formatted for input to the SBEACH model for 72 hour time periods encompassing the entire time period of storm surge and storm wave effects for each storm. The 72-hr time period for Ivan included the

3-day period of September 15-17, 2004. The 72-hr time period for Opal included the 3-day period of October 3-5, 1995. Evaluation was performed to determine any wave set-up components included in the tide gage data since the gage location was found to be well within the surf zone limits of both Ivan and Opal. The SBEACH model computes set-up within the model. Therefore, wave set-up included in the tide gage data must be removed from the storm tide data to ensure that set-up is not overly accounted for in the storm erosion modeling evaluation. More detail about procedures used to adjust the tide gage data accordingly will be discussed further below.

2.1.c Wave Data

Hurricane Ivan

Measured wave data for Hurricane Ivan was obtained from NDBC buoy 42039 which is the nearest NDBC buoy and known wave data source for Ivan to Panama City Beach. The 42039 buoy is located approximately 100 miles SSW of the Panama Beach City pier. Significant wave height, dominant wave period, and mean wave direction values from the buoy data were transformed from deep water (-307 m) at the buoy location to a 40 ft. depth offshore of Panama City Beach for use in the SBEACH model.

Wave transformation was performed through use of a WIS Phase III wave transformation routine developed through the USACE-CHL and contained in the Coastal Engineering Design and Analysis System (CEDAS) software package, which also contains the SBEACH software, available from Veri-Tech, Inc. A plot of the deep water wave data recorded by NDBC buoy 42039 is shown in Figure 9.

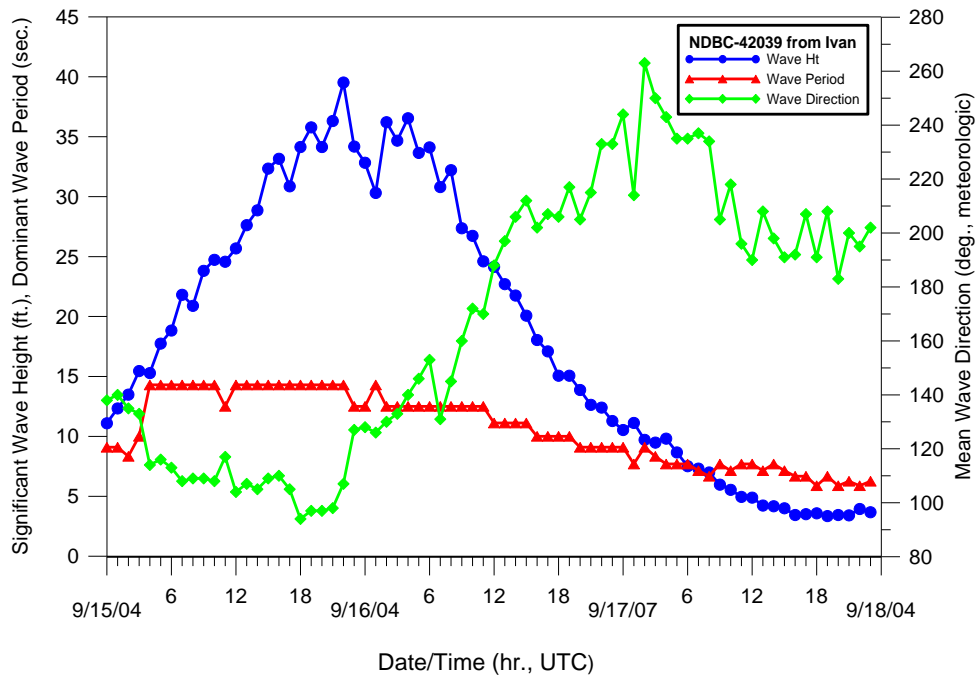


Figure 9. Deep water wave conditions for Hurricane Ivan at NDBC buoy 42039

The deep water buoy data was initially transformed to a 100 ft. depth within intermediate water depths. The wave data at the 100 foot depth was then transformed to a 40 ft. shallow water depth coincident with general seaward depth limits of the profile survey depths. Transformed wave conditions established at the 40 ft. depth used as input wave conditions for Ivan in SBEACH are shown in Figure 10. Specific comparison between the wave heights from Ivan at the deep water buoy and the nearshore transformed wave heights is shown in Figure 11.

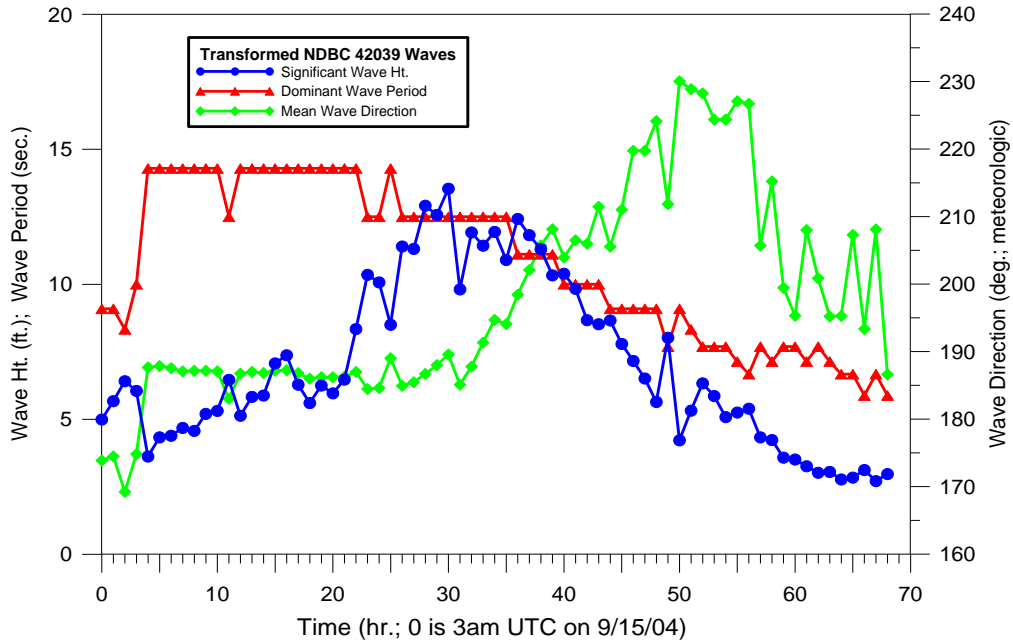


Figure 10. Transformed NDBC buoy wave conditions at 40 ft. depth for Hurricane Ivan

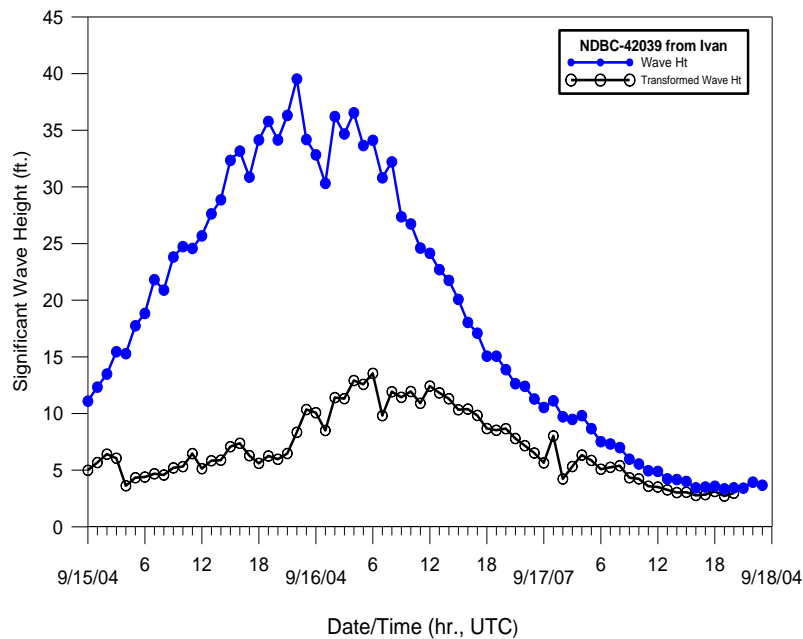


Figure 11. Comparison of NDBC buoy waves with transformed waves for Hurricane Ivan

