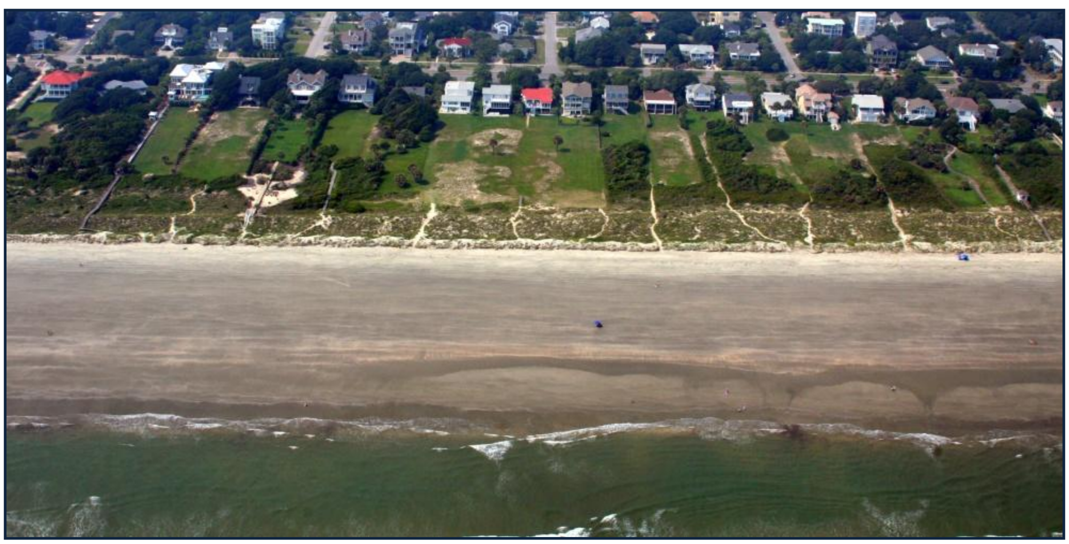
2008 BEACH RESTORATION PROJECT
ISLE OF PALMS SOUTH CAROLINA

Monitoring Report No 3
November 2011



Prepared for:

City of Isle of Palms

2008 Isle of Palms Beach Restoration Project

YEAR 3 MONITORING REPORT

Prepared for:

City of Isle of Palms

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[2300YR3]

NOVEMBER 2011

COVER PHOTO: Aerial views of Isle of Palms along the northeast end (upper) and 25th Avenue to 29th Avenue (lower) after passage of Hurricane *Irene* in August 2011.

[Photos by Steven Traynum]

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EXECUTIVE SUMMARY

This report presents results of Year 3 beach and inlet monitoring following the 2008 beach restoration project at the Isle of Palms, which was accomplished in May–June 2008 under permit P/N 2007-02631-2IG. As part of the Operations, Monitoring, and Contingency Plan (CSE 2008a) for the project, annual surveys are being conducted to track the performance of the project, measure sand volumes remaining, and provide a condition survey of the beach, inlets, and shoals from Dewees Inlet to Breach Inlet. Year 3 monitoring involved a condition survey and collection of sediment samples in late June 2011. These data are compared with pre-project and post-project conditions in the project area (north of 53rd Avenue). Data for remaining areas of the Isle of Palms and Breach Inlet are compared with earlier surveys by CSE and SCDHEC–Office of Ocean and Coastal Resource Management (OCRM). The report includes:

- Shoreline history and summary of the 2008 beach restoration project.
- Description of the data collection and analysis methods.
- Monitoring results by section of shoreline using seven (7) reaches along the island.
- Nourishment volume remaining within the project limits.
- Identification of local erosion "hot spots."
- Discussion of findings.

The present report follows the Year 1 monitoring report (CSE 2009a) and an interim report (CSE 2010) along with the Year 2 monitoring report (CSE 2011) which presented volume changes through September 2010 (Table A). This report continues those analyses through the June 2011 beach condition. All surveys since March 2009 have used the same baseline (shore-parallel stationing system based on distance from the Breach Inlet bridge), which was established following the project to encompass the entire island. Cross-shore volume calculation limits and depth limits were adjusted profile-by-profile in an attempt to fully account for all measurable volume change occurring at a profile. This results in certain volumes slightly differing from previous reports. Where this occurred, previous profile volumes were recomputed using the new limits.

TABLE A. Important dates of events related to the 2008 beach nourishment project and subsequent monitoring.

Milestone	Date	Comment
Beach Condition Survey	Jul 2007	
Pre-Construction Survey	Mar 2008	
Project Construction	May-Jun 2008	934,000 cubic yards placed along 10,200 feet of shoreline
Monitoring Survey	Mar 2009	93 percent of nourishment volume remained within the fill placement area
Monitoring Survey	Sep 2009	81 percent of nourishment volume remained within the fill placement area
Year 1 Monitoring Report	Dec 2009	
Monitoring Survey	Mar 2010	73 percent of nourishment volume remained within the fill placement area
Monitoring Survey	Sep 2010	72 percent of nourishment volume remained within the fill placement area
Permit Application Submitted	Oct 2010	
Year 2 Monitoring Report	Mar 2011	
Monitoring Survey	Jun 2011	66 percent of nourishment volume remained within the fill placement area
Year 3 Monitoring Report	Nov 2011	

The 2008 beach restoration project obtained sand from deposits ~2.5 miles offshore and placed 933,895 cubic yards (cy) in three reaches between 53rd Avenue and Dewees Inlet. As of June 2011 (~3 years after project completion):

- Reach A (53rd Avenue to Beach Club Villas) retained ~36.7 percent of the nourishment volume.

- Reach B (Mariners Walk Villas to the 18th fairway of Wild Dunes Links Course) retained ~76.1 percent of the nourishment volume.

- Reach C (a 1,000-foot length of Dewees Inlet shoreline adjacent to the 17th hole and 18th tee of the Wild Dunes Links Course) retained ~138.7 percent of the nourishment volume (Fig A).

Collectively, the project reaches retained ~66 percent of the nourishment fill as of June 2011. Overall, the island lost 155,000 cy (4.2 cubic yards per foot) of sand between September 2010 and June 2011. This is opposite the historical accretion trend at Isle of Palms.

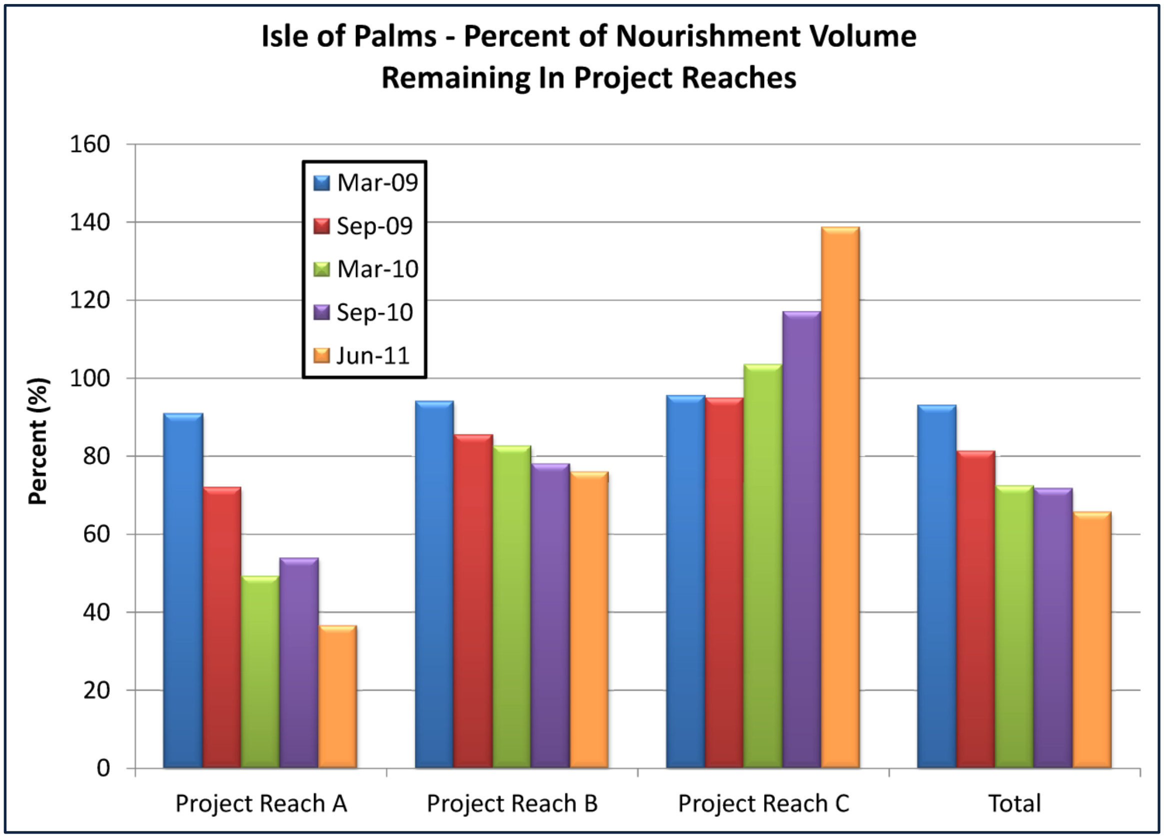

FIGURE A. Percent of nourishment volume remaining in project areas as of June 2011.

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TABLE OF CONTENTS

PAGE

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1.0 INTRODUCTION

This monitoring report is provided to the City of Isle of Palms by Coastal Science & Engineering (CSE) as part of a three-year agreement for beach monitoring following the 2008 Isle of Palms beach restoration project (P/N 2007-02631-2IG, CSE 2008b). This report details the fifth data collection after nourishment. It follows submission of the Year 1 monitoring report (CSE 2009a), the Year 2 interim monitoring report (CSE 2010), and the Year 2 monitoring report (CSE 2011). Discussions presented herein are based on comparisons of pre-project and post-project data with surveys performed in March and September of both 2009 and 2010 and in June 2011.

The analyses presented in this report provide an updated condition of the beach ~36 months after the completion of the restoration project. There are several objectives of post-project beach monitoring, some of which are required by the conditions of the permits. This report provides beach profile volumes along the length of the Isle of Palms (IOP), including detailed volume changes in the project areas. It also addresses the present physical and environmental condition of the beach and offshore borrow areas impacted by the project, including sand grain size, beach slope, beach compaction, and borrow area infilling rates. Ground and aerial photography are included to identify features such as dunes, escarpments, sand texture and color, as well as to give a visual representation of the beach width for comparison with previous and future surveys.

1.1 Setting

Isle of Palms is an ~7-mile-long, southeast-facing, barrier island located ~8 miles east of Charleston, South Carolina. It is bounded by Dewees Inlet and Dewees Island to the northeast and Breach Inlet and Sullivan's Island to the southwest. A feature typical of the central South Carolina barrier islands is the "drumstick" shape (Hayes 1979) produced by the interaction of waves and tides, and formation of prominent ebb-tidal deltas at the inlets. Seaward shoals of each delta produce wave refraction and variable longshore transport rates. This leads to a wider upcoast (northern) end and a relatively thin downcoast end (Breach Inlet end, Fig 1.1). The wider end of the island is influenced by shoal bypassing, a process whereby sand is periodically released from the inlet delta and moved onshore through wave action. This process occurs at somewhat regular intervals (average interval between events from 1941 to 1997 is 6.6 years, Gaudiano 1998) and contributes to the overall health of the island. However, it also can cause focused erosion in areas adjacent to the shoal attachment zone (Kana et al 1985).

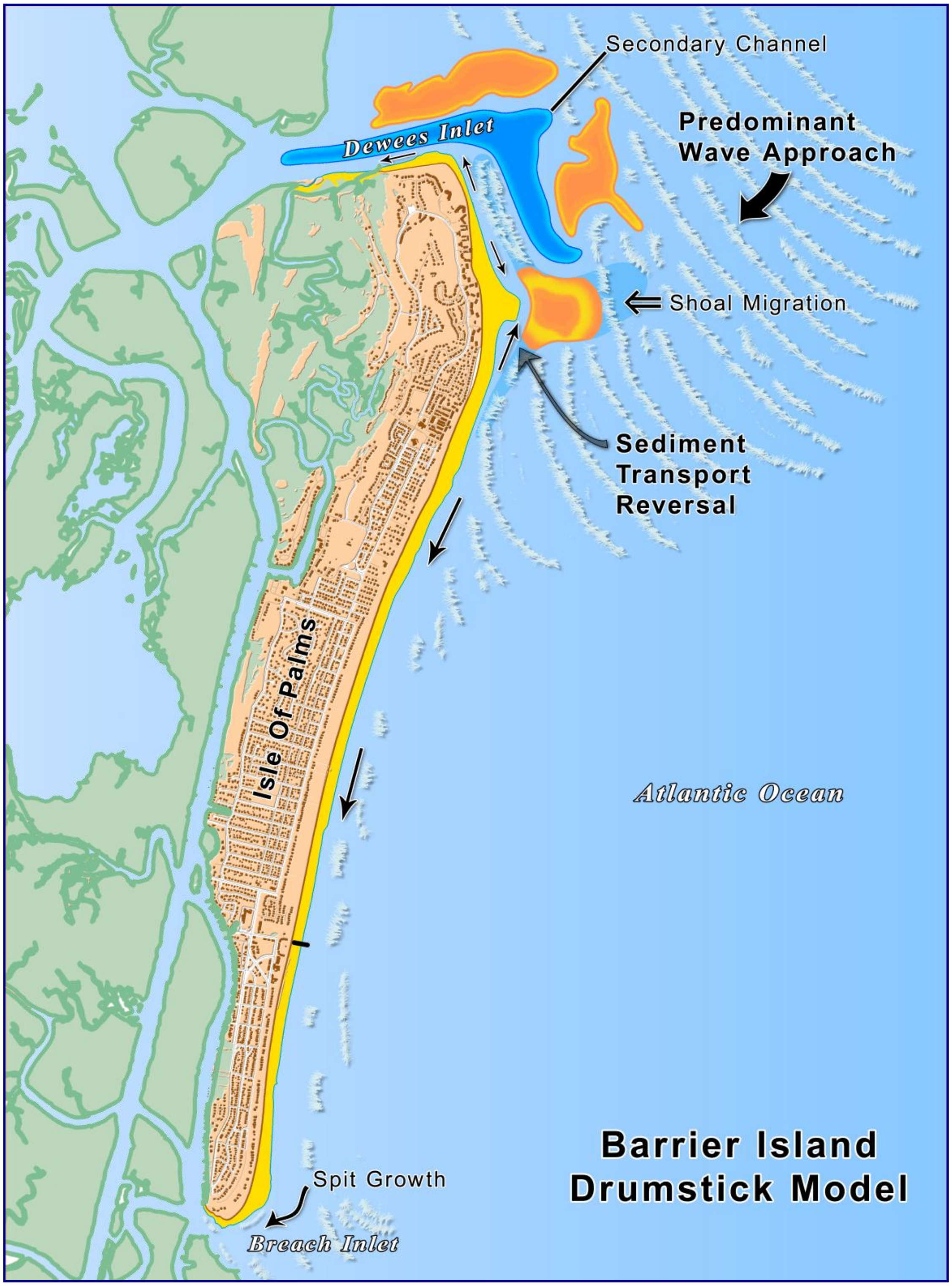

FIGURE 1.1. Isle of Palms is a typical "drumstick" barrier island (after Hayes 1979), where the upcoast end is wider due to sediment accumulation through shoal-bypass events, and the downcoast end usually forms a growing recurve spit. Other examples of drumstick barrier islands along South Carolina are Bull Island, Kiawah Island, and Fripp Island. Zones of sediment transport reversal generally occur in the lee of delta shoals which are situated offshore. Upon shoal attachment to the beach, transport directions in the vicinity of the shoal switch, spreading sand away from the attachment point (see for example — Fig 1.2).

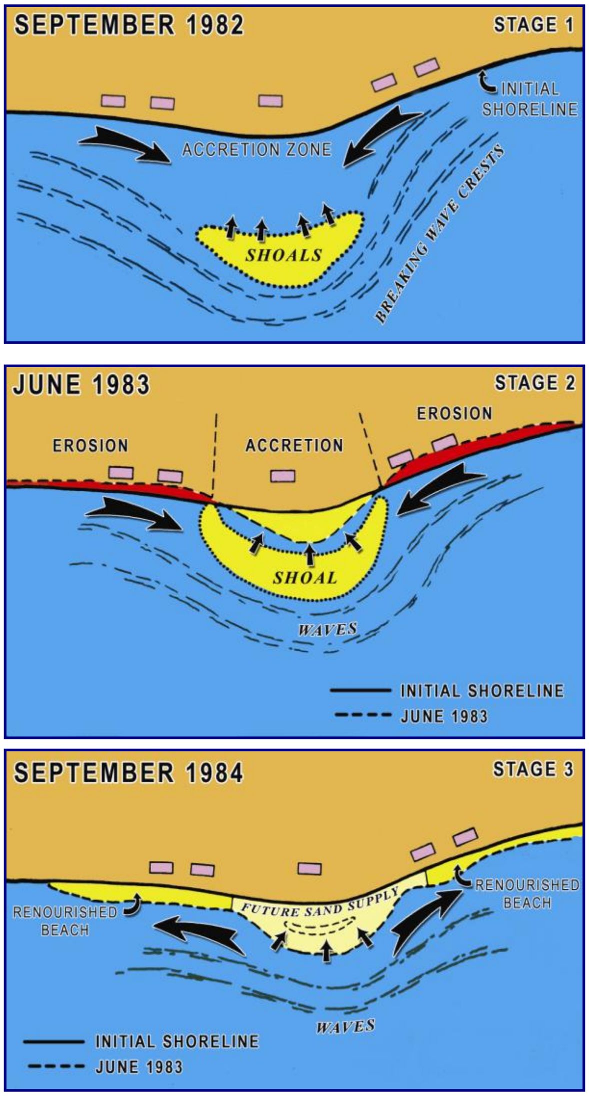

FIGURE 1.2.

[LEFT]
Schematic of the shoal-bypass cycle originally modeled from a bypass event at IOP. During Stages 1 and 2 of the cycle, accretion in the lee of the shoal is accompanied by erosion on either side of the attachment site. (After Kana et al 1985)

[RIGHT]
Shoal-bypass event at the northeastern end of IOP. The upper photo shows a shoal in Stage 1 of the bypass cycle in March 1996. The middle image, taken in 1997, shows that the shoal is beginning to attach to the beach and is in Stage 2 of the bypass cycle. The lower image (from December 1998) shows the shoal completely attached (Stage 3), and sand has spread to previously eroded areas.

The long-term accretion trend at Isle of Palms is a direct result of shoal bypassing at Dewees Inlet. Numerous episodic events have deposited sand on the northeastern end of the island (Gaudiano 1998). The annual average sand gain from shoal-bypass events is ~100,000 cubic yards per year (cy/yr); however, ~120,000–130,000 cy/yr are typically lost to downcoast areas each year, leaving a net sand deficit of ~20,000–30,000 cy/yr at the northeastern end (CSE 2007a). A more detailed explanation of the coastal processes and erosion history of Isle of Palms is provided in CSE (2007a, 2008b, 2009a).

The shoal-bypassing event which led to the 2008 project appears to have begun around 2003. By 2004, some areas (eg – Port O'Call) experienced 150 ft of beach recession in one year (ATM 2006). In February 2007, exposed bars extended nearly one-half mile offshore around Beach Club Villas and the Wild Dunes Property Owners beach house (Fig 1.3). The southern part of the attaching shoal was already in Stage 3 with some sand moving south to nourish other parts of IOP; the northern side remained in Stage 2. As Figure 1.3 shows, all properties north of Beach Club Villas had lost their dry-sand beach by then. To protect buildings, property owners placed ~5-gallon-sized sand bags along the scarped dune. These bags were quickly destroyed or washed away, and property owners replaced them with large (1 cy) sand bags in front of buildings for protection. Erosion continued into 2008, eventually claiming half of the signature 18th hole of the Wild Dunes Links Course and leaving no dry beach (even at low tide) in front of several properties.

FIGURE 1.3.

[UPPER]

February 2007 oblique aerial image of the northeastern end of IOP showing the approaching shoal in Stage 2 of the bypass cycle.

Note loss of dry beach and various shore-protection measures from Mariners Walk Villas to the 18th fairway (red-outlined arrows – focused erosion).

[LOWER]

Small, 5-gallon-sized sand bags (left) and large 1 cy-sized sandbags (right) installed by property owners to temporarily offer protection to buildings.

Prior to the 2008 project, little to no beach was present at low tide near the Ocean Club condominiums.

Left image courtesy of Coastal Carolina University Beach Erosion Research and Monitoring Program.

1.2 The 2008 Isle of Palms Beach Restoration Project

The Wild Dunes Community Association retained CSE in May 2007 to develop an analysis of erosion and prepare a plan for long-term restoration of the beach. CSE (2007a) determined that upward of 900,000 cy should be added along the northeastern end of IOP to restore the sand deficit and provide reserves that will accommodate future erosion events over an approximate ten-year period. Following a number of community meetings and discussions with City and State officials, the City of Isle of Palms elected to proceed with the final design and planning for the project.

The specific objectives of the 2008 beach restoration project were to:

- Restore the recreational beach along the northeastern erosion zone of IOP from 53rd Avenue to the terminal groin along Dewees Inlet, excluding areas with a sand surplus in the active sand-bypassing zone or which were likely to receive sand as a result of natural spreading to downcoast areas.
- Restore a protective beach seaward of buildings such that dune enhancement may be initiated by the applicant and individual property owners.
- Remove emergency sandbags placed by property owners, all of which were in violation of OCRM permits after approximately November 2007.
- Place nourishment volumes of variable section quantities to reduce the variability of beach width caused by inlet sand-bypassing processes.
- Provide a protective buffer between existing infrastructure and the ocean.
- Improve the overall aesthetics of the beach and enhance its recreational value.
- Restore habitat for nesting sea turtles.

Construction Contract

The City of Isle of Palms entered into a contract with Weeks Marine of Covington (LA) for placement of 780,000 cy of sand along 9,200 linear feet of beach. Two change orders increased the total volume to 847,400 cy over 10,200 ft of beach and added a fill section to the Dewees Inlet shoreline. The original bid was for $7,914,100, and the total cost after the change orders was $8,402,090. Weeks Marine selected Dirt Cheap Inc (Charleston SC) as subcontractor to remove sandbags installed by property owners. Weeks Marine was required to have U.S. Coast Guard certifications and licenses, a contractor's license to work in the state of South Carolina, and a business license in the City of Isle of Palms.

Project Construction

The restoration project was designed to add ~850,000 cy of sand to ~10,200 linear feet of beach (Fig 1.4). The fill was to be placed in three reaches. Reaches A and B were located along the oceanfront spanning from ~53rd Avenue to the 18th fairway of the Wild Dunes Links Course, separated by an accretion zone associated with the shoal-bypassing event. Reach C represented a portion of the Dewees Inlet shoreline. Roughly 2,600 linear feet of Reach A bordered publically accessible areas of the City. The remaining fill bordered the Wild Dunes community. Design fill volumes for full sections (excluding tapers) were 75 cy/ft in Reach A, 140 cy/ft to 180 cy/ft for Reach B, and 27 cy/ft in Reach C.

Pumping began in Reach B, along the most severely eroded area of Wild Dunes. Once Reach B was complete, Reach C along Dewees Inlet was filled, followed by Reach A between 53rd Avenue and Beach Club Villas. Borrow area A was used to fill the majority of Reach B. Borrow area C was used to fill the northern end of Reach B and all of Reach C. Borrow area B was the sediment source for Reach A. The design berm was set at an elevation of +6 ft NAVD, with the beach face sloping at 1 on 20 (1 on 12 in Reach C due to the naturally steeper shoreline along inlets). A storm berm (set at +8 ft NAVD) was incorporated in the design along the most severely eroded areas of Reach B.

The final volume added to the beach calculated from Weeks Marine's surveys was 933,895 cy, which was ~10 percent greater than the design volume of 847,400 cy. The overage of 86,495 cy was not a pay quantity as stated in the contract; therefore, the City was only required to pay for the contract volume of 847,400.

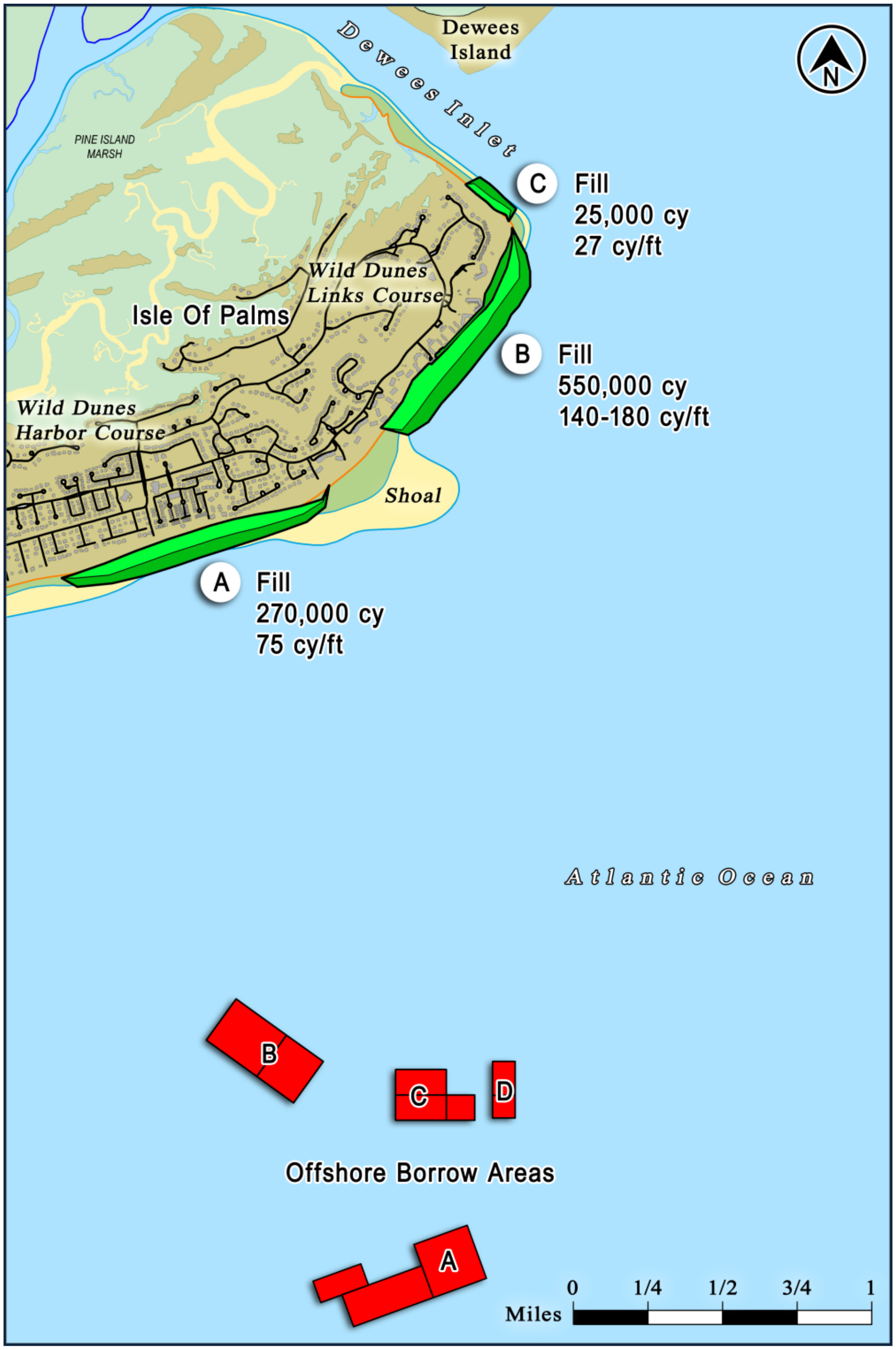

FIGURE 1.4. Project map of the 2008 IOP restoration project. The project was designed to nourish sections of the beach and provide sufficient sand to offset losses associated with long-term erosion as well as an ongoing shoal-bypass event. Borrow areas were located 2-3 miles offshore. Area D was not dredged.

Post-Project Monitoring Requirements

Several monitoring requirements were outlined in the conditions of the permit and in the OMCP (CSE 2008a). Many of the requirements involved aspects of project construction and have already been completed. Monitoring efforts which extend beyond project construction will be addressed through work performed in the present monitoring contract (CSE Project 2300), as well as work that was included in the project contract (CSE Project 2277). Specific monitoring requirements which are ongoing are as follows:

- Borrow area bathymetric surveys including production of digital terrain models (DTMs) and calculation of infilling rates.
- Beach compaction measurements and escarpment monitoring prior to turtle nesting season.
- Sediment quality analysis of the fill with comparison to pre-project and post-project conditions.
- Monitoring of beach slopes (profiles).
- Borrow area (offshore) and fill area (beach) benthic macrofauna surveys comparing pre-project and post-project densities. [CSE Project 2277 data were provided in separate reports.]

The present compliance status regarding the above-listed requirements is outlined in later sections of this report. No permit-related monitoring is required beyond 2011.

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2.0 METHODS

Monitoring efforts for the present report were performed in late June 2011. Changes in the volume of sand in the active beach zone were evaluated by obtaining topographic and bathymetric data along shore-perpendicular transects at established locations along the beach (herein referred to as the baseline, Fig 2.1). The baseline for the present report is modified from the project baseline (pre-2009) to encompass the entire island. Modifications were also made around turns in the baseline, which provide better detail and greater consistency when compareing beach volume changes. The present baseline spans from the center of the Breach Inlet Bridge (station 0+00) and continues to Cedar Creek spit at the northeastern end of the island (station 376+00). The new baseline overlaps the baseline used in the project beginning at 53rd Avenue, which was the location of project station 0+00; that station is now station 222+00. Stationing relates to the distance along the shore with the number before the "+" symbol representing 100 feet (ft). Therefore, station 36+00 is 3,600 ft from station 0+00. The baseline is generally set landward of the present active beach to allow for future erosion/accretion.

Topographic data were collected via RTK-GPS (Trimble™ R8 GNSS), which provides position and elevation measurements at centimeter accuracy. Beach profiles were obtained by collecting data at low tide along the dunes, berm, and active beach to low-tide wading depth. Overwater work was then performed at high tide to overlap the land-based work (Fig 2.2) and was collected with RTK-GPS coupled with an Odom HydroTrak™ precision echo sounder mounted on CSE's shallow-draft vessel, the *RV Congaree River*. Profiles were collected from the most landward accessible point in the dune system to a minimum of 1,500 ft from the baseline. Profiles in the project area extended up to 15,000 ft offshore to encompass the shoals associated with Dewees Inlet and to monitor changes in bathymetry in the vicinity of the nourishment borrow areas. Alongshore spacing of the profiles ranged from 200 ft to 1,000 ft with the more closely spaced profiles in the project area and along Breach Inlet. Comparative profiles from CSE's monitoring efforts are shown in Appendix A. The complexity of areas impacted by inlets requires more detailed analysis (closer profile spacing) to fully incorporate volume changes associated with shoal-bypassing events and inlet migration. Bathymetric data were collected in the borrow areas at 100-ft spacing for comparison to pre-dredging and post-dredging DTMs.

