Modeling the response of a beach restoration project in Louisiana to two consecutive hurricanes

Naveen Khammampati

Louisiana State University and Agricultural and Mechanical College

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MODELING THE RESPONSE OF A BEACH RESTORATION PROJECT IN LOUISIANA TO TWO CONSECUTIVE HURRICANES

A Thesis
Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

In
The Department of Civil and Environmental Engineering

by

Naveen Khammampati
B.S, Osmania University, 2000
M.S, Lamar University, 2003

December 2011
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ABSTRACT

The current study is concentrated in modeling the cross-shore beach profile evolution and severe erosion of the dune (overwash) of a restored barrier island due to Hurricanes Gustav (2008) and Ike (2008) in coastal Louisiana. Pre-storm and post-storm survey data sets of Chaland Headland located in Plaquemines Parish, LA, were analyzed and categorized based on the overwash processes, and numerically modeled using SBEACH (Storm-induced BEAch CHange). The model results were compared with the measured topographic data. A total of 10 survey profiles were used in this study.

SBEACH simulates cross-shore beach, berm and dune erosion produced by storm waves and water levels. The model was calibrated for site specific conditions; sensitivity tests were conducted with varying water levels, wave heights and median grain sizes. Hurricanes Gustav and Ike forcing conditions were applied and the model profiles were then compared with survey profiles.

It was found that, although SBEACH is capable of reproducing the shape of the post-storm profiles to some extent, the amount of measured erosion on the foreshore slopes of the measured beach profile is much greater than the modeled erosion. Dune erosion of the measured profiles is also greater than the modeled profiles. It is also found that some of the empirical parameters of SBEACH need to be adjusted beyond the recommended values to obtain better simulation results.

SBEACH does not account for any longshore sediment transport due to longshore currents. Also the surge level gradient across the profile is not considered in the model. In general, the beach profile evolution processes are three-dimensional and complex. Although a one dimensional model could be a helpful tool in the preliminary stages of a project to estimate the shape of the post-storm profile, the three dimensional effects should be considered to obtain accurate results, in particular under hurricane conditions.
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CHAPTER 1 INTRODUCTION

1.1 Background

The role of barrier islands in the reduction of wetland loss and the protection of bays and estuaries behind the islands is vital in a coastal environment. Coastal areas are home to a wealth of natural and economic resources and are the most developed areas in the nation. The narrow fringe comprising 17 percent of the contiguous U.S. land area is home to more than half of the nation's population (National Ocean Service). Many of these coastal areas are backed by barrier islands. These barrier islands experience frequent erosion and accretion due to a number of processes such as eolian transport, longshore sediment transport in the surf zone due to breaking waves and wind-induced current, cross-shore sediment transport due to waves and current and storm-induced overwashing (Ravens and Sitanggang, 2007). Therefore, these shorelines are dynamic in nature. The response of the shoreline to these events can be divided into short-term and long-term, depending on the time scale of changes.

Coastal Louisiana has the highest rate of shoreline change and land loss in the Gulf of Mexico. Louisiana leads the nation in coastal erosion and wetland loss (Sallenger, jr. et al., 1992). Within the past 100 years, Louisiana's barrier islands have decreased on average in area by more than 40 percent, and some islands have lost 75 percent of their area (Penland and Boyd, 1981). In addition to the land loss due to barrier island shoreline change, wetlands are also lost extensively due to the submergence and destruction of the Mississippi River delta plain (Penland et al., 1990). This subsidence and erosion are often results of both human and natural processes. The natural delta cycle of a river begins with construction of a delta lobe. After many years, this lobe is abandoned as the river system relocates to another area which offers a sharper and steeper route to the downstream. After abandonment of an older delta lobe, which would cut off the primary supply of fresh water and sediment an area would undergo compaction, subsidence, and erosion, form bayous, lakes, bays, and sounds. Manmade control structures which limit the fresh water supply and sediment also cause subsidence and erosion.

About 90% of the Louisiana Gulf shoreline is experiencing erosion, which increased from an average of -8.2 ± 4.4 m/yr (-26.9 ± 14.4 ft./yr) in the long-term to an average of -12.0 m/yr (39.4 ft./yr) in the short term. Short sections of the shoreline are accreting as a result of
lateral island migration. The highest rates of Gulf shoreline erosion in Louisiana coincide with subsiding marshes and migrating barrier islands such as the Chandeleur Islands, Caminada-Moreau Headland, and the Isles Dernieres (Morton et al., 2004)

One of the barrier systems of the coastal Louisiana is the Plaquemine Barrier System. Plaquemine/Barataria Barrier system is approximately 32 miles long between Grand Terre Islands and Sandy Point. It is located about 30 miles northwest to the mouth of the Mississippi River. Barrier islands that are part of the Plaquemines shoreline include Sandy Point, Pelican Island, Shell Island, Chaland Headland (Pass de la Mer area), Cheniere Ronquille, and the Grand Terre Islands (Figure 1.1). This shoreline is divided by many inlets, such as Pass Abel, Quatre Bayoux, Pass Ronquille, Pas de la Mer, Chaland Pass, and Fontanelle Pass.

Figure 1.1 Plaquemine Barrier Islands (Lca.gov)
The long term shoreline change rate is about -6.2 m/yr (20.34 ft/yr) and short term shoreline change rate is -11.9 m/yr (39 ft/yr) for the Plaquemines barrier system (Penland et al., 2003). Long term shoreline change appear to be smaller for the Plaquemines shoreline compared to the overall coastal Louisiana, but the short term shoreline change rate is almost similar to that of coastal Louisiana. Figure 1.2 shows the historical shoreline change of the Plaquemine barrier islands shoreline.

![Figure 1.2 Plaquemine Historical Shoreline Change (1884 to 1996)](image)

Significant erosion and landward movement of the barriers was observed in the Plaquemines Barrier System in the past century and the islands were also reduced in size. Over time, these islands were lowered in elevation and breached, resulting in the loss of wetlands.

To protect the coastal Louisiana, many restoration projects are constructed under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). Since its inception, 151 coastal restoration or protection projects have been authorized, benefiting over 110,000 acres in Louisiana.
1.2 Study Area

Chaland Headland restoration is one of the restoration projects completed under the CWPPRA act. It is located approximately 12 miles to the east of Grand Isle, La in Plaquemines Parish and is part of the Plaquemines/Barataria Barrier Island Complex. This headland is approximately 3 miles long and is located between two inlets, Pass La Mer and Chaland Pass (Figure 1.3).

Figure 1. 3 Location Map

This project was completed in 2007, at a cost of approximately $20 million. This Project produced 230 acres of beach and 254 acres of marsh. The amount of fill material placed was approximately 2.4 million cubic yards for the beach and 0.9 million cubic yards for the marsh. A year after the project’s completion, Hurricanes Gustav and Ike made land fall on the Gulf coasts of Louisiana and Texas, causing severe dune erosion.
1.3 Hurricanes

A year after the completion of the project, Hurricane Gustav made landfall as a Category 2 hurricane on September 1, 2008 near Cocodrie, Louisiana. Within a period of 11 days, another hurricane, Hurricane Ike, made landfall near Galveston, Texas.