Hurricane Opal

Measured wave data for Hurricane Opal from NDBC buoy 42039 was not obtained at the buoy and is not available. However, wave hindcast data for the Hurricane Opal time period is available and was obtained from the USACE-CHL for nearshore areas at Panama City Beach. Significant wave height, wave period, and wave direction from WIS Station 183 located at approximately 12 miles offshore of Panama City Beach in water depths of approximately 95 feet were transformed to a 40 foot water depth. The WIS Station 183 wave conditions for Opal are shown in Figure 12. Wave transformation was performed through use of the WIS Phase III routine contained in the CEDAS software. The transformed waves used as input wave conditions for Opal in SBEACH are shown in Figure 13.

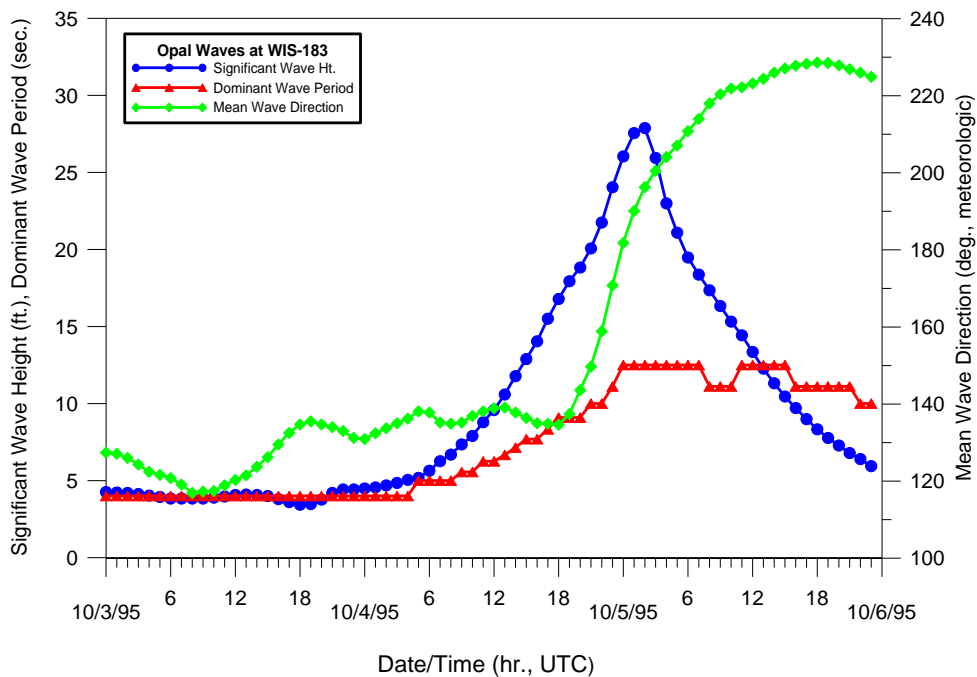


Figure 12. Hurricane Opal wave conditions at WIS Station 183 near Panama City Beach

It is noted that the transformed wave parameters shown in Figures 10 and 13 were adjusted to account for the travel time from the buoy to the 40 foot nearshore depth for Ivan and from the WIS station location to the 40 foot depth for Opal. These time adjustments were necessary to properly simulate these waves in coincident time with the storm tide hydrograph from the NOS tide gage.

A time shift applied for wave travel time for Ivan was 3 hours and for Opal was 1 hour. The time shifts were based on formulations and procedures for estimated wave celerity from deep water to shallow water contained in the USACE Shore Protection Manual (1984). The applied time shifts are approximate for the measured range of waves. Specific comparison between the wave heights from Opal at the WIS station and the transformed nearshore wave heights is shown in Figure 14.

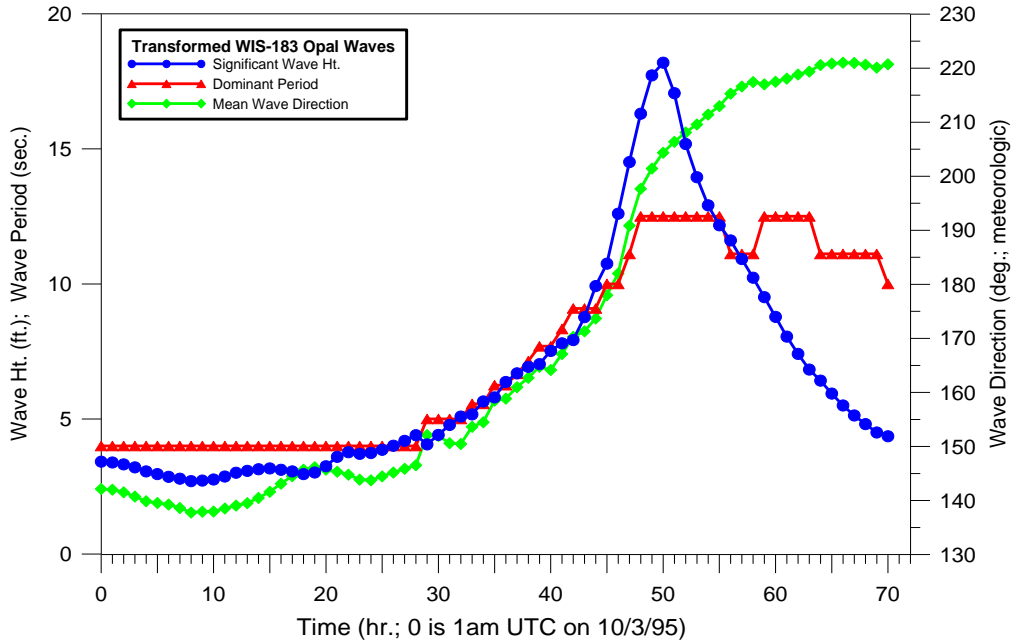


Figure 13. Transformed WIS wave conditions at 40 ft. depth for Hurricane Opal

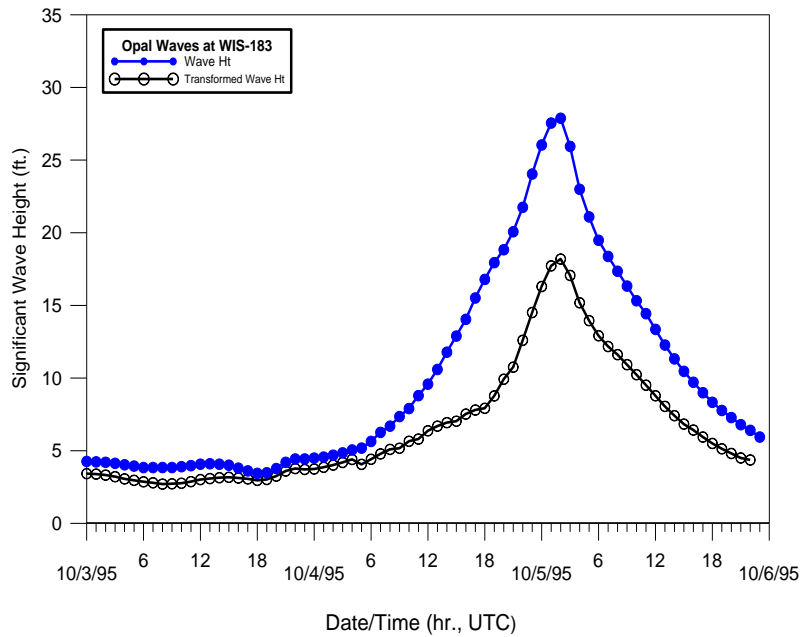


Figure 14. Comparison of NDBC buoy waves and transformed waves for Hurricane Opal