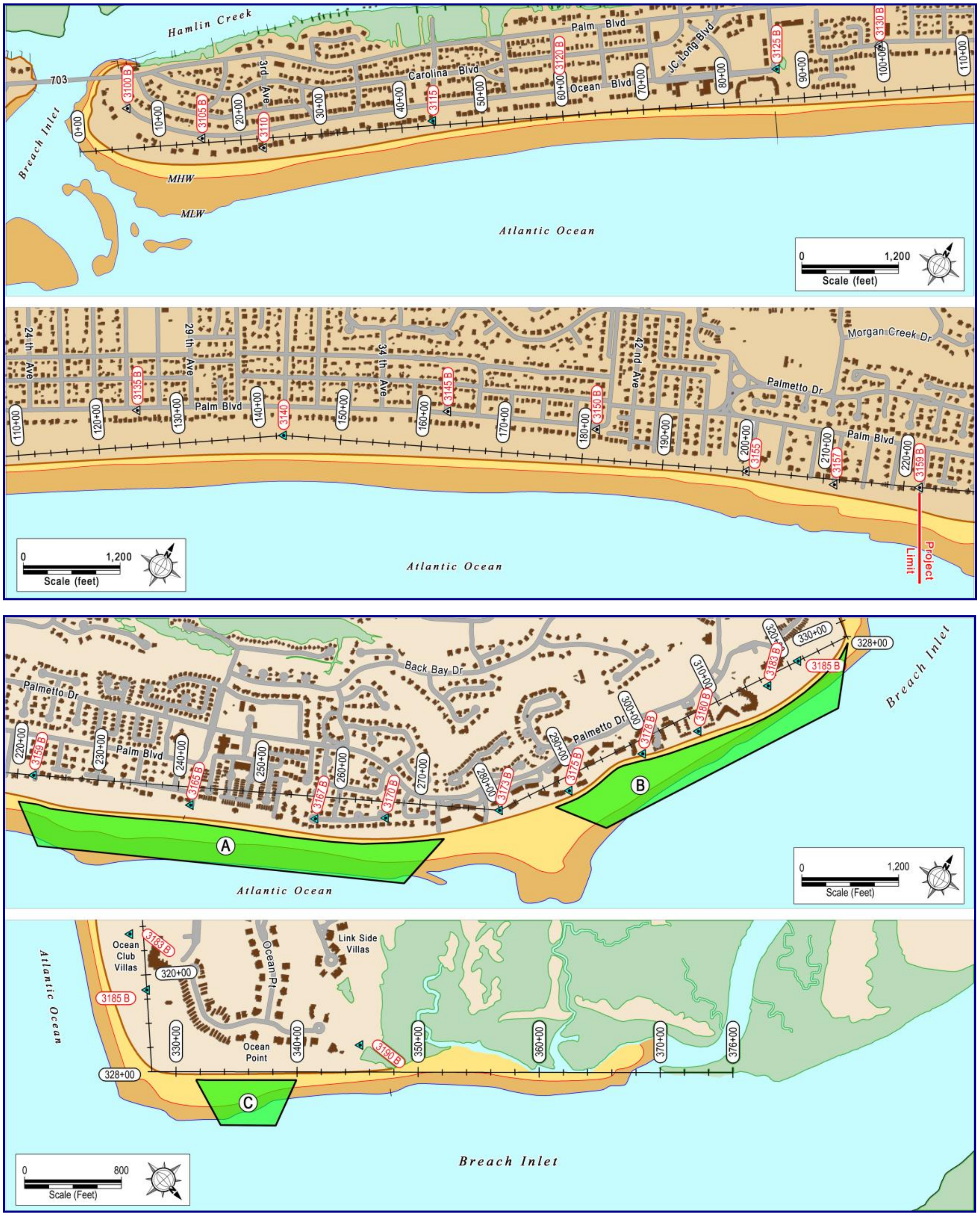


FIGURE 2.1 CSE established a monitoring baseline to encompass the length of IOP. The baseline between stations 222+00 and 376+00 corresponds to the baseline used in the 2008 project (project stations 0+00 through 174+00). Red labels indicate locations of OCRM survey monuments. CSE profile sections are oriented perpendicular to the baseline while OCRM profiles are perpendicular to the local beach azimuth. [CSE and OCRM azimuths are significantly different only at Breach Inlet.]

FIGURE 2.2. CSE beach monitoring methods include land-based data collection using Trimble™ RTK GPS from the backshore to low-tide wading depth and over-water work using RTK GPS linked to a precision echosounder aboard CSE's shallow draft boat (RV *Congaree River).*

To better understand regional sand volume changes, seven reaches were defined along Isle of Palms. By combining several profiles into a reach, it is easier to identify overall sediment gains and losses over large portions of the beach. In the project area, the reaches differ from reaches used during construction so as to encompass areas where no work was performed. [Some sections of this report may refer to volume changes within constructed project reaches and will be clearly indicated.] The reaches used for monitoring purposes are shown in Figure 2.3 and are defined as follows:

Reach 1	0+00 – OCRM 3115	Breach Inlet to 6th Avenue
Reach 2	OCRM 3115 – OCRM 3125	6th Avenue to Sea Cabins Pier
Reach 3	OCRM 3125 – OCRM 3140	Sea Cabins Pier to 31st Avenue
Reach 4	OCRM 3140 – 222+00	31st Avenue to 53rd Avenue
Reach 5	222+00 – 280+00	53rd Avenue to Property Owners Beach House
Reach 6	280+00 – 328+00	Property Owners Beach House to Dewees Inlet
Reach 7	330+00 – 370+00	Dewees Inlet Shoreline

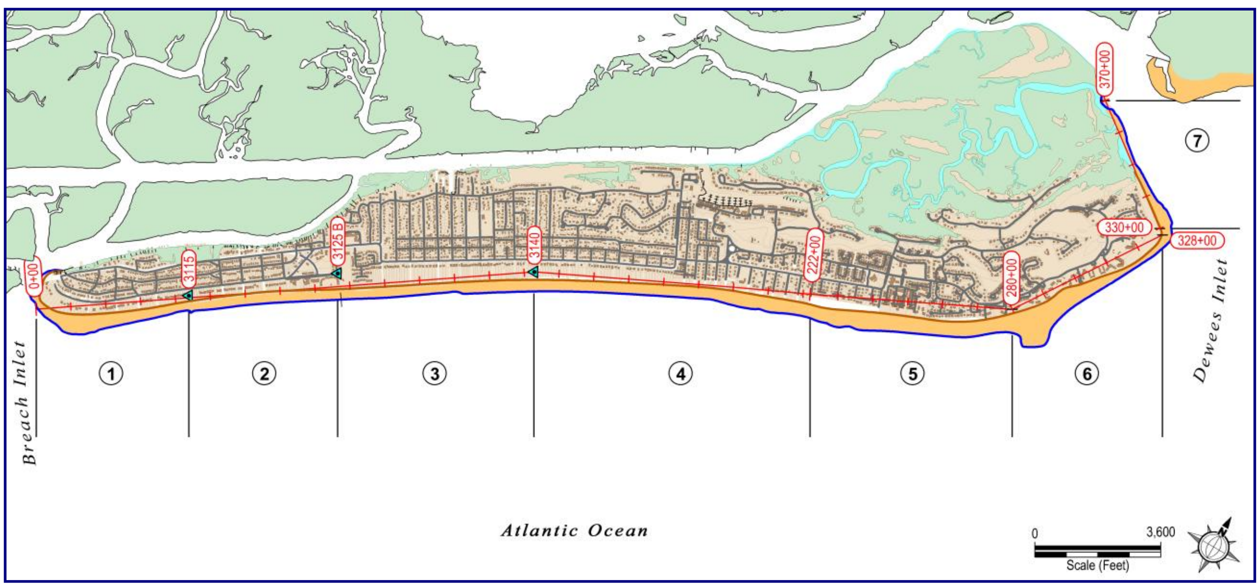


FIGURE 2.3. Location map of the reaches used in post-project monitoring at Isle of Palms. The 2008 beach restoration project occurred in subareas within Reaches 5, 6, and 7.

To determine changes in beach volume along IOP, beach profile data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which converts 2D profile data in x–y format to 3D volumes. The software provides a quantitative and objective way of determining ideal minimum beach profiles and how the sand volume per unit length of shoreline compares with the desired condition. It also provides an accurate method of comparing historical profiles—as the volume method measures sand volumes in the active beach zone rather than extrapolating volumes based on single-contour shoreline position (ie – from aerial photography). Unit-volume calculations can distinguish the quantity of sediment in the dunes, on the dry beach, in the intertidal zone to wading depth, and in the remaining area offshore to the approximate limit of profile change. Figure 2.4 depicts the profile volume concept. The reference boundaries are site-specific, but ideally encompass the entire zone over which sand moves each year.

Sand volume was calculated between the primary dune and between −9 ft and −18 ft NAVD. The lower calculation limit was site-specific, as profiles in the center of the island and along Dewees Inlet generally have deeper closure depths than areas in the unstable inlet/shoal zones. Comparative volumes and volume changes were computed using standard procedures (average-end-area method, in which the average of the area under the profiles computed at the ends of each cell is multiplied by the length of the cell to determine the cell's sand volume). Certain adjustments were made to account for changes in the baseline direction and for volumes at the turn in the baseline at Dewees Inlet.

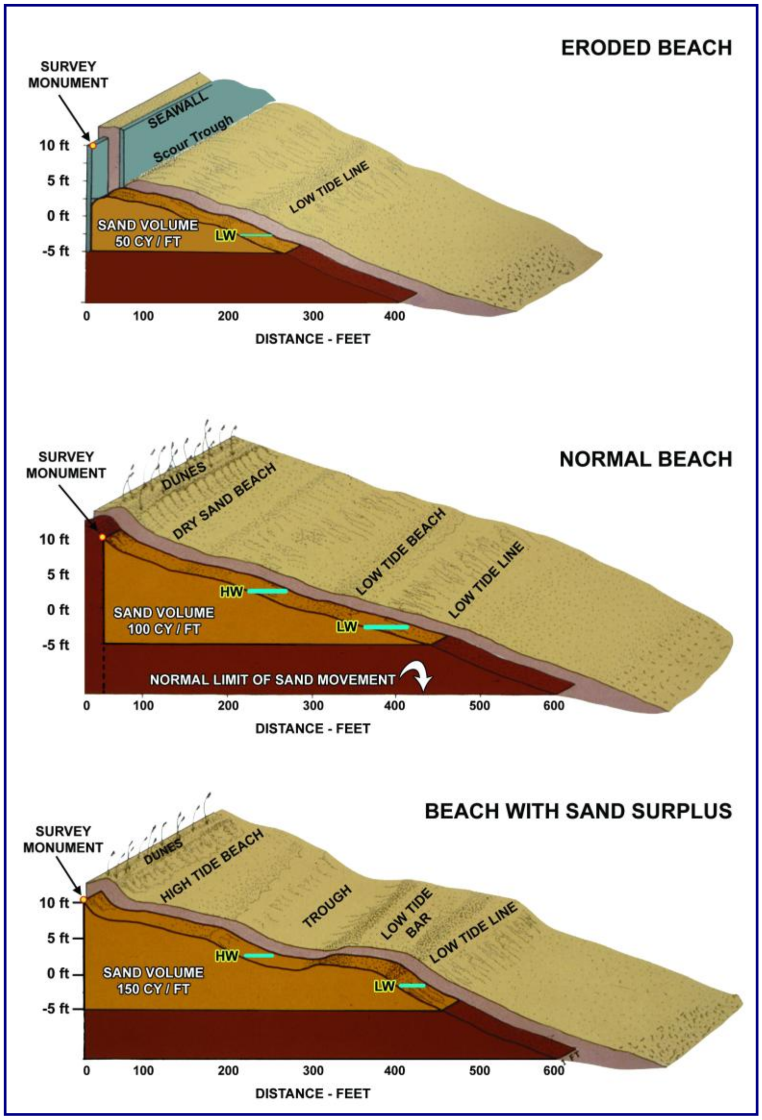


FIGURE 2.4. Calculation of unit-width profile volumes is a means of comparing the condition of one section of beach with another. Profile volumes are the amount of sand contained in a one-foot length of beach between specified elevations. [After Kana 1990]

Sand volumes for offshore areas were calculated from digital terrain models (DTMs) produced from MATLAB and AutoCAD® Civil 3D®. DTMs are digital 3D representations of the topography and bathymetry of an area and are useful for calculating changes in contour positions and calculating sediment volumes. Position data were entered into software as x–y–z coordinates and were processed to provide cross-section profiles and volumes. DTMs from the 2011 data collections were compared with earlier collections (pre-project and post-project) to determine changes in shoal positions and volumes as well as infilling rates of the offshore borrow areas. Color contour maps were also produced from the DTMs.

Beach compaction measurements were performed in February 2011 in accordance with conditions of the permit. Triplicate measurements were made at depths of 6 inches, 12 inches, and 18 inches at the toe of the dune and middle of the berm every 500 ft in the project area. Several stations outside of the project area were sampled to provide a "native" compaction value. Results of the compaction measurements and subsequent communication with USFWS indicated that the project area **did not** need to be tilled. Results of the compaction measurements and the accompanying letter were submitted to USFWS (Appendix B).

Sediment samples from the nourished beach were collected in June 2011. These samples were analyzed as outlined in the OMCP (CSE 2008a), using 0.25-phi intervals for grain-size analysis. Percent by weight of calcium carbonate was analyzed through dissolution with dilute HCl. At each sampling site, five samples were collected—one each from the toe of dune, middle of berm, berm crest, mid beach face, and low-tide terrace (if applicable). Sample transects were collected at 2,000-ft spacing throughout the project area, and additional samples were collected in adjacent unnourished areas for comparison. To provide island-wide sediment characteristics, four transects were included outside of the project area at ~1-mile intervals between Breach Inlet and 53rd Avenue.

Results of the borrow area survey, compaction measurements, and sediment density are given in Section 3.6.

3.0 RESULTS

3.1 Beach Condition in Monitoring Reaches

Results of the June 2011 data collections are presented in this section. Where applicable, profiles from these dates are compared to previous CSE profiles. Volume changes are discussed in detail beginning at the upcoast end of the island, along the Dewees Inlet shoreline, then progressing south toward Breach Inlet. Unit volumes for each station and reach are given in Figure 3.1, Table 3.1, and Table 3.2.

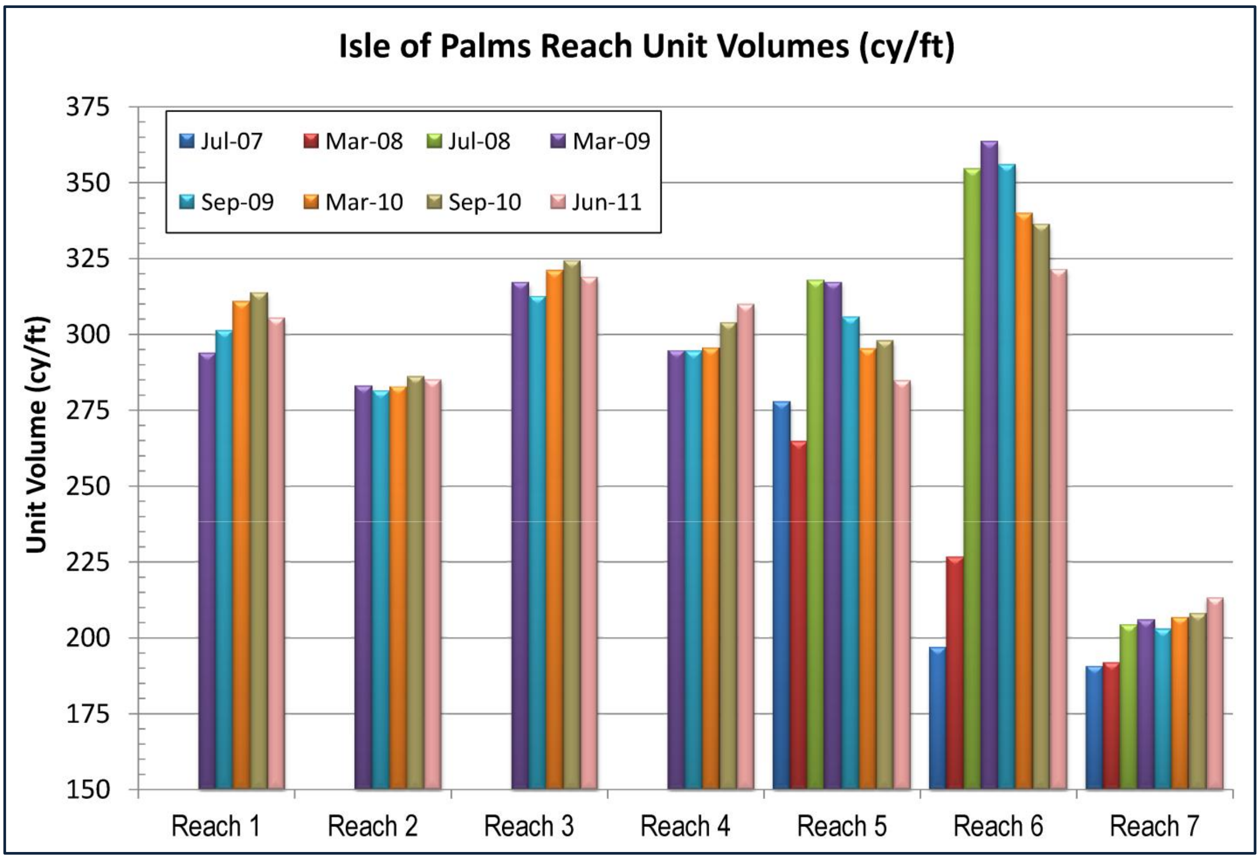


FIGURE 3.1. Average unit-width volumes for each monitoring reach at Isle of Palms. See Figure 2.3 for reach boundaries. Unit volumes were calculated from the primary dune to a profile-specific depth, generally between −9 ft and −13 ft NAVD for the beachfront. Nourishment occurred prior to the July 2008 data collection in Reaches 5, 6, and 7. Design-fill unit volumes for full sections were ~75 cy/ft in Reach 5, ~140-180 cy/ft in Reach 6, and ~27 cy/ft in Reach 7. See Figure 2.1 for beach nourishment locations.

TABLE 3.1. Profile unit-width volumes for each monitoring station at Isle of Palms. Nourishment occurred between stations 224 to 274 and stations 286 to 340 prior to the July 2008 data collection. Volumes are calculated between the approximate crest of the primary dune and the indicated "elevation lens" depth. Nourishment areas are highlighted in blue (project reach A), green, (project reach B), and yellow (project reach C). As additional surveys are completed, calculation limits may change to better encompass volume changes. This results in small differences in reported volumes between the present and earlier reports.

Reach	Line	Elevation Lens (ft NAVD)	Distance to Next (ft)	Unit Volume (cy/ft)						
				Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11
Reach 1	3100	-13	0			548.8	347.2	402.7	366.7	-
	3105	-11	0			406.3	523.4	519.6	530.1	496.4
	0	-10	400			294.5	221.1	335.0	287.3	301.4
	4	-10	400			275.8	244.5	281.8	279.4	251.8
	8	-10	400			271.8	289.1	273.6	277.5	285.9
	12	-10	400			387.8	424.3	403.7	422.3	388.5
	16	-10	400			350.0	389.4	367.0	382.6	357.8
	20	-10	270			271.7	317.3	316.4	317.4	303.1
	3110	-11	730			295.4	311.6	323.7	323.5	318.3
	30	-12	1000			275.9	276.9	293.2	300.9	301.8
	40	-12	390			261.2	261.3	268.3	272.4	270.2
Reach 2	3115	-12	610			294.4	288.1	299.6	293.0	293.0
	50	-12	1000			293.2	296.7	297.6	305.3	298.7
	60	-12	1000			265.6	269.5	274.4	274.7	274.7
	70	-12	1000			284.1	282.7	272.7	280.1	284.9
	80	-12	670			276.3	265.7	270.8	274.9	270.5
Reach 3	3125	-12	330			312.4	308.1	315.8	314.0	312.1
	90	-13	1000			300.9	292.5	306.4	302.0	303.1
	100	-13	1000			311.1	304.4	318.1	324.0	315.0
	110	-13	1000			307.2	306.8	319.1	316.5	309.6
	120	-13	500			330.4	323.6	325.6	336.6	330.6
	3135	-12	500			315.4	314.3	304.5	318.6	313.1
	130	-13	1000			298.9	294.1	302.6	300.9	297.5
	140	-13	290			371.1	367.3	377.4	383.5	376.6
Reach 4	3140	-12	710			296.0	292.4	297.5	305.4	299.0
	150	-13	1000			311.5	299.5	305.2	309.7	311.3
	160	-13	290			297.8	284.6	275.8	283.1	291.6
	3145	-12	710			268.2	263.7	243.2	249.2	263.8
	170	-13	1000			292.5	291.8	290.3	293.4	289.8
	180	-12	150			277.7	275.7	287.0	293.6	295.4
	3150	-12	850			289.6	295.3	303.2	315.0	315.0
	190	-12	1000			280.6	275.9	278.6	293.7	310.8
	200	-12	200			316.5	307.9	311.9	328.9	337.7
	202	-12	200		280.5	317.7	325.0	323.1	337.3	341.1
	204	-12	200		286.8	315.9	333.0	331.6	343.5	344.8
	206	-12	200		288.7	314.3	336.4	337.7	344.8	346.4
	208	-11	200		255.9	281.6	294.1	310.6	308.8	311.9
	210	-11	200		287.8	306.7	328.2	334.2	341.7	346.6
	212	-11	200		258.0	274.0	298.1	303.9	310.7	316.0
	214	-11	200		251.7	281.8	305.3	304.3	306.3	321.3
	216	-11	200		253.4	286.8	302.3	298.9	303.1	317.0
	218	-11	200		274.5	309.6	312.9	308.9	318.8	332.6
	220	-11	200		269.5	305.9	309.1	306.1	315.1	327.8
Reach 5	222	-10	200	252.0	261.0	292.6	295.7	295.6	305.9	322.4
	224	-10	200	221.5	233.5	269.0	273.0	269.1	271.3	288.3
	226	-10	200	217.6	225.3	274.0	286.8	276.0	276.8	281.8
	228	-10	200	222.6	252.1	292.2	299.8	275.3	288.4	285.6
	230	-10	200	233.0	284.4	306.3	307.4	298.8	304.6	296.5
	232	-10	200	241.6	284.5	303.9	304.6	301.4	299.6	294.5
	234	-10	200	245.9	320.5	335.1	327.9	321.9	319.7	317.6
	236	-10	200	214.2	295.1	317.1	300.6	301.7	297.7	294.7
	238	-10	200	204.8	294.6	318.1	299.6	303.7	297.9	296.4
	240	-10	200	184.4	277.6	307.6	285.8	288.9	283.3	285.9
	242	-10	200	182.6	273.6	304.3	283.8	283.5	282.3	280.0
	244	-10	200	189.8	283.1	313.0	297.7	289.6	290.0	281.0
	246	-10	200	181.8	271.0	286.4	271.4	263.5	264.5	262.6
	248	-10	200	188.7	272.2	280.5	267.2	255.5	258.1	255.9
	250	-10	200	188.5	282.2	278.3	261.2	253.7	254.2	248.6
	252	-10	200	197.9	291.9	275.9	265.5	253.3	253.2	245.8
Reach 5 (continued)	254	-10	200	197.5	298.1	270.3	267.1	247.5	242.3	236.0
	256	-10	200	212.3	313.2	276.2	273.8	248.0	240.7	233.6
	258	-10	200	201.7	297.6	256.8	252.6	219.5	214.6	216.7
	260	-10	200	229.1	305.9	270.5	256.9	215.3	216.8	216.5
	262	-10	200	283.5	346.2	340.9	297.5	263.5	276.0	251.1
	264	-10	200	289.4	349.3	340.9	300.6	270.5	267.1	197.5
	266	-10	200	303.7	374.3	328.9	303.3	242.1	264.1	227.7
	268	-10	200	292.7	338.1	272.0	266.2	236.3	250.1	232.8
	270	-10	200	365.0	394.5	314.9	312.5	291.7	309.0	267.2
	272	-10	200	363.2	377.0	326.0	307.7	287.1	308.2	277.7
	274	-10	200	341.5	344.6	300.7	289.8	297.7	307.6	293.4
	276	-10	200	461.8	459.1	427.9	399.1	439.8	433.3	417.3
	278	-10	400	463.2	415.2	384.9	371.7	450.2	436.7	426.2
Reach 6	280	-10	200	461.0	436.6	602.3	603.9	535.3	557.5	458.7
	282	-10	200	501.0	440.4	616.0	634.9	521.9	549.6	411.5
	284	-10	200	515.3	522.2	627.9	679.5	567.3	583.0	497.7
	286	-10	200	445.3	471.8	553.2	587.5	500.8	506.8	452.7
	288	-10	200	333.0	423.8	433.6	453.8	447.5	445.8	442.6
	290	-10	200	255.4	357.3	387.9	390.9	398.7	391.1	412.7
	292	-10	200	246.8	355.6	382.7	389.3	400.7	377.8	423.4
	294	-10	200	235.7	363.0	378.1	380.7	397.9	370.7	395.9
	296	-10	200	213.5	354.7	359.8	353.7	378.9	352.3	375.0
	298	-10	200	191.1	354.1	349.5	339.4	360.0	337.2	356.5
	300	-10	200	173.6	347.5	336.8	323.6	340.8	320.5	339.7
	302	-10	200	149.8	339.3	329.5	306.7	319.0	305.8	317.6
	304	-10	200	141.5	333.2	307.5	289.8	293.3	283.0	292.3
	306	-10	200	171.7	372.6	359.8	312.2	316.7	305.7	310.8
	308	-10	200	155.4	341.0	301.7	287.0	275.9	260.9	260.9
	310	-10	200	152.6	312.9	284.6	241.6	236.1	233.9	245.9
	312	-10	200	111.2	281.0	234.7	215.2	205.2	194.3	192.6
	314	-10	200	86.9	246.1	198.9	169.0	163.7	170.6	156.0
	316	-10	200	136.4	309.3	268.6	252.7	245.7	254.3	235.4
	318	-10	200	128.2	312.0	272.7	256.8	241.4	251.8	229.4
	320	-10	200	140.9	324.5	284.3	271.8	260.8	264.8	238.8
	322	-10	200	205.4	368.5	336.5	318.2	297.0	295.5	267.3
	324	-10	200	212.3	361.7	342.8	331.6	298.6	304.0	270.8
	326	-10	200	174.1	291.2	314.4	309.9	288.6	290.1	258.3
	328	-10	100	241.0	285.3	341.4	321.5	299.8	307.5	259.6
Reach 7	330	-18	200	228.2	262.4	281.7	297.0	329.3	348.6	374.3
	332	-18	200	286.9	333.6	340.5	344.8	367.4	383.5	389.5
	334	-18	200	252.6	295.8	324.2	328.5	338.6	349.0	357.5
	336	-18	200	232.8	284.0	281.2	291.3	298.3	300.7	319.1
	338	-18	200	214.7	261.2	247.8	240.3	240.1	245.2	252.3
	340	-18	200	204.6	244.6	223.2	216.1	209.4	212.5	218.4
	342	-18	200	227.6	246.4	239.2	232.7	226.1	226.1	232.4
	344	-18	200	201.1	209.5	208.3	205.0	196.9	196.4	198.6
	346	-18	200	198.4	198.1	201.8	197.7	190.0	189.3	193.5
	348	-15	200	150.9	147.2	150.7	149.0	141.8	136.2	147.2
	350	-15	200	170.1	169.7	170.7	167.5	167.2	165.5	165.1
	352	-15	200	159.8	160.4	155.2	153.3	155.4	157.3	158.9
	354	-15	200	170.1	171.1	168.1	165.0	167.0	171.8	174.2
	356	-15	200	186.5	185.6	183.1	177.9	183.7	185.1	189.1
	358	-15	200	175.3	171.9	173.1	163.8	173.4	174.5	180.0
	360	-15	200	177.2	172.0	174.4	164.2	179.7	175.7	181.8
	362	-15	200	173.3	167.4	173.1	164.5	172.4	174.9	174.4
	364	-15	200	146.2	141.2	137.5	139.7	136.3	145.2	136.3
	366	-13	200	137.4	131.6	146.1	138.9	135.0	131.2	136.8
	368	-13	200	168.9	174.2	183.7	178.5	187.0	177.0	174.2
	370	-13	0				176.0	202.5	178.8	193.5

TABLE 3.2. Isle of Palms reach volume analysis from March 2008 through June 2011. Nourishment occurred May-June 2008, prior to the July 2008 data collection. Volumes are calculated for each profile to a profile-specific depth, and then extrapolated to the next profile using the average-end-area method. The March 2008 data collection represents the pre-nourishment condition. As additional surveys are completed, calculation limits may change to better encompass volume changes. This results in small differences in reported volumes between the present and earlier reports.

			Total Volume (cy)							Average unit Volume (cy/ft)						
Reach	Limits	Length (ft)	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11
Reach 1	0-3115	4,390	-	-	1,289,419	1,322,510	1,363,795	1,376,987	1,340,611	-	-	293.7	301.3	310.7	313.7	305.4
Reach 2	3115-3125	4,280	-	-	1,210,927	1,204,056	1,210,097	1,224,707	1,219,861	-	-	282.9	281.3	282.7	286.1	285.0
Reach 3	3125-3140	5,620	-	-	1,781,858	1,756,250	1,803,023	1,822,223	1,791,564	-	-	317.1	312.5	320.8	324.2	318.8
Reach 4	3140-222	7,910	-	-	2,329,739	2,329,332	2,337,148	2,403,086	2,450,949	-	-	294.5	294.5	295.5	303.8	309.9
Reach 5	222-280	6,000	1,587,593	1,905,827	1,902,750	1,833,722	1,770,696	1,787,429	1,708,389	264.6	317.6	317.1	305.6	295.1	297.9	284.7
Reach 6	280-328	4,900	1,109,721	1,737,374	1,780,813	1,743,807	1,664,778	1,647,178	1,574,542	226.5	354.6	363.4	355.9	339.8	336.2	321.3
Reach 7	330-370	4,000	766,568	816,758	822,893	810,992	826,350	832,184	852,642	191.6	204.2	205.7	202.7	206.6	208.0	213.2

			Net Change Since Previous							Unit Change Since Previous (cy/ft)						
Reach	Limits	Length (ft)	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11
Reach 1	0-3115	4,390	-	-	-	33,092	41,285	13,192	-36,376	-	-	-	7.5	9.4	3.0	-8.3
Reach 2	3115-3125	4,280	-	-	-	-6,870	6,041	14,610	-4,846	-	-	-	-1.6	1.4	3.4	-1.1
Reach 3	3125-3140	5,620	-	-	-	-25,608	46,773	19,200	-30,659	-	-	-	-4.6	8.3	3.4	-5.5
Reach 4	3140-222	7,910	-	-	-	-407	7,815	65,939	47,863	-	-	-	-0.1	1.0	8.3	6.1
Reach 5	222-280	6,000	-78,699	318,233	-3,076	-69,028	-63,026	16,732	-79,040	-13.1	53.0	-0.5	-11.5	-10.5	2.8	-13.2
Reach 6	280-328	4,900	146,076	627,653	43,439	-37,006	-79,029	-17,599	-72,636	29.8	128.1	8.9	-7.6	-16.1	-3.6	-14.8
Reach 7	330-370	4,000	4,393	50,190	6,135	-11,901	15,358	5,834	20,459	1.1	12.5	1.5	-3.0	3.8	1.5	5.1
Total Change Since Previous			71,771	996,076	46,498	-117,729	-24,783	117,908	-155,236	1.9	26.8	1.3	-3.2	-0.7	3.2	-4.2

			Net Change Since Prenourishment (cy)							Unit Change Since Prenourishment (cy/ft)						
Reach	Limits	Length (ft)	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11	Mar-08	Jul-08	Mar-09	Sep-09	Mar-10	Sep-10	Jun-11
Reach 5	222-280	6,000	-	318,233	315,157	246,129	183,103	199,835	120,796	-	53.0	52.5	41.0	30.5	33.3	20.1
Reach 6	280-328	4,900	-	627,653	671,092	634,086	555,057	537,458	464,822	-	128.1	137.0	129.4	113.3	109.7	94.9
Reach 7	330-370	4,000	-	50,190	56,324	44,424	59,782	65,615	86,074	-	12.5	14.1	11.1	14.9	16.4	21.5
Total Change Since Prenourishment			-	996,076	1,042,574	924,638	797,942	802,909	671,692	-	26.8	28.1	24.9	21.5	21.6	18.1

Reach 7 (Dewees Inlet) Volume Changes

FIGURE 3.2. **[UPPER LEFT]** Reach 7 in December 2007. **[UPPER RIGHT]** June 2008 near the end of the project. **[LOWER]** August 2011 (post-*Irene*). [Upper images by TW Kana] [Lower image by S Traynum]

Dewees Inlet (Fig 3.2, previous page) generally receives less wave energy than the rest of the Isle of Palms due to the sheltering effects of the ebb-tidal delta associated with the inlet. Shorelines along stable inlets usually show less dynamic volume changes than ocean-facing beaches; however, over time, they can experience severe erosion due to several factors.

One factor thought to contribute to localized erosion along the Dewees Inlet shoreline is wave focusing through breaks in the inlet delta (Kana and Dinnel 1980). Breaks between the outer shoals on the Dewees Island side of the channel allow larger waves or destabilizing diffracted waves to reach the IOP shoreline and cause localized erosion. A low profile groin was built in 1981 near the 17th tee of the Wild Dunes Links Course to trap sand moving into Dewees Inlet and slow erosion (Kana et al 1985). The monitoring reach (Fig 3.3) extends from the turn in the shoreline near the 18th tee to the end of Cedar Creek spit.