Table 1. Hurricane Gustav and Ike Characteristics (Weather Research Center)

<table>
<thead>
<tr>
<th>Year</th>
<th>Hurricane</th>
<th>Max Sustained Winds (Knots)</th>
<th>Radius of Tropical Storm Winds (n. mi)</th>
<th>Radius of Hurricane Winds (n. mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Gustav</td>
<td>130</td>
<td>150</td>
<td>60</td>
</tr>
<tr>
<td>2008</td>
<td>Ike</td>
<td>95</td>
<td>240</td>
<td>110</td>
</tr>
</tbody>
</table>

Figure 1. Tracks of Hurricanes Gustav and Ike
Gustav formed as a tropical storm on Monday, August 25, 2008 in the Caribbean, south of the Dominican Republic. It eventually made landfall near Cocodrie, Louisiana, or about 70 miles southwest of New Orleans, on September 1st as a strong Category 2 hurricane with sustained winds of 110 mph. From the inception to the landfall, Gustav varied from a tropical depression (with maximum sustained wind speed of 29 mph) to a Category 4 hurricane (with maximum sustained wind speed of 138 mph).

Hurricane Ike began as a tropical wave off of the coast of Africa around August 29, 2008. It made landfall on September 12th at Galveston, Texas (tropicalweather.net). From the inception to landfall, Ike varied from a tropical depression (with maximum sustained wind speed of 34.5 mph) to a Category 4 Hurricane (with maximum sustained wind speed of 138 mph).

Table 1.1 provides these storms characteristics and Figure 1.4 provides the track of the two hurricanes.

1.4 Objectives and Hypothesis

The objectives of this thesis are to evaluate the ability of the SBEACH (Storm-induced BEAch Change) model to predict the response of Chaland Headlands beach restoration project to two consecutive hurricanes and quantify the sediment volume changes using pre, post and modeled profiles.

From the literature reviewed, it is understood that the SBEACH model is a useful tool to model the overwash and beach responses under storm conditions on a variety of beach profiles. When SBEACH is used to model the entire length of the project, it is hypothesized that at the center of the headland, the model will reproduce the shape of the post-storm beach in better agreement with the measured profiles compared to both ends of the project location because SBEACH is a one dimensional model, whereas the sediment transport and morphology changes in the nearshore are three-dimensional in nature. To test this hypothesis and to further investigate the capabilities of the model to reproduce the post-storm profiles, SBEACH was utilized for this study.

To achieve the objectives, the following tasks were performed. A detail explanation describing the model capabilities, limitations and assumptions is also provided in Chapter 4.
• Analyze the pre and post storm profiles

• Review the literature involving beach profile changes, dune evolution and overwash mechanism under severe storm conditions to understand the concepts behind shoreline changes.

• Perform data analysis

• Model the profiles using SBEACH with site specific calibrated parameters and perform sensitivity tests for the model.

• Discuss the results and observations.
2. REVIEW OF LITERATURE

2.1 Introduction

Barrier Islands are generally dynamic in nature. These islands continuously change in shape, location and orientation due to a number of factors, such as waves, storm impacts, winds currents, etc. One of the important factors is the impact of an extreme storm event.


Leatherman’s (1976) work involved the quantification of overwash processes and conceptualized a new model regarding the functioning of barrier dunes during storms versus flow dissipation by overwash.

Vellinga (1983, 1986) had developed an empirical model for the dune erosion based on extensive large wave tanks. This was one of the widely used methods during late 80’s in the United States to predict the dune erosion.

Dean (1991) had described the equilibrium beach profile characteristics and its applications. In this work it was shown that, for the examined beach profile, the effect of wave set-up was small compared to expected storm tides during a storm. Also, depending on the beach profile parameters, profile evolution from a uniform slope was shown to result in five different profile types.

Kobayashi (2003) explained the importance of numerical modeling as a design tool for coastal structures. He showed that these models governed by the conservation laws have been found to be successful for the coastal problems.

Wang et al., (2005) has studied the morphological and sedimentological impacts of Hurricane Ivan and post-storm beach recovery of barrier islands along the Northwestern Florida coasts. It was indicated in this study that storm wave set-up and swash run-up played an important role in controlling the elevation of beach erosion.
Tinh (2006) utilized the updated SBEACH to model the overwash. This work indicated that the numerical model SBEACH successfully reproduced the volume and shape of washover deposits on a variety of beach profiles and for a variety of beach profile change morphologies including a low barrier island, a barrier with a fore dune, dune destruction, dune rollover, and barrier rollover. This work also indicated that the model failed to simulate crest accumulation and morphology changes on back barriers with significant changes in flow regime.

Hartog et al., (2008) discussed the mechanisms that influence the beach nourishment project and indicated that design aspects such as shoreline orientation, hurricanes, winter storms, and dredging of offshore borrow areas influence the performance of a beach nourishment project.

In a recent work by Kuiper (2010) focused on the influence of vegetation on the restored Chaland Headland shoreline changes due to Hurricanes Gustav and Ike using 2DV profile model in Delft3D-FLOW. It was indicated in this study that the dominant overwash response during Gustav is dune destruction, the dune erodes and the barrier profile starts to translate in landward direction. This study also indicated that, the computed end profiles were well comparable with measured post-storm profiles indicating the dominant cross-shore processes. It was recommended in this study that a full 3D model to be used to investigate the influence of long shore processes.

2.2 Storm Impact Scale

Sallenger (2000) has proposed a scale that categorizes the tropical and extra-tropical storm impacts to the natural barrier islands. Four regimes namely ‘swash’, ’collision’, ‘overwash’ and ‘inundation’ were defined. These regimes were labeled from level-1 to level-4 corresponding to the regime names.

In Figure 2.1, R_{HIGH} and R_{LOW} represent high and low elevations of the landward margins of swash relative to a vertical datum. D_{HIGH} and D_{LOW} represent elevations of the crest and base of the dune.

Swash regime is the condition where the swash is confined to the foreshore of the beach. Under this condition, beach foreshore erodes and sand is transported offshore and is returned to the beach after mild storms over several weeks.
Collision regime occurs when the runup collides with the base of the dune, causing the dune to erode. Unlike swash regime erosion, the sand transported does not return to the beach.

Overwash regime is the condition when the runup height increases to the crest of the dune and causes overwash.

Inundation regime is the condition when the storm surge is sufficiently higher than the crest of the dune and the barrier is completely submerged.

Figure 2.2 provides the impact level and its definition for each of the above discussed regime.

<table>
<thead>
<tr>
<th>Regime</th>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Swash Regime</td>
<td>$R_{\text{high}} &lt; \frac{D_{\text{low}}}{D_{\text{high}}}$</td>
<td>Run-up is restricted to the foreshore and beach.</td>
</tr>
<tr>
<td>2 Collision Regime</td>
<td>$\frac{D_{\text{low}}}{D_{\text{high}}} \leq \frac{R_{\text{high}}}{D_{\text{high}}} &lt; 1$</td>
<td>Run-up collides with the base and face of the dune and dune erosion occurs in the form of dune scarping.</td>
</tr>
<tr>
<td>3 Overwash Regime</td>
<td>$\frac{R_{\text{high}}}{D_{\text{high}}} \geq 1$ and $\frac{R_{\text{low}}}{D_{\text{high}}} &lt; 1$</td>
<td>Run-up exceeds the dune crest and causing features such as washover fans.</td>
</tr>
<tr>
<td>4 Inundation Regime</td>
<td>$\frac{R_{\text{low}}}{D_{\text{high}}} \geq 1$</td>
<td>The entire barrier is submerged and erosion processes become similar to surf zone processes.</td>
</tr>
</tbody>
</table>

Figure 2.2 Storm Impact Scale for Barrier Islands (Sallenger, 2000)
2.3 Overwash

During an extreme storm event, overwash (runup and inundation) plays a dominant role in the beach profile evolution of low-dune barrier islands. Runup overwash occurs due to the wave overtopping, as shown in Figure 2.3 and inundation overwash occurs due to complete flooding, as shown in Figure 2.4. Here, S is the surge height, R is the runup height, and dc is the barrier elevation. ∆R is the excess runup and db is the water level in the bay.