2.2 Model Input Parameters

Primary input information required for application of the SBEACH model include data and information related to the coastal reach where the model is applied and to specific coastal storm conditions. The specific storm tide and wave data described

previously above were incorporated into the SBEACH model for the required storm input. Required reach data included the topographic/ bathymetric survey data for the Panama City Beach study area for model calibration evaluation and other site-specific data and information, including sediment grain size and water temperature.

Other required reach-specific parameters include sediment transport parameters. The sediment transport parameters may be adjusted within recommended range of values limits. Adjustment of these values may assist in achieving improved model calibration. A set of default values for the sediment transport parameters and other reach parameters is provided within the SBEACH model software. The default values and recommended range of values for reach-specific parameters including sediment transport parameters are listed in Table 1 below.

Specific parameter units are also shown in Table 1. Sensitivity evaluation was conducted by adjustment of each of the reach sediment transport parameters and other reach parameter variables throughout the range of values. Sensitivity testing also included evaluation of variations in reach (beach and offshore profiles) grid size and model execution time step. Sensitivity of including storm wind effects, as well as, utilizing wave randomization were also evaluated.

Table 1. Listing of SBEACH Input Parameters

Sediment Transport Parameters	Default Value	Range of Recommended Values
Transport rate coefficient, K	$1.75 e^{-006} (m^4/N)$	$0.25 e^{-006} - 2.5 e^{-006}$
Overwash transport parameter	0.005	0.002 - 0.008
Coefficient for slope dependent term, ϵ	$0.002 (m^2/s)$	0.001 - 0.005
Transport rate decay coeff. multiplier, λ	$0.5 (m^{-1})$	0.1 - 0.5
Water temperature	20 (deg C)	0 - 40
Other Coastal Reach Parameters		
Landward surf zone depth	0.3 (m)	0.15 - 0.5
Effective grain size (mean D50)	0.35 (mm)	0.15 - 1.0
Maximum slope prior to avalanching	45 deg	15 - 90 deg

2.3 Model Calibration Results

The sensitivity evaluation described above resulted in setting most all of the reach input parameters at the default values. However, it was determined that improved model calibration results were achieved by increasing the transport rate coefficient parameter, K, and the coefficient for slope dependent term, ϵ , to the maximum values within the recommended range of values. Therefore, a K value of $2.5 e^{-006} (m^4/N)$ and an ϵ value of 0.005 was used for the final model calibration. It is noted that vertical elevations for the model calibration evaluation work is in NGVD29. This allowed for easier comparison with previous high-frequency erosion model analyses by BSRC (2006) for this area.

Other site-specific, storm-specific parameter values used in the calibration included sediment grain size data from the Panama City Beach restoration project and water temperature data from the NOS weather station on the pier. Grain size and water temperature for Opal and for Ivan were 0.25 mm and 27 (deg C), and 0.30 mm and 27 (deg C), respectively.

It is noted that the model calibration evaluation in this study is focused on and, therefore, essentially limited to the upland beach and dune portions of the evaluated profiles. Detailed comparisons and analyses of measured versus computed profile response to the storm event simulations in offshore portions of the profiles were not conducted herein.

It is also noted that initial sensitivity testing with wind speed and direction varied over a wide range of input conditions resulted in a conclusion that including wind effects in the model would not significantly alter the model results. Therefore, wind data for Opal and Ivan were not added to the storm input in SBEACH.

It was determined that the Panama City Beach tide gage location was within the limits of SBEACH-generated set-up (wave and/or wind; not specified in the SBEACH software) for Ivan and Opal. As a result, storm tide data for Ivan and Opal were adjusted accordingly to account for the water level increase generated by SBEACH. The water level increase (presumed to be set-up) was extracted from the SBEACH output on an hourly basis at the tide gage location throughout the storm duration. These set-up values were then subtracted from the tide gage hourly readings. The resulting adjusted storm tide hydrograph was then used in SBEACH and, subsequently, the maximum water elevations with set-up generated by SBEACH at the tide gage location were checked for comparison with the measured tide gage readings.

The graph in Figure 15 depicts, for Ivan, the measured storm tide readings from the gage (blue line), as well as, the water elevation plus set-up output from SBEACH based on the measured storm tide input (black line). Also shown in the upper graph in Figure 15 is the adjusted measured storm tide with the SBEACH-generated water elevation increase subtracted from the original measured storm tide (red line), and the final storm tide values from SBEACH based on the adjusted measured storm tide (green line).

The accompanying lower graph in Figure 15 shows the water elevation difference between the original measured storm tide and the resulting SBEACH water elevation plus set-up output (red line). Also shown in the lower graph is the difference in the adjusted measured storm tide and final SBEACH water elevation plus set-up output (green line). The blue line in the lower graph depicts the net difference between those two accompanying lines.

The result of this storm tide adjustment exercise is to produce storm tide output values from SBEACH which coincide with (match) the measured storm tide from the tide gage, which is the case as shown in Figure 15. Figure 16 shows the same graph information as Figure 15 for Hurricane Opal.