FIGURE 3.3. Station map of the Dewees Inlet area (Reach 7). Reach 7 spans from station 330+00 near the 18th tee to station 368+00 near Cedar Creek spit. The approximate limits of nourishment Reach C are identified by the yellow bar. The 1981 low profile groin is positioned near station 348+00. [March 2009 aerial image by Independent Mapping Consultants Inc]

Reach 7 has been generally accretional since the 2008 project. The only measured net erosion was between March and September 2009 (−11,900 cy). Since July 2008, the reach has gained ~35,900 cy (9.0 cy/ft) including a gain of ~20,500 cy (5.1 cy/ft) between September 2010 and June 2011. Reach 7 presently contains ~86,000 cy (21.5 cy/ft) more sand than the pre-nourishment condition (March 2008).

Accretion observed in Reach 7 has been mostly confined to the seaward (eastern) end of the reach (Fig 3.4). Stations 330+00–336+00 (17th green to the 18th fairway) have gained an average of 66.2 cy/ft since completion of the nourishment project in July 2008 (Fig 3.5). The rest of the reach shows an average loss of 2.4 cy/ft with erosion most severe between station 338+00 and station 346+00 (17th fairway to 17th tee). This area eroded between July 2008 and March 2010, but since has stabilized. The net loss between station 338+00 and station 346+00 since July 2008 is 12.9 cy/ft. The section of shoreline between the groin and Cedar Creek Spit has been fairly stable since the project, accreting 2.3 cy/ft on average.

Vegetation has become well established along the accreted berm between station 330+00 and station 342+00 as well as along the line of sand fencing installed after the project. Photos from Reach 7 area shown in Figure 3.6.

> [Note: These results are based on profile volumes between the foredune and −13 ft to −18 ft NAVD. They do not include changes along the Dewees Inlet channel margin between −18 ft and −38 ft, the approximate inlet depth along the reach.]

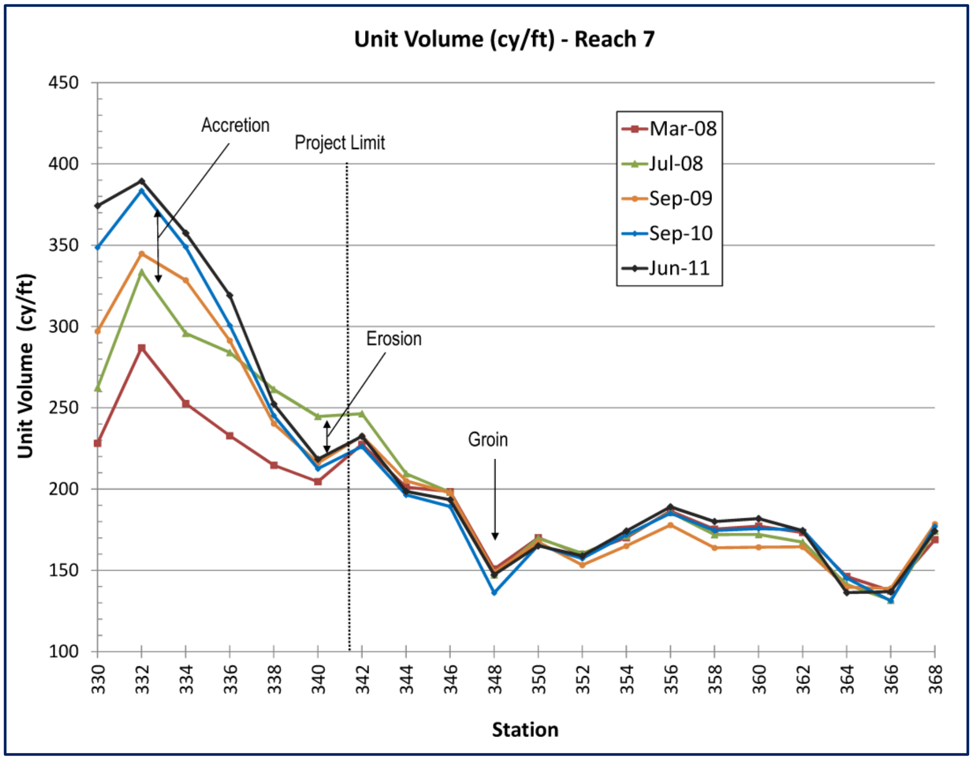


FIGURE 3.4. Unit volumes for stations in Dewees Inlet. Profiles in the southwestern portion of the reach (17th green – 18th tee) have accreted following the project, while the remaining stations have been stable or have eroded. The difference between 2011 (black line) and post-nourishment (green line) shows the volume change since nourishment.

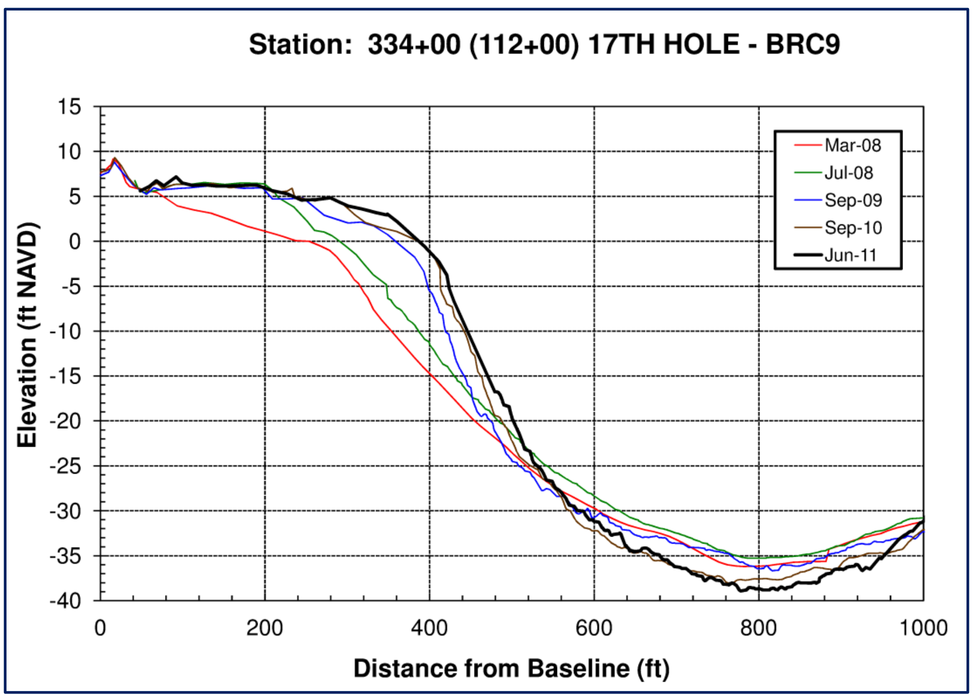


FIGURE 3.5. Profiles from station 334+00 (near the 17th green) in the Dewees Inlet project area. This profile currently contains 51.5 cy/ft more sand than immediately after the project. The new sand migrated from the oceanfront in the opposite direction to the normal play of golfers along the 18th fairway.

FIGURE 3.6. View looking northwest in Reach 7 in the vicinity of the 17th green of the Wild Dunes Links Course in October 2007 (upper) and June 2011 (lower).

Reach 6 – Property Owners Beach House to Dewees Inlet

FIGURE 3.7. Reach 6 in December 2007 (upper left), June 2008 near the end of the project (upper right), and September 2009 (lower left) and August 2011 (lower right) following Hurricane *Irene*.

[Upper images by TW Kana; lower left image by C Jones; lower right image by S Traynum]

Reach 6 (Fig 3.7, previous page) extends from the Wild Dunes Property Owners Beach House ~4,900 ft northeast to the 18th fairway, where the beach turns into Dewees Inlet (station 280+00 to station 328+00, Fig 3.8). Shoal-bypassing events have highly impacted this area since the island's formation. Depending on the location and timing of the bypass events, the shoreline can change hundreds of feet over a period of several months (Kana et al 1985, Gaudiano 1998). As was the case in 2007-2008, the shoreline may encroach on development in this reach when shoal-bypass events are prolonged. Previous studies have suggested that the background, long-term erosion for the northeastern end of IOP is between 15,000 cy/yr and 30,000 cy/yr even though the estimated average volume of sand added by each shoal-bypass event is ~500,000 cy (CSE 2007a). This means that, while large fluctuations in the shoreline and severe local erosion may occur, the long-term erosion rate for the area is relatively low. Sand simply migrates from one area of the beach to another and is either transported back to Dewees Inlet or downcoast to IOP, eventually being replaced by offshore sand through another shoal-bypassing event.

FIGURE 3.8. Reach 6 spans from the Wild Dunes Property Owners Beach House (station 280+00) to the 18th fairway of the Wild Dunes Links Course (station 328+00). The approximate limits of nourishment Reach B are identified by the yellow bar. March 2009 aerial image by Independent Mapping Consultants Inc.

Prior to nourishment in June 2008, most of Reach 6 was severely eroded with profile volumes seaward of development well below an ideal condition. Property owners had piled sand bags against buildings for protection, and little or no dry beach was present (see Fig 1.3). The condition was beginning to improve just before the nourishment as the shoal attaching at the western end of the reach was in Stage 3 of the bypass cycle. Sand was moving from the shoal toward Dewees Inlet, but not quickly enough to restore the beach along most properties north of the Wild Dunes Property Owners Beach House.

Additional sand was needed to supplement the natural sand transport condition. Between March and July 2008, ~628,000 cy of sand were added to the reach through nourishment and natural spreading of sand from the shoal (the design volume for this reach was 550,000 cy). Average profile unit volumes increased from 226 cy/ft to 355 cy/ft (calculated to −10 ft NAVD).

Since July 2008, the reach has shown accretion in the western portion and erosion in the central and eastern portions (Fig 3.9). Accretion in the western area of the reach is a result of the emergence and attachment of two shoals off the Wild Dunes Property Owners Beach House. The first shoal formed shortly after completion of the project, originating on the same "swash platform" which produced the "2006" shoal. Wave action moved sand from the seaward end of the shoal toward the beach, where it built on itself to produce a visible sandbar in the vicinity of the Wild Dunes Property Owners Beach House. The second shoal formed by April 2010 and attached around September 2010. The new shoal attached a few hundred feet to the north of the previous shoal.

Between September 2010 and June 2011, some of the shoal sand spread to the north, leading to accretion between station 290+00 and station 306+00 (Mariners Walk to Port O'Call) (Fig 3.10). No additional emergent shoals are visible in aerial imagery obtained in July or August 2011. Spreading of the 2010 shoal led to net volume loss in the attachment area (stations 280+00 to 288+00), though the recreation beach actually accreted at stations 286+00 and 288+00. The shoal attachment area of Reach 6 lost ~65,700 cy of sand between September 2010 and June 2011, while stations 288+00 through 310+00 to the north gained ~37,900 cy. The remaining stations (312+00–238+00, north of Seascape) lost ~44,800 cy of sand. Total volume loss for the reach was ~72,600 cy (14.8 cy/ft) between September 2010 and June 2011.

Figure 3.9 shows the beach condition in Reach 6 since March 2008 (pre-nourishment condition). Erosion was initially rapid following nourishment (July 2008–September 2009) between stations 300+00 and 324+00 (Summer Dunes Land to the 18th fairway), but since then has slowed substantially over most of the area. Erosion north of Ocean Club has increased since September 2009. Much of the initial loss is likely due to adjustment of the nourishment fill as sand from the area migrated north to the Dewees Inlet (Reach 7) shoreline. CSE used DTMs to estimate sand volume at the corner of Reach 6 and Reach 7 (not included in the previous volume calculations). Based on the DTMs, ~50,000 cy of sand have deposited between Reaches 6 and 7 since July 2008. This volume is sand which was lost from Reach 6.

Overall, Reach 6 retains 464,800 cy (94.9 cy/ft) more sand than the pre-nourishment condition (Fig 3.11). It has lost ~162,800 cy (33.2 cy/ft) since July 2008. If accumulation between station 328+00 and 330+00 are considered, true losses from the beach between the Wild Dunes Property Owners Beach House and Dewees Inlet is reduced to ~113,000 cy (23.1 cy/ft).

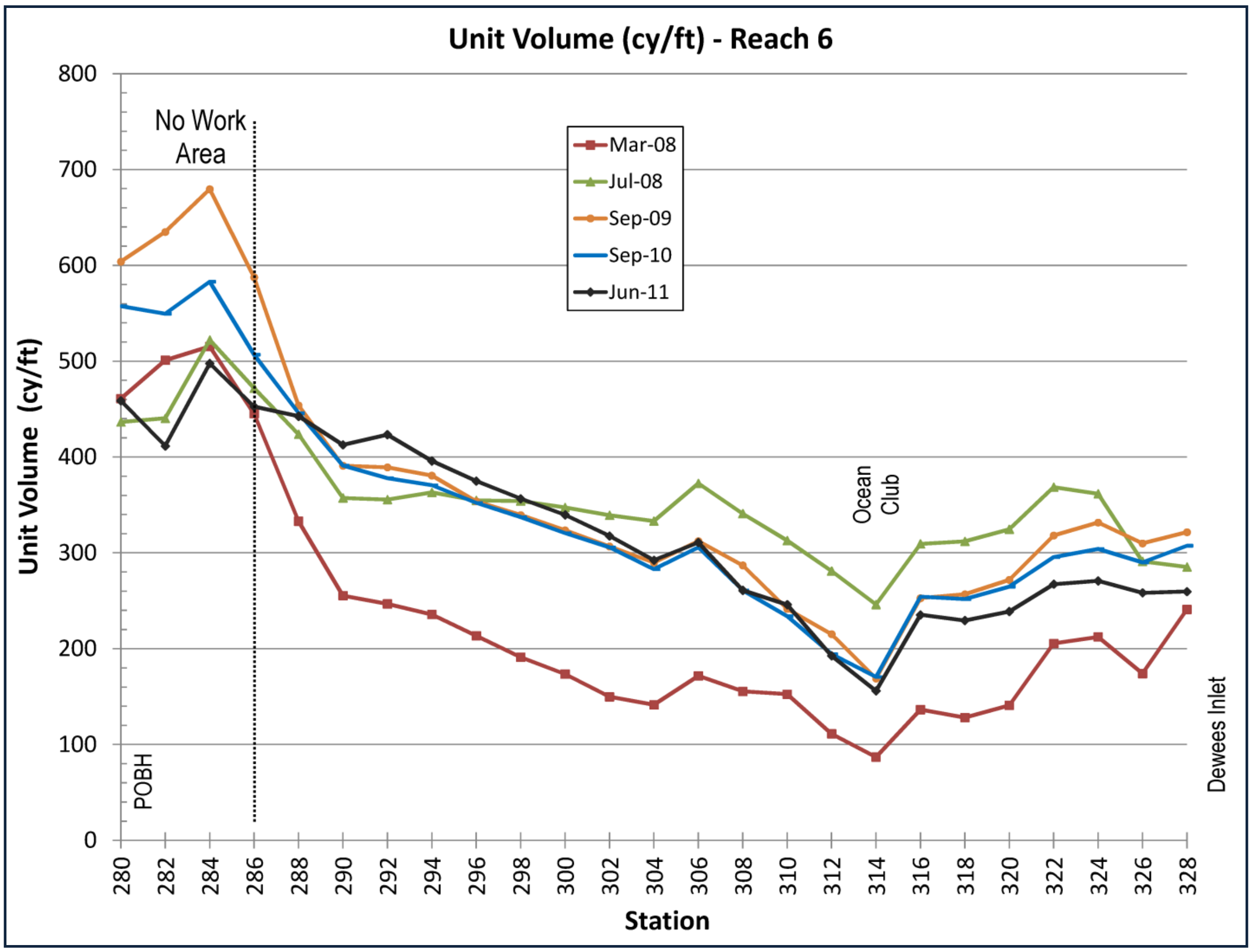


FIGURE 3.9. Profile unit-width volumes for stations in the Reach 6. Erosion has dominated the northeastern portion of the reach, while accretion has occurred in the southwestern portion of the reach. The beach was much more stable from 2009 to 2011.

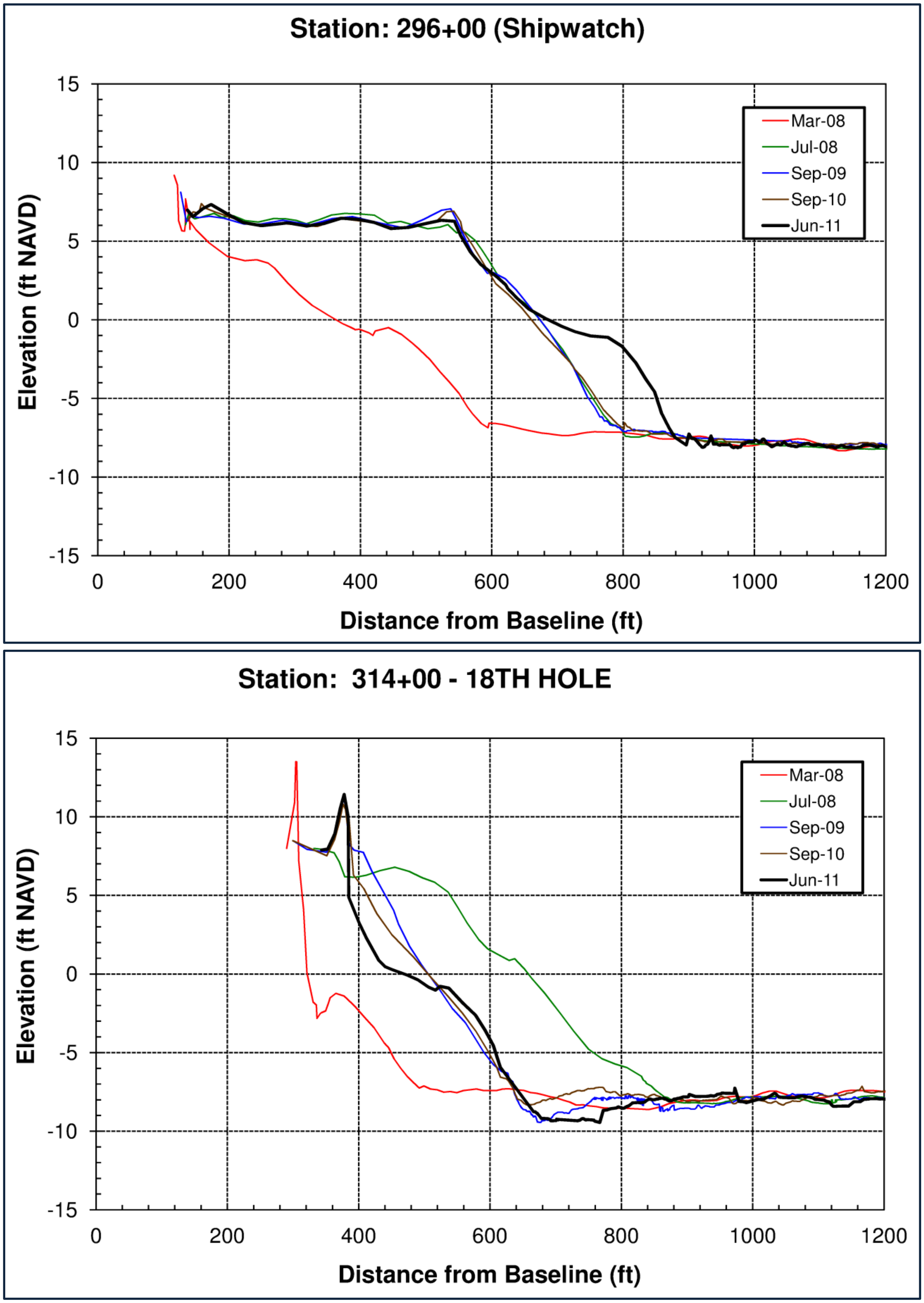


FIGURE 3.10. Profiles from stations in Reach 6. Station 296+00 has remained stable since July 2008 (though accreted in the lower profile over the past year), while station 314+00 has experienced significant erosion. Over the past year at station 314+00 (near the Ocean Club complex), erosion occurred in the upper and underwater profiles while the low-tide wading area accreted.

FIGURE 3.11.

[UPPER] View south in December 2007 near Summer Dunes Lane prior to the project.

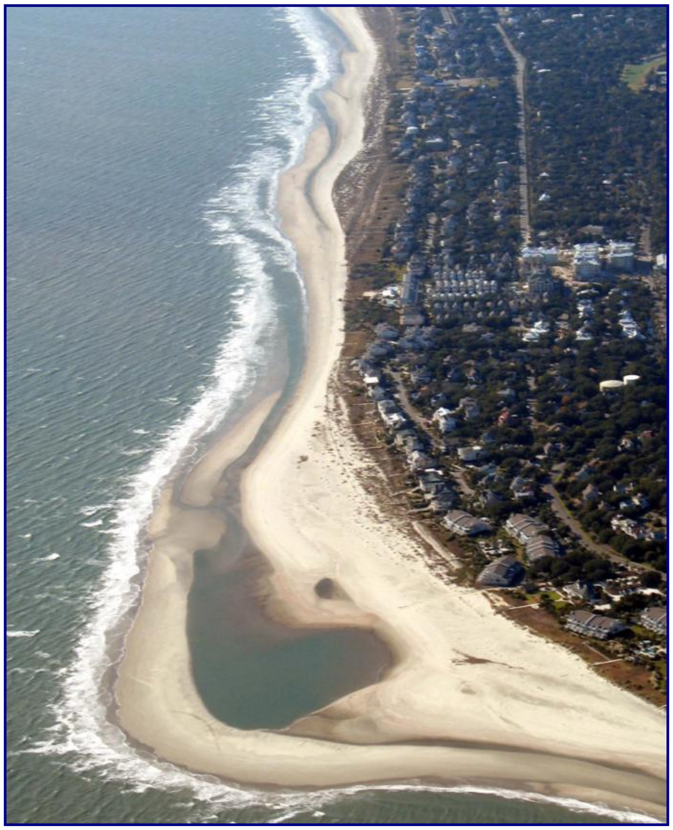
[MIDDLE LEFT] View north in December 2007 near Summer Dunes Lane prior to the project

[MIDDLE RIGHT] View north of the same area in June 2008 immediately following the project.

[LOWER] The same area in June 2011 looking south (left image) and north (right image).

[Photos by S. Traynum and Weeks Marine]

Reach 5 – 53rd Avenue to Property Owners Beach House



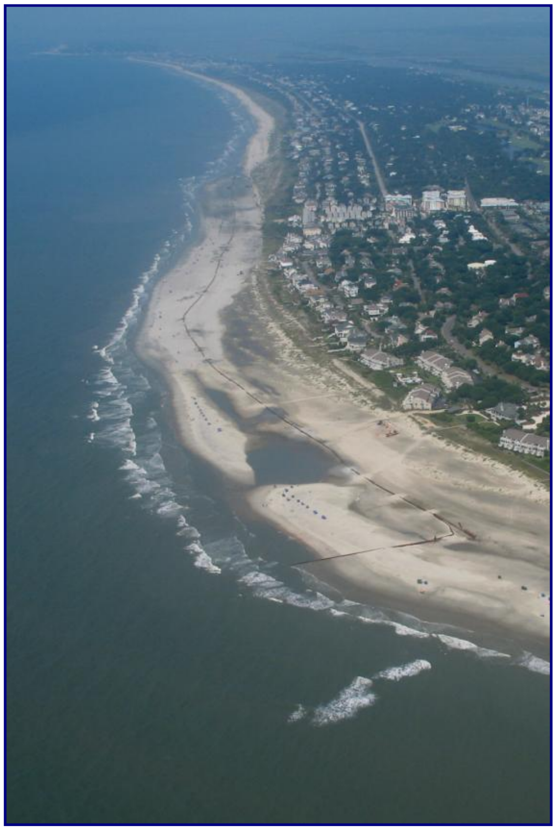


FIGURE 3.12.

[UPPER LEFT]
Reach 5 in December 2007.

[UPPER RIGHT]
June 2008 (during final completion of the project – note dredge pipeline on the beach).

[LOWER] August 2011

Upper images by TW Kana.
Lower image by S Traynum.

Reach 5 (Fig 3.12, previous page) spans ~6,000 ft between 53rd Avenue and the Wild Dunes Property Owners Beach House and encompasses project Reach A (Fig 3.13, stations 222+00 thru 280+00). Like Reach 6, this area is greatly influenced by shoal-bypass events, especially at the northern end of the reach where the majority of shoals attach to the beach. Prior to the 2008 nourishment, an erosional arc had formed in the area of the Wild Dunes Grand Pavilion (Fig 3.14, station ~248+00). Erosional arcs are typical in areas adjacent to shoal attachment sites because of wave refraction and sediment transport reversals, which drive sand from these areas into the lee of the shoal during Stages 1 and 2 of the shoal-bypass cycle. Immediately prior to nourishment, the “2006” shoal had completely attached (Stage 3) at the northern end of the reach, and sand was beginning to spread into the eroded areas.

FIGURE 3.13. Reach 5 spans from 53rd Avenue (station 222+00) to the Wild Dunes POBH (station 280+00). The approximate limits of nourishment Reach A are identified by the yellow bar. [March 2009 aerial image by Independent Mapping Consultants Inc]

Reach 5 gained ~318,000 cy of sand between March and July 2008; this included nourishment and natural accretion from the shoal attachment (cf – Table 3.2). The design volume was 270,000 cy, and CSE estimates ~340,000 cy of sand were added to the project area between March and July 2008. [Note the project reach limits differ from the monitoring reach, producing the difference in accretion numbers.] Design fill unit volumes were ~75 cy/ft throughout area A, decreasing in the taper sections. Dry beach width increased up to ~225 ft in this reach.

The northern portion of Reach 5 was highly erosional prior to the nourishment project, losing up to 45 cy/ft between July 2007 and March 2008. The rest of the reach was more stable, gaining sand at most stations. Erosion prior to the project was due to spreading of the “2006” shoal, which attached to the beach in 2007 at the northern end of the reach. The bulge of sand created an unnatural shape in the shoreline until wave action worked this area into a straighter shoreline between 2007 and 2008.

FIGURE 3.14. Reach 5 and Reach 6 in September 2007 (upper), March 2009 (middle) and April 2010 (lower). Note the erosional arc in the 2007 image adjacent to the Wild Dunes Grand Pavilion (left center of image). The "2008" shoal is visible in the middle image, and the "2010" shoal in the lower image. [See Figure 3.34 for 2011 image.]

Since project completion in June 2008, emergence of new shoals off the beach at Wild Dunes Property Owners Beach House caused the northern two-thirds of the reach to erode rapidly as sand from this area deposited directly behind the attaching shoal (in Reach 6). Erosion peaked by March 2010 with portions of the reach showing total losses of ~76 cy/ft relative to the March 2008 condition (Fig 3.15). Between March and September 2010, stations near Dunecrest Lane gained ~14–22 cy/ft; however, these stations eroded between September 2010 and June 2011 (ranging from +2.2 cy/ft to −69.6 cy/ft).

The majority of Reach 5 has been generally stable or has showed only minor erosion. Between 53rd Avenue and the western end of Beachwood East (stations 222+00–260+00), erosion averaged 1.1 cy/ft. The remaining portion of the reach (stations 262+00–278+00) averaged 29.1 cy/ft erosion. The area between Beachwood East and the Wild Dunes Property Owners Beach House (stations 260+00–278+00) presently contains less sand than the pre-nourishment condition; however, as shown in Figure 3.15, the area still retains sufficient unit volumes to maintain a dry beach and similar volumes as the beach further to the south. Erosion of the northern end of Reach 5 is due to spreading of shoal sand and losses to downcoast areas. The erosion has contributed to the stability of the southern two-thirds of the reach and accretion of the area south of Reach 5 (between the Citadel Beach House and 53rd Avenue). Figure 3.16 shows representative profiles from Reach 5.

The area of Reach 5 of most concern is at the western end of Beachwood East (near station 256+00). As of June 2011, the minimum distance between a structure and the +5 ft NAVD contour was 162 ft, compared to 168 ft in September 2010. This area remained stable from September 2010 to June 2011, but should be monitored closely. A protective dune and dry beach is still present at this location.

Overall, Reach 5 lost ~79,000 cy (13.2 cy/ft) of sand between September 2010 and June 2011. Since the 2008 project, the Reach has lost ~197,400 cy (32.9 cy/ft), similar to the erosion rate of Reach 6 (33.2 cy/ft) over the same period. The reach still retains ~120,800 cy more sand than the March 2008 condition.

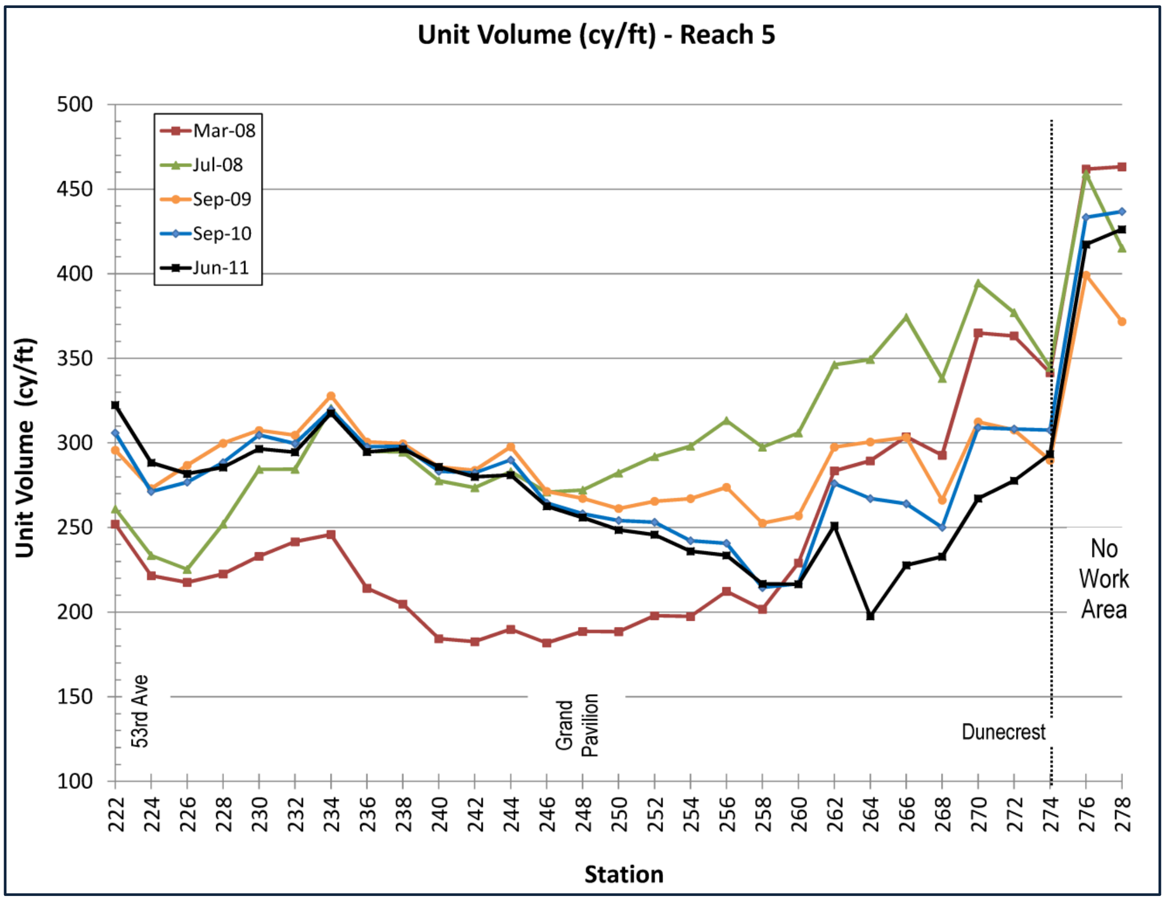


FIGURE 3.15. Profile unit-width volumes in Reach 5. Erosion in the northern part of the reach (stations 250-278) is associated with erosion of excess sand resulting from shoal attachment events in 2006, 2009, and 2010.