Donnelly et al., (2006) categorized the cross-shore beach profile changes caused by overwash into seven different cross-shore morphology change types. Figure 2.5 shows these regimes. These regimes are described as follows.

Figure 2.3 Definition Sketch Showing Overwash by Wave Runup (after Donnelly et al., 2004)

Figure 2.4 Definition Sketch Showing Overwash by Complete Inundation (after Donnelly et al., 2004)
- Crest Accumulation is the accumulation of the sediment on the beach crest.
- Landward Translation of Dune is the movement of the dune/berm landward.
- Dune Lowering is a reduction in the dune height and volume.
- Dune Destruction is that a prominent dune is no longer observed.
- Barrier Accretion is the sediment accretion on the subaerial portion of the island.
- Barrier Rollover (short-term) is a washover deposit extending from the subaerial portion to the subaqueous bay-side of the island.
- Barrier Disintegration is the erosion over the entire subaerial barrier island.

Figure 2. 5 Cross-shore Responses to Overwash -Solid lines indicate pre-storm profile and the dotted line is the post-storm profile. (After Donnelly, 2008)
Different magnitudes of overwash processes result in the deposition of sand known as washover. It is defined as the sediment that is transported and deposited inland by overwash (Williams 1978).

Three common forms of washover deposits are the washover fan, washover terrace, and sheet wash deposits. Figure 2.6 is a schematic plan view over a typical dune line or beach crest subject to overwash, illustrating the common overwash deposit types. The shape and extent of the fans depend on pre-storm topography, existence of beach tracks, roads and other anthropogenic influences and vegetation (Donnelly and Sallenger, 2007).

Figure 2.6 Morphological Deposits Occurring During Overwash (after Donnelly et al., 2004)
CHAPTER 3 DATA COMPILATION AND ANALYSIS

3.1 Introduction

Essential data required in modeling the storm impacts on the restored beach is categorized as follows:

- Topographic data
- Hydrodynamic data
- Geotechnical data

Survey data includes pre and post-storm study profiles; hydrodynamic data consists of time series of wave, water level and peak period during the study period of the storm event and the characteristic of the sediment such as, median grain size is part of the geotechnical data required for modeling.

3.2 Topographic Data

To evaluate the storm impacts on the study site, profile data sets before and after the storms are required. Post-storm profiles are useful to compare with the modeled results.

Construction of the study project pertaining to the beach has begun in May 2006 and was completed by the end of the year 2006. The project had the “final completion” in January of 2007. Topographic data sets before the construction and after the construction are available for the study purpose. These data sets after the construction are referred as pre-storm profiles. Hurricane Gustav and Hurricane Ike events were occurred in the month of September 2008. Topographic data sets after the storm events are referred as post-storm profiles. These data sets are also available for the study. A table describing the timing pertaining to the study is also provided (Table 3.1).

Location of these profile data sets is shown in Figure 3.1. Stationing of these profiles is also shown in this figure. An arbitrary baseline that was established at the time of the design of this project is also used as a baseline in this study for the purpose of same stationing of the profiles.
To verify that the baseline of this study coincide with the original baseline, data sets from this study are compared with original datasets and are found to be in agreement (Appendix B).

A review of pre and post-storm survey data indicate that data points of pre-storm survey are dense and their extent in relation to the baseline is limited compared to the post-storm survey. Whereas the survey data points on the post-storm extend beyond the pre-storm data points in to the offshore. Therefore, for the study purpose, 10 profile sets, which are common in the Pre and Post-storm surveys, were selected. These profile sets are shown in Figures 3.2 through 3.11. Each of these profiles extends approximately 1500 ft. (457 m) towards the land and 1500 ft. (457 m) towards offshore and these profiles are approximately 1450 ft. (442 m) apart.

Table 3.1 Timing of Project Related Events

<table>
<thead>
<tr>
<th>Action Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-construction Survey</td>
<td>May 19, 2006</td>
</tr>
<tr>
<td>Actual construction pertaining to beach begin</td>
<td>May 29, 2006</td>
</tr>
<tr>
<td>Survey of post construction (Pre-storm)</td>
<td>November 11, 2006</td>
</tr>
<tr>
<td>Hurricane Gustav and Ike (Storms)</td>
<td>September 1 and 13, 2008</td>
</tr>
<tr>
<td>Post-storm survey data</td>
<td>April 08, 2009</td>
</tr>
</tbody>
</table>
Figure 3.1 Location and Stationing of the Survey Profiles

Figure 3.2 Profile at Station 14+68
Figure 3.3 Profile at Station 29+20

Figure 3.4 Profile at Station 43+72
Figure 3.5 Profile at Station 58+23

Figure 3.6 Profile at Station 72+75
Figure 3. 7 Profile at Station 87+28

Figure 3. 8 Profile at Station 101+80
Figure 3. 9 Profile at Station 116+32

Figure 3. 10 Profile at Station 130+84
3.3 Data Analysis

To understand the behavior of the dune in response to storm impacts, one of the useful methods is to categorise these profiles by comparing the pre and post-storm data sets. As discussed in the literature review section, Donnelly (2006) categorised the cross-shore beach profile changes caused by overwash into seven different cross-shore morphology change types. In Donnelly’s (2006) study, more than 110 sets of pre- and post-storm cross-shore beach profiles showing overwash occurrence were assembled and some consistencies in the morphologic response of the profiles were observed; hence, the responses were categorised.

Comparing pre and post-storm profiles and based on the seven categories proposed by Donnelly, profile sets for this study are also categorised. In reviewing the profile sets for this study, it was observed that some of the profiles do not fit into any of this classification; instead these are combination of two different classifications, namely “Dune destruction” and “Rollover”. Therefore the profile sets falls under this category were named as “Combined Dune destruction and Rollover”. One of the reasons for this combined behavior of the post-storm profiles is that these profiles are result of a low dune barrier island due to two consecutive storms.
as opposed to the result of one storm event that is typically studied by others. This response is shown in Figure 3.12.

Table 3.2 provides the categorization of these profile sets. As seen from the response to overwash that “barrier rollover” is a major response observed in the west end of the profiles with “combined dune destruction and rollover” in the middle and “landward translation” is the major response on the east end of the study area.

In addition to this categorization, the volume of the sediment lost and the volume of the sediment that is accreted on to the beach is also calculated and is presented in Table 3.3. It can be seen from this table that the eroded volume is greater than the accredited volume by an approximate factor of 5. It is also noted from the sediment volume calculations that the highest erosion observed between Stations 14+68 and 29+20, lowest erosion between Stations 87+28 and 101+80. Similarly, highest accretion observed between stations 116+32 and 130+84, lowest accretion between Stations 29+20 and 43+72. Along the western side of the project, more erosion and less accretion are observed, while along the eastern side of the project, more accretion and less erosion are observed.

From the above analysis (Figure 3.13), it is observed that western side of the project experienced more erosion compared to the eastern side. Similarly, the amount of accretion on the eastern boundary of the project is more prominent compared to the western boundary.

Also, utilizing the pre and post-storm profiles, some of the typical beach profile parameters are calculated. Figure 3.14 shows these typical parameters and Table 3.4 provides these parameters for the pre and post-storm profiles.
3.4 Hydrodynamic Data

Two sets of hydrodynamic data were used in this study to evaluate the storm impacts. This data consists of time series of wave height, time series of water level and time series of peak period for the study duration at the project site. Duration of the study is from August 31st 2008 to September 14th 2008.

One of the hydrodynamic data sets used in this study was obtained from the numerical models ADCIRC and SWAN (Courtesy of Dr. Kelin Hu & Dr. Q. Jim Chen, Department of Civil Engineering, LSU). Nine locations at the study site were chosen to obtain the hydrodynamic data. These locations are shown in Figure 3.15. Location 5 was used in the study because of its location in relation to the entire study site. It is to be noted that the results of SBEACH run using this hydrodynamic data are referred as “SBEACH run-1” from here on.