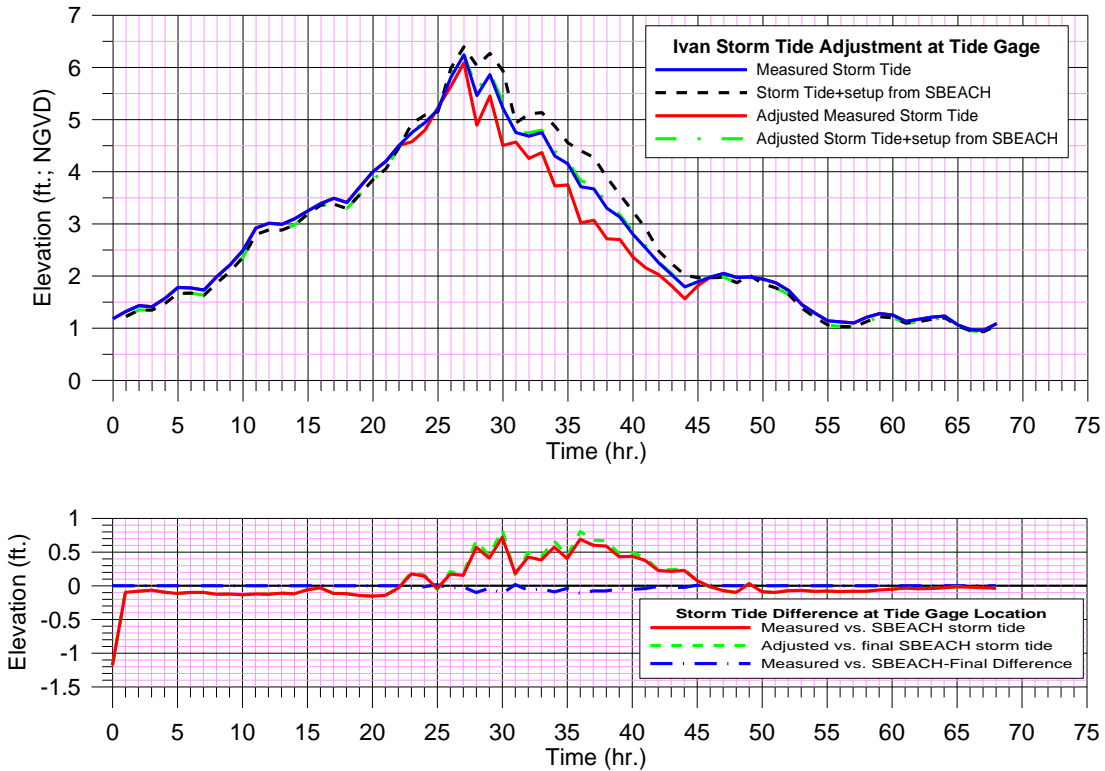


Figure 15. Measured storm tide for Hurricane Ivan and adjusted for SBEACH setup

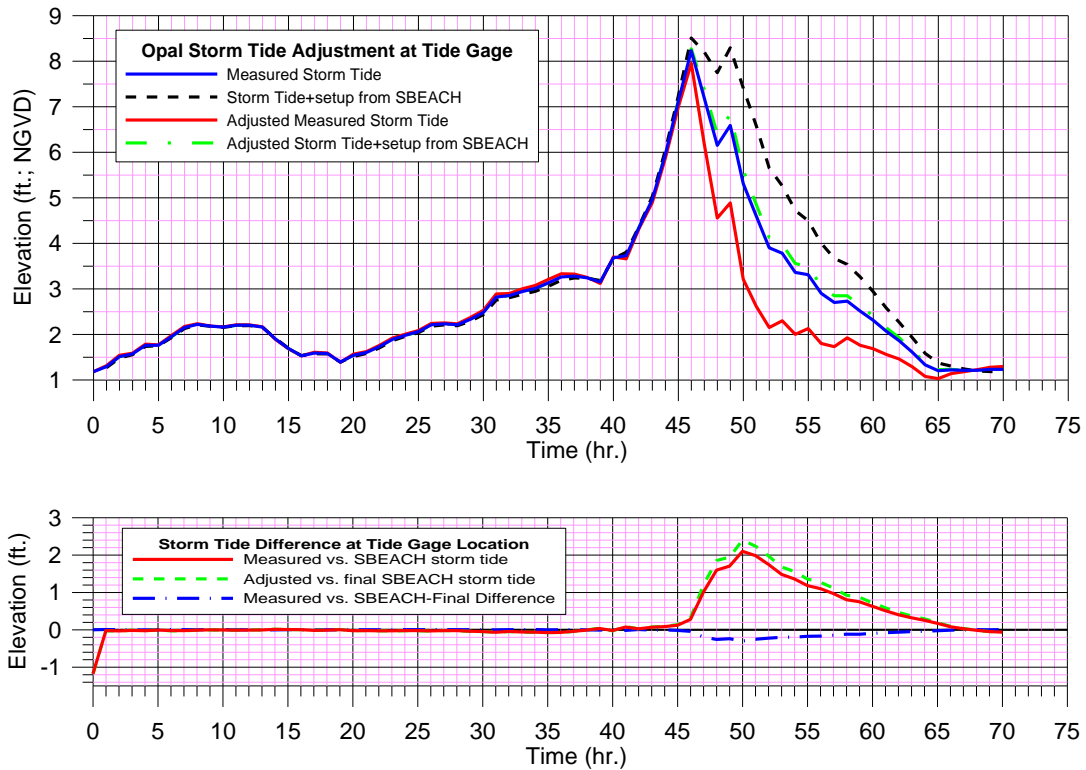


Figure 16. Measured storm tide for Hurricane Opal and adjusted for SBEACH setup

Hurricane Ivan Calibration Results

Based on the final model input values described above, model calibration for Hurricane Ivan was found to show very good agreement between measured and computed storm-generated erosion. Comparison of horizontal beach and dune profile recession at one foot elevation contour intervals was conducted in the calibration evaluation. Average contour recession values for 19 profiles evaluated for Ivan are shown in Figure 17.

In addition to the model-computed erosion shown in Figure 17 based on the measured and transformed wave data from Ivan, computed erosion is also shown in Figure 17 based on constant wave input. Model sensitivity testing was performed with constant wave input for comparison with the measured wave data results. Several constant wave conditions in addition to default values given in SBEACH were evaluated. Wave heights of 10 and 12 feet in combination with wave periods of 8, 10, 12, and 14 seconds were evaluated. A wave height of 10 feet and wave period of 12 seconds, which is consistent with approximate average periods for the Ivan data, resulted in the best agreement with the measured data, as well as, with the computed results using the transformed measured Ivan wave data as model input.

It is noted that post-storm beach recovery is evident in the post-storm profiles below approximately the 5 foot contour elevation. The beach recovery artificially obscures the calibration results in the lower beach contour elevations below approximately the 5 foot elevation. As a result, agreement between measured and computed erosion is unreliably

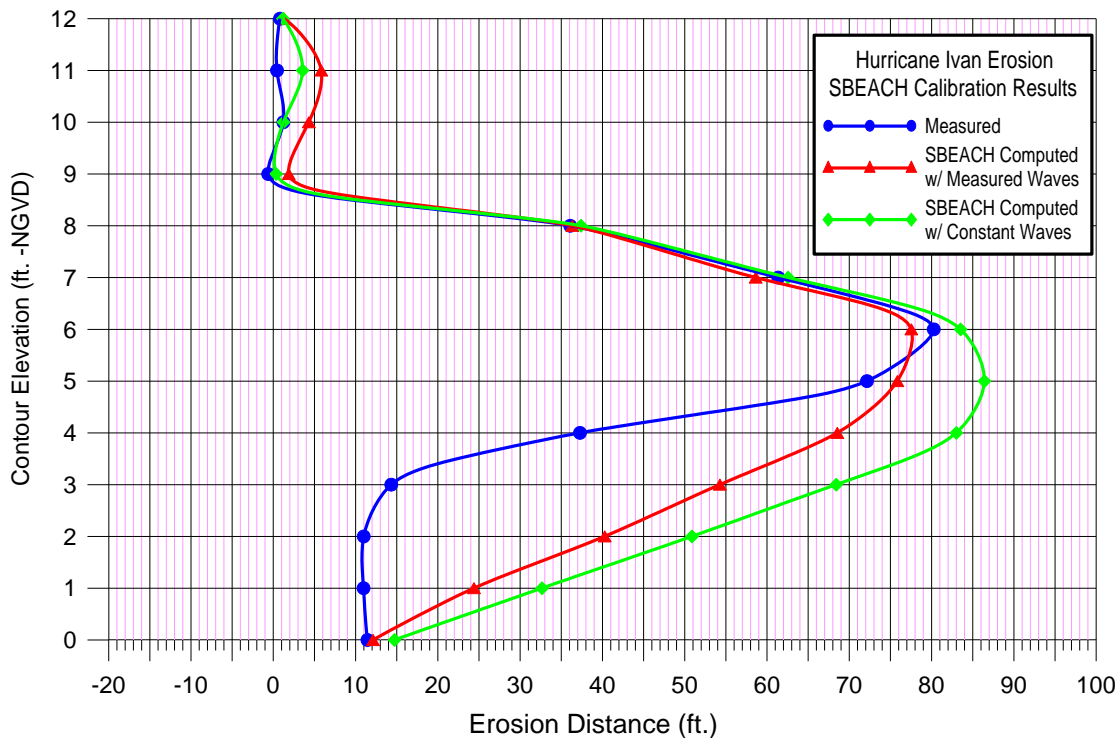


Figure 17. Pre- and post-Ivan measured vs. computed erosion for SBEACH calibration