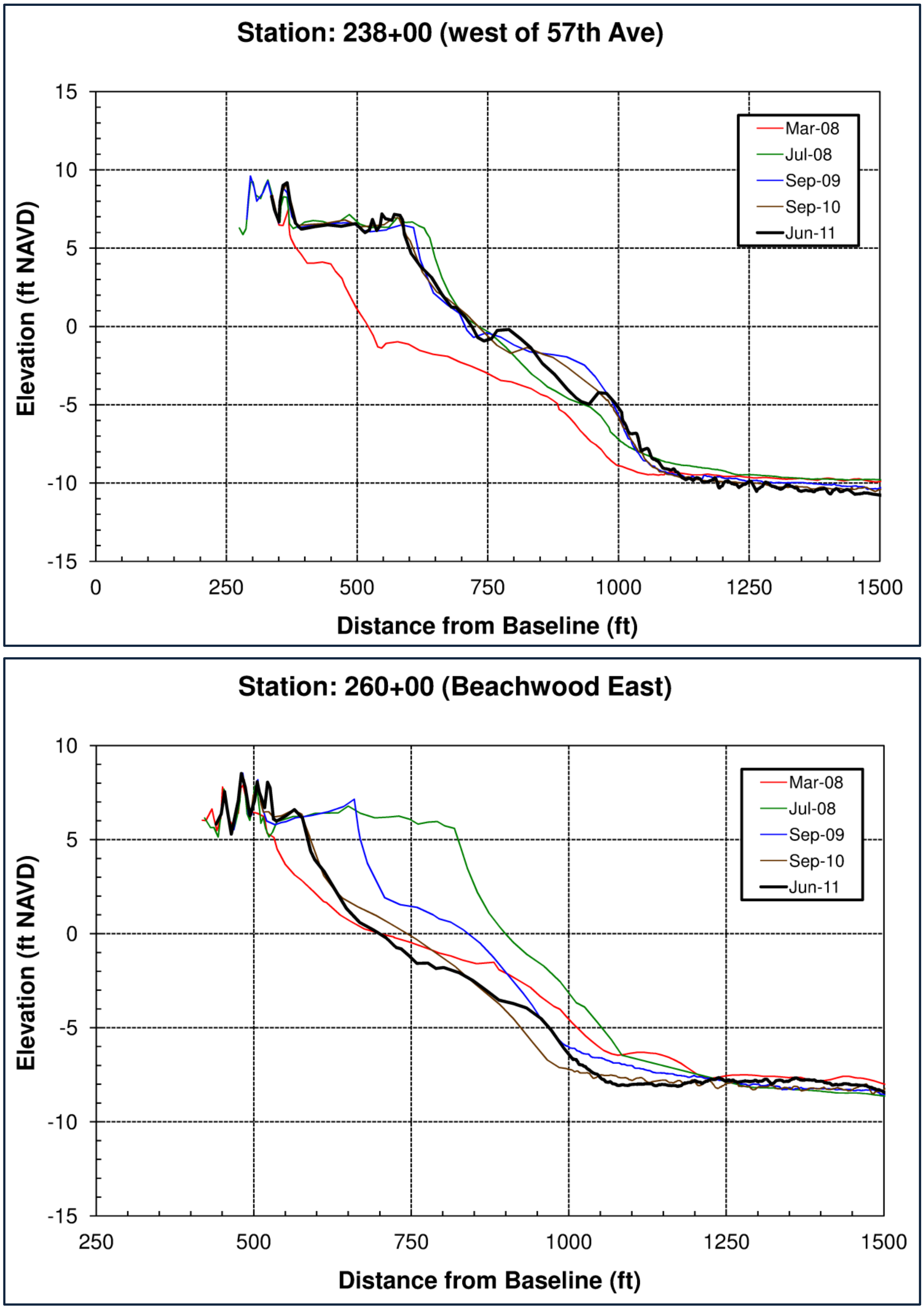


FIGURE 3.16. Profiles from station 238+00 (upper) and 260+00 (lower) in Reach 5. Station 238+00 has remained fairly stable, while the Beachwood East area eroded rapidly between July 2008 and March 2010, then gained sand between March 2010 and September 2010, and remained fairly stable between September 2010 and June 2011. Despite the erosion, a wide dune field still offers protection for structures in this area.

FIGURE 3.17. View northeast from station 254+00 (adjacent to Seagrove Villas) prior to the project in October 2007 (upper) and views northeast (middle left) and southwest (middle right) in September 2009. Station 248+00 views in June 2011, looking south (lower left) and north (lower right). An erosional arc associated with the 2006 shoal-bypass event had formed in this area prior to the project (see Fig 3.14). The dark-colored band of sediments in the upper photo are "heavy minerals" such as ilmenite which concentrate at the base of dunes along eroding shorelines. Light-colored sands are typically quartz and feldspar in this setting.

Downcoast Reaches 2–4 (6th Avenue to 53rd Avenue)

Reaches 2–4 represent the central portion of the island and have historically been stable to accretional over the past century. The reaches are considered to be outside of the direct influence of Dewees and Breach Inlets and are classified as "S" for standard erosion zones by SCDHEC–OCRM. Erosion/accretion signatures along "S" zones tend to be predictable over the long term. Short-term changes in sand volume are generally smaller in magnitude than in areas close to inlets (SCSGC 2001).

Together, Reaches 2–4 represent 17,810 ft of shoreline between 6th and 53rd Avenues (Fig 3.18). CSE established profile stations at 1,000-ft spacing and reoccupied monuments established by SCDHEC–OCRM, which have been surveyed generally every year since the early 1990s. CSE profiles were obtained in March and September of 2009 and 2010 and in June 2011 as part of the present monitoring agreement between the City and CSE. Unit volume changes for Reaches 1–4 are shown in Figure 3.19.

From March 2009 to September 2009, the three reaches lost ~34,000 cy of sand over the ~18,000 ft of shoreline represented. This translates to a unit volume change of 1.93 cy/ft (erosion), which is opposite the historical trend (SCSGC 2001). Between September 2009 and March 2010, these areas accreted ~61,700 cy (3.5 cy/ft); and between March and September 2010, Reaches 2–4 gained 98,300 cy (5.5 cy/ft). From September 2010 to June 2011, the reaches gained ~12,350 cy (0.7 cy/ft). All of the gain was attributed to Reach 4, which accreted 6.1 cy/ft. Reaches 2 and 3 lost 1.1 and 5.5 cy/ft (respectively). Reaches 2–4 have gained 139,900 cy (7.9 cy/ft) since March 2009 (CSE's first island-wide monitoring event).

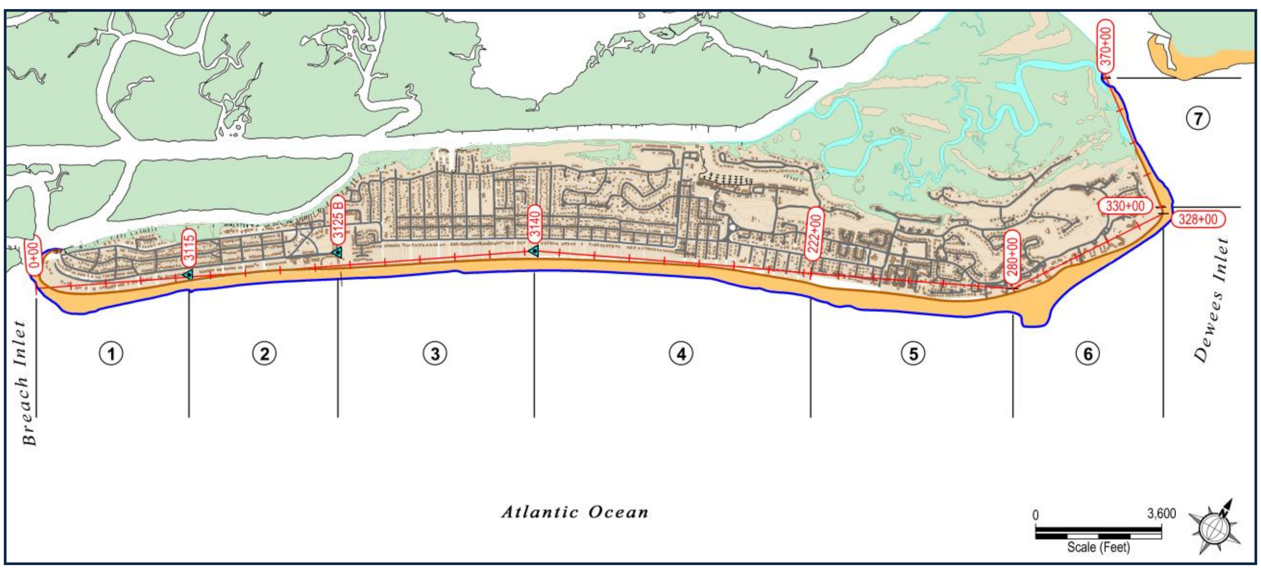


FIGURE 3.18. Monitoring reach boundaries.

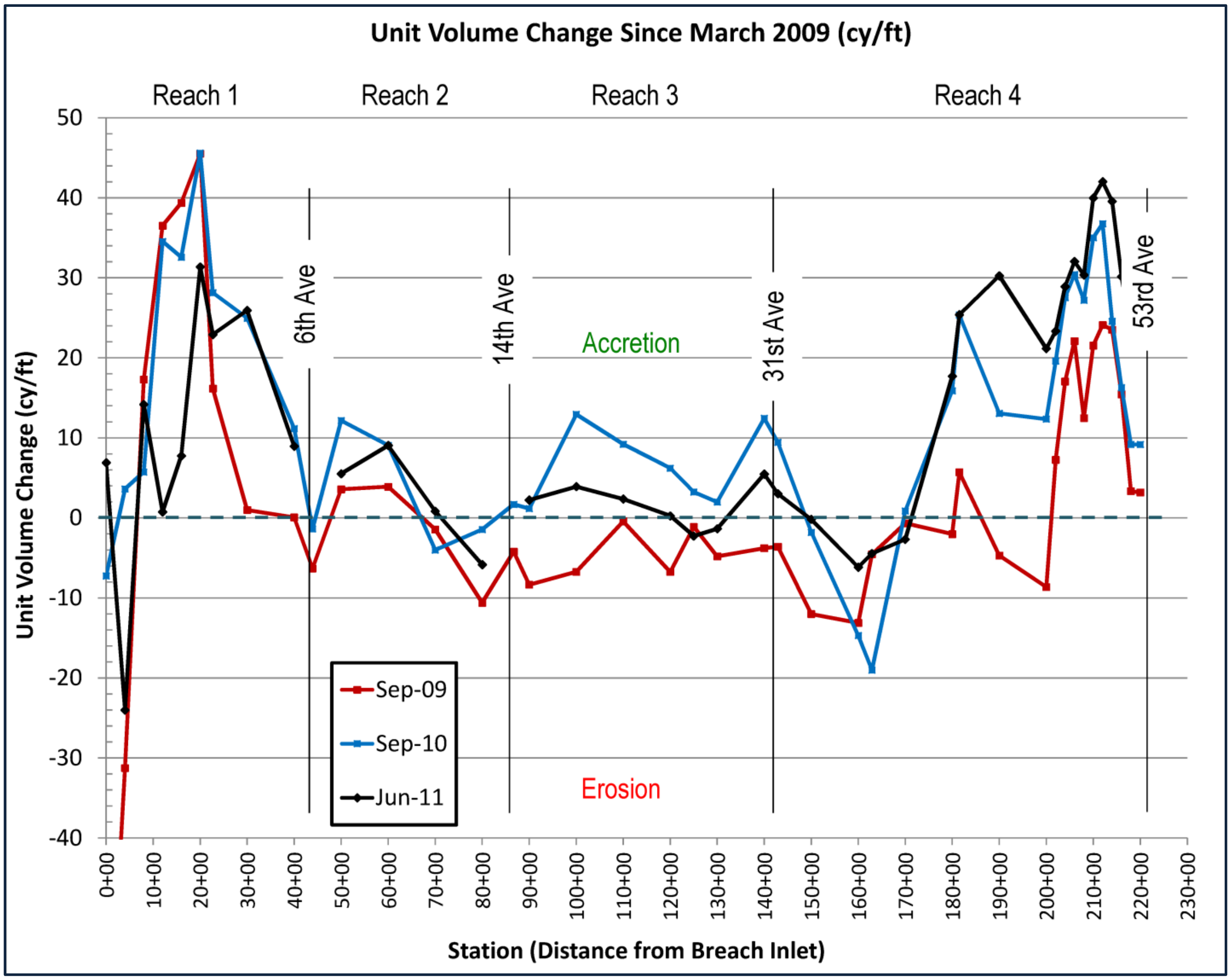


FIGURE 3.19. Profile unit-width volume change (cy/ft) between March 2009 and later dates for Reaches 1-4. CSE established and surveyed profiles spaced 1,000 ft apart in the Isle of Palms reaches and reoccupied monuments surveyed annually by SCDHEC-OCRM. Historically, these reaches have been accretional; however, between March and September 2009, most stations outside of the influence of the inlet or project were erosional. Since September 2009, most stations have shown accretion and are currently healthier than the March 2009 condition (ie – where the black line is greater than zero). The higher rates and sequence of changes along Reach 4 illustrate the downcoast spread of nourishment sand from Reach 5. [Changes are relative to the March 2009 condition.]

Reach 4 – 31st Avenue to 53rd Avenue

Reach 4 spans 7,910 ft between 31st Avenue and 53rd Avenue (stations OCRM 3140 to CSE 222+00, Fig 3.20). Being immediately downdrift of the 2008 nourishment project, it should, therefore, benefit from losses of nourishment sand from the project area. The reach lost ~1,800 cy (0.2 cy/ft) between March and September 2009, but has since gained sand. Between September 2010 and June 2011, all but one (total 19) station in Reach 4 accreted, averaging 6.9 cy/ft (cf – Fig 3.19). Highest accretion rates were observed at the northern end of the reach adjacent to the nourishment area. Significant accretion was also present between 41st Avenue and 46th Avenue and near 36th Avenue (11.5 cy/ft). Overall, the reach has gained 47,900 cy (5.1 cy/ft) since September 2010 and retains 121,200 cy (15.3 cy/ft) more sand than the March 2009 condition. Representative profiles are shown in Figure 3.21.

Historical accretion along this reach (combined with sufficient setbacks for development) has led to a substantial dune system between most structures and the beach. As long as there is slow steady accretion, the foredune will continue to build wider and higher, offering more storm protection to property behind the dunes (Fig 3.22).

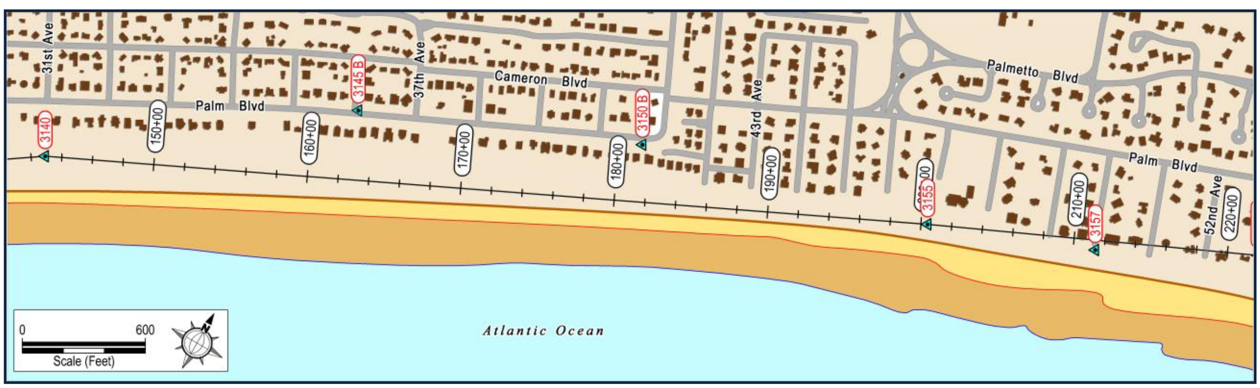
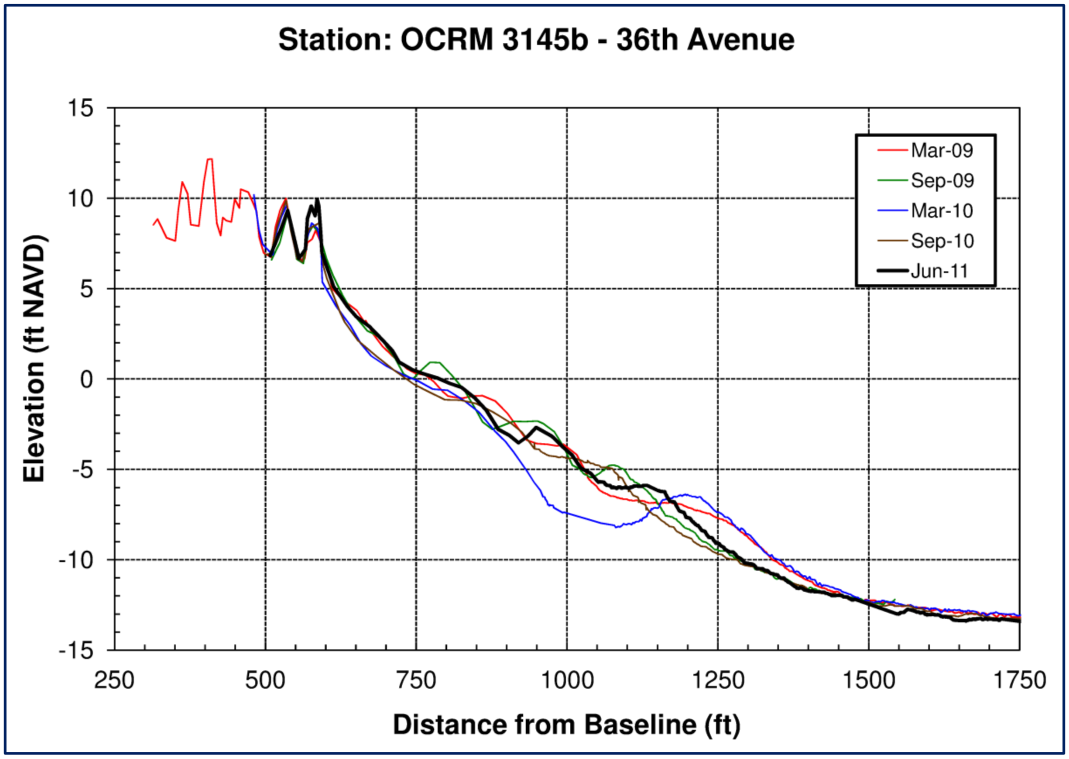


FIGURE 3.20. Reach 4 spans from stations OCRM 3140 (31st Avenue) to CSE 222+00 (53rd Avenue).



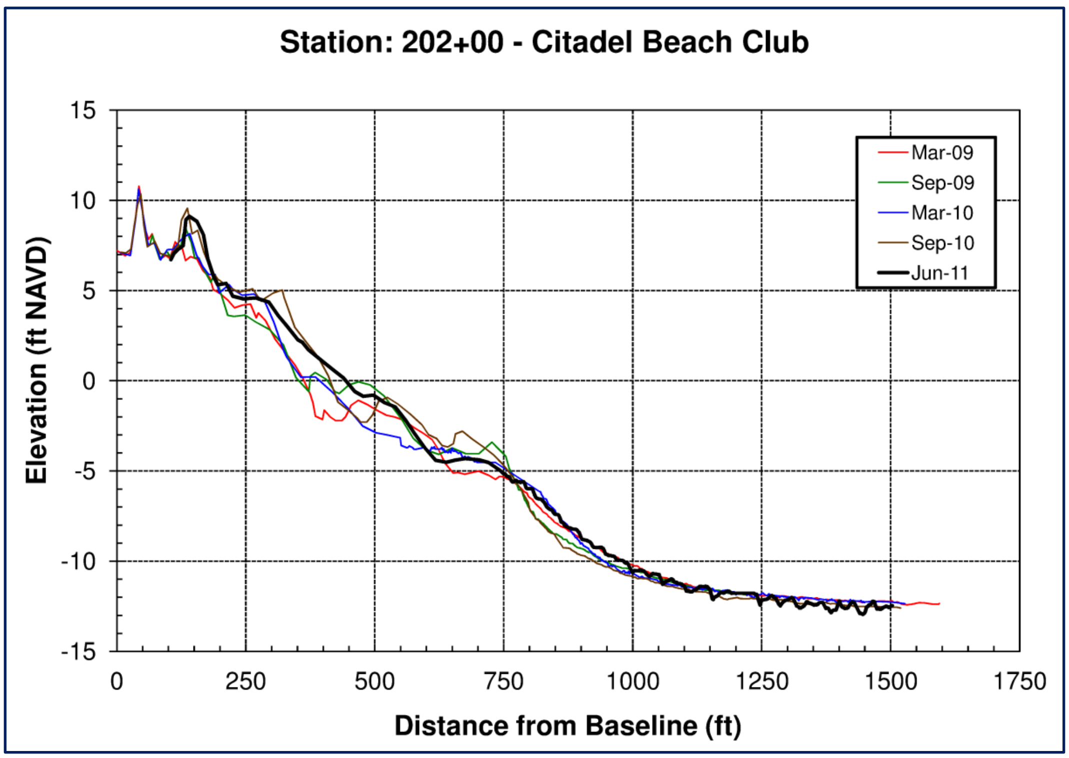


FIGURE 3.21. Profiles from OCRM station 3145b (upper) in Reach 4 showing accretion since 2010. The profile at station 202+00 (lower), near the Citadel Beach House, has accreted over 100 ft since the nourishment project in 2008. Convergence of profiles offshore suggests the local depth of closure (DOC–limit of significant change in bottom elevation over a defined time at a site) is ~12 ft NAVD.

FIGURE 3.22.

Photos from station 170+00 (near 38th Avenue, upper two photos) and station 202+00 (near Citadel Beach House, lower two photos).

[Photos by P McKee, August 2011]

Reach 3 – Sea Cabins Pier at 14th Avenue to 31st Avenue

Reach 3 spans the oceanfront between Sea Cabins Pier at 14th Avenue and 31st Avenue (OCRM monuments 3125 to 3140, Fig 3.23). As previously mentioned, the long-term trend in this area is stable to accretional. Profiles from OCRM station 3135 (near 27th Avenue) show the beach in this area has gained ~40 ft in width at the +5-ft NAVD contour (Fig 3.24) over the past ten years. A similar trend is evident at OCRM station 3125 (14th Avenue) with dune growth and beach widening over the past ten years.

Reach 3 was the most erosional of the downcoast reaches between March and September 2009, losing ~25,600 cy (4.6 cy/ft). Between September 2009 and September 2010, the reach accreted, gaining ~66,000 cy (11.7 cy/ft). However, from September 2010 to June 2011, the reach lost nearly half of that volume (30,700 cy or 5.5 cy/ft).

Erosion was moderate between stations 110+00 and 140+00 (24th Avenue to 31st Avenue), ranging from 3.3 cy/ft to 7.0 cy/ft. Erosion was more severe at station 100+00 (21st Ave), which lost 9.0 cy/ft (Fig 3.24). The southernmost portion of the reach (stations OCRM 3125 and 90+00, near Sea Cabins Pier) showed volume changes of −2.0 cy/ft and +1.1 cy/ft. The 7.3 cy/ft/yr lost over the entire reach (between September 2010 and June 2011) is a slower rate than the 9.0 cy/ft loss that occurred between March and September 2009.

Overall, the reach has gained ~9,700 cy since March 2009. All stations except 120+00 and OCRM 3135 (near 27th Avenue) contain more sand than the March 2009 condition.

Figure 3.25 shows the beach condition after Hurricane *Irene* passed in late August 2011.

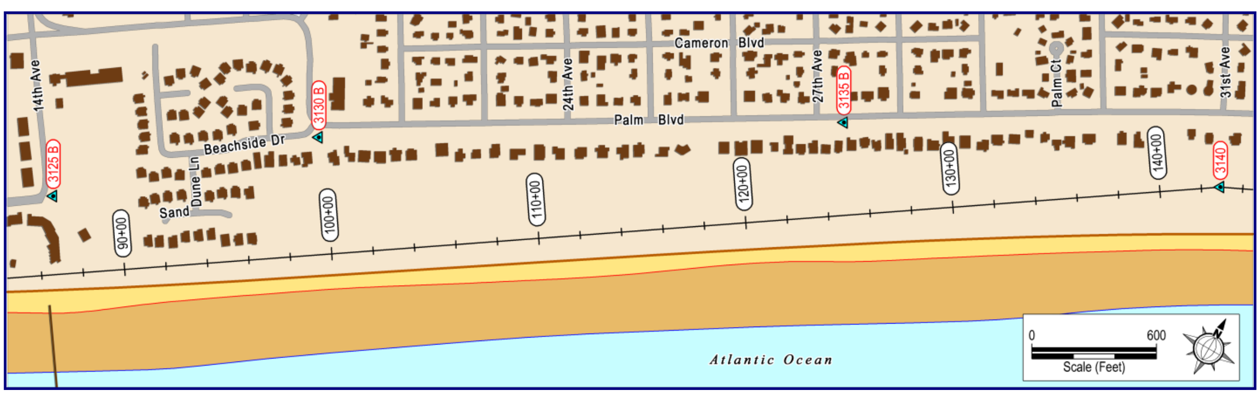
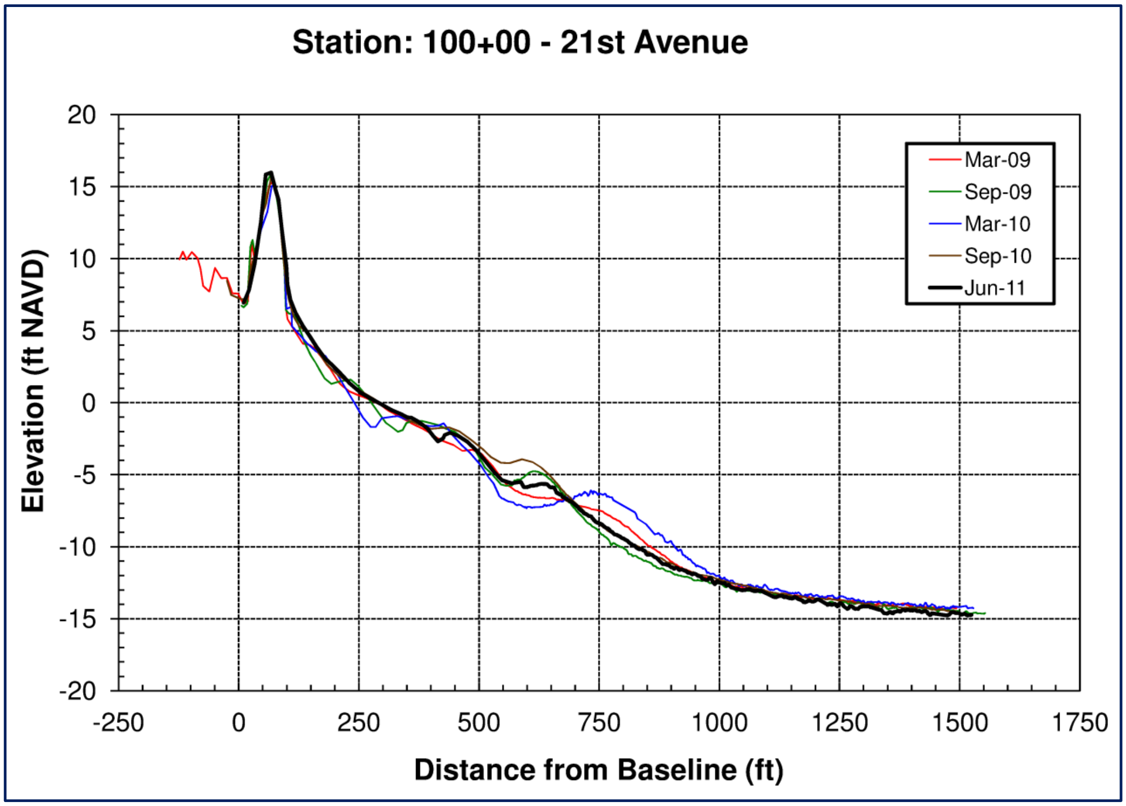


FIGURE 3.23. Reach 3 spans from station OCRM 3125 (Sea Cabins Pier) to station OCRM 3140 (31st Avenue).



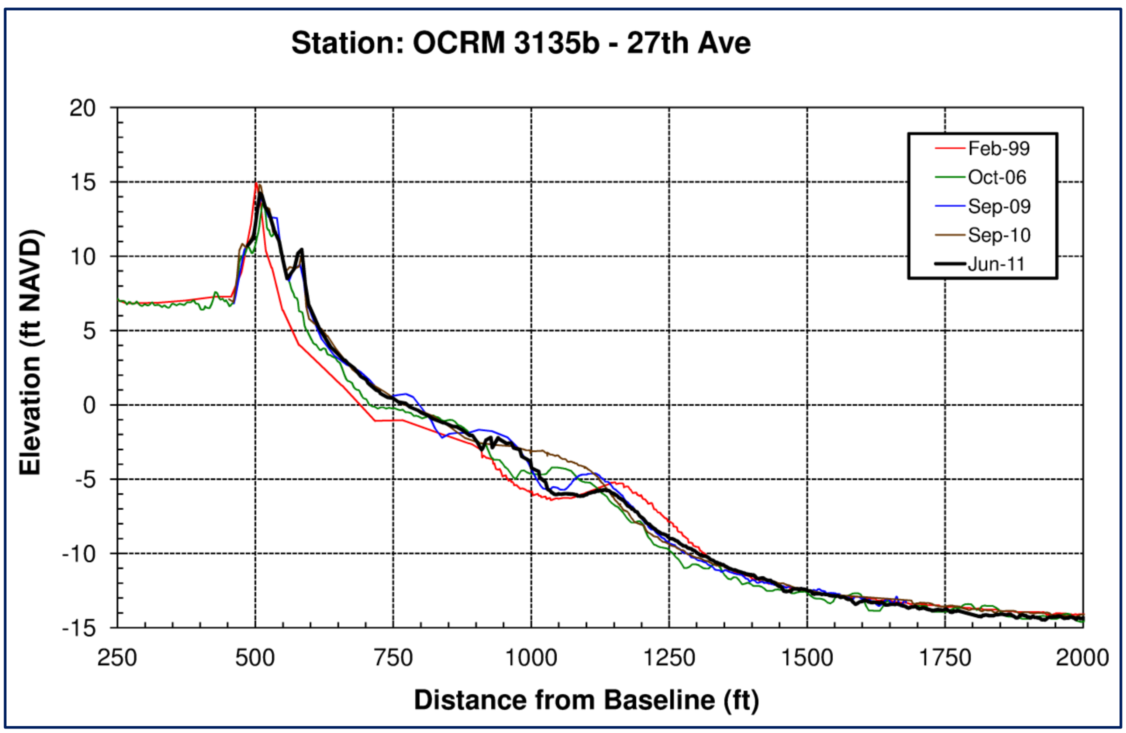


FIGURE 3.24. Profiles from station 100+00 (upper) and OCRM station 3135b (lower), showing long-term accretion since 1999. Protective dunes reach to +15 ft NAVD in this area and have been building since 1998. [Profiles prior to March 2009 courtesy SCDHEC-OCRM.]

FIGURE 3.25. Aerial views along 27th Avenue to 30th Avenue (upper) and 25th Avenue to 29th Avenue (lower) after passage of Hurricane *Irene* in August 2011.

Reach 2 – 6th Avenue to Sea Cabins Pier

Reach 2 spans 4,280 ft between 6th Avenue and Sea Cabins Pier (OCRM monuments 3115–3125) (Fig 3.26). Since March 2009, Reach 2 has been fairly stable, gaining a total of 8,900 cy (2.1 cy/ft). Volume change was variable through the reach between September 2010 and June 2011, ranging from −6.7 cy/ft to +4.8 cy/ft. Overall, the reach lost approximately 4,800 cy (1.1 cy/ft) from September 2010 to June 2011. All properties maintain a substantial setback (greater than 100 ft) from the dry beach and, given the historical accretion, are not likely to be impacted by typical erosional events (minor storms, seasonal cycles, etc) (Fig 3.27).