Location-5 is approximately 1 mile offshore from the project site and the water depth below MSL is about 14 ft. (4.27m). Hydrodynamic data at this location is also shown in Figure 3.16.

Modeled hydrodynamic data was only available for a period (August 31st to September 7th) during which Hurricane Gustav occurred. But to evaluate the impact of two consecutive hurricanes on the study site, Hurricane Gustav peak conditions were extended up to September 14th during which Hurricane Ike occurred.

In addition to the above data, wind speed and wind direction is also required as an option in SBEACH. This data was obtained from NOAA National Data Buoy Center’s Buoy located at the station 8761724, Grand Isle, Louisiana. This station is located about 15 miles southwest of the study site and is the closest station data available for the study purpose. Figure 3.17 shows the wind direction and Figure 3.18 shows the wind speed. Wind direction shown in the Figure 3.17 is the direction the wind is coming from in degrees clockwise from true North.
Table 3. 2 Categorization of the Profiles Based on their Response to Overwash

<table>
<thead>
<tr>
<th>STATION</th>
<th>CROSS-SHORE RESPONSE TO OVERWASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>14+68.00</td>
<td>Barrier Rollover</td>
</tr>
<tr>
<td>29+20.00</td>
<td>Dune Destruction</td>
</tr>
<tr>
<td>43+72.00</td>
<td>Combined Dune destruction and Rollover</td>
</tr>
<tr>
<td>58+23.00</td>
<td>Combined Dune destruction and Rollover</td>
</tr>
<tr>
<td>72+75.00</td>
<td>Barrier Rollover</td>
</tr>
<tr>
<td>87+28.00</td>
<td>Combined Dune destruction and Rollover</td>
</tr>
<tr>
<td>101+80.00</td>
<td>Barrier Rollover</td>
</tr>
<tr>
<td>116+32.00</td>
<td>Combined Dune destruction and Rollover</td>
</tr>
<tr>
<td>130+84.00</td>
<td>Landward Translation</td>
</tr>
<tr>
<td>145+35.00</td>
<td>Landward Translation</td>
</tr>
</tbody>
</table>
Table 3. 3 Volume of Sediment Erosion and Accretion (Figures pertaining to the volumetric calculations indicating the erosion and accretion are shown in Appendix A.)

<table>
<thead>
<tr>
<th>STATION</th>
<th>VOLUME OF EROSION (CU.YD)</th>
<th>VOLUME ACCRETION (CU.YD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 14+68 - To 29+20</td>
<td>223528.3</td>
<td>18188.3</td>
</tr>
<tr>
<td>From 29+20 - To 43+72</td>
<td>204652.3</td>
<td>13208.7</td>
</tr>
<tr>
<td>From 43+72 - To 58+23</td>
<td>193321.9</td>
<td>34824.6</td>
</tr>
<tr>
<td>From 58+23 - To 72+75</td>
<td>170378.2</td>
<td>38270.0</td>
</tr>
<tr>
<td>From 72+75 - To 87+28</td>
<td>133714.0</td>
<td>32207.3</td>
</tr>
<tr>
<td>From 87+28 - To 101+80</td>
<td>127818.5</td>
<td>29420.5</td>
</tr>
<tr>
<td>From 101+80 - To 116+32</td>
<td>175114.3</td>
<td>25803.7</td>
</tr>
<tr>
<td>From 116+32 - To 130+84</td>
<td>192705.8</td>
<td>64291.4</td>
</tr>
<tr>
<td>From 130+84 - To 145+35</td>
<td>137260.7</td>
<td>56066.5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1558494.0</strong></td>
<td><strong>312281.0</strong></td>
</tr>
</tbody>
</table>
Figure 3. 12 Overwash Response – Combined Dune Destruction and Barrier Rollover

Figure 3. 13 Trend of Sediment Erosion and Accretion
Table 3. 4 Beach Profile Parameters

<table>
<thead>
<tr>
<th>AVG. DUNE ELEVATION (ft/m)</th>
<th>NEARSHORE BEACH SLOPE</th>
<th>SUB-AERIAL BEACH SLOPE</th>
<th>REAR DUNE SLOPE</th>
<th>REAR BARRIER SLOPE</th>
<th>AVG. DUNE ELEVATION (ft/m)</th>
<th>NEARSHORE BEACH SLOPE</th>
<th>SUB-AERIAL BEACH SLOPE</th>
<th>REAR DUNE SLOPE</th>
<th>REAR BARRIER SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.35/1.63</td>
<td>0.005</td>
<td>0.008</td>
<td>0.021</td>
<td>0.001</td>
<td>4.25/1.29</td>
<td>0.006</td>
<td>0.017</td>
<td>0.009</td>
<td>0.002</td>
</tr>
<tr>
<td>5.91/1.80</td>
<td>0.004</td>
<td>0.012</td>
<td>0.023</td>
<td>0.001</td>
<td>3.07/0.94</td>
<td>0.006</td>
<td>0.027</td>
<td>0.011</td>
<td>0.002</td>
</tr>
<tr>
<td>5.90/1.80</td>
<td>0.008</td>
<td>0.015</td>
<td>0.025</td>
<td>0.001</td>
<td>2.91/0.88</td>
<td>0.007</td>
<td>0.022</td>
<td>0.010</td>
<td>0.003</td>
</tr>
<tr>
<td>5.78/1.76</td>
<td>0.007</td>
<td>0.016</td>
<td>0.024</td>
<td>0.002</td>
<td>3.02/0.92</td>
<td>0.005</td>
<td>0.032</td>
<td>0.017</td>
<td>0.003</td>
</tr>
<tr>
<td>6.31/1.92</td>
<td>0.013</td>
<td>0.022</td>
<td>0.019</td>
<td>0.004</td>
<td>5.67/1.73</td>
<td>0.007</td>
<td>0.030</td>
<td>0.067</td>
<td>0.001</td>
</tr>
<tr>
<td>5.92/1.80</td>
<td>0.012</td>
<td>0.017</td>
<td>0.026</td>
<td>0.001</td>
<td>3.50/1.06</td>
<td>0.008</td>
<td>0.024</td>
<td>0.008</td>
<td>0.003</td>
</tr>
<tr>
<td>5.83/1.78</td>
<td>0.010</td>
<td>0.025</td>
<td>0.016</td>
<td>0.005</td>
<td>5.58/1.70</td>
<td>0.008</td>
<td>0.019</td>
<td>0.020</td>
<td>0.005</td>
</tr>
<tr>
<td>4.71/1.44</td>
<td>0.010</td>
<td>0.007</td>
<td>0.050</td>
<td>0.004</td>
<td>3.71/1.13</td>
<td>0.007</td>
<td>0.025</td>
<td>0.010</td>
<td>0.002</td>
</tr>
<tr>
<td>3.56/1.08</td>
<td>0.011</td>
<td>0.005</td>
<td>0.090</td>
<td>0.001</td>
<td>4.36/1.33</td>
<td>0.007</td>
<td>0.027</td>
<td>0.013</td>
<td>0.001</td>
</tr>
<tr>
<td>4.47/1.36</td>
<td>0.004</td>
<td>0.026</td>
<td>0.017</td>
<td>N/A</td>
<td>4.75/1.45</td>
<td>0.007</td>
<td>0.013</td>
<td>0.024</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Figure 3. 14 Typical Beach Profile Parameters
Figure 3. 15 Locations of Modeled Hydrodynamic Data Sets

Figure 3. 16 Hydrodynamic data (From the numerical models)
Figure 3. 17 Wind Direction at Grand Isle, La

Figure 3. 18 Wind Speed at Grand Isle, La
The second hydrodynamic data set is a combination of measured and projected data. Time series of significant wave height, water level and peak period (August 31st 1:00 AM to September 11 2008) was obtained from gauges installed prior to Hurricane Gustav at the study site (Dr. Kennedy et al., 2010). Location of this gauge in relation to the project site is shown in Figure 3.19. This gauge is located approximately 0.25 miles from the project and the water depth is about 8 ft. (2.44m).