shown to be not nearly as good in the lower contours as is found in higher elevations between 5 and 10 foot elevations. Despite the recovery-affected data in the lower beach contours, there is close agreement between the measured and computed profiles within the upper beach contour elevations for the pre- and post-Ivan profile data. Associated maximum water elevation plus set-up values produced in the SBEACH output for the 19 profile locations result in an average value of approximately 8.6 feet (NGVD).

This peak storm tide value of 8.6 feet (NGVD) equates to an associated storm return period for Ivan of approximately 20-25 years for the Panama City Beach study area. This associated return period for Ivan using the SBEACH maximum water elevation value is based on peak storm tide elevation values vs. return period analyses from storm surge studies for Bay County performed by the FSU-BSRC (1996). It is noted that the storm tide duration and related hydrograph shape for Ivan may have produced beach and dune erosion which is characteristic of a storm of greater return period than a 20-25 year storm. However, the favorable calibration results for Ivan are considered to be sufficient basis for use of the SBEACH model with the associated input parameters in high-frequency storm erosion analyses in Walton and Okaloosa counties. Maximum wave height and water elevations for Ivan from the final model calibration runs at R40 adjacent to the Panama City Beach pier is shown below in Figure 18.

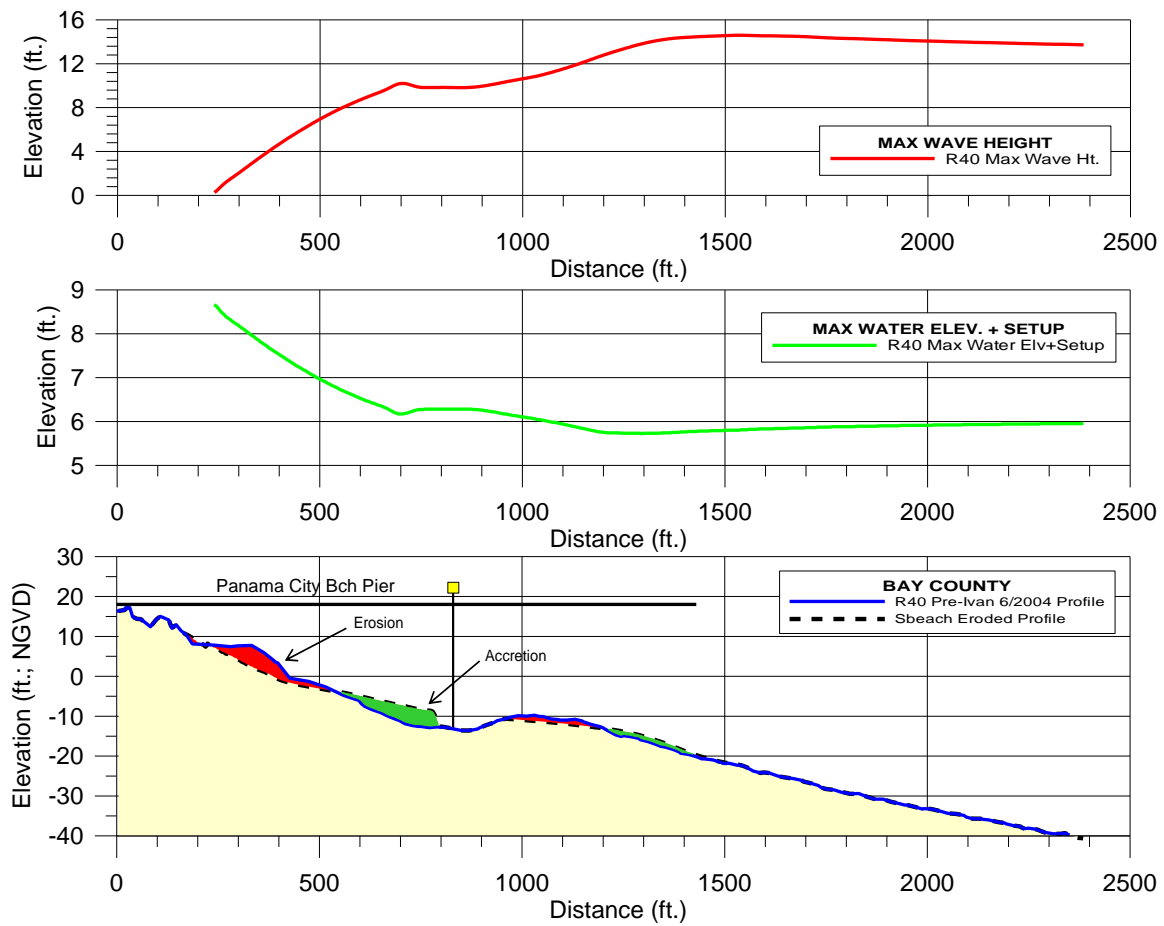


Figure 18. Max. wave ht. and water elevation for Ivan from SBEACH at R40 near pier

Hurricane Opal Calibration Results

Based on the final model input values, model calibration for Hurricane Opal was not found to show good agreement like Ivan between measured and computed storm-generated erosion. In particular, dune recession above approximately the 10 foot elevation is under-predicted by SBEACH by 2 to 4 times the measured dune recession. Average contour recession values for the 25 profiles evaluated for Opal are shown in Figure 19 below.

It is evident that additional model revisions or strategies are needed to improve the model calibration results, particularly for the dune elevations above approximately the 10 foot elevation contour, such as application of multiplier factors. The application of multiplier factors or other strategies are beyond the intent and scope of this study work.