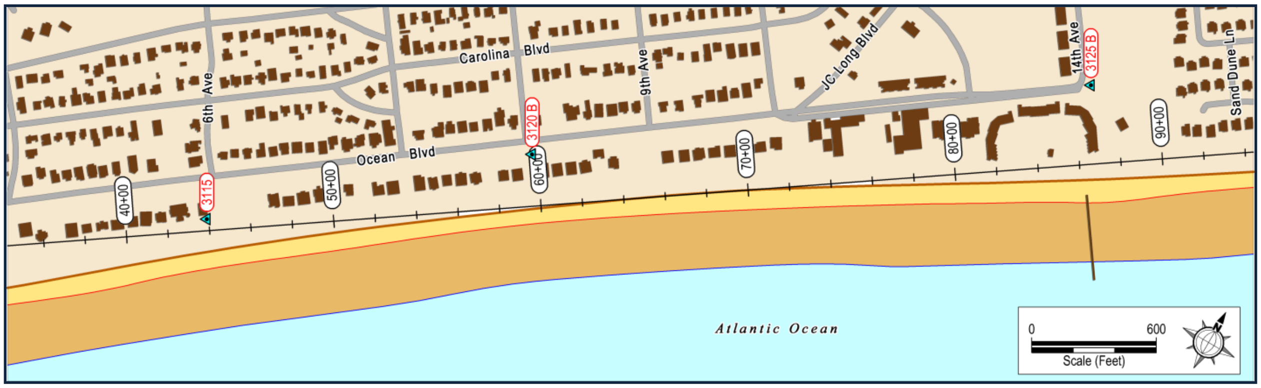
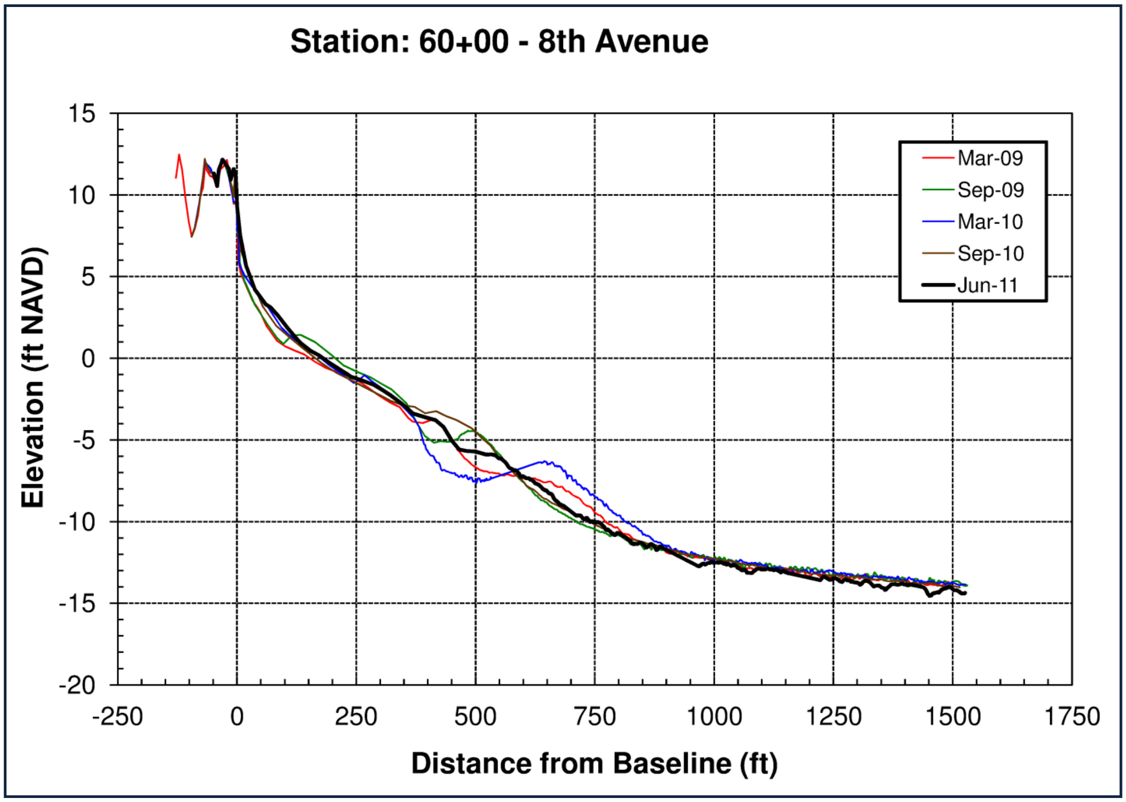


FIGURE 3.26. Reach 2 spans from OCRM 3115 (6th Avenue) to OCRM 3125 (Sea Cabins Pier).



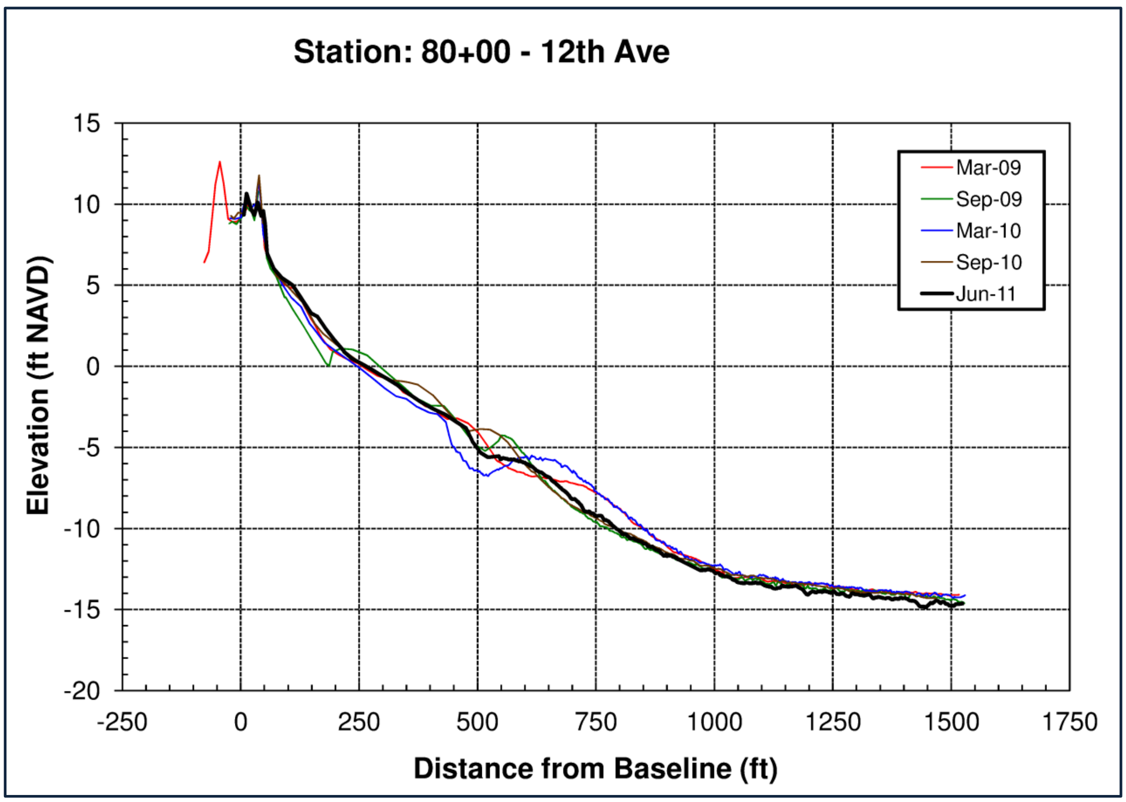


FIGURE 3.27. Profiles from station 60+00 (8th Avenue, upper) and station 80+00 (12th Avenue, lower). Reach 2 has remained generally stable since September 2010.

FIGURE 3.28. June 2011 photos from (upper) 8th Avenue (station 7542) and (lower) in front of the Windjammer (station 7549, just south of the pier).

Reach 1 – Breach Inlet

Reach 1, between Breach Inlet and 6th Avenue (Fig 3.29), is classified as an unstabilized inlet erosion zone due to the dynamic nature of the shoals associated with the inlet delta. While labeled as unstable, the long-term trend for this reach is accretional with an estimated growth of ~8.9 ft/yr (linear beach width). The historical accretion trend in this reach is due to a plentiful sand supply from upcoast and sand trapping by the Breach Inlet ebb-tidal delta. Sand supply originates from shoal-bypass events at Dewees Inlet and longshore sand transport from north to south over the length of IOP. Excess sand is deposited along the southern spit of the island (Reach 1) and in the Breach Inlet ebb-tidal delta. Shoals of Breach Inlet form a protuberance in the shoreline, which backs sand up along the oceanfront much like a terminal groin traps sand. Changes in this area are related to bars from the inlet delta migrating onto the beach or marginal flood channels moving landward or seaward. Such natural processes lead to rapid changes in the beach volume compared to the central IOP reaches.

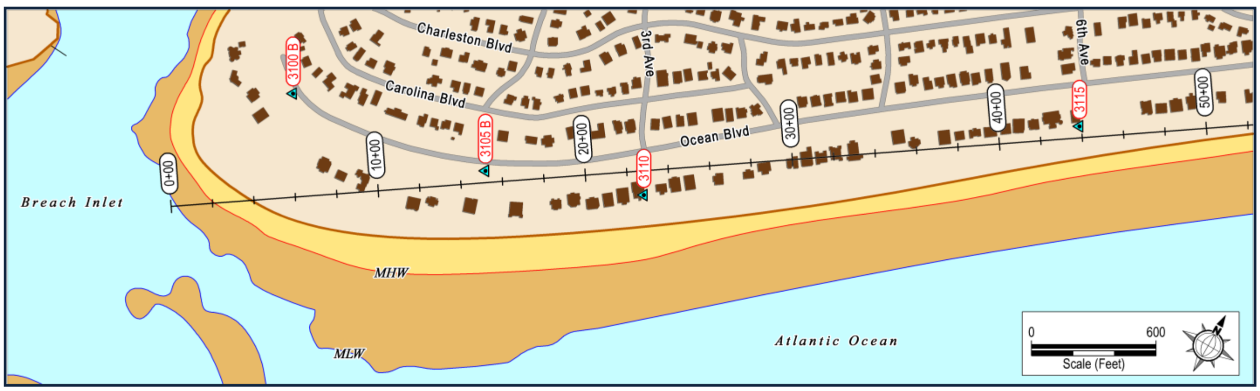


FIGURE 3.26. Reach 1 spans between Breach Inlet and 6th Avenue.

The Breach Inlet reach accreted for all periods between March 2009 and September 2010, although the amount decreased between each survey. Since September 2010, the reach eroded a total of ~36,900 cy (8.3 cy/ft). Erosion was most severe between stations 12+00 and 20+00 (between 2nd and 3rd Avenues), averaging 24.3 cy/ft. Profiles from this area show that the erosion was confined to the underwater portion of the profile (below mean low water). The dunes remained stable. This area tends to be where the northern portion of the Breach Inlet ebb-tidal delta attaches to the IOP beach. It appears that the connecting bar between the inlet delta and the beach changed configuration since September 2010, and sand shifted toward the inlet and offshore to the delta.

Also of note is that the marginal flood channel at stations 4+00 and 8+00 infilled between September 2010 and June 2011. Profiles show that the channel, which reached to −8 ft NAVD in September 2010, was not evident at these locations (Fig 3.30) in June 2011. This is also seen in the DTMs shown in Figure 3.31 (indicated by letter A). Note the lack of the yellow hue near A in the June 2011 model. Marginal flood channels are dynamic features that have a direct impact on the adjacent shoreline, although the changes are often temporary. The long-term trend near Breach Inlet is accretion, and this will continue as long as sufficient sediment from northern IOP migrates downcoast.

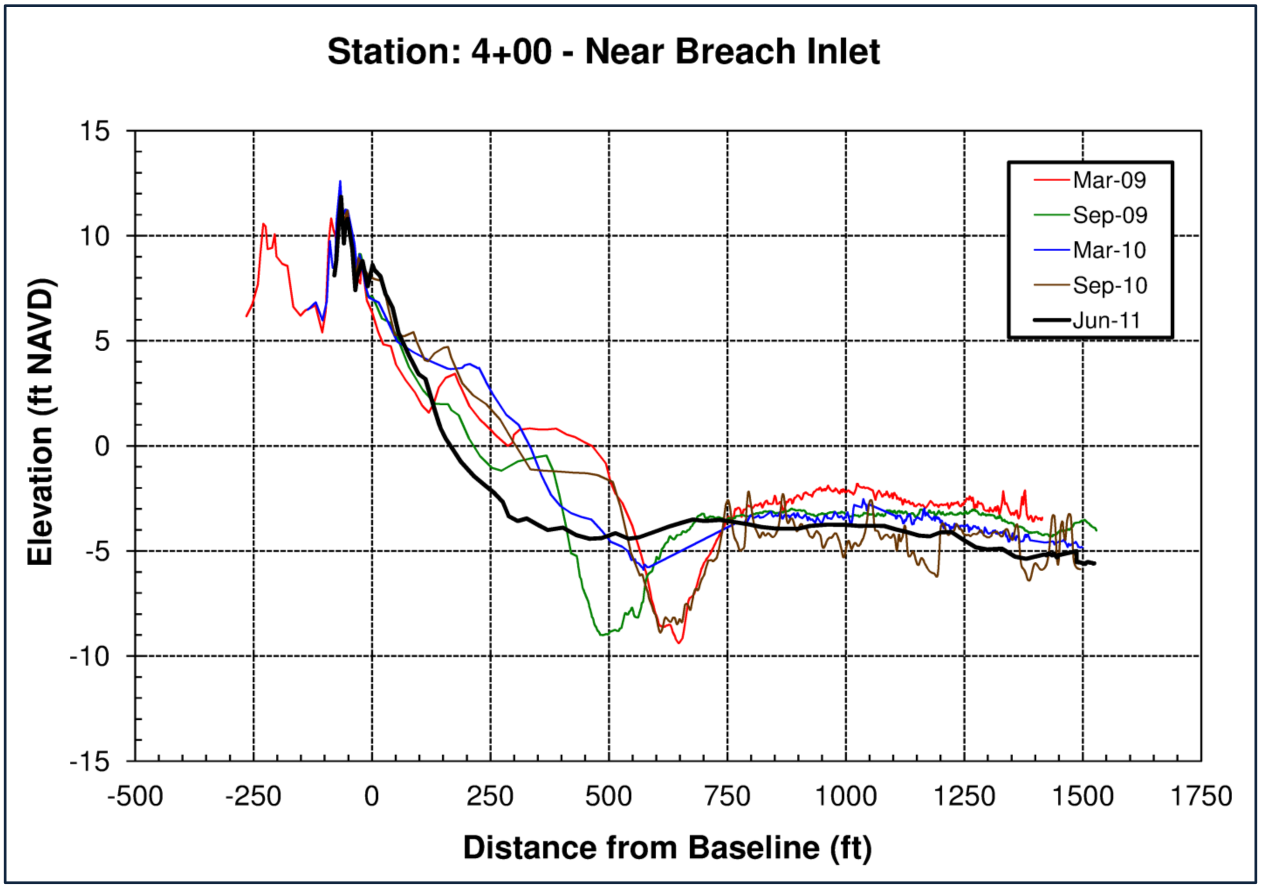
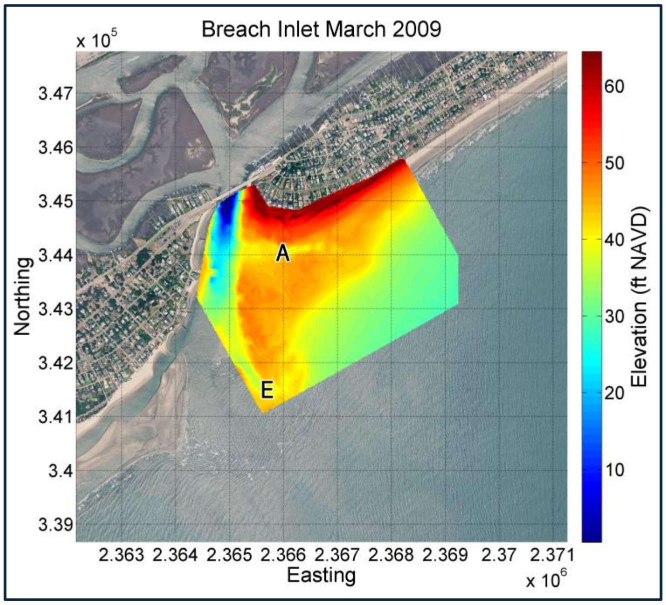
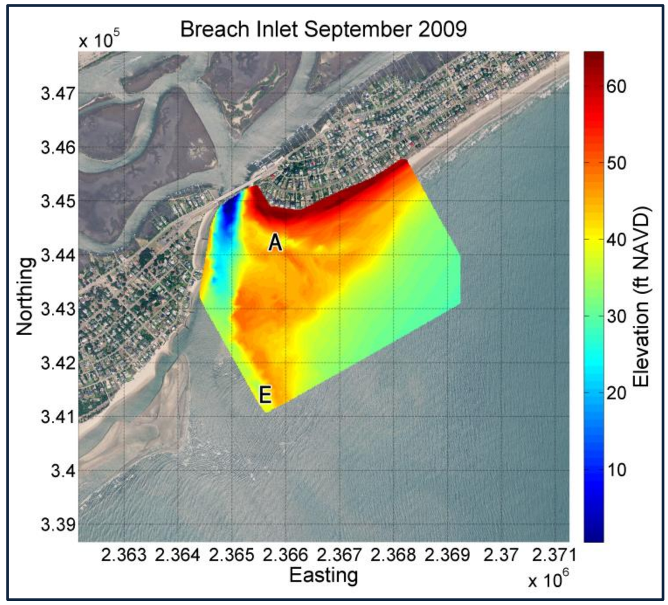
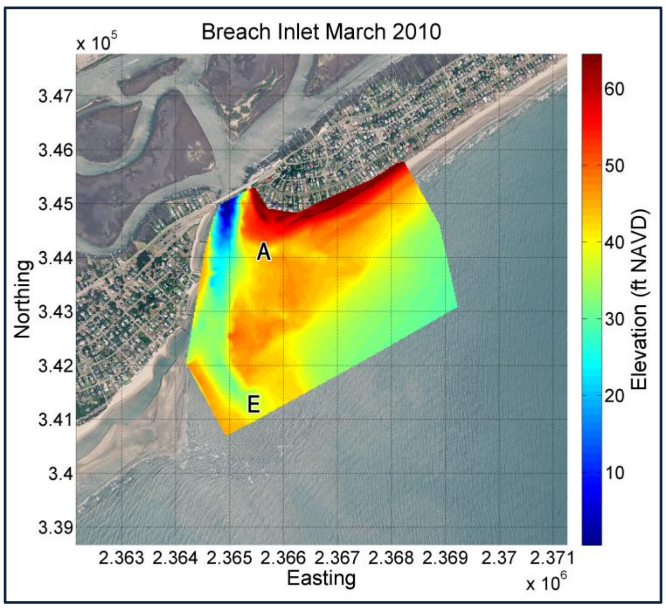
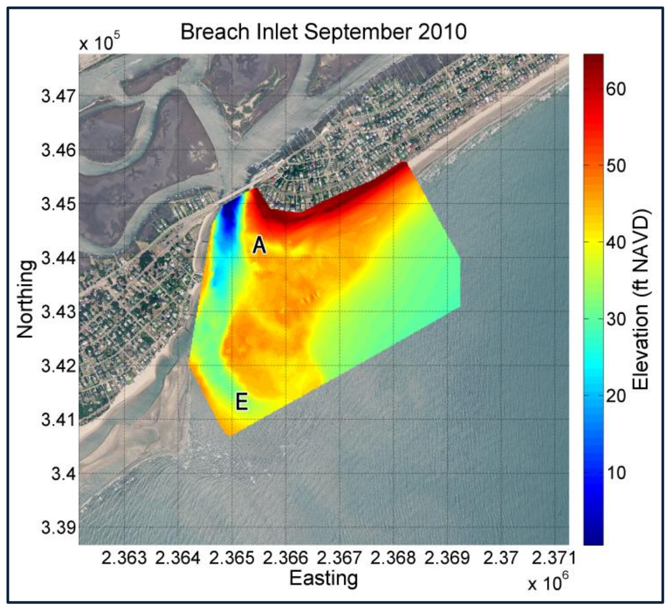


FIGURE 3.30. Profiles from station 4+00 near Breach Inlet. A marginal flood channel migrated landward between March and September 2009, but had returned to its March 2009 position as of September 2010. A defined channel was not present in June 2011 as the channel had infilled.









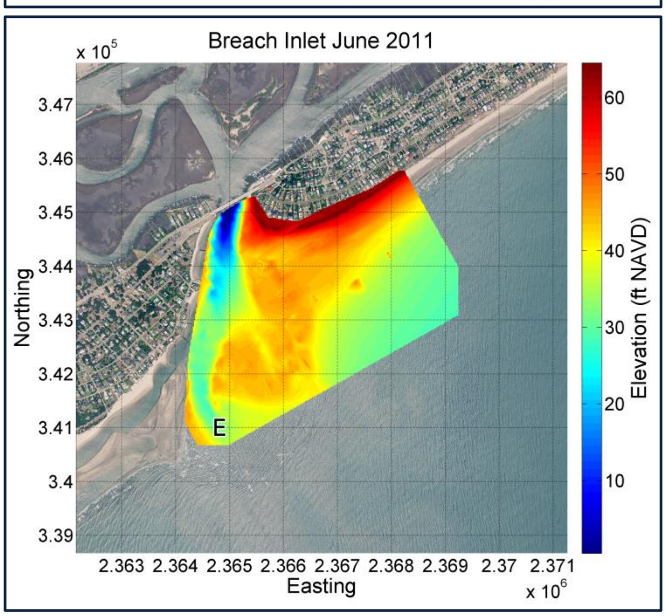


FIGURE 3.31.

Color DTMs of Breach Inlet and neighboring IOP shoreline.

Note the presence of a marginal flood channel (yellow hue near A) from 2009 to 2010, but lack of the feature in 2011.

The secondary ebb channel (E) at the lower left edge of each image is now the new main channel.

A channel avulsion event is occurring where the main inlet channel realigns from a westward to a southerly orientation.

CSE noted changes to the main channel of Breach Inlet in the Year 1 monitoring report (CSE 2009a). It was first observed that a secondary ebb channel was becoming more developed and was oriented perpendicular to the shoreline. The secondary channel continued to develop through 2010 as an ongoing channel avulsion event cut off the old main channel. A large shoal migrated landward toward Sullivan's Island, which infilled the old main channel and restricted tidal flows through it. By June 2011, the old channel was almost completely infilled and the secondary channel (E) was the dominant path for tidal currents.

This event is analogous to the event presently occurring at the northeastern end of IOP, though the scale is smaller (Fig 3.32). Much like the event at Dewees Inlet (discussed in Section 3.3), the new main channel is already migrating to the southwest. As it migrates, it will facilitate shoal attachment on Sullivan's Island. It also could lead to erosion of the IOP beach as it creates a sediment "sink" (a place where sediment accumulates) in the ebb-tidal delta. Sand from IOP will fill the void left by the migrating channel. Historically, sufficient sediment has reached the inlet to provide sand to the inlet while maintaining a healthy beach on the IOP side of Breach Inlet.

FIGURE 3.32. Aerial image of Breach Inlet taken 15 April 2011 (TW Kana). A channel (C) avulsion has triggered a large shoal-bypass event on Sullivan's Island (S). The new main channel is oriented more perpendicular to the shoreline. Only a minor remnant of a marginal flood channel (M) was present on the Isle of Palms side when this photo was taken.

3.2 Shoal Management Project Conditions

As of this writing, a permit has been issued by SC DHEC–OCRM for a sand manipulation project to move up to 250,000 cy of sand twice over a five-year period from the shoal attachment area to critically eroded areas. A permit application to USACE is still pending. To ensure that all areas of the shoreline maintain a sufficient beach width, sand would only be excavated from an area at least 400 ft from any building line. A trigger was established at 100 ft from the buildings, creating a minimum acceptable beach condition. The trigger is based on the distance from the building to the +5 ft NAVD contour (just below the berm elevation).

As of June 2011, ~775 ft of shoreline near the Ocean Club building and 18th fairway showed a beach width less than the trigger distance (Fig 3.33). Since a portion of the beach meets the trigger threshold, the City may proceed with a management project (assuming issuance of the USACE permit and satisfactory completion of pre-project permit conditions). The available borrow area contains ~155,000 cy of sand as of June 2011 to −3 ft NAVD (a typical excavation depth). Actual available volume and nourishment needs would be established immediately prior to project construction. CSE recommends in the event the City decides to move forward with a project, a condition survey should be performed to establish these quantities.

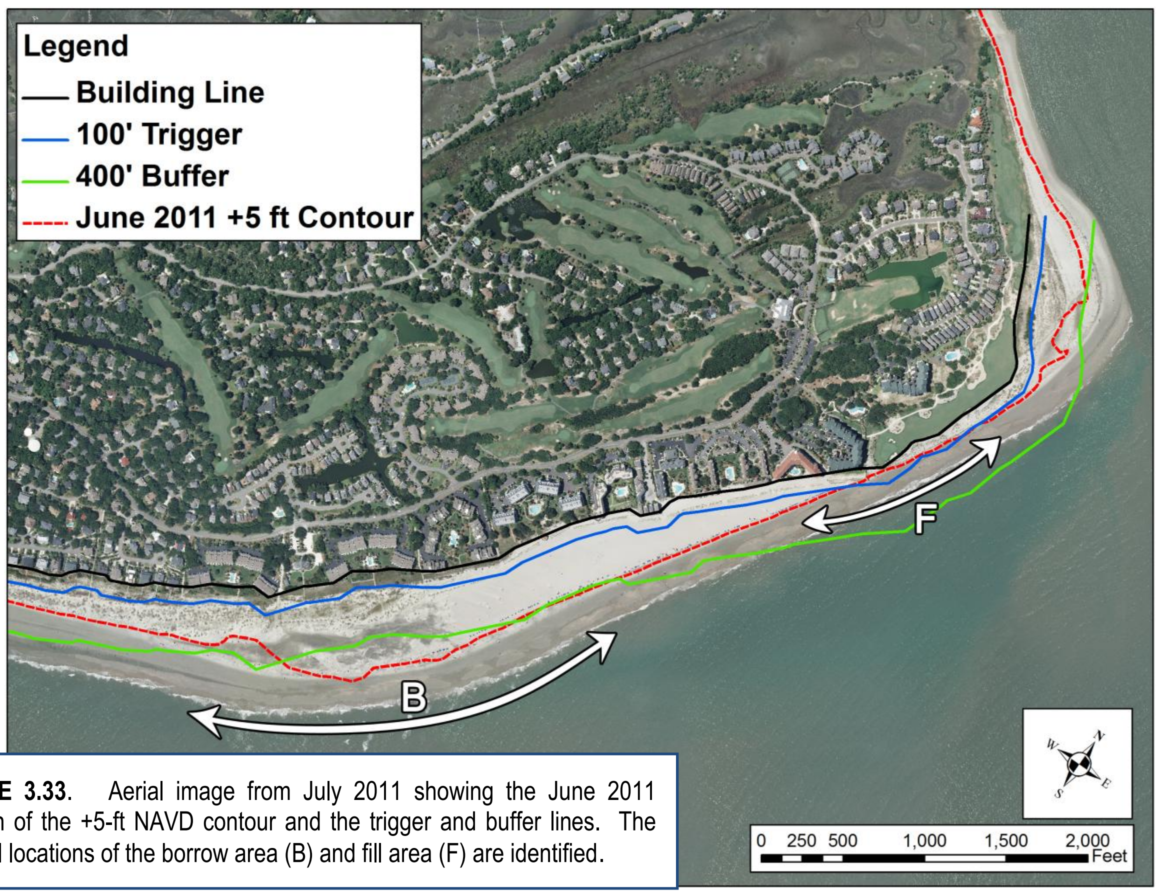


FIGURE 3.33. Aerial image from July 2011 showing the June 2011 location of the +5-ft NAVD contour and the trigger and buffer lines. The general locations of the borrow area (B) and fill area (F) are identified.

3.3 Shoal Bypassing

Between March and September 2009, a bypassing shoal ("2008" shoal) fully attached to the beach just north of the Wild Dunes Property Owners Beach House. It originated from the same platform of sand as the previous shoal-bypass event, which ultimately led to the need for the nourishment project in 2008. In March 2009, the "2008" shoal was separated from the beach by a narrow and relatively deep channel as seen in the 2009 aerial image (cf – Fig 3.14) and profile from station 282+00 (Fig 3.34). Using a DTM from the March 2009 monitoring data, CSE estimates ~330,000 cy of sand came ashore in the "2008" shoal. This shoal had completely attached by September 2009.

Another shoal emerged by April of 2010 (Fig 3.34). This shoal appeared smaller than the previous shoal and attached a few hundred feet to the north of the Wild Dunes Property Owners Beach House. The shoal emerged and attached quickly, and is estimated to contain less than 100,000 cy of sand. Net accretion was observed in the shoal attachment area (between stations 260+00 and 286+00) between March and September 2010 as the shoal attached to the beach. This resulted in some recovery of the most severely eroded portions of Reach 5 (near Dunecrest Lane). Recovery was also observed near the 18th hole of the Wild Dunes Links Course as sand that had recently added (via the 2010 shoal attachment) to the southern portion of Reach 6 (between Mariners Walk and Summer Dunes Lane) eroded and was transported north. Between September 2010 and June 2011, sand continued to erode from the shoal attachment area and spread to adjacent areas, though volume analysis confirms that there is a net loss of sand from the northeastern end.

The two shoals that emerged following the nourishment project built from a large platform of sand on the southern side of the Dewees Inlet delta. The platform, which slopes offshore in the vicinity of the Wild Dunes Property Owners Beach House, is estimated to contain over 4.3 million cubic yards of sand. It is likely that this platform will continue to be a source of sand for shoal-bypass events. Shoals are built as sand from the outer portions of the platform is transported landward by wave action. As more sand is added, the shoals build higher and, in turn, experience more breaking wave energy. Once shoals are emergent, they tend to migrate faster than submerged bars. Just as discrete waves can be observed moving toward the beach, discrete shoals produce episodic bypassing events every few years.

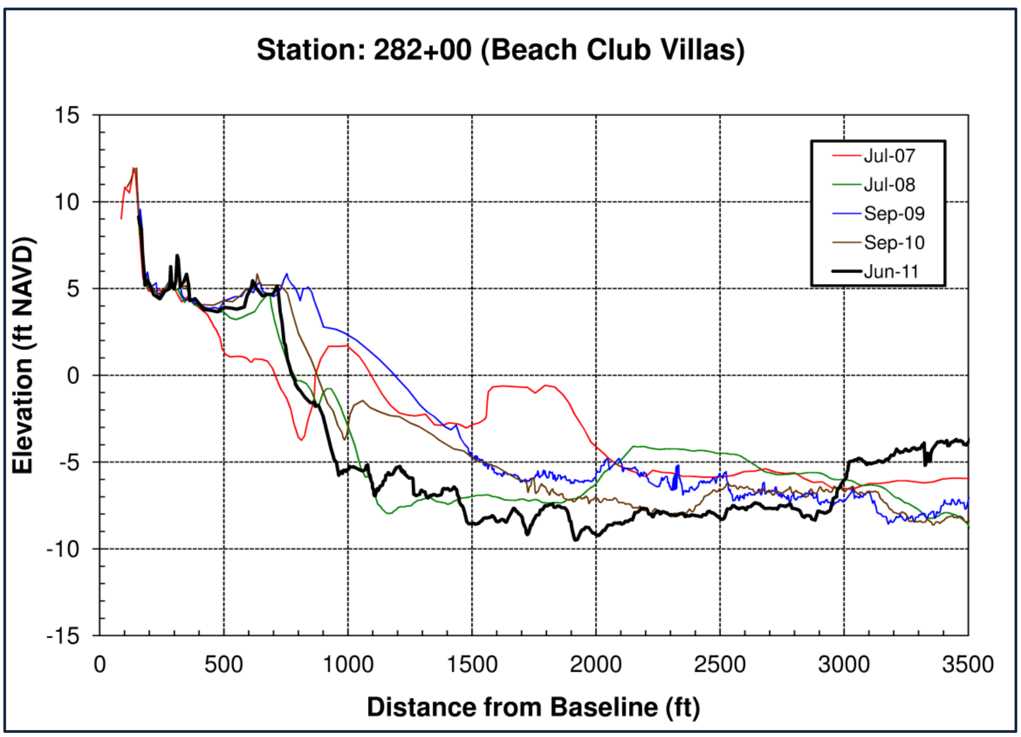


FIGURE 3.34. **[UPPER]** July 2011 aerial image of the northeastern end of Isle of Palms. No shoal was present as of August 2011. Section 1 indicates the location of the profile shown in Figure 3.39. **[LOWER]** Profiles from station 282+00 near the Wild Dunes POBH show the landward migration of shoals since 2007. Note the "2006" shoal (red line) attached to the shoreline with an ephemeral lagoon in July 2007 and completely welded to the beach in July 2008 (green line). The "2008" shoal attached in September 2009 (blue line). The 2010 shoal was much smaller than the previous two and essentially attached in September 2010 (brown line). The beach has receded since September 2010; however, collapse of the ebb-tidal delta of the old shoal is leading to buildup of sand ~3,000 ft from the beach. This sand will eventually migrate onshore. Note 0 ft NAVD is approximate mean sea level.