Figure 3.19 Location of Measured Hydrodynamic Data

Water level data from 9/11/08 13:00 to 9/14/08 23:30 was obtained from NOAA tides and currents station located at Grand Isle, La. Significant wave height from 9/11/08 13:00 to 9/12/08 13:00 was projected to have a constant elevation difference from the water level data (wave height typically increases with increased water levels) and the rest of the significant wave height data is mirror image of the rising limb. Time series for the peak period is also calculated similar to the wave height data (Figure 3.20). It is to be noted that the results of SBEACH run using this hydrodynamic data are referred as “SBEACH run-2” from here on.
Figure 3. 20 Hydrodynamic Data (From field measurements)
CHAPTER 4  NUMERICAL MODELING

4.1 Introduction

Researchers and engineers have developed models to predict the response of barrier islands to the nearshore processes that are affected by the constantly varying winds, waves, and storm surge etc. The complex nature of the coastal environment has led some modelers to rely more heavily on empirical evidence rather than the pure physics associated with existing processes (Carroll, 2004). Campbell (2005) discusses these models abilities to predict the performance of barrier island nourishments in the mixed sediment barriers of Louisiana.

Three types of models (Analytical, Empirical and Numerical) are mainly used to understand the physics and quantify the cross-shore response. Each of the models has its advantages and limitation. The assumption of many shoreline evolution models is that the beach profile moves landward and seaward in response to a longshore sand imbalance while retaining the same cross-shore shape (Dean, 2002; Hanson and Kraus 1989).

In this thesis, a numerical model developed originally by Larson and Kraus (1989) was used to estimate the response of a beach nourishment project in Louisiana to two consecutive hurricanes.

4.2 SBEACH Model

The SBEACH (Storm-induced BEAch CHange Model) model simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels. The latest version allows simulation of dune erosion in the presence of a hard bottom.

The overwash algorithm in the previous version of SBEACH was developed by Kraus and Wise (1993) to simulate dune erosion. Later, Larson et al., (2004) updated the overwash algorithm.

One of the fundamental assumptions of SBEACH is that sediment transportation occurs mainly by the dissipation of energy from breaking waves. Also, longshore transport is neglected and it is assumed that profile change is solely due to the cross-shore transportation which is the dominant mechanism during storm events.
In SBEACH, the beach profile was divided into different zones of cross-shore transport based on characteristics of hydrodynamics across the profile (Miller 1976, Svendsen, Madsen and Hansen 1978, Skjelbreia 1987). Empirical relationships were derived between wave conditions and the development and movement of major profile features. Figure 4.1 shows different zones of cross-shore sand transport. These zones are described as follows.

I. Pre-breaking zone

II. Breaker transition zone

III. Broken wave zone

IV. Swash zone

V. Dune crest zone

VI. Landward zone

Figure 4.1 Definition Sketch for Different Zones of Cross-shore Sand Transport (Tinh, 2006)
Equations for sediment transport rates in these zones are discussed in this section. A series of five reports describing the model has been produced by the U.S Army Corps of Engineers. The first report contains a review of laboratory and field studies, quantification of morphologic features, the numerical model and the applications of the model (Larson and Kraus, 1989). Further field testing is provided in the second report (Larson et al., 1990). The third report serves as a user’s manual (Rosati et al., 1993). Report four describes model revisions which improved the random wave component (Wise et al., 1996). Report five discusses the representation of hard bottoms (Larson and Kraus 1998). Below are the equations for sediment transport rates in the six zones.

Zone I: \[ q = q_b e^{-\lambda_1(x-x_b)} \] if \( x_b < x \) \hspace{1cm} (1)

Zone II: \[ q = q_p e^{-\lambda_2(x-x_p)} \] if \( x_p < x \leq x_p \) \hspace{1cm} (2)

Zone III: \[ q = K \left[ D - D_{eq} + \frac{\varepsilon dh}{K dx} \right], D > \left[ D_{eq} - \frac{\varepsilon dh}{K dx} \right] \] if \( x_s \leq x \leq x_p \) \hspace{1cm} (3)

\[ 0, D \leq \left[ D_{eq} - \frac{\varepsilon dh}{K dx} \right] \]

Zone IV: \[ q_{sw} = K_e 2\sqrt{2gR^2} \left( 1 - \frac{\varepsilon}{R} \right)^2 (\tan \beta_l - \tan \beta_e) \] \hspace{1cm} (4)

Zone V: \[ q_D = K_B 2 \sqrt{\frac{2g}{R}} (R - Z_D)^2 \] \hspace{1cm} (5)

Zone VI: \[ q_f = \frac{q_D}{1 + \frac{q_D}{\beta_D}} \] \hspace{1cm} (6)

where

\( q = \) Sediment transport rate

\( q_b = \) Transport rate at the breaking point

\( q_p = \) Transport rate at the plunge point
$q_{sw}$, $q_D$ and $q_f$ = Sediment transport in the swash zone, beach crest zone and landward zone

$D$ = Energy dissipation per unit water volume

$D_{eq}$ = Energy dissipations equilibrium value

$K_c$, $K$, $K_b$ and $\varepsilon$ = Empirical transport coefficients

$X$ = cross-shore coordinate

$u_b$ = Front speed of the uprushing wave

$\beta_l$ = Local foreshore slope

$\beta_c$ = Equilibrium foreshore slope

In the original overwash algorithm which was later updated by Larson et al., (2004), the profile was divided into three regions: swash zone, beach crest zone and landward of crest zone. Figure 4.2 depicts these zones.

Equations to calculate the sediment transport $q_{sw}$ in the swash zone were given by Larson et al., (2001, 2004)

![Figure 4.2: Three Regions of Sediment Transport Described in Overwash Algorithm (ERDC/RSM-TN-15, 2004)](image-url)
\[ q_{sw} = K_c \frac{u_b^2}{g} (\tan \beta_l - \tan \beta_e) \frac{t_o}{T} \]  \hspace{1cm} (7)

where

\( q_{sw} \) = Sediment transport in the swash zone

\( K_c \) = Empirical transport coefficient

\( u_b \) = Front speed of the uprushing wave

\( g \) = Acceleration due to gravity

\( \beta_l \) = Local foreshore slope

\( \beta_e \) = Equilibrium foreshore slope

\( t_0 \) = Time duration which a specific location is submerged

\( T \) = Swash period

Using the equations for \( u_b \) and \( R \) (runup height) as discussed in the SBEACH reports the sediment transport in the swash zone is given as

\[ q_{sw} = K_c 2\sqrt{2g} R^{2/3} (1 - \frac{z}{R})^2 (\tan \beta_l - \tan \beta_e) \]  \hspace{1cm} (8)

where

\( z \) = Vertical distance from SWL to the location where \( u_b \) is calculated.