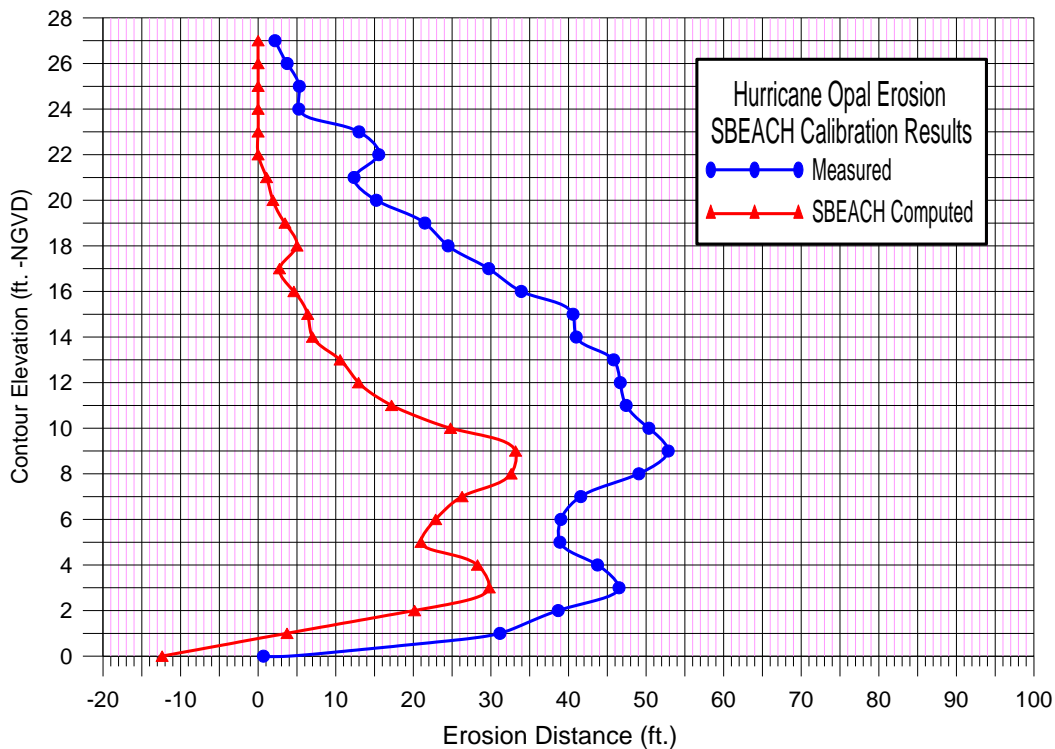


Figure 19. Pre- and post-Opal measured vs. computed erosion for SBEACH calibration

As noted previously, Opal was more characteristic of a lower-frequency storm event than Ivan. Associated maximum water elevation plus set-up values for Opal produced in the SBEACH output for the 25 evaluated profile locations resulted in an average value of approximately 10.8 feet (NGVD). This peak storm tide value is within the approximate range of observed limits of wave uprush evident in the post-storm measured profiles and reported high water marks surveyed in the study area after Opal.

The peak storm tide value of 10.8 feet (NGVD) equates to an associated return period for Opal of approximately 50-60 years for the Panama City Beach study area based on peak

storm tide elevation vs. return period values from storm surge studies for Bay County performed by BSRC (1996).

Therefore, the model calibration results for Opal are not considered to be as applicable to high-frequency storm erosion simulation as the results from Ivan. As such, the lack of good model calibration results for Opal, particularly for dune elevation contours, is not considered to substantially reduce the basis of the Ivan calibration for use of the SBEACH model in high-frequency storm erosion analyses in Walton and Okaloosa counties.

Maximum wave height and water elevations for Hurricane Opal from the final model calibration runs at R40 adjacent to the Panama City Beach pier is shown below in Figure 20.

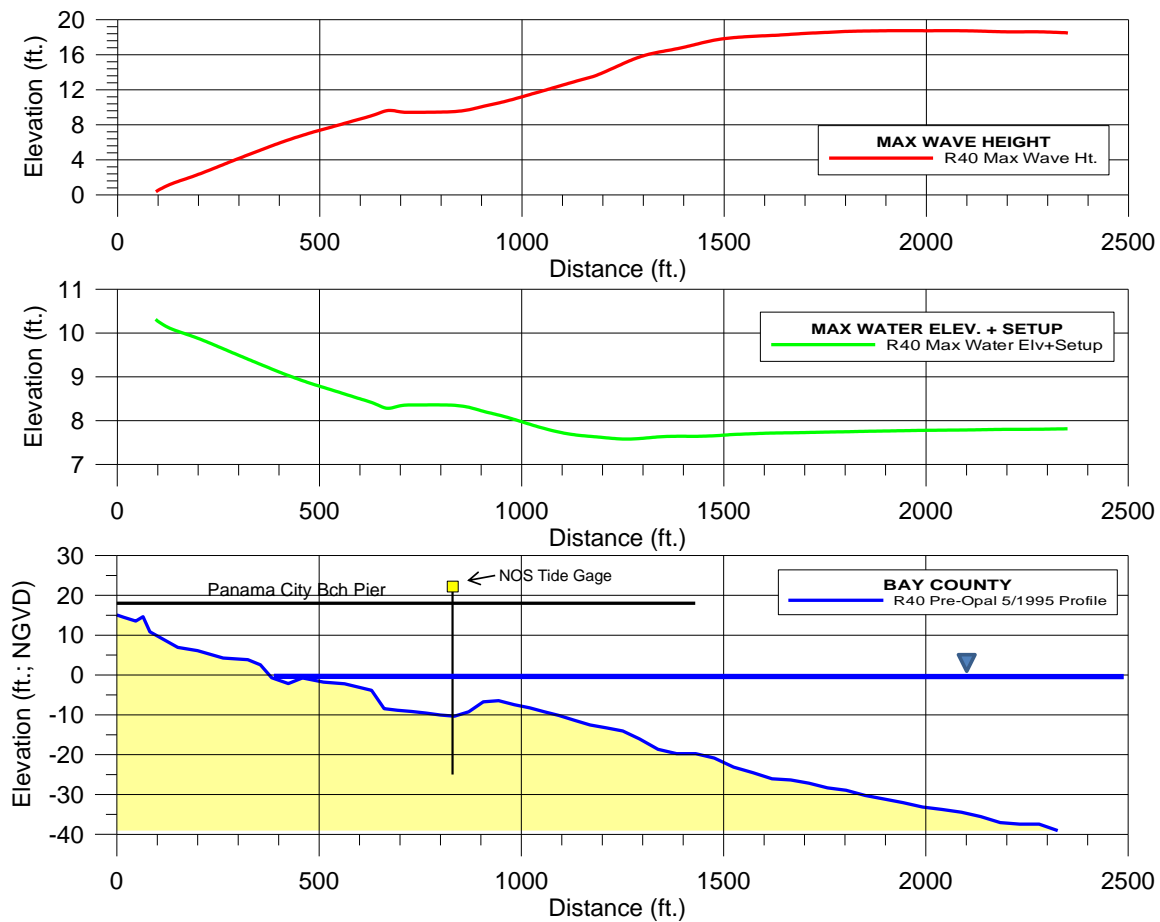


Figure 20. Max. wave ht. and water elevation for Opal from SBEACH at R40 near pier

Graphic plots of the measured and SBEACH-generated pre- and post-storm erosion profiles are provided in Appendix I of this report. Two sets of plots are provided in Appendix I, one for the Hurricane Ivan calibration work and one for the Hurricane Opal calibration work.

A summary listing of recommended SBEACH model input parameters for high-frequency storm erosion simulation for the Panama City Beach through Okaloosa County region in the Florida Panhandle is provided in Table 2 below. These recommended input parameters are based on the model calibration results described above.

Table 2. Recommended SBEACH Input Parameters For High-Frequency Storm in Panama City Beach and Walton and Okaloosa Counties

Sediment Transport Parameters	Recommended Values for HF Storm for Panama City Beach, WL & OK Co.
Transport rate coefficient, K	2.5×10^{-6} (m ⁴ /N)
Overwash transport parameter	0.005
Coefficient for slope dependent term, ϵ	0.005 (m ² /s)
Transport rate decay coeff. multiplier, λ	0.5 (m ⁻¹)
Water temperature	27 (deg C)
Other Coastal Reach Parameters	
Landward surf zone depth	0.3 (m)
Effective grain size (mean D50)	0.30 (mm) (PCBch)
	0.30 (mm) (WL Co.)
	0.34 (mm) (OK Co.)
Maximum slope prior to avalanching	45 deg
Suggested Wave Input Conditions	
Wave Height, H (ft)	10 (ft) (constant)
Wave Period, T (sec)	12 (sec) (constant)
Wave Direction, α (deg)	0 (deg; i.e., shore-normal)

3.0 Walton County SBEACH Application

3.1 Model Configuration

The SBEACH model configuration for Walton County for high-frequency storm erosion simulation, including model input parameters, was based on the model calibration results from Panama City Beach described above. A specific sediment grain size input value of 0.3 mm was based on information compiled for recent beach restoration projects in Walton County. Sediment transport input parameter values determined from the model calibration work were used for Walton County.