3.4 Dewees Inlet and Delta

Dewees Inlet's ebb-tidal delta is the sand source responsible for the historical accretion along IOP (SCSGC 2001). Since the 1950s, the seaward end of the main channel has been deflected to the south due to dominant wave forcing from the northeast driving sand to the southwest. The southerly deflection results in the large platform of sand in the nearshore of the north-eastern end of the island (discussed in the previous section). The channel has generally been bounded by a large sand shoal on the northeast and southeast, separated by a secondary channel which runs parallel to the inlet (between IOP and Dewees Island). The cross-sectional area of the inlet (measured at station 362+00) is ~35,000 square feet (ft^2) (3,250 m^2) and shows long-term stability.

While the Dewees Inlet delta has remained in a fairly similar position since the 1950s, recent observations (since 2007) show large-scale changes are occurring. An event occurring in the 1940s shows features similar to present conditions within the inlet. Aerial photos from the event are shown in Figure 3.35. The images from the 1940s and 1950s suggest there was a channel avulsion event which realigned the main ebb channel from a southwest to a southeast orientation. This allowed a significant quantity of sand to attach to the beach, creating a barrier beach/lagoon system in the process. Note the presence of the feature (arrow) in the 1949 image (Fig 3.35). The barrier beach was pushed onshore over the next decade, closing the lagoon and adding a large sand supply to the IOP beach.

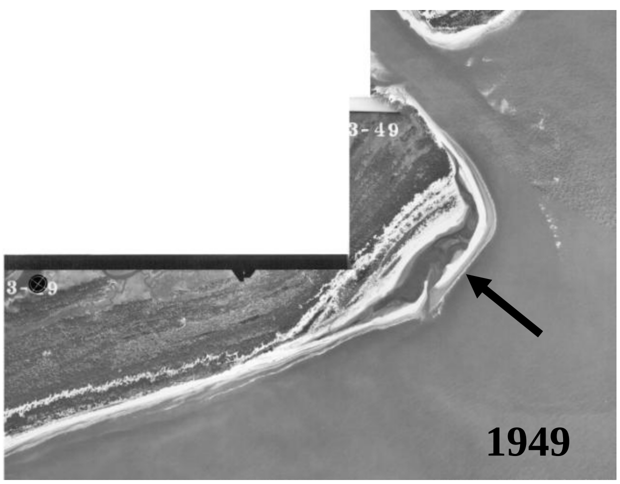
Perhaps the most significant observation from the sequence of photos in Figure 3.35 is that in 1944, the inlet channel (C) was oriented to the southeast. This differs from the southwest orientation of the outer channel observed in 1957 (and possibly 1954). Also of note in the 1944 image is the extensive, sparsely vegetated beach/dune area. Lack of dense shrub vegetation indicates that a broad section of the oceanfront accreted, likely within the previous 10–20 years. At some point prior to 1944, the active beach was positioned in the vicinity of the stable tree line but accreted rapidly, leaving the wide sparsely vegetated area that is visible in the 1944 photo.

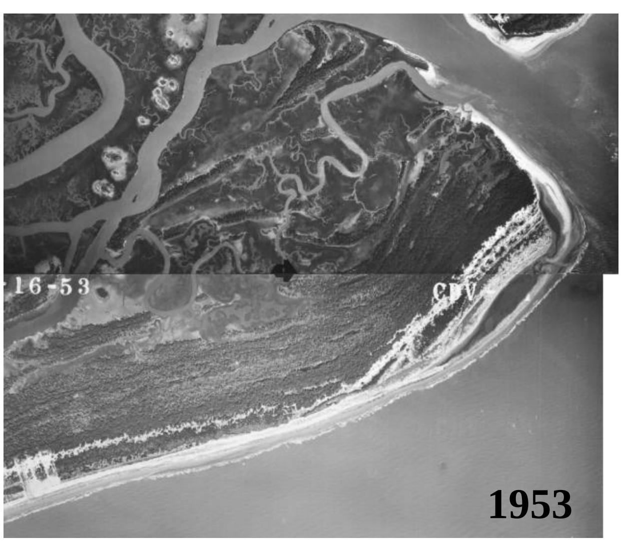
By 1949, a large shoal had enveloped the northern end of the island. Isolated shoals (visible offshore in the 1944 image) merged and migrated onshore, creating the barrier beach/lagoon system at the northeastern end of IOP. A central flushing channel for the lagoon can be seen in the 1949 and 1954 images (Fig 3.35). While the orientation of the main inlet channel is difficult to determine from the 1949 and 1954 photos, the 1954 photo shows deflection of flows to the southwest, indicating the channel was probably oriented to the southwest at that time. It is clear by 1957 that the channel is deflected to the southwest. Between 1949 and 1957, the incipient lagoon narrowed as waves overwashed the barrier beach and drove sand into the lagoon.

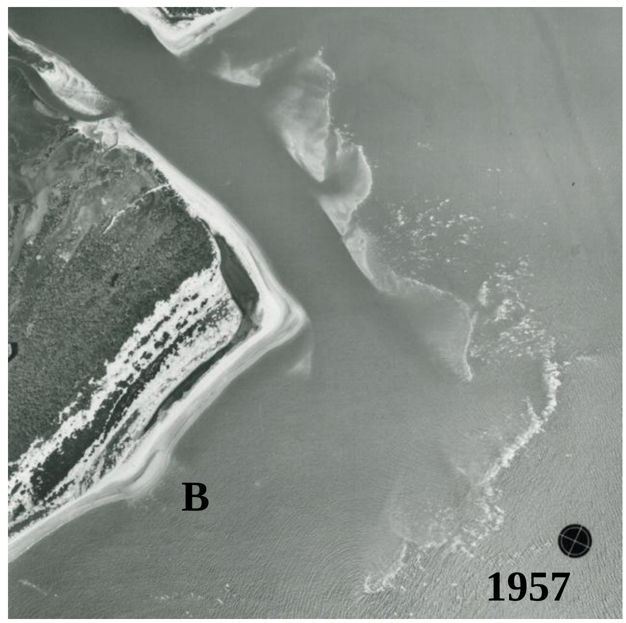
FIGURE 3.35.

Sequence of vertical aerial photos of the northeastern end of Isle of Palms, showing a set of photos spanning 1949-1963. A large shoal-bypass event likely due to a channel avulsion impacted the island during this time period, creating a washover barrier and lagoon which eventually infilled and created new beach and dune habitat.

Photo sequence begins (left column from top) in 1944, 1949, and 1953, then continues (right column from top) in 1954, 1957, 1963. [Note that images are not at the same scale.]





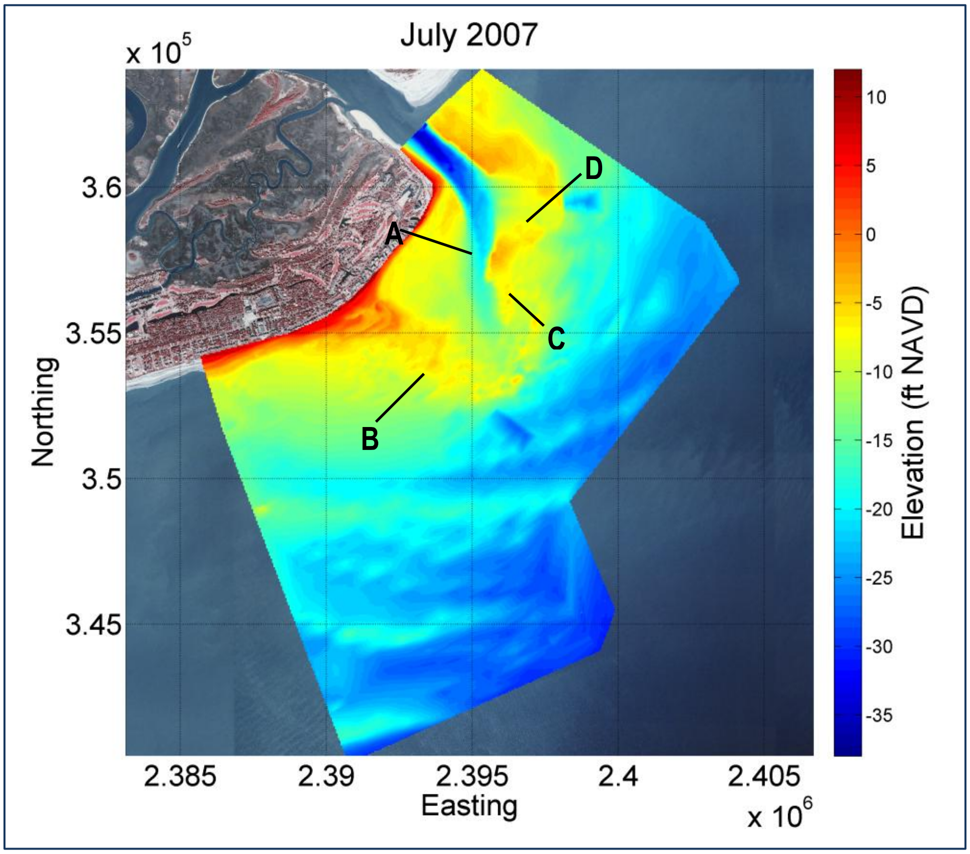


The 1957 photo also shows the first signs of the typical shoal-bypass events which have occurred periodically since then (and have been described in this report) with a bulge in the shoreline (B) created by a recent shoal attachment. By 1963, the incipient lagoon had completely infilled, and the shoreline was shaped similarly to what exists today.

Monitoring efforts by CSE reveal that the ebb-tidal delta of Dewees Inlet has experienced significant changes since 2007. These changes suggest that an event similar to the one which took place in the 1940s–1950s is occurring. Whether a similar large-scale event sufficient to produce a barrier beach like the one in 1949 occurs is uncertain. However, a channel avulsion at Dewees Inlet would free more than enough sediment on the downcoast side of the delta to produce a similar feature. This is why comprehensive surveys of the ebb-tidal delta are important. Figures 3.36 through 3.38 show DTMs of the inlet between July 2007 and June 2011 with features of interest labeled:

- **A**) Dewees Inlet 2007 main channel.
- **B**) The shoal platform and site of recent bypass events.
- **C**) Offshore shoal on the seaward limit of the Dewees Inlet main channel.
- **D**) Dewees Inlet 2011 main channel and its associated spillover lobe.

Changes in the ebb-tidal delta morphology are evident in the series of DTMs from 2007 to 2011. The most significant changes occurring since September 2010 were the landward migration of the southern tip of the offshore shoal, continued landward migration of the old terminal lobe and seaward expansion of the new terminal lobe, and southwest migration of the new channel. Overall, the delta morphology is changing in an expected pattern for a channel avulsion event. It is apparent now that the old main channel is completely closed and unlikely to reform in its old position. Instead, the new channel will likely migrate to the southwest over the next several years, eventually returning to the position of the old main channel. While this occurs, much of the sand which forms the platform (B) and the outer shoal (C) will migrate onshore.



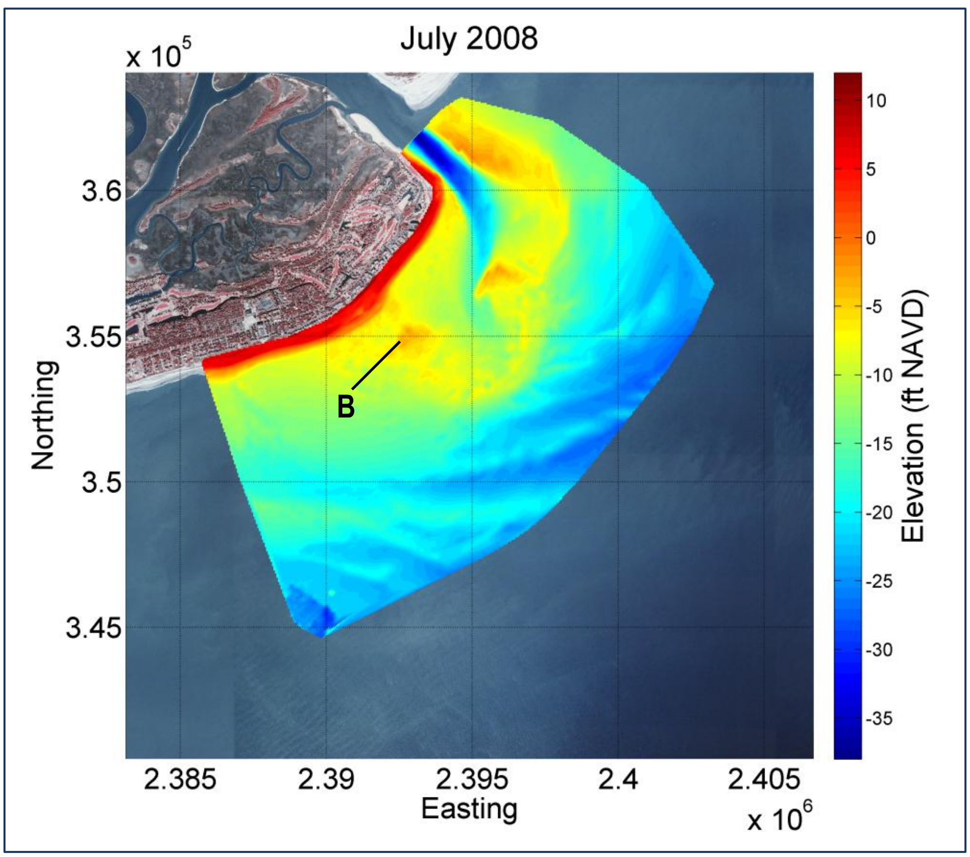


FIGURE 3.36. DTMs from July 2007 (upper) and July 2008 (lower) showing changes in the shoals of the Dewees Inlet ebb-tidal delta. Labels are described in the text.

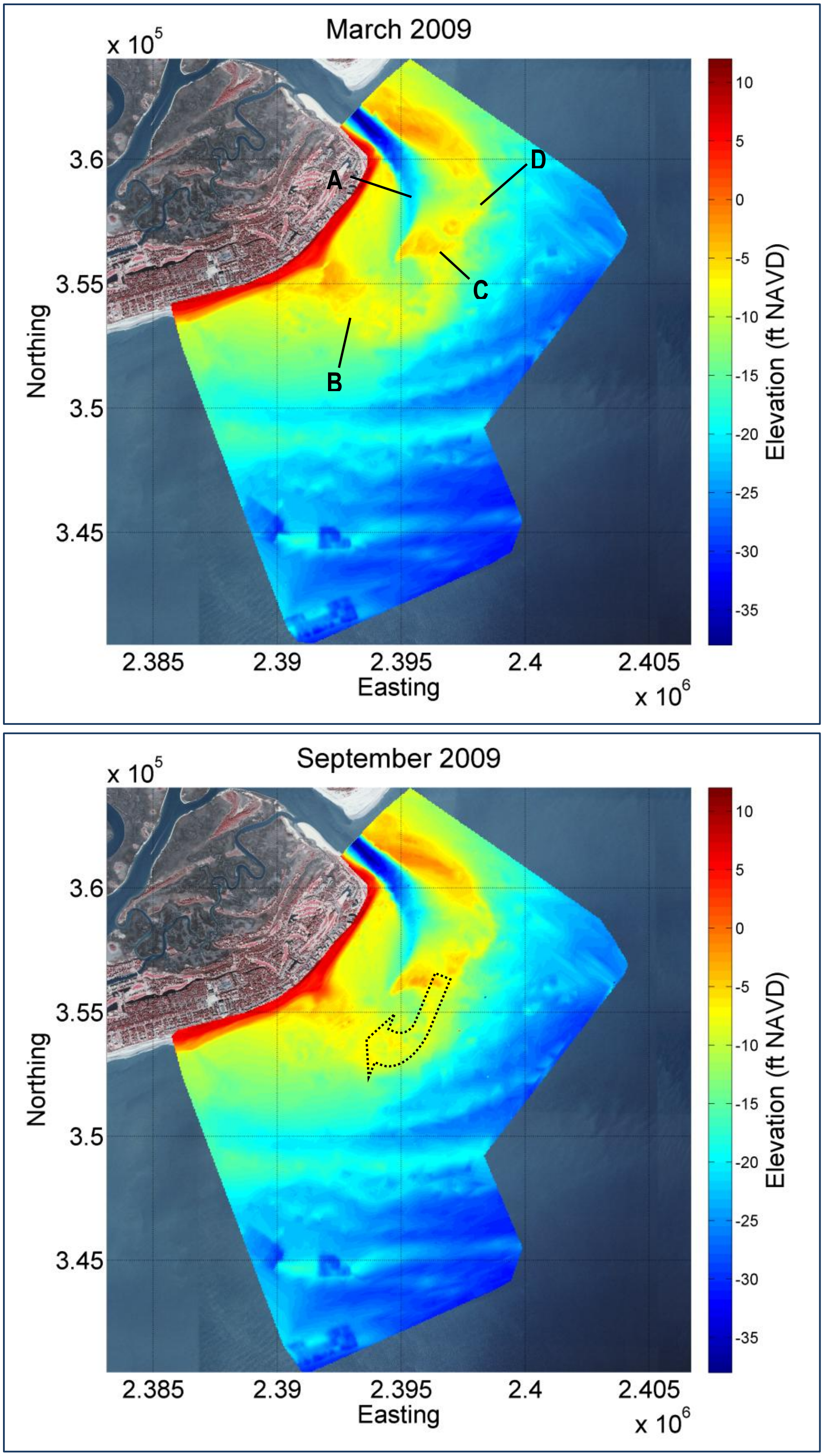
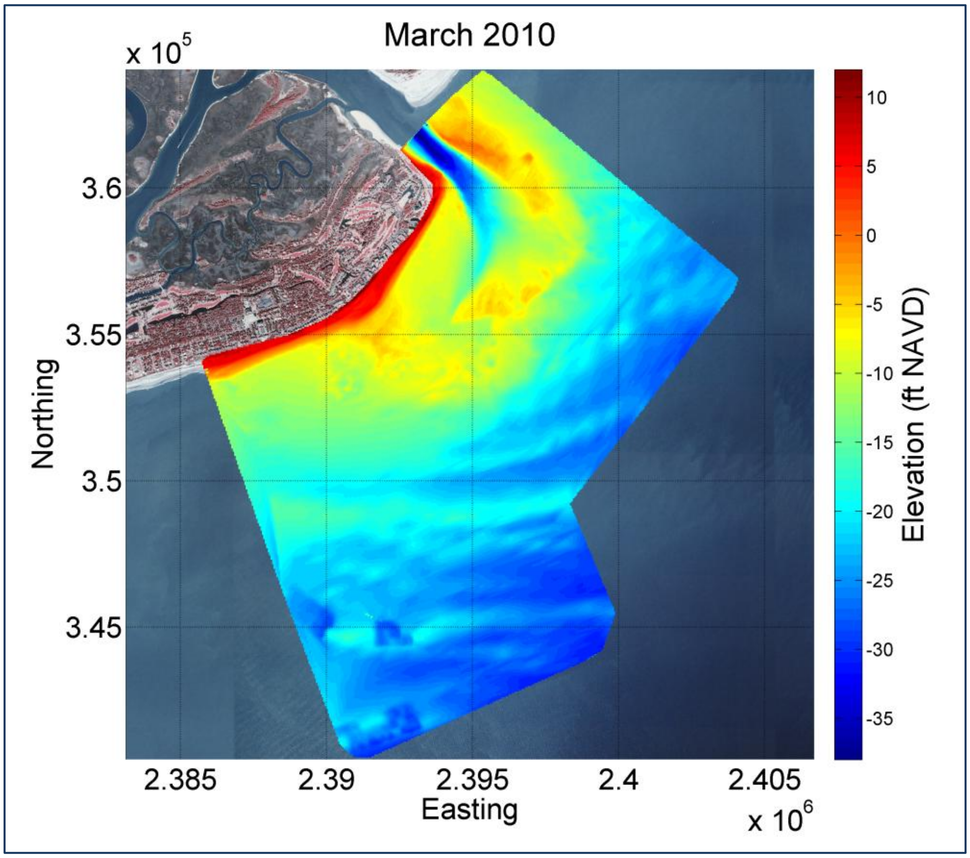


FIGURE 3.37. DTMs from March (upper) and September (lower) 2009 showing changes in the shoals of the Dewees Inlet ebb-tidal delta. Labels are described in the text. The general sand transport pathway is highlighted by the arrow. Borrow areas for the project are the small deep-blue patches at the lower corners of the DTMs.



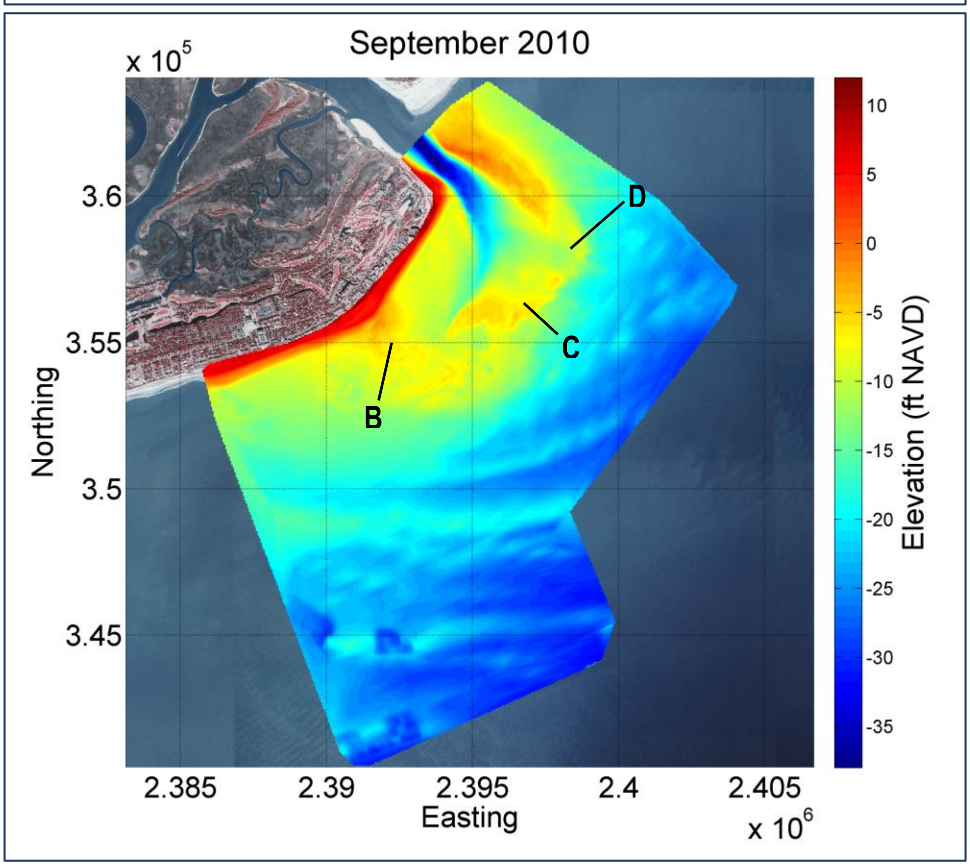


FIGURE 3.38. DTMs from March (upper) and September (lower) 2010 showing changes in the shoals of the Dewees Inlet ebb-tidal delta. By September 2010, the 2007 main channel essentially closed as the outer shoal (C) merged with the shoal platform (B). Borrow areas for the project are the small deep-blue patches at the lower corners of the DTMs.

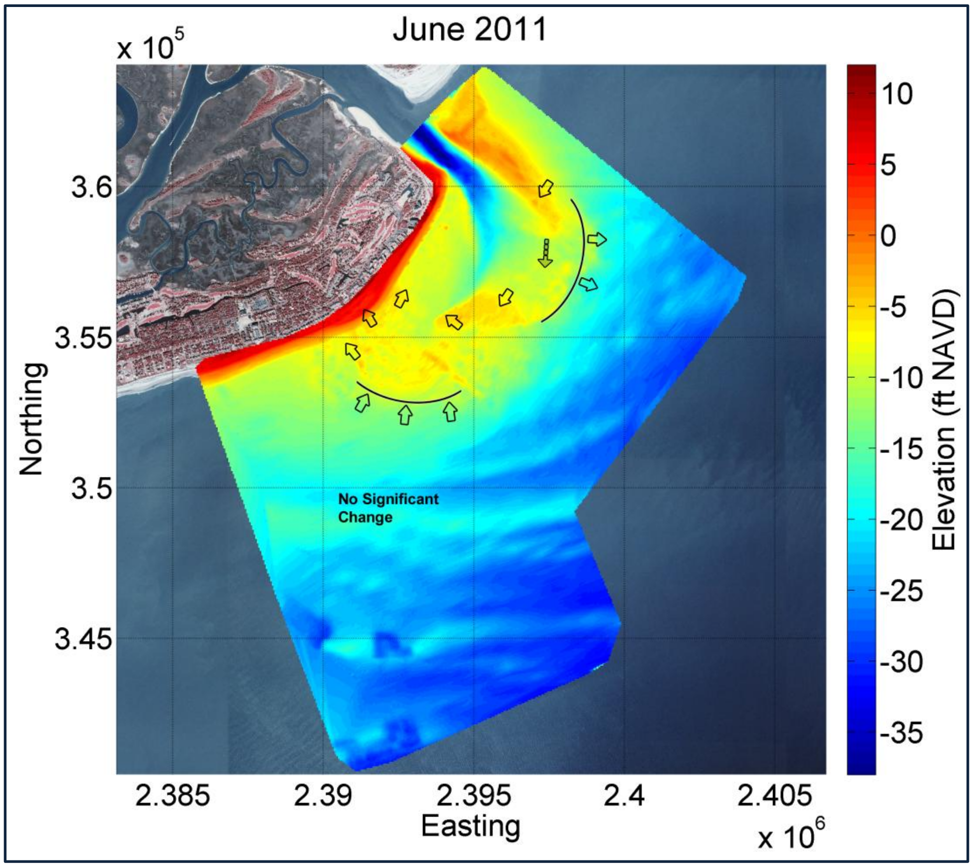


FIGURE 3.39. DTM from June 2011 showing changes in the shoal of the Dewees Inlet ebb-tidal delta.. Borrow areas for the project are the small deep-blue patches at the lower corners of the DTM. Open arrows indicate the general sediment transport patterns. The dashed arrow indicates movement of the channel.

Between July 2007 and September 2010, the outer shoal (C) generally moved towards the southwest with the leading edge migrating through the old main channel. Some evidence of landward migration was seen in the body of the shoal between March and September 2010; however between September 2010 and June 2011, the landward migration was much more pronounced. Figure 3.40 shows a profile from station 294+00 (Shipwatch Villas). Note the area between 2,500 ft and 4,000 ft from the baseline. The leading edge of the shoal had not intersected this profile as of September 2009, and the remnant of the old main channel is seen as the depression in the blue line. By September 2010, the leading edge of the shoal had reached the station (brown line) and filled in the old channel. The landward edge of the shoal at this time was ~3,100 ft from the baseline (or 2,500 ft from the beach). Between September 2010 and June 2011, the shoal migrated ~500 ft landward while also migrating southwest (resulting in the increased width of the shoal compared to the 2010 condition). At this location the landward edge of the shoal was ~2,000 ft from the beach in June 2011.

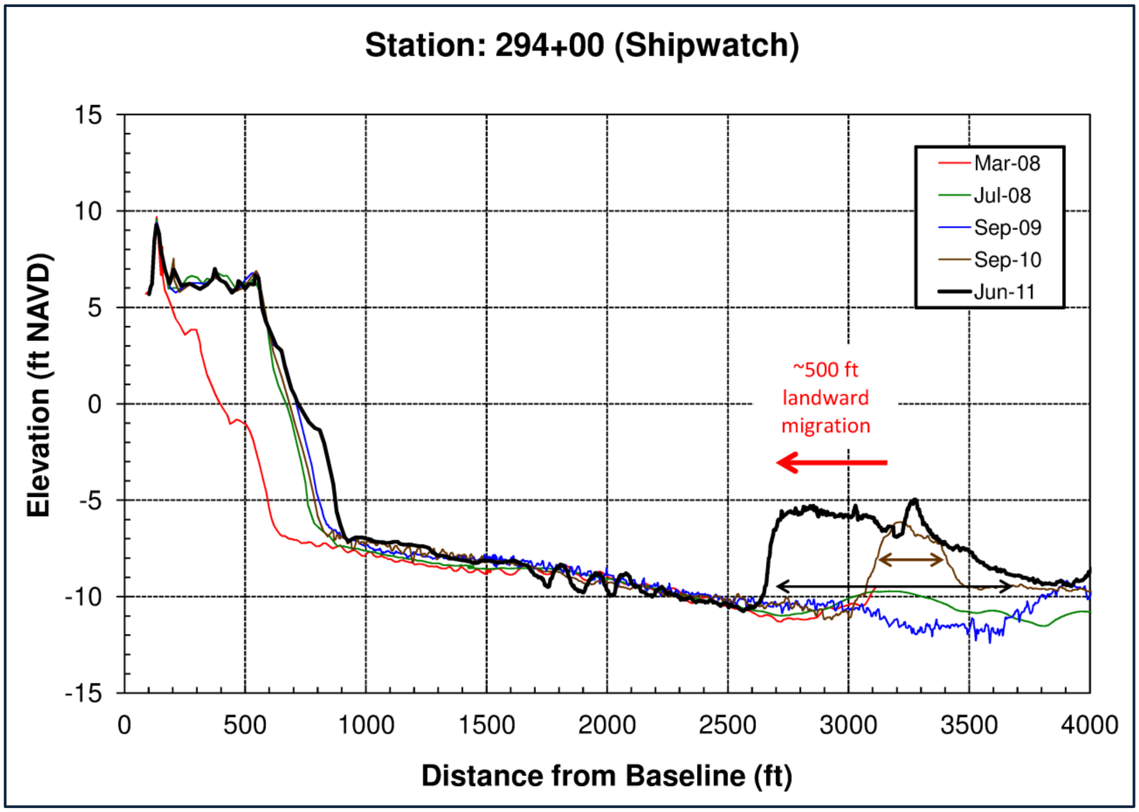


FIGURE 3.40. Profile from station 294+00 (Shipwatch Villas).

The DTMs (Figs 3.36–3.39) also show that the new terminal lobe (outer crest of the ebb-tidal delta) is continuing to grow seaward of the new main channel. This is an indication that ebb-tidal currents have increased through the secondary channel as the main channel has shoaled. Increased velocity is responsible for widening and deepening the secondary channel, and sand removed by this process is being deposited further offshore, forming the new terminal lobe. Cross-sections of the new main channel are given in Appendix C. The lobe has pushed the −12 ft contour up to 1,400 ft seaward since 2007, including up to 250 ft since September 2010. CSE expects the new channel to rotate from southeast to southwest over the next few years (Fig 3.41).

While the terminal lobe of the new channel is expanding seaward, the terminal lobe of the old channel is collapsing towards the shoreline. Since 2007, the −12 ft contour has migrated landward 200–700 ft in the area of the old terminal lobe (see Fig 3.41). This sand will continue to migrate landward and merge with the beach over the next few years. The new main channel is migrating toward the southwest much like the outer shoal. Dominant sediment transport from the northeast is forcing the channel (and associated shoals) to the southwest.