In the crest zone, the assumption is that the sediment transport rate in the overwash is proportional to the average rate of water flow crossing the top of the beach during a swash cycle. This is expressed as

\[ q_D = K_g \sqrt{\frac{2g}{R}} (R - Z_D)^2 \]  \hspace{1cm} (9)
where

\[ q_{D} = \text{Sediment transport in the crest zone} \]

\[ K_{b} = \text{Non-dimensional empirical coefficient (about = 0.005)} \]

\[ Z_{D} = \text{Height of the beach crest above still water level.} \]

In the landward zone of the crest the transport rate in the flow is,

\[ q_{f} = \frac{q_{D}}{1 + \mu s/ \delta_{D}} \quad x < x_{D} \quad (10) \]

where

\[ q_{f} = \text{Sediment transport in the zone landward of the crest} \]

\[ \mu = \text{Empirical coefficient} \]

\[ s = \text{Coordinate originating at } x = x_{D} \]

\[ \delta_{D} = \text{Width of flow at the beach crest} \]

4.3 Model Setup

The SBEACH model requires the following input files to simulate the cross-shore profile changes

- Initial beach Profile
- Profile configuration: This includes the grid size, landward boundary of the profile, number of grids, median grain size and other sediment transportation parameters
- Storm configuration: This data includes the time series of wave height, peak period and water levels with options of entering wind speed, wind angle and wave angle.

In this thesis, a total of 10 profiles were used for the modeling purpose. Both pre- and post-storm profiles were available to compare the model results with the measured profiles. These profiles are shown in the “Data compilation and data analysis” chapter. A grid spacing of 20
ft. (6m) was used. Median grain size is obtained from the original design report and is verified as 0.11 mm. Storm configuration data is also discussed in Chapter 3.

Time series of the significant wave height, peak period and water levels include both the hurricanes, hurricane Gustav and hurricane Ike. Two hydrodynamic data sets are used in this study, the first data set is shown in Figure 3.16 and the second data set is shown in Figure 3.20. Both hurricanes are considered as one continuous storm for the purpose of modeling.

4.4 Calibration

The Calibration of SBEACH was done as part of the original design by the design engineers. These calibrations were performed based on the observed impacts of Hurricanes Isidore and Lili. Pre and post-storm survey profiles were used for calibration (Survey profiles of September 2002 and December 2002, respectively). Several simulations of Hurricanes Isidore and Lili were conducted in this design using wind velocities at Grand Isle and observed waves at NOAA Buoy 42041. Three prominent parameters that influence the changes to shoreline in the SBEACH model are the transport rate coefficient, $K$ ($2.5 \times 10^{-7} - 2.5 \times 10^{-6}$ m$^4$/N), overwash transport parameter (0.005) and the coefficient for slope dependent term, $\varepsilon$ (0.001-0.005 m$^2$/sec). In the design report, these calibrated values were shown as $K = 2.5 \times 10^{-7}$ m$^4$/N, coefficient for slope dependent term = 0.001 m$^2$/s and transport rate decay = 0.3. To reproduce these results shown in the report, a model run using the same parameters was performed and the results were found to be in agreement (Figure 4.3 shows the hydrodynamic data and Figure 4.4 shows the model results).

In addition to these parameters, there are other parameters in the model, including, the spatial rate of decay, avalanching angle and the depth of foreshore. Values shown in the above parentheses are the recommended values in the model. The Transport rate coefficient and coefficient for slope dependent terms can only be calibrated within these default limits and there is no option of increasing these values beyond these limits in SBEACH model. However the overwash transport parameter can be increased for the calibration purposes.

To further understand the effects of the above parameters, additional sensitivity tests were performed as shown in Table 4.1.
Figure 4. 3 Hydrodynamic Data for SBEACH Test Case

Figure 4. 4 Reproduction of SBEACH Result Presented in the Original Design Report
4.5 Sensitivity

SBEACH was tested for sensitivity to empirical coefficients provided in the model as well as to the key forcing parameters such as wave height and water level as well as the median grain size to evaluate the model response.

Table 4. 1 Sensitivity of Empirical Coefficients

<table>
<thead>
<tr>
<th>Transport rate coefficient (m^4/N)</th>
<th>Slope dependent term(m^2/sec)</th>
<th>Overwash transport coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.50E-07</td>
<td>0.001</td>
<td>0.005</td>
</tr>
<tr>
<td>1.50E-06</td>
<td>0.003</td>
<td>0.01</td>
</tr>
<tr>
<td>2.50E-06</td>
<td>0.005</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Profile at station 87+28 is used for the sensitivity test purposes. A total of 27 simulations were performed to test the model. As the transport rate coefficient increases, it significantly increases both the bar height and bar volume in the initial time steps which causes the profile evolution to approach its equilibrium rapidly. As the slope dependent term increases, flatter equilibrium profile forms and more sediment moves offshore. When the overwash transport rate is increased beyond the default limits, it is found that it increases the sediment transport rate. Therefore higher values of the Transport rate coefficient, slope dependent term and overwash transport coefficients shown in the Table 4.1 are used in the modeling.

Figure 4.5 provides the effect of varying the slope dependent term. Though increasing the value does not provide a significant volume change, the erosion on the foreshore of the slope is considerably higher for the higher values of the slope dependent term. Therefore at the study site a slope dependent term value of 0.005 (m²/N) produced closer results when compared with the post-storm profile.

Figure 4.6 shows the effects of varying the overwash transport rate coefficient. From the figure it can be observed that increasing the overwash transport rate increases the erosion. As the measured profile shows lot of erosion on the foreshore, the higher value of the overwash transport rate is used for modeling all of the study profiles.
It is interesting to note that a default value of 0.005 is recommended in SBEACH. Increasing this value beyond the recommended value produces increased erosion. This coefficient is increased beyond 0.02 and found that the simulation produces disturbed results that are not acceptable in their original condition (These results are not shown here). Therefore a value of 0.02 was used in the modeling.

Figure 4.7 shows the effects of varying sediment transport rate coefficient. It can be seen clearly that increasing this value also increases the sediment transportation along the sub-aerial slope of the beach; it is to be noted that this also results in an accretion along the nearshore slope of the beach. For the purpose of modeling a transport rate coefficient of $2.5 \times 10^{-6}$ is used.

Figure 4.8 shows the sensitivity response of SBEACH to wave height. Figure 4.9 depicts the sensitivity response to water level change and Figure 4.10 is the response to varying median grain size. Table 4.2 lists the parameters that were varied.
Figure 4. 6 Effects of Varying the Overwash Transport Coefficient

Figure 4. 7 Effects of Varying the Transport rate Coefficient
Table 4. 2 Sensitivity Test for the Hydrodynamic Data

<table>
<thead>
<tr>
<th>Wave height (Hs, ft/m)</th>
<th>Water level (ft/m)</th>
<th>Median grain size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/0.6</td>
<td>2/0.6</td>
<td>0.11</td>
</tr>
<tr>
<td>4.5/1.4</td>
<td>4/1.2</td>
<td>0.15</td>
</tr>
<tr>
<td>6/1.8</td>
<td>6.15/1.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Wave Height**

To test the effects of the wave height and to evaluate the response of SBEACH, wave height is varied from 2 to 6 ft (0.6 to 1.4 m) with water level and peak period remaining constant. Figure 4.8 shows the effects of varying the wave heights. It can be seen that increasing the wave height increases the erosion. It is noted that when the wave height is increased with a constant water level (Water level is maintained at 0 ft for all of the simulations) the erosion at the toe of the beach slope is increased. There is a small increase in the erosion on the nearshore slope of the beach. No sediment transport was observed on the sub-aerial slopes of the beach profile.