Storm tide hydrographs developed by BSRC (2009) for 15- and 25-year storms were used as storm input in SBEACH for Walton County. As with the model calibration work in Bay County, consideration was given to accounting for the set-up component in the storm tide elevations, as well as, set-up computations within SBEACH. As a result, revised, adjusted versions of the FSU-BSRC hydrographs were used.

The BSRC hydrographs were adjusted down in elevation to compensate for the set-up generated by SBEACH. The hydrograph reduction was a proportional reduction of the BSRC hydrograph based on average SBEACH set-up output at 127 FDEP survey profile range locations throughout Walton County. Use of the adjusted BSRC hydrographs resulted in final average maximum water elevations with set-up values from SBEACH which were equivalent to the BSRC peak storm tide elevations for the 15- and 25-year storm tide hydrographs.

A graph depicting the original BSRC 15- and 25yr storm tide hydrographs and the adjusted/reduced hydrographs used in the final SBEACH erosion model runs for Walton County is shown in Figure 21. Time series values for the adjusted/reduced hydrographs are tabulated in Appendix IV in both NGVD29 and NAVD88 vertical datums. The NGVD values are converted to NAVD in Walton County by subtracting 0.4 feet.

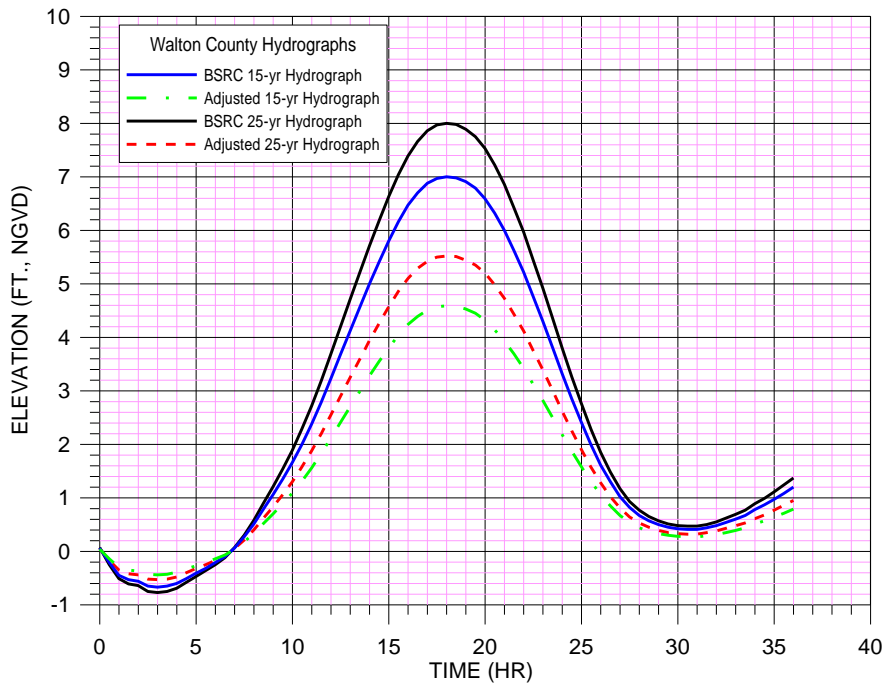


Figure 21. 15- and 25-yr BSRC and adjusted storm tide hydrographs for Walton Co.

Specific wave conditions associated with 15- and 25-year return interval storm events for SBEACH model input were not found to be available at the time of this study. Development of such wave conditions were beyond the scope of this study. However, testing performed during the model calibration phase of this study presented earlier in this report (see Figure 17 above) revealed that a constant wave condition can provide

comparable and reasonable results for a high-frequency storm event. Therefore, the constant wave conditions were used in the SBEACH model for the 15 and 25-year storm simulations.

3.2 Model Application and Results

Graphic plots of the 15 and 25-year storm erosion profiles generated from SBEACH for Walton County for the 127 range location profiles are provided in Appendix II of this report. The survey profiles used as the input profiles in SBEACH are BBCS profiles from July 2007. The plots in Appendix II are shown in NAVD vertical datum.

The map in Figure 22 below depicts the FDEP profile range locations across the Walton County shoreline.

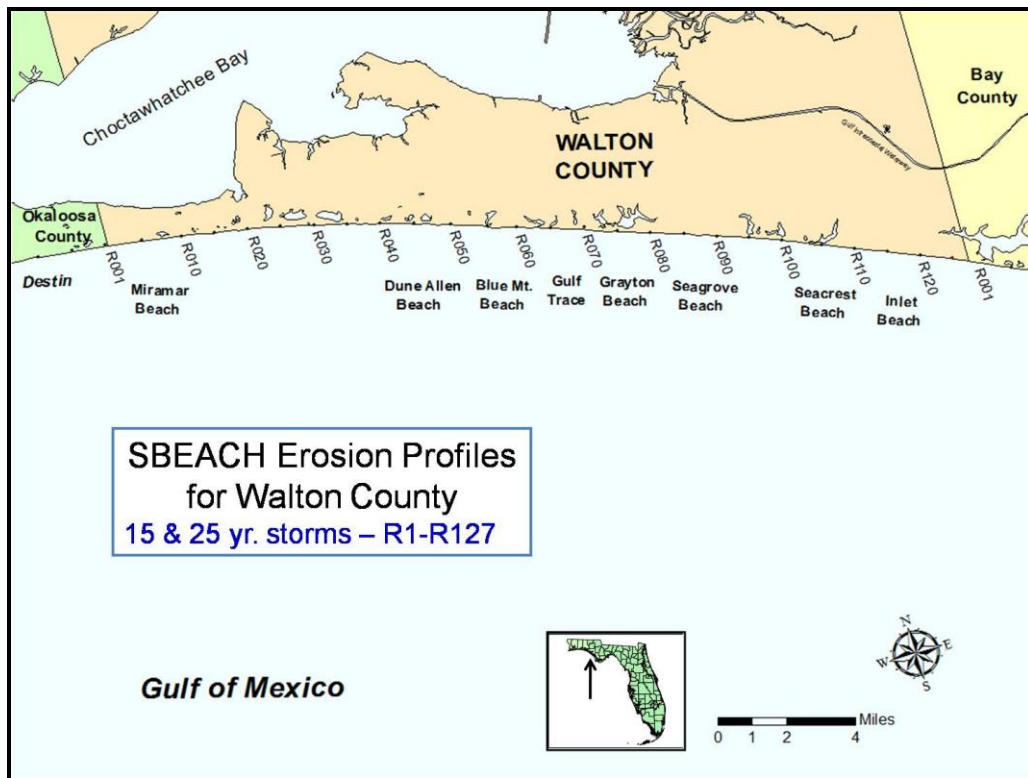


Figure 22. Map of FDEP profile range locations across the Walton County shoreline

4.0 Okaloosa County SBEACH Application

4.1 Model Configuration

As with Walton County described above, the SBEACH model configuration for Okaloosa County for high-frequency storm erosion simulation, including model input parameters, was based on the model calibration results from Panama City Beach described above. A

specific sediment grain size input value of 0.34 mm was based on information compiled for recent beach restoration project studies in Okaloosa County. Sediment transport input parameter values determined from the model calibration work were used for Okaloosa County.