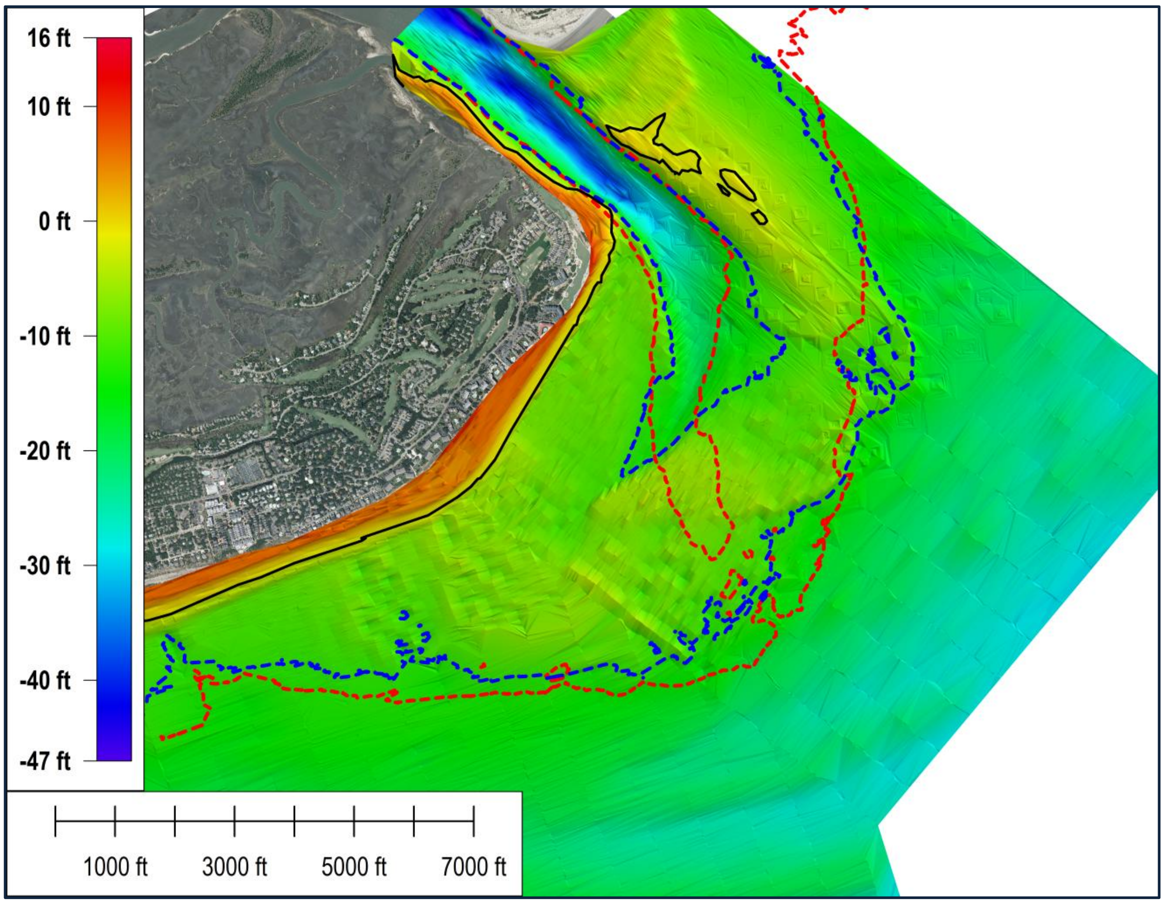


FIGURE 3.41. DTM of the Dewees Inlet ebb-tidal delta. The dashed lines represent the −12-ft contour in 2007 (red) and 2011 (blue). The black line is the mean low water contour.

Between September 2010 and June 2011, the outer edge of the channel migrated ~450 ft to the southwest (Fig 3.42). CSE expects the new channel to rotate from southeast to southwest over the next few years. Eventually, the new main channel will reach the position of the old main channel and typical shoal-bypassing cycles will continue (see Fig 3.35).

CSE bases these assumptions of future changes on previous events at IOP as well as on a similar event observed at Kiawah Island. CSE has worked intermittently at Kiawah Island since the 1970s, providing shoreline analysis and restoration plans to the Town. Kiawah Island has a similar shape as IOP and is controlled by the same shoal-bypassing process which directs the shape of IOP. There, two large shoal-bypass events, containing an estimated total of 5 million cubic yards of sand migrated onshore, creating a barrier beach/ lagoon system spanning nearly 3 miles around the northeastern end of the island. At the eastern end of Kiawah Island, the quantity of sand was so large that the incipient beach formed dunes of sufficient height to prevent overtopping. This stopped the landward migration of the barrier berm, leaving the new beach ~1,500 ft seaward of the pre-existing beach and forming a mature marsh-filled lagoon between the new beach and the older shoreline (Fig 3.43).

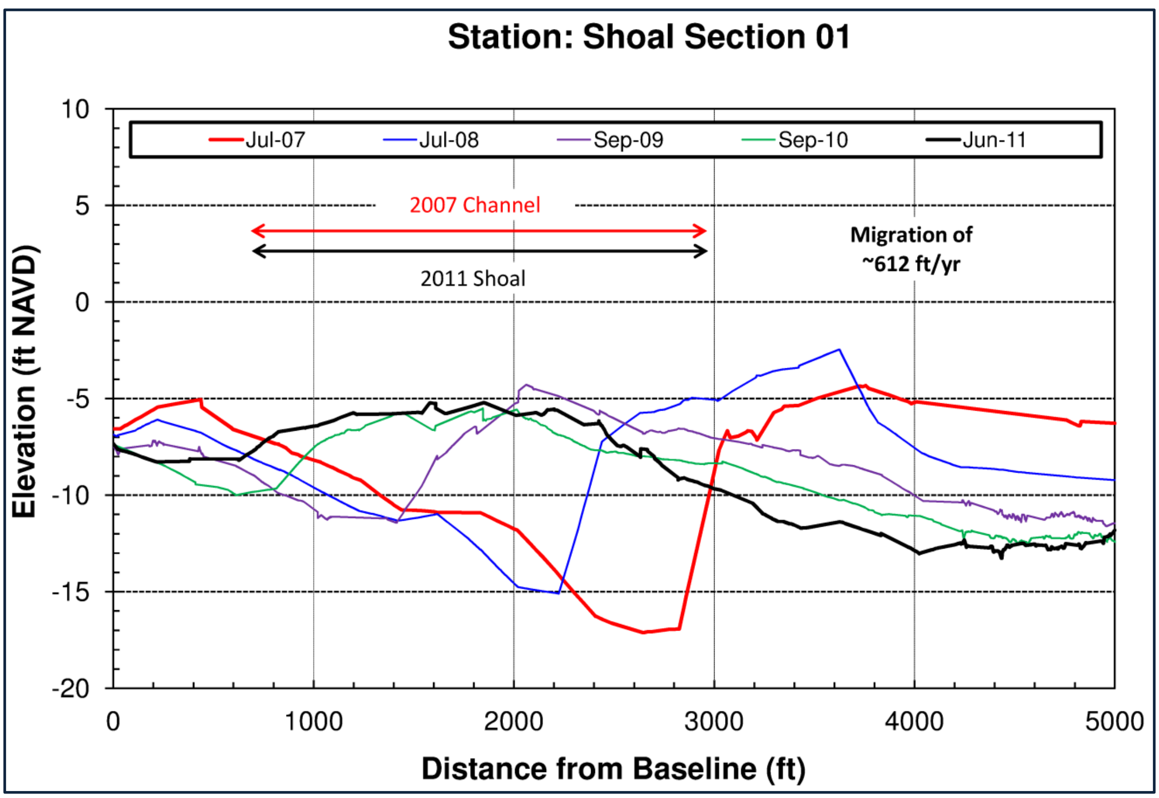


FIGURE 3.42. Cross-section through the outer portion of the 2007 Dewees Inlet main channel. The section runs generally parallel to the shore beginning offshore of the Wild Dunes Property Owners Beach House and extending to the northeast. The southwest movement of the shoal is shown as the right-to-left movement of the shoal's leading edge in this graphic [beginning on the "bump" in the red line at ~3,000 ft, then moves through the blue, purple, green, and finally black (2011) lines]. See Figure 3.34 for location of the transect.

FIGURE 3.43. Shoal-bypass events at Kiawah Island. The upper image from 1998 shows two shoals estimated to contain ~5 million cubic yards of sand. Shoal 1 was attached and had built a barrier beach ~1,500 ft seaward of the original shoreline. A marsh was forming in the created lagoon. The second shoal was attached at the north end, but still in Stage 2 of the bypass cycle at the south end. The lower image is the same area in April 2010. By this time the second shoal had completely attached and was in the process of forming a new outer beach. Marsh had developed throughout the lagoon, leaving a network of tidal creeks flushing the new system. [Source: CSE 2007, 2010]

Due to the ongoing channel avulsion at Dewees Inlet, several million cubic yards of sand may be released to IOP over the next decade or so. As of June 2011, CSE estimates ~2.75 million cubic yards of sand are present above −12 ft NAVD, between the beach and the new channel. Changes to the beach associated with such a large release of sand are uncertain, but may include significant areas of localized accretion and erosion, much like what was present prior to the 2008 beach restoration project. It is still unclear whether sand will migrate ashore as a single large shoal (similar to the 1940s event at IOP and recent shoal-bypassing events at Kiawah Island – CSE 2005, 2007b, 2009b), or whether there will be an increase in scale and/or frequency of usual-scale, shoal-bypass events such as those impacting IOP in recent years. Since no emergent shoal was present as of August 2011, it appears to be more likely that sand will attach as a large event, rather than multiple smaller events. Monitoring over the next year will likely provide a better prediction regarding the method of sand attachment. The uncertainty of rates and the rapidity of changes in the ebb-tidal delta, inlet channels, and shoal platform point to the importance of annual monitoring.

3.5 Project Area Volume Changes

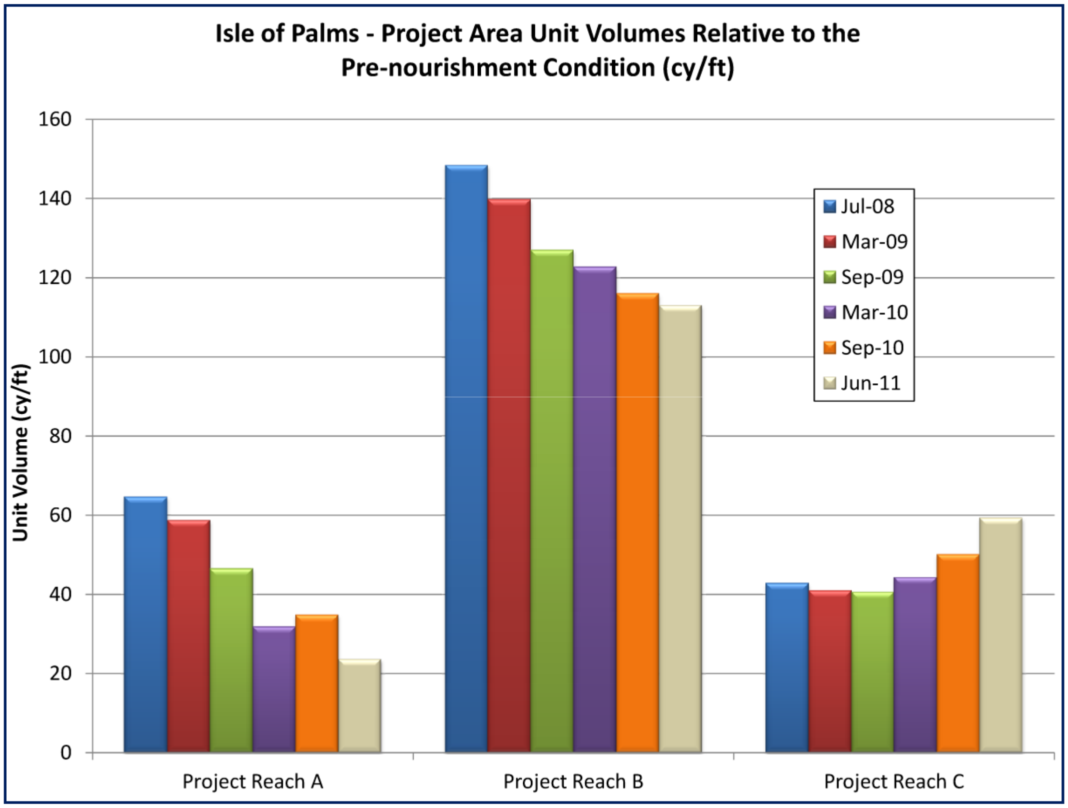
The following section provides volume change results within the limits of the 2008 nourishment project boundaries. It provides a measure of how much sand is left within the initial alongshore fill limits. While these results are useful for measuring project performance, it should be noted that sand gained or lost from these areas may be accounted for in adjacent areas as noted in Section 3.1.

Within the fill limits of the *Dewees Inlet* project area (nourishment Reach C, Fig 3.44), the beach continued to gain sand. **Overall, the project reach gained ~9,200 cy (9.2 cy/ft) since September 2010, leaving it with 138.7 percent of the nourishment volume remaining** (Fig 3.45). As of June 2011, Reach C contained ~59,200 cy more sand than the pre-nourishment condition. Accretion between station 330+00 and station 338+00 (area of the 18th tee and fairway) is likely due to losses in Reach 6. The volume change trends along the 18th fairway of the Wild Dunes Links Course, which wraps around the northeastern point of the island, provide an indicator of net sand transport from the oceanfront to the inlet shoreline in this area, consistent with the findings of Kana and Dinnel (1980).

The length of beach within the project boundary Reach B (between Shipwatch and the 18th fairway) presently retains 113.0 cy/ft more sand than the pre-nourishment condition (compared to 148.4 cy/ft immediately following nourishment). **As of June 2011, 76.1 percent of the nourishment volume remains in project Reach B.** Overall project Reach B lost ~12,700 cy (2.9 cy/ft) of sand since September 2010. [Calculation excludes the taper sections, which would bias the results.]

Project Reach A was the most erosional project reach, losing ~58,000 cy since September 2010. The project area presently retains an average of 23.7 cy/ft more sand than the pre-nourishment condition compared to 64.6 cy/ft more sand immediately post-nourishment. In March 2009, 90.8 percent of the nourishment volume remained in the project area. This reduced to 72.0 percent in September 2009, 49.2 percent in March 2010, and then increased to 53.9 percent in September 2010 **before declining to 36.7 percent remaining in June 2011** (see Fig 3.17). CSE believes erosion of the reach is due to losses to downcoast areas as well as continued straightening of the shoreline following recent shoal-bypass events.

FIGURE 3.41. Reaches for the 2008 nourishment project. The graphic shows the project baseline with 0+00 located at 53rd Avenue (monitoring station 222+00).



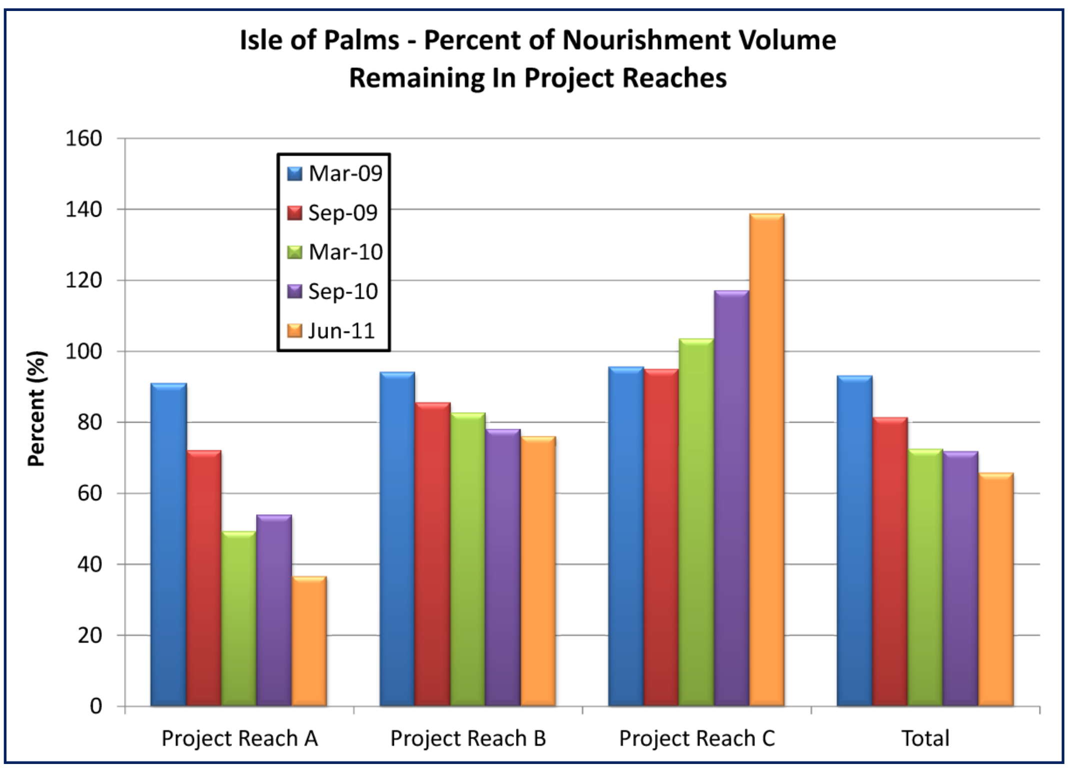


FIGURE 3.45. **[UPPER]** Project area unit volumes relative to the pre-nourishment (March 2008) condition, which is zero on these graphs. [Note that the project area limits differ from monitoring reach limits.] **[LOWER]** Percent of nourishment volume remaining in each project area.

3.6 Required Post-Project Monitoring

Borrow Areas

Three separate borrow areas were used in the 2008 nourishment (Fig 3.46). A fourth area (D) was available but was not used. The borrow areas were situated on offshore ridges and were limited to excavation depths of ~7 ft at the request of permitting agencies to avoid creation of deep holes. Elevation contours of the pre-nourishment condition are shown on Figure 3.46. Special conditions of the permit required topographic monitoring of the borrow areas for three years. Data were collected at 100-ft spacing throughout each of the borrow areas, extending beyond the limit of each area to account for changes near the boundaries.

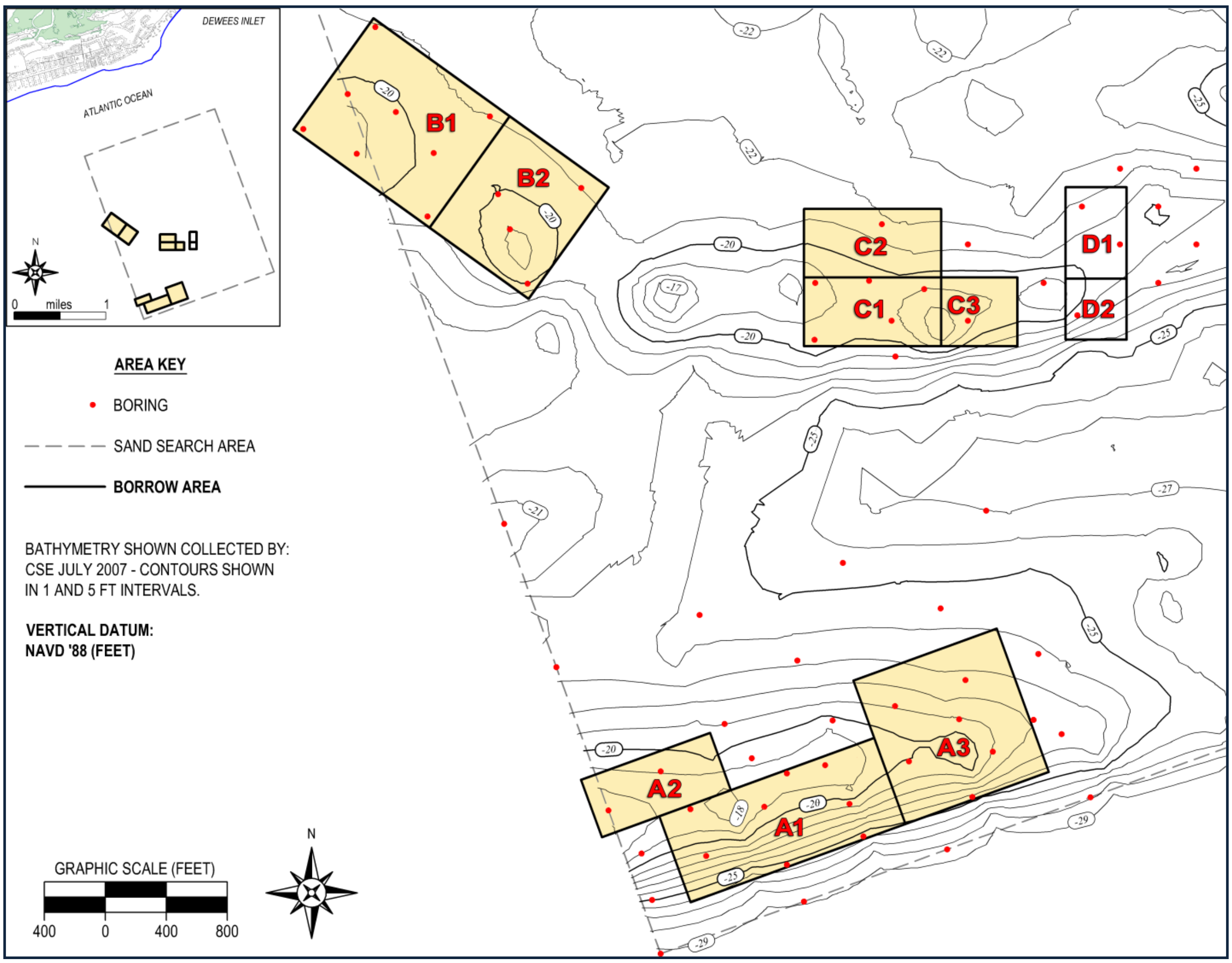


FIGURE 3.43. Locations of the borrow areas used in the 2008 nourishment project. ("D" areas were not used.) Contours show bathymetry in July 2007, prior to the project. The borrow areas were situated on topographic highs as recommended by resource agencies.

DTMs from the post-dredging survey in 2008 and June 2011, as well as a residual DTM (change between the two surveys), are shown in Figures 3.47–3.48. [Note that the DTMs are presented at the same scale, but the spatial juxtaposition has been altered for presentation purposes.] Profile sections for each borrow area are presented in Figure 3.49. Generally, deeper portions of each borrow area have infilled, while higher areas have eroded. Infilling is also occurring at the boundaries of borrow areas where material from undredged areas is falling into the dredged area. Most of the change occurred between the post-dredging condition and March 2009, and the areas have remained fairly stable since then.

Borrow Area A shows a net change loss of 59,600 cy as of June 2011. A total of 508,000 cy was dredged from Borrow Area A. Borrow Area B has gained 49,500 cy between the post-dredge and June 2011 conditions. Total dredged volume in Borrow Area B was ~404,000 cy; therefore, ~12 percent of the dredge volume had been replaced by June 2011. Borrow Area C infilled 3,800 cy by June 2011, representing ~1 percent of the 258,200 cy dredge volume. Note that dredge volumes were calculated from before and after surveys of the borrow areas and not by volumes placed on the beach. In-place volumes are smaller than dredge volumes due to losses of fine material at the beach during pumping.

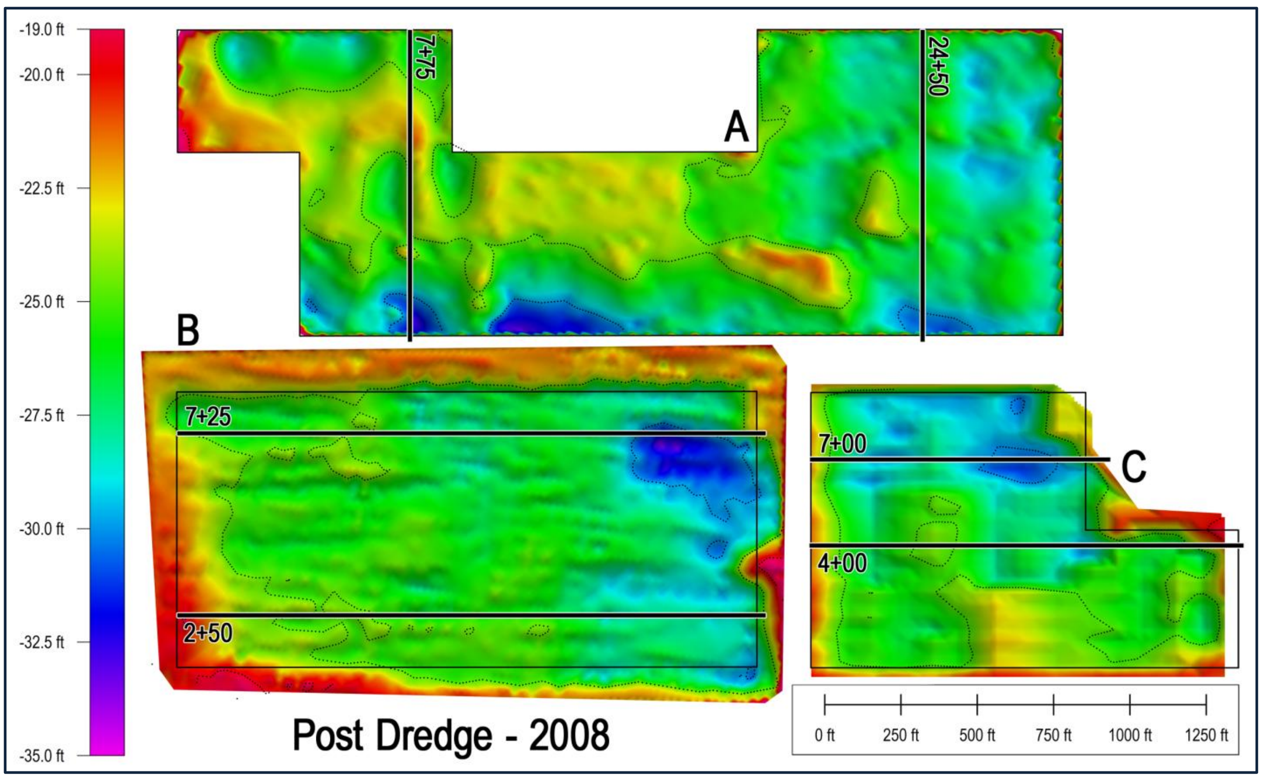
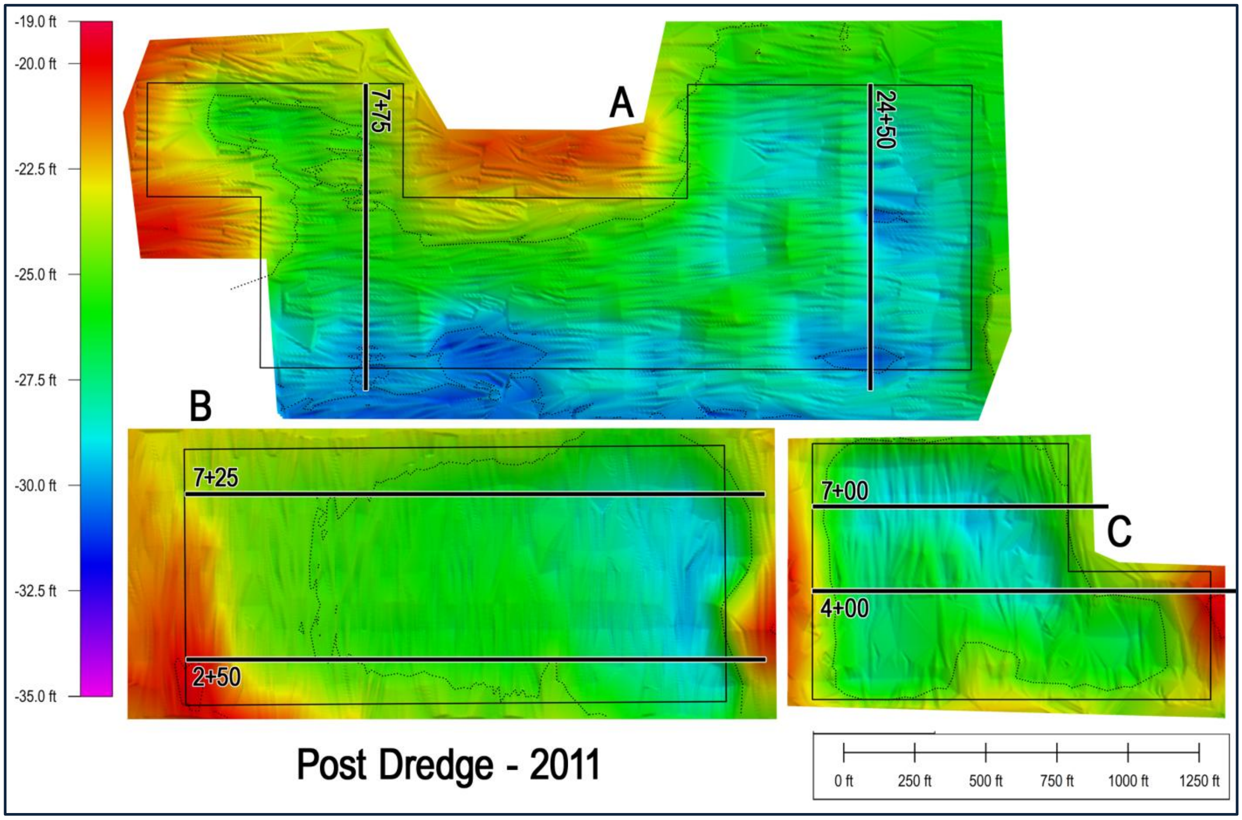


FIGURE 3.44. DTM models of borrow areas after nourishment in May 2008. [Solid black lines are the locations of sections in Figure 3.47.]



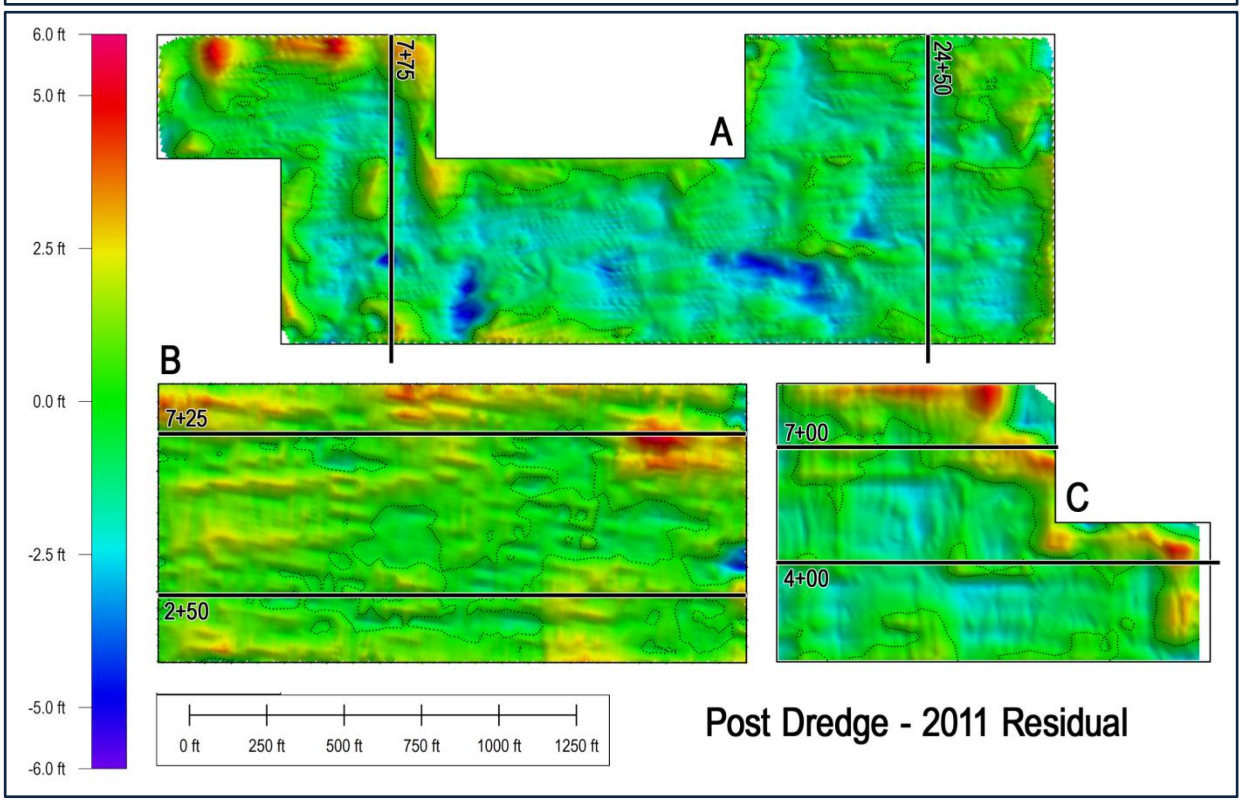


FIGURE 3.48. **[UPPER]** DTM models of borrow areas 37 months after nourishment in June 2011. **[LOWER]** DTM models of elevation change between June 2008 and June 2011. The dashed contour line represents the 0 contour, indicating no change. Blue colors show areas which have decreased in elevation; reds and yellows show areas gaining elevation. [Note solid black lines are the locations of sections in Figure 3.49.]