**Water Level**

To test the effects of changing the water level and to evaluate the response of the SBEACH, water level is varied from 2 ft (0.6m) to 6.15 ft (1.9m) with wave height and peak period remaining constant. For Hurricanes Gustav and Ike, water level ranged from a minimum of -0.29 ft. (0.08m) to a maximum of 7.69 ft. (2.34m). Figure 4.9 shows the effects of varying the water levels. From this sensitivity test it is observed that increasing the water level increases the sand transport along the sub-aerial slopes of the beach profile. It is also observed that as the water level increases, the resulting beach profile forms an overall milder slope. In other words, it resulted in erosion on the sub-aerial slope and deposition on the nearshore slopes of the beach profile. Another observation made during this sensitivity test was that increasing the water level to 7 ft. (2.14 m) (Inundation over wash) results in no major changes in the profile compared to the profile with water level of 6.15 ft. (1.9 m)
Figure 4.3 Sensitivity of SBEACH to Varying Wave Height

Figure 4.4 Sensitivity of SBEACH to Varying Water Level
Median Grain Size

For this sensitivity test, median grain size is varied from 0.11 mm to 0.20 mm; the results of this sensitivity test are shown in the Figure 4.10. As the median grain of the sand becomes finer, more erosion on the sub-aerial slopes of the beach profile is observed. Also as the median grain size of the material becomes coarser less erosion was observed.

Figure 4.5 Sensitivity of SBEACH to Varying Median Grain Size
CHAPTER 5 RESULTS AND DISCUSSION

5.1 Model Results and Comparison

In this chapter, the results of SBEACH simulations are presented. A total of 10 profiles were simulated. Two hydrodynamic data sets are used in the simulation of each profile. The first data set is the time series of water level, wave height and peak period from the numerical models (ADCIRC and SWAN) and the second data set is the time series of water level, wave height and peak period obtained from the field measurements (Detailed description of the hydrodynamic data is provided in Section 3.4). In the following section “SBEACH run-1” refers to the results of SBEACH when the first hydrodynamic data set is used and “SBEACH run-2” is refers to the results of SBEACH when the second hydrodynamic data set is used.

Profile at station 14+68:

Station 14+68 is the first profile located at the western end of the studied area. Landward limit of the pre-storm profile at this station is about 1000 ft. (305 m) from the baseline and the offshore limit of the same is about 1500 ft. (457 m) comprising a total of about 2500 ft. (762 m) in length. Similarly the post-storm measured profile is about 3600 ft. (1097 M) in length with 1800 ft. (548.6 m) on both sides of the baseline. Based on the response to overwash this profile is categorized as “barrier rollover”.

Visual inspection of the measured pre-storm and post-storm profiles at this location reveals that there is a lot of erosion along the sub-aerial and nearshore slopes of the beach profile. It also indicates some deposition along the back barrier at this station.

Both hydrodynamic data sets used in the SBEACH modeling provided almost the same results. Some observations using the results of the SBEACH at this profile are as follows:

- Dune destruction
- Deposition of sediment along the back barrier
- Deposition of the sediment along the sub-aerial slope of the beach profile
Even though the overall observations indicate similar pattern to the measured profile, SBEACH was unable to reproduce the measured profile.

Profile at station 29+20:

At station 29+20, after Hurricanes Gustav and Ike, the dune was completely destructed. The average dune elevation before the storm was about 6 ft. (1.82 m) and the back barrier elevation was approximately 2.5 ft (0.76 m). Post-storm profiles indicate 2.5 ft (0.76 m) and lower elevations along the dune and back barrier. Erosion along the toe of the beach profile was much greater compared to the erosion along the nearshore slope of the beach profile.

The following are the observations made from the SBEACH results

- Both data sets (SBEACH run-1 and SBEACH run-2) indicate similar sediment transportation pattern.
- Dune is reduced in width and moved landward.
- Erosion on the sub-aerial beach profile and small deposition on the nearshore slopes of the beach profile.
- Overall seaward slope of the beach profile is milder compared to the post-storm profile.

Figure 5.2 SBEACH Results at Station 29+20

Sediment volume calculations using measured pre and post storm profiles between station 14+68 and station 29+20 indicate an erosion of 223528.3 cubic yards and a deposition of 18188.3 cubic yards. Whereas SBEACH run-1 indicates a mere 24414 cubic yards of erosion and 20959 cubic yards of deposition indicating the inability of SBEACH to reproduce the measured profile at this location also. Similarly, SBEACH run-2 indicates a 28031 cubic yards of erosion and 21631 cubic yards of deposition, which is consistent with SBEACH run-1 results.
Profile at station 43+72:

Visual comparison of the pre-storm and post-storm profiles indicates a combined dune destruction and barrier rollover at this station.

SBEACH model results indicate erosion of dune and a minor landward translation of the dune, which is not consistent with the measured data. SBEACH run-1 indicates more erosion and landward transition compared to SBEACH run-2 results. At this location also SBEACH was unable to reproduce the measured data.

Sediment volume calculations from the measured pre and post-storm profiles between station 29+20 and station 43+72 indicate 204652.3 cubic yards of erosion and 13208.7 cubic yards of deposition. SBEACH run-1 results indicate 24190 cubic yards of erosion and 23282 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 25823 cubic yards of erosion and 21544 cubic yards of deposition.

Figure 5. SBEACH Results at Station 43+72
Profile at station 58+23:

Similar to the profile at Station 43+72, visual inspection of the pre and post-storm profiles indicates a dune destruction and barrier rollover at this station.

SBEACH model results indicate erosion of dune and a slight landward translation of the dune, which is not consistent with the measured data. SBEACH run-1 indicates more erosion and landward transition compared to SBEACH run-2 results. At this location also SBEACH was unable to reproduce the measured data.

Sediment volume calculations from the measured pre and post-storm profiles between station 43+72 and station 58+23 indicate 193321.9 cubic yards of erosion and 34824.6 cubic yards of deposition. SBEACH run-1 results indicate 26283 cubic yards of erosion and 27064 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 27968 cubic yards of erosion and 25533 cubic yards of deposition.

![Profile at Station 58+23](image)

Figure 5. 4 SBEACH Results at Station 58+23
Profile at station 72+75:

Station 72+75 is approximately at the middle of the study area. Dune lowering with a landward translation was observed when the pre and post-storm profiles are compared.

SBEACH run-1 model results also indicate the lowering of the dune and erosion along the sub-aerial and nearshore slopes of the beach profile. SBEACH run-2 results show minor erosion along the crest of the dune when compared with SBEACH run-1. Even though the entire volume of the sediment deposited/eroded at this location is not accurately reproduced by SEBACH run-1, the overall shape of the modeled profile is relatively consistent with the erosion/deposition patterns of the measured profile.

Sediment volume calculations from the measured pre and post-storm profiles between station 58+23 and station 72+75 indicate 170378.2 cubic yards of erosion and 38270 cubic yards of deposition. SBEACH run-1 results indicate 30979 cubic yards of erosion and 30883 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 32346 cubic yards of erosion and 29761 cubic yards of deposition.

Figure 5. SBEACH Results at Station 72+75
Profile at station 87+28:

Visual inspection of the pre and post-storm profiles indicates majorly dune destruction with a slight rollover of the barrier.

SBEACH run-1 model results indicate erosion of dune and landward translation of the dune, which is not consistent with the measured data. Also, SBEACH run-1 and SBEACH run-2 profiles indicate erosion on the sub-aerial slope of the beach profile with minimum deposition on the nearshore slope. Both runs are consistent in reproducing the results along the foreshore slopes but differ in the dune area.

Sediment volume calculations from the measured pre and post-storm profiles between station 72+75 and station 87+28 indicate 133714 cubic yards of erosion and 32207 cubic yards of deposition. SBEACH run-1 results indicate 32391 cubic yards of erosion and 31410 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 32005 cubic yards of erosion and 29436 cubic yards of deposition.

![Profile at Station 87+28](image)

**Figure 5.6 SBEACH Results at Station 87+28**
Profile at station 101+80:

Stations 101+80 to the end of the project are considered to on the eastern end of the study area. Visual inspection of the pre and post-storm profiles indicates a “barrier rollover”.