As with Walton County, storm tide hydrographs developed by BSRC (2008) for 15- and 25-year storms were used as storm input in SBEACH for Okaloosa County. As with the model calibration work in Bay County, consideration was given to accounting for the set-up component in the storm tide elevations, as well as, set-up computations within SBEACH. As a result, revised, adjusted versions of the FSU-BSRC hydrographs were used.

Similar to Walton County, the BSRC hydrographs were adjusted down in elevation to compensate for the set-up generated by SBEACH. The hydrograph reduction was a proportional reduction of the BSRC hydrograph based on average SBEACH set-up output at 50 FDEP survey profile range locations throughout Okaloosa County. Use of the adjusted BSRC hydrographs resulted in final average maximum water elevations with set-up values from SBEACH which were equivalent to the BSRC peak storm tide elevations for the 15- and 25-year storm tide hydrographs.

A graph depicting the original BSRC 15- and 25yr storm tide hydrographs and the adjusted/reduced hydrographs used in the final SBEACH erosion model runs for Okaloosa County is shown in Figure 23. Time series values for the adjusted/reduced hydrographs are tabulated in Appendix IV in both NGVD29 and NAVD88 vertical datums.

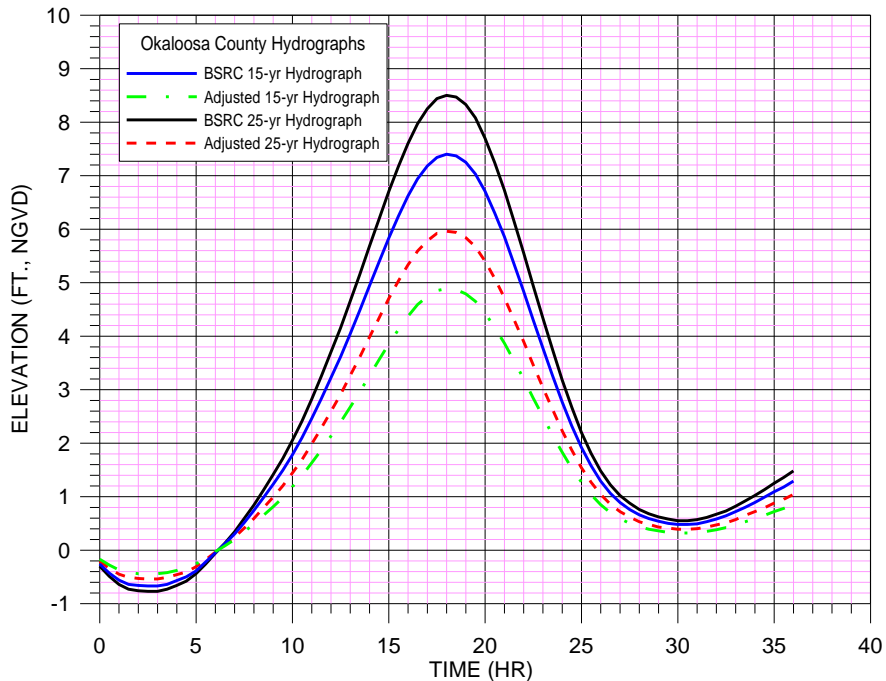


Figure 23. 15- and 25-yr BSRC and adjusted storm tide hydrographs for Okaloosa Co.

The NGVD values are converted to NAVD in Okaloosa County by subtracting 0.4 feet.

Also, as with Walton County, specific wave conditions associated with 15 and 25-year return interval storm events for SBEACH model input were not found to be available at the time of this study for Okaloosa County. As described previously, development of such wave conditions were beyond the scope of this study.

However, testing performed during the model calibration phase of this study presented earlier in this report (see Figure 17 above) revealed that a constant wave condition can provide comparable and reasonable results for a high-frequency storm event. Therefore, the constant wave conditions were used in the SBEACH model for the 15 and 25-year storm simulations.

4.2 Model Application and Results

Graphic plots of the 15 and 25-year storm erosion profiles generated from SBEACH for Okaloosa County for the 50 range location profiles are provided in Appendix III of this report. The survey profiles used as the input profiles in SBEACH are BBCS profiles from June 2007. The plots in Appendix III are shown in NAVD vertical datum.

The map in Figure 24 below depicts the profile range locations across the Okaloosa County shoreline.

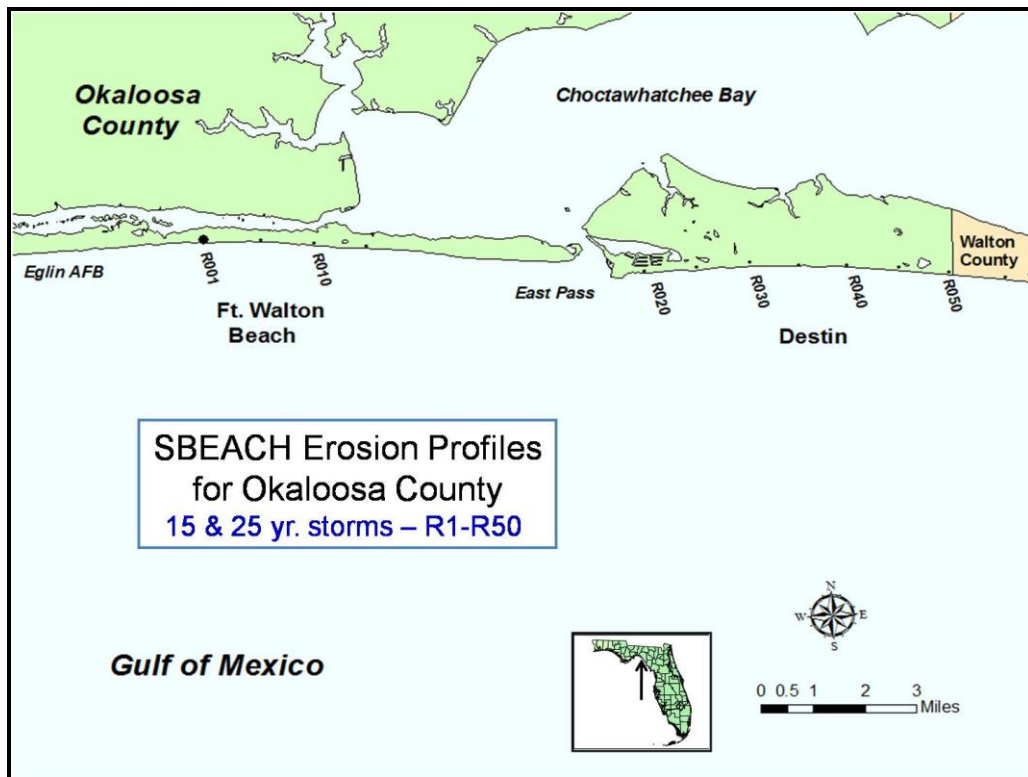


Figure 24. Map of FDEP profile range locations across the Okaloosa County shoreline

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