SBEACH run-1 model results also indicate the barrier rollover at this location. SBEACH run-2 results show minor erosion along the sub-aerial slope of the beach profile. Even though the entire volume of the sediment deposited/eroded at this location is not accurately reproduced by SBEACH run-1, the overall shape of the modeled profile is relatively consistent with the erosion/deposition patterns of the measured profile. SBEACH run-2 was unable to reproduce the shape of the measured profile.

Sediment volume calculations from the measured pre and post-storm profiles between station 87+28 and station 101+80 indicate 127818 cubic yards of erosion and 29420.5 cubic yards of deposition. SBEACH run-1 results indicate 30288 cubic yards of erosion and 30414 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 29017 cubic yards of erosion and 27952 cubic yards of deposition.

![Profile at Station 101+80](image)

Figure 5. 7 SBEACH Results at Station 101+80
**Profile at station 116+32:**

Combined dune lowering and barrier rollover is the overwash response observed at the station 116+32. Also, considerably large amount of erosion is observed on the nearshore slope of the measured profile when compared with pre-storm profile.

Both the SBEACH run-1 and SBEACH run-2 results in relatively good reproduction of the profile change along the dune but were unable to reproduce the vast erosion observed along the sub-aerial and nearshore slopes of the beach profile at this station.

Sediment volume calculations from the measured pre and post-storm profiles between station 101+80 and station 116+32 indicate 175114.3 cubic yards of erosion and 25803.7 cubic yards of deposition. SBEACH run-1 results indicate 25837 cubic yards of erosion and 26415 cubic yards of deposition. Similarly, SBEACH run-2 results indicate 32388 cubic yards of erosion and 30342 cubic yards of deposition.

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**Figure 5.8 SBEACH Results at Station 116+32**
Profiles at stations 130+84 & 145+35:

Stations 130+84 and 145+35 are on the eastern end of the study area. Post-storm profiles show a landward translation of the dune at these locations.

Both SBEACH run-1 and SBEACH run-2 results in relatively good reproduction of the profile change along the back barrier of the dune but were unable to reproduce the erosion observed along the dune crest, sub-aerial and nearshore slopes of the beach profile at this station.

Tables 5.1 and 5.2 provide the sediment volume calculations.

Figure 5. 9 SBEACH Results at Station 130+84
Figure 5. 10 SBEACH Results at Station 145+35

Table 5. 1 SBEACH run-1 Erosion/Accretion Calculations
Table 5. 2 SBEACH run-2 Erosion/Accretion Calculations

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Total measured erosion between stations 14+48 and 145+35 is approximately 1558494 cubic yards. SBEACH run-1 predicted the total erosion as 235295 cubic yards. This is approximately less by a factor of 6.6. SBEACH run-2 predicted the total erosion as 269360 cubic yards; this is less than the measured by a factor of 5.8. Total measured accretion/deposition was approximately 312281 cubic yards. Both SBEACH runs predicted this less by a factor of 1.35.
CHAPTER 6   CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Numerical modeling is a useful tool to simulate shoreline changes. Results of this modeling provide beneficial information to coastal engineers in predicting beach behavior in response to storm events. Most of the studies in this area of interest generally concentrate on understanding a barrier island’s response to a single storm event. But this research investigates the shoreline response to two consecutive storm events using the SBEACH numerical model. SBEACH is widely used in the industry by coastal engineers in modeling beach erosion due to storm impacts.

Sediment volume calculations show that after Hurricanes Gustav and Ike (2008), the Chaland Headland beach restoration project experienced a lot of foreshore erosion and destruction of dune in some areas. Data analysis of pre- and post-storm profiles indicates a trend of increasing erosion from eastern end of the study area to the western end. Also, sediment deposition is increased from western end to the eastern end. These suggest strong three-dimensional flows. There was longshore sediment transport in addition to cross-shore transport. Also, in a previous work done by Kuiper (2010) at this project location, it was indicated that in reality a significant amount of sand from the nearshore is transported in long shore direction instead of reworking across the gulf side of the profile due to cross-shore processes. Another important mechanism is the gradient of the water levels in the bay side and gulf sides of the beach, which also transports the sediment to the lee side of the barrier island. Overwash (Runup and Inundation) was a dominant process during these storm events. Categorizing the post-storm profiles based on the response to overwash has revealed a new observation that many of these profiles fit in a new category named “Combined dune destruction and Barrier rollover”. It is noted that all of the post-storm profiles showed a consistent sub-aerial and nearshore beach profile slopes when compared to the pre-storm profiles.

The sensitivity of the model results to the empirical coefficients in SBEACH has been tested for the site specific conditions. It was found that overwash transport coefficient plays a major role in the sediment transport (Figure 4.6). Increasing it beyond the recommended values
in SBEACH resulted in profiles that are relatively closer to the actual measured post-storm profiles.

Forcing data (Wave height, water level and peak period) is the key for modeling beach changes in SBEACH. Sensitivity tests indicated that the model results are highly sensitive to the water level and median grain size changes. In the present SBEACH version there is no provision made to model the inundation overwash, therefore the sensitivity tests for inundation overwash produced an inconsistent (disturbed) profile.

The model results indicate SBEACH captures some of the trends of the measured profiles at dune crest, back barrier and sub-aerial beach areas, but it was unable to reproduce the erosion observed along the nearshore slopes of the beach at any of the modeled profiles.

6.2 Recommendations

SBEACH is one of the tools available to model the cross-shore beach profile changes. Assumptions made in this model are that sediment transport occurs mainly due to breaking waves, and profile change is solely due to the cross-shore transportation. Even though SBEACH did not reproduce the measured post-storm beach profiles, many useful observations related to the shoreline change processes were presented in this study.

The SBEACH model can be further improved to better incorporate the processes involved in the barrier island morphological changes. More detailed investigations are necessary to improve the knowledge and modeling approach to beach erosion under direct impact of hurricanes. These following are the recommendations made for further improvements of numerical model in predicting barrier island changes.

- Nearshore sediment transport is highly three dimensional in broken, low-crest barrier island systems. Therefore the three dimensional effects, including the longshore transport, should be considered.

- Hydraulic gradient (difference in water levels) is also one of the factors causing sediment transportation between the ocean and bay. Therefore, this gradient should also be considered when modeling the cross-shore profile changes of low dune barriers.
• Descriptions of the effects of friction losses and vegetation on the flow on the backside of beach profile (Donnelly et al. 2005) are needed and implemented into the model.

• Beach monitoring programs should be in place for restored barrier islands to obtain accurate field data.
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APPENDIX A (A1-A10)

PROFILES SHOWING THE SEDIMENT EROSION/DEPOSITION
APPENDIX B (B1-B5)

COMPARISON OF ORIGINAL DESIGN AND STUDY PROFILES
VITA

Naveen Khammampati, the son of Nirmala and Raja Rao Khammampati, was born on December 27, 1978, in Khammam, Andhra Pradesh, India. After completion of his undergraduate studies in India, he came to United States to pursue Master’s degree in Civil Engineering from Lamar University, Beaumont, Texas and graduated in the fall of 2003 with specialization in water resources engineering. He started his career as an engineer intern at Cooper Engineering, Inc., Mandeville, Louisiana in 2004. In 2007 he started working at ABMB Engineer, Inc. At present, he is working as a professional engineer in Civil Engineering at ABMB Engineers, Inc. He attended the Master of Civil engineering program at Louisiana State University from August 2008. He will receive the degree of Master of Science in Civil Engineering from the Department of Civil and Environmental Engineering in December, 2011 with the specialization in Coastal Engineering.