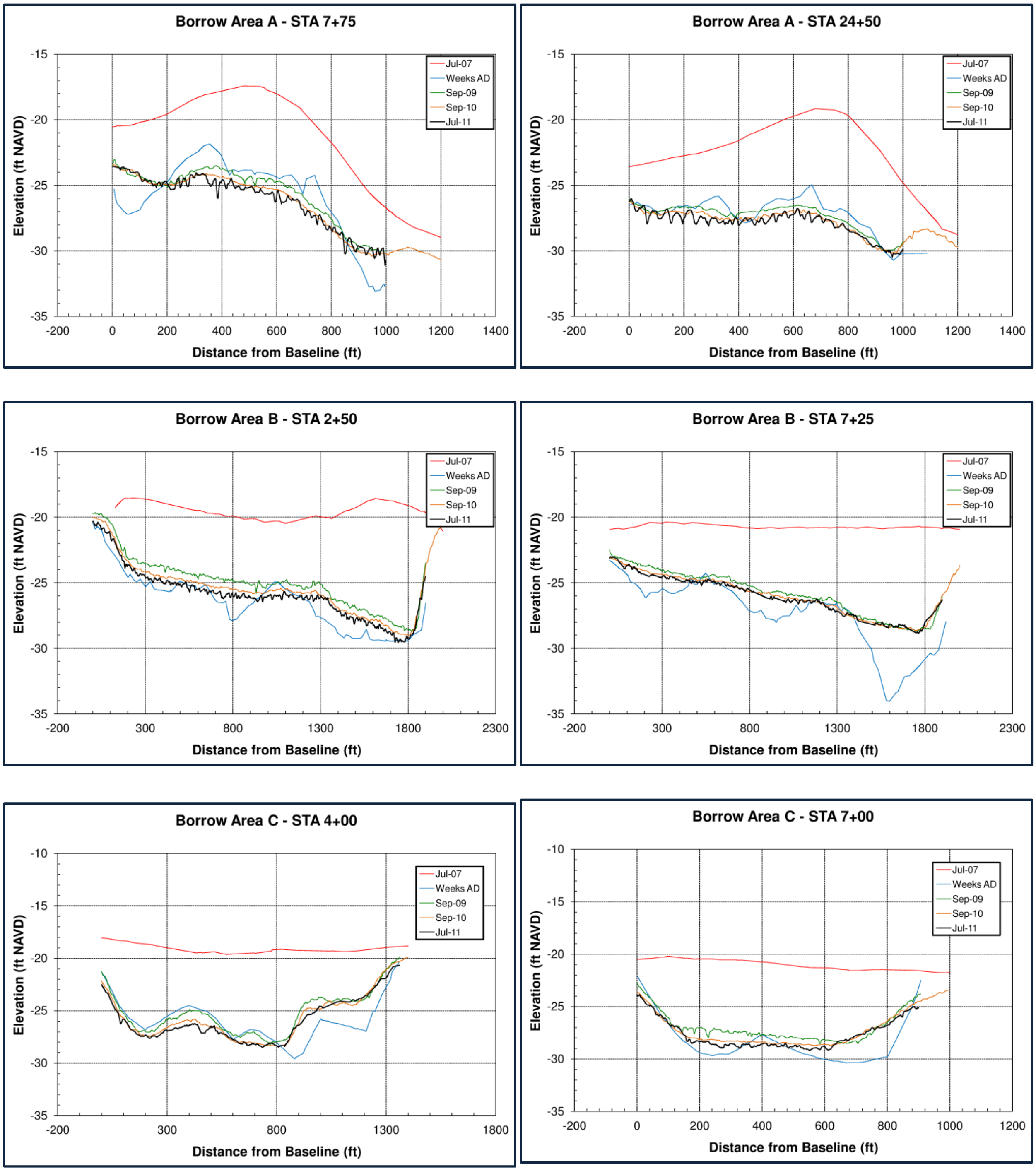


FIGURE 3.49. Profile sections of the three borrow areas used in the 2008 beach restoration project. Locations of profiles are shown in the DTMs of Figures 3.47 and 3.48. Note deeper portions have infilled, whereas some higher areas have eroded. Waves, currents, and gravity act to smooth the bathymetry which was left in an unnatural state after dredging. [AD = after dredging condition survey]

It is important to note that small surveying errors computed over a large area can yield volume changes in which the volume associated with the survey error can be much greater than actual volume changes. For example, a survey error of 0.5 ft results in volume changes of ~42,000 cy in Borrow Area A (51.8 acres). As depths increase, survey errors can be magnified due to changes in the speed of sound of seawater, salinity, turbidity, and waves. In general, infilling rates over a six-month time period are likely less than the overall potential survey error, which can make short-term changes difficult to determine. However, by computing longer term changes, survey errors are averaged out, and a better understanding of the total change is possible, assuming the profile is changing more than the relative survey error. CSE prefers to avoid adjusting data unless a clear pattern can be observed.

Sediment quality in the borrow areas is beyond the scope of the present report; however, it is addressed in biological monitoring reports prepared by CSA South Inc (CSA 2009). Generally, some fine material (mud) is accumulating in the dredged areas, likely inhibiting future use of each area for nourishment purposes. Sediment quality and topography will continue to change in the borrow areas, and future geotechnical studies would be needed prior to determining the potential suitability for re-use of any area.

*Sediment Quality**

Part of the post-project monitoring efforts included collection and analysis of surficial sediment samples over the length of IOP. These analyses track changes in the quality of the nourishment sand as the fill continues to adjust and be reworked by waves. Samples were collected immediately post-project in July 2008, then in July 2009 and July 2010. The 2009 and 2010 samples also included stations in the central and southern portions of the island. Samples were collected at five locations in the cross-shore direction (see Section 2 – Methods). Grain-size distribution and descriptive statistics for each sample collected in 2010 are given in Appendix D.

Prior to nourishment, CSE collected native beach samples in the project area for compatibility analyses with nourishment sediments. These results showed a native grain size of 0.253 millimeter (mm) with 11.1 percent (by weight) calcium carbonate ($CaCO_3$). Following nourishment, mean grain size increased to 0.384 mm in the project area (compared to 0.181 mm outside of the project area, Table 3.4). Average mean grain size has decreased since the project, with the 2011 mean grain size in the project area at 0.221 mm. Shell ($CaCO_3$) content increased to 25.2 percent following nourishment, but has since decreased to 7.7 percent in the project area.

[*Note: As of this draft, only half of the sediment samples had been completed. Numbers will be updated for the final report.]

TABLE 3.4. Sediment grain size and shell content for the post-project along with 1-year, 2-year, and 3-year post-project sediment samples. Both grain size and shell content in the project area have decreased since July 2008, becoming closer to the pre-project values.

IOP Post-Project Sediment Analysis		JUL 2008		JUL 2009		JUL 2010		JUN 2011	
		Mean (mm)	% $CaCO_3$	Mean (mm)	% $CaCO_3$	Mean (mm)	% $CaCO_3$	Mean (mm)	% $CaCO_3$
Dune	Non Project	0.164	4.2	0.195	3.0	0.190	3.0	0.178	2.6
	Project	0.455	24.5	0.269	7.4	0.235	8.0	0.205	3.2
Mid Berm	Non Project	0.170	2.7	0.213	3.8	0.189	3.4	0.177	3.4
	Project	0.482	31.1	0.359	24.4	0.307	18.6	0.241	8.4
Berm Crest	Non Project	0.175	2.8	0.210	5.1	0.191	3.2	0.182	3.2
	Project	0.408	29.4	0.268	8.4	0.268	13.6	0.218	8.0
Beach Face	Non Project	0.193	6.3	0.278	12.3	0.232	8.5	0.210	8.0
	Project	0.332	22.7	0.339	19.5	0.310	14.2	0.216	9.4
LTT	Non Project	0.201	10.4	0.231	11.5	0.182	8.5	0.192	6.2
	Project	0.246	18.1	0.198	9.6	0.205	11.5	0.227	9.5
Average	Non Project	0.181	5.3	0.225	7.1	0.197	5.3	0.188	4.7
	Project	0.384	25.2	0.287	13.9	0.265	13.2	0.221	7.7

In the project area, grain size was highest in the upper beach area (dune, mid berm, and berm crest) in July 2008 as wind-blown sand had not accumulated immediately after the project (Fig 3.50). Grain size decreased significantly in each of those areas by July 2009 and continued to decrease in the dune, mid berm, and berm crest through 2011. All portions of the beach profile show finer sand in 2011 than the post-nourishment condition. Finer sand in the upper beach is a result of accumulating wind-blown sediment, whereas finer sand along the beach face and low-tide terrace is a result of waves rearranging sediment to a natural distribution (and input of finer sand from shoal-bypass events). Coarser grained sizes are expected along the beach face, where wave energy is more focused for longer periods of time. The upper beach is expected to continue to become finer as more wind-blown sand accumulates and high waves and tides deposit finer material on the upper beach.

The initial increase in grain size and shell content was expected as the fill material was slightly coarser and contained a higher percentage of shell than the native material. The coarser fill was placed to prolong the life of the nourishment, since larger grain sizes are more slowly eroded (Dean 2002). Sediment characteristics would be expected to eventually stabilize in the project area. However, recurring shoal-bypass events introduce new sand into the system and redistribute sediment along the beach. Thus, sediment texture at any given location will be influenced by shoal-bypassing events as well as the nourishment project.

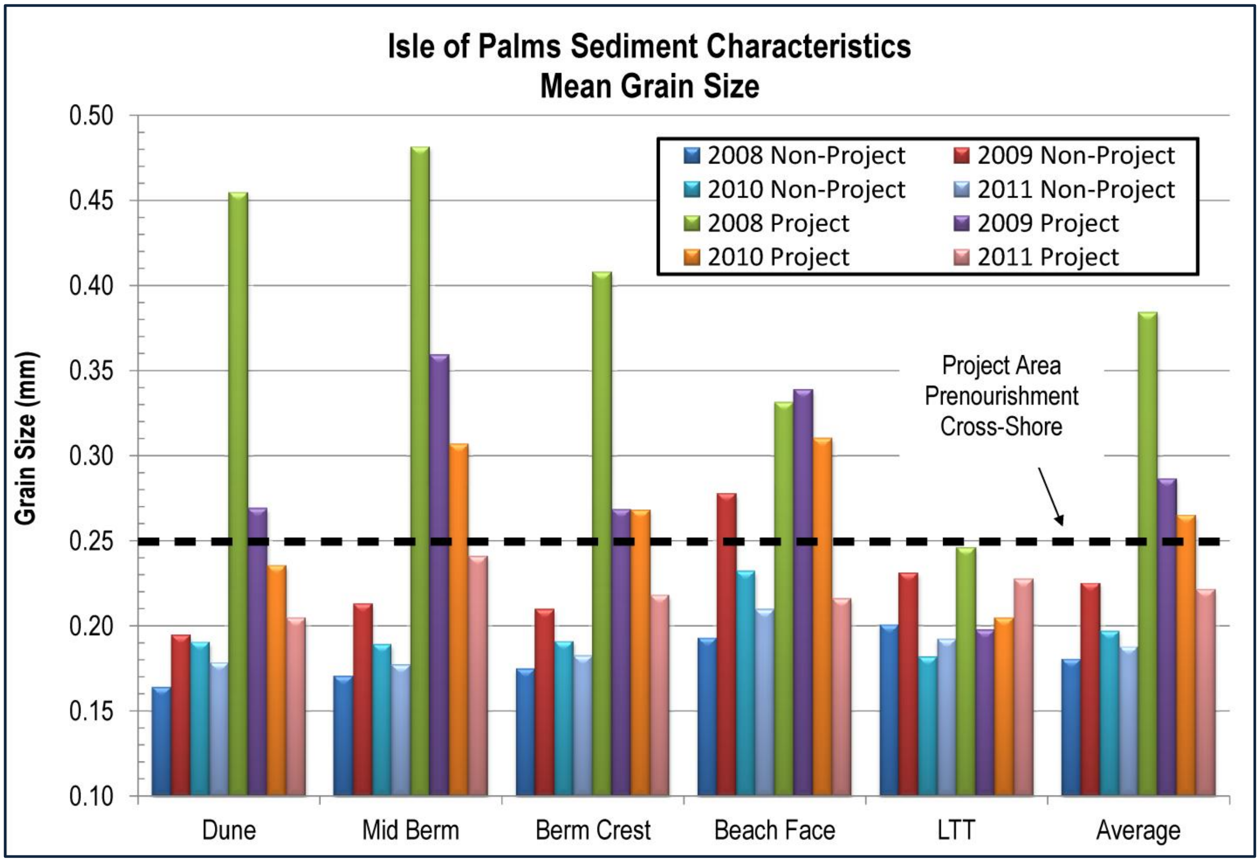
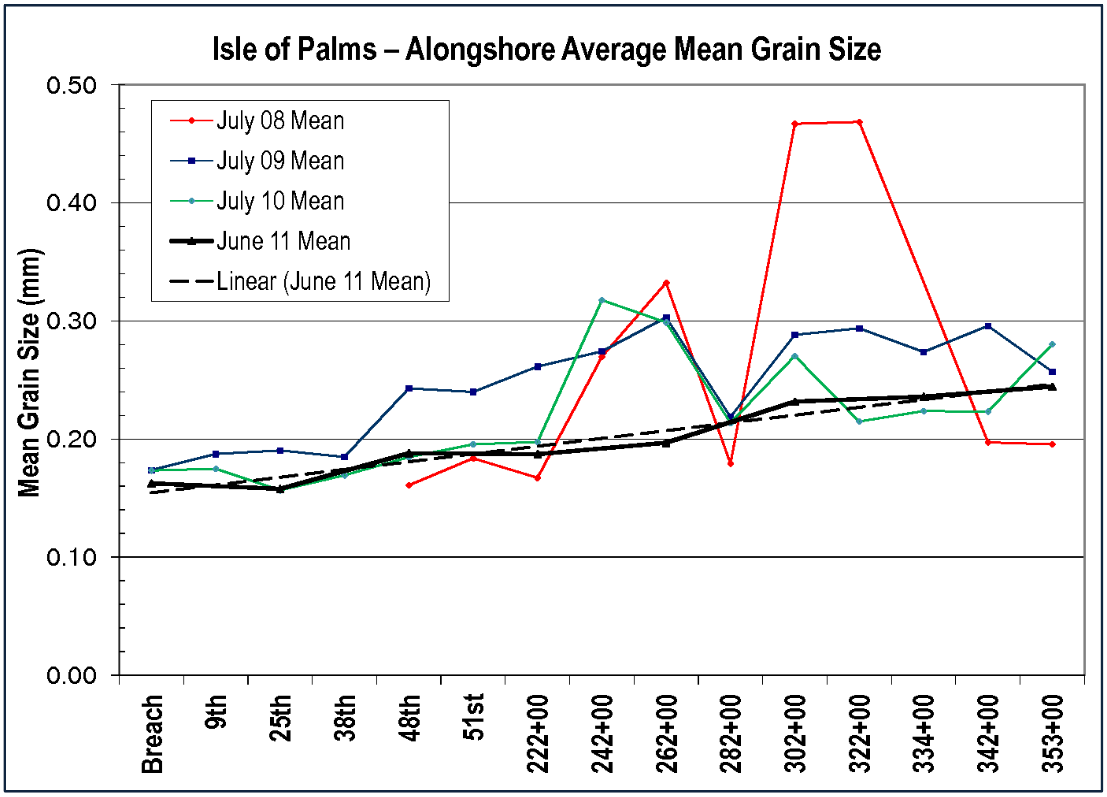


FIGURE 3.50. Cross-shore, grain-size distribution for Isle of Palms following the 2008 restoration project. Note how the upper beach (dune, mid berm, and berm crest) became finer between 2008 and 2009 and continues into 2011. This is an expected trend associated with accumulation of wind-blown sand. All cross-shore locations except the low-tide terrace (LTT) show a decreasing trend.

Figure 3.51 shows the distribution of grain sizes and shell content over the length of IOP. It is apparent from the graphs that grain size is coarser and shell content is higher at the northeastern end and tends to become finer in the downcoast direction (toward Breach Inlet). Finer grain sizes are more easily eroded and transported by wave action, and it follows that finer material can travel farther than coarser material under similar wave energy. The northeastern end is the sediment source for the rest of the island; therefore, finer material is eroded from the northeastern end and moves downcoast. Over time, it produces an alongshore gradient of mean grain size and shell content.

Compaction

The nourishment area was tilled in early July 2008, following completion of pumping. Tilling was required in several areas in 2010 and was performed by a local contractor. Compaction was measured again in early 2011 and results were submitted to USFWS. USFWS indicated that tilling would not be necessary in 2011. This was the final required compaction monitoring effort.



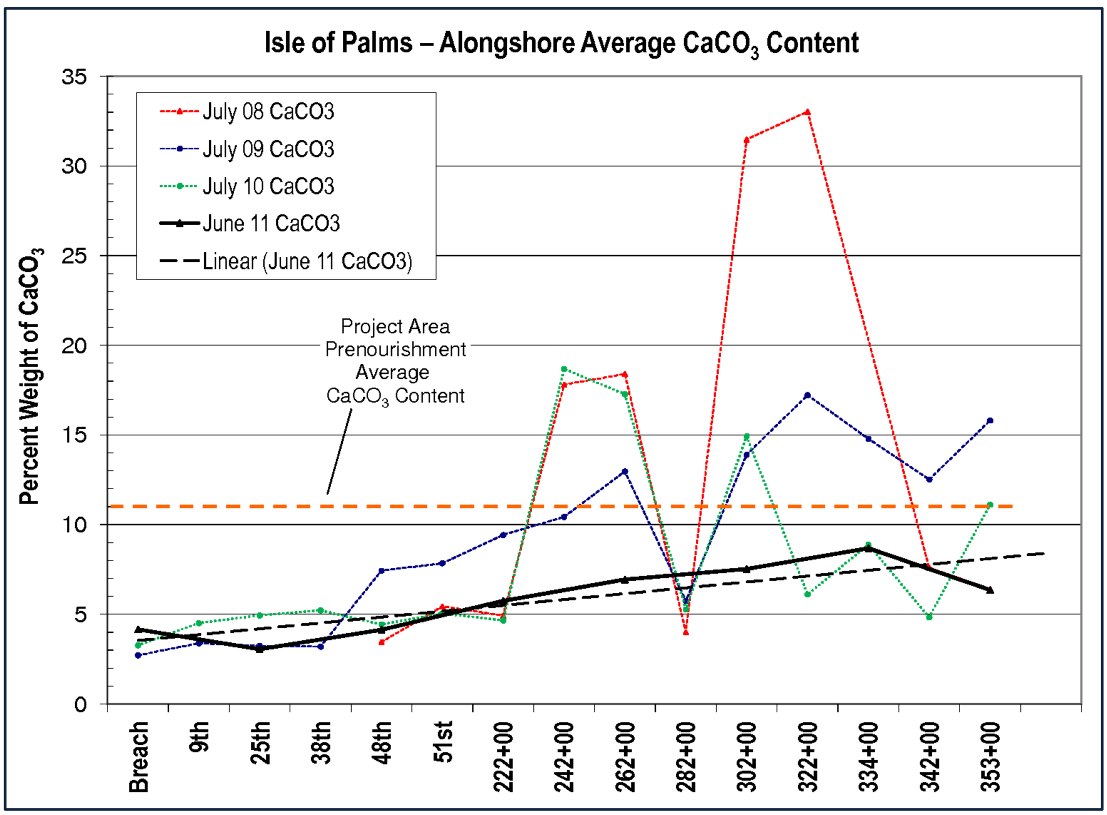


FIGURE 3.51. Alongshore distribution of average grain size (upper) and shell content (lower) (cross-shore average at each station). It is apparent from the graph that sediment becomes finer toward Breach Inlet. This is a function of nourishment sand being slightly coarser than the native sand supply as well as normal longshore transport of finer sand away from the northeastern end. This also results in the alongshore gradient in shell content.

3.7 Sand Fencing/Dune Growth

Installation of sand fencing was included in the project design in areas lacking existing dunes or vegetation. Installed in "v-shaped" sections spaced ~10 ft apart (Fig 3.52), fencing was placed in May 2009 between Beach Club Villas and Ocean Club as well as along the Dewees Inlet shoreline. Dune vegetation was also installed in a 15-ft-wide swath surrounding the fencing. Sand fencing aids in dune building by accumulating wind-blown sand. Vegetation also acts to block wind and accumulate sand. While vegetation would naturally spread to the nourished areas, which would then begin to build dunes, installation of the fencing and vegetation speeds the process. A desirable goal is to build a dune line along the back beach as high and wide as possible to provide storm protection to buildings. A secondary benefit is creation of habitat for beach organisms.

As of June 2011, the sand fencing had accumulated 2–3 ft of sand in many areas. The fencing is expected to continue to trap sand as long as the areas are fronted by an area of dry-sand beach and are not regularly impacted by overwash. It is very likely that natural vegetation and dune growth will occur in nourishment areas seaward of the fencing, where a large platform of dry berm is situated between the fencing and the normal high-tide limit. Portions of sand fencing were washed out near the 18th green during passage of Hurricane *Irene*.

FIGURE 3.52. **[LEFT]** Sand fencing in Reach 5 in June 2011. There is less dune growth in this area than in Reach 6. **[RIGHT]** Sand fencing and vegetation in Reach 6 from Ocean Club in August 2011 during Hurricane *Irene*. The +6-ft NAVD berm was overtopped; however, only the dune near the Ocean Club boardwalk showed any damage. The +8-ft NAVD storm berm was not overtopped.

In areas of the island already possessing dunes and/or vegetation (nourished and unnourished areas), natural dune building was evident in many of the profiles. Of particular interest is the area in front of the Wild Dunes Grand Pavilion, which has lower and narrower dunes than most other areas of the island. Profile 248+00 shows the dune grew ~0.5 ft between September 2010 and June 2011, and nearly 3 ft since March 2008—the pre-nourishment condition (Fig 3.53). Dune growth at this location may slow as sand fencing and vegetation located seaward of the present foredune become more established and intercept sand moving across the dry beach. It is preferable to allow natural dune building at the most landward portion of the dry beach possible. This will allow formation of a larger dune in a more stable area. CSE recommends evaluating future placement of fencing prior to installation to encourage maximum dune growth at stable locations.

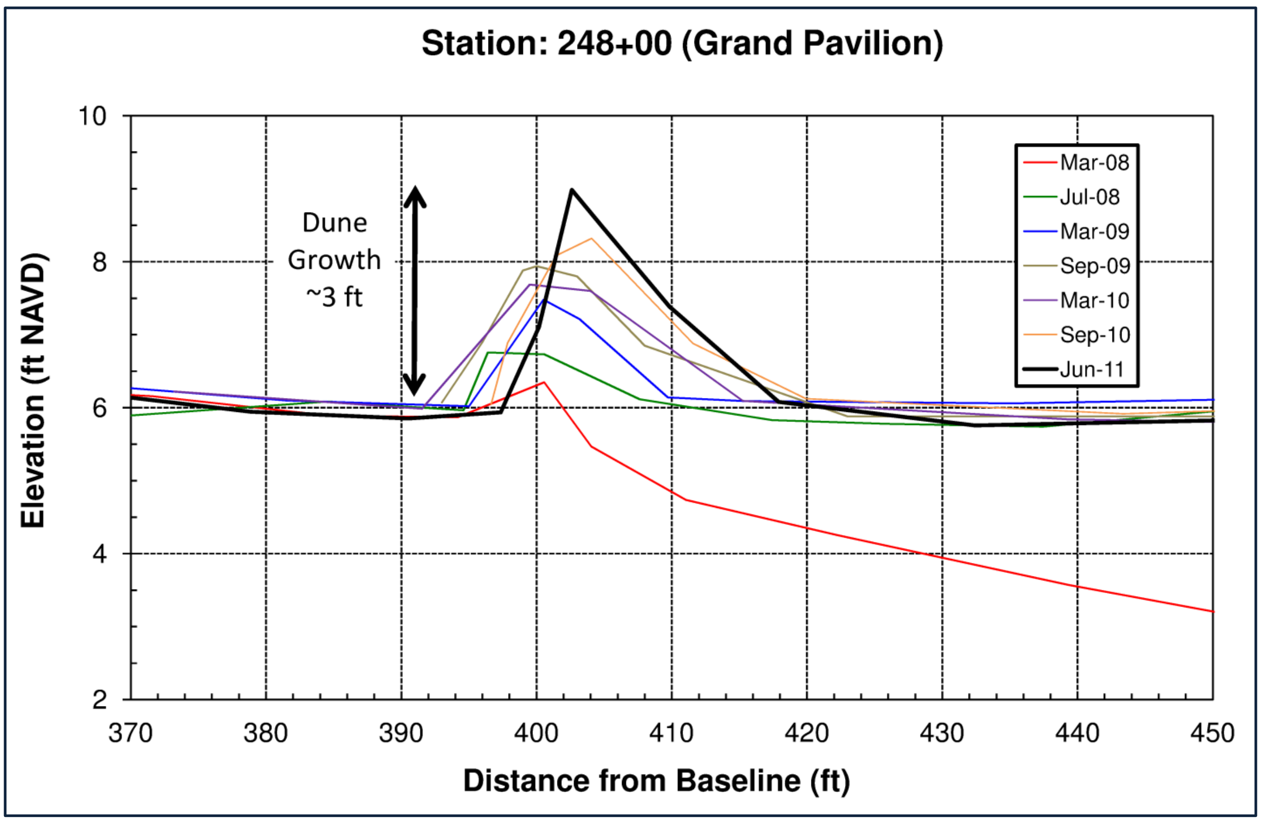


FIGURE 3.53. Evidence of dune growth at station 248+00 (adjacent to the Wild Dunes Grand Pavilion) following nourishment (May-June 2008). Elevation of the dune has increased ~3 ft naturally since the pre-project condition. Dune growth may slow in this area as the dune further seaward (at the sand fencing) becomes larger, intercepting more sand.

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4.0 DISCUSSION AND RECOMMENDATIONS

Monitoring efforts conducted before and after the 2008 beach restoration project at IOP show that the condition of the beach over the length of the island is dependent on the release of sand from the Dewees Inlet ebb-tidal delta. Periodically, sand in the downcoast portion of the delta is worked by waves into an exposed shoal, which then migrates landward until it attaches to the beach. The shoal acts as a breakwater, causing the beach to build out in its lee. Sand accumulation in the lee of the shoal is produced through erosion of sand from adjacent areas. This process accounts for rapid shoreline changes (often measuring several hundred feet) while the shoal is migrating to the beach.

While offshore, the shoals interrupt normal sediment transport to downcoast areas, leaving the rest of the island deprived of sand. Once attached, sand spreads to eroded areas, and longshore transport is restored to the rest of the island. The extreme erosion and accretion associated with shoal-bypass events is temporary. In the long term, each event adds sand to the system and is responsible for the historical accretion observed over the length of the island.

CSE has obtained seven detailed topographic data sets since 2007, when the severely eroded condition of the beach at the northeastern end of the island led the community to begin looking for a solution to the erosion problem. These data offer a detailed description of the morphology of the Dewees Inlet delta and changes in the size and position of the delta shoals. Surveys of the inlet are the key prerequisite for prediction of future changes along the beach at IOP.

Beach profiles, collected as part of the monitoring, detail volume changes in the 2008 project area before and after nourishment. They also provide analyses of the beach condition for the rest of the island, outside of the project area. The underlying theme suggested by the data is that while shoals are migrating onshore, erosion occurs in the adjacent areas, and sediment transport to downcoast areas is interrupted. Once attached, sand from the shoal restores eroded areas, and sediment transport is restored to downcoast areas.

Significant findings of the present report are highlighted as follows:

- Isle of Palms lost ~155,000 cy (4.2 cy/ft) of sand between September 2010 and June 2011. Approximately 24,000 cy were lost from the area downcoast (south) of 53rd Avenue while ~131,000 cy were lost north of 53rd Avenue.

- Erosional hotspots occurred near Beachwood East (stations 262+00 through 272+00), the shoal attachment area near Beach Club Villas, and along the seaward facing portion of the 18th fairway of the Links Course.

- No new emergent shoals are visible and presently attaching to the beach following attachment of a small shoal in September 2010; however, the sand platform extending from the beach remains a dominant underwater feature. It is expected to provide an ongoing sand source for more shoal-bypassing events in the next several years as the terminal lobe of the old channel collapses.

- The outer shoal of the 2007 Dewees Inlet main channel is beginning to merge with the existing sand platform attached to the beach and has essentially closed the old main channel. Landward migration of the outer shoal increased since September 2010 with the shoal moving ~500 ft closer to the beach as of June 2011. It is clear that a channel avulsion event is occurring, and a large quantity of sand is in the process of migrating toward the beach.

- It is presently unclear how the channel avulsion event compares to a similar event observed in the 1940s–1950s. It is possible that major morphological changes including formation of a barrier beach/lagoon system around the northeastern end of IOP may occur over the next decade as a new inlet channel matures.

- Breach Inlet is also undergoing a channel avulsion event, with the old main channel essentially cut off (infilled) and the new channel oriented more perpendicular to the shoreline. This may be contributing to erosion along the IOP beach near Breach Inlet. Migrating sand from IOP will be deposited along the terminus of the new channel and will form a terminal lobe (much like what is occurring at Dewees Inlet). No long-term negative impacts are expected along the IOP shoreline.

- Presently, ~775 ft of shoreline meet the 100-ft trigger for initiation of a sand redistribution project. The area begins at the Ocean Club building and extends to the 18th fairway. As of June 2011, there are ~155,000 cy above −3 ft NAVD and beyond the 400-ft buffer limit in the proposed borrow area.

The present monitoring effort focused on changes in the shoals of Dewees Inlet and Breach Inlet. CSE's surveys involved closely spaced transects in these areas so that DTMs (contour maps) could be developed. Seven detailed maps (see Figs 3.36–3.39) of Dewees Inlet (encompassing the period July 2007 to June 2011) confirm the changes described above.

Few inlets in the United States have been surveyed in such detail to document rates of change in the shoals and channels of ebb-tidal deltas. CSE surveys on the updrift side of Breach Inlet similarly provide clearer evidence of channel shifts that encroach on IOP or that release sand bars for migration and attachment to the beach.

CSE's 2011 surveys confirm that:

- About 66 percent of the nourishment volume remains within the fill placement limits. Much of the "lost" volume is accounted for in the buildup downcoast. This represents a loss of 11.6 percent per year.

- North of 53rd Avenue, the beach ranged between severe erosion and substantial accretion. Erosion was likely due to downcoast movement of sand from the project area (end losses) and spreading of sand recently added by a series of shoal attachments since 2004.

- Opposite to the historical trend, areas south of 53rd Avenue have lost sand since 2010. Overall, total volume losses over the beach south of 53rd Avenue were minor (1.1 cy/ft). All areas south of 53rd Avenue possess substantial setbacks and are protected from minor storm events. [Note: A major storm like Hurricane *Hugo* would overtop the beach and penetrate into development areas. The extra beach width created by the nourishment project would lessen, but not eliminate, the impact of storm surges.]

CSE believes that wave propagation through the new main channel toward Ocean Club, the 18th hole, and nearby areas will change in relation to channel development and the evolution of the new outer bar. The combination of wave refraction around the shoal platform off the Wild Dunes Property Owners Beach House and wave diffraction through the secondary channel are the underlying reasons for irregular shoreline changes along Wild Dunes. Variations in wave energy and sediment transport inside the Dewees Inlet ebb-tidal delta are the root cause of the erosion and deposition patterns observed in this area of coast over the past 30 years. Any mitigation measures for dealing with short-term erosion events should seek to work in concert with the controlling wave and sediment-transport processes, recognizing that some of the natural controls dwarf all emergency beach restoration measures to date.

Status of Permit Compliance Measures

Borrow area surveys were completed in March and September of 2009 and 2010, and in June 2011. Results are included in this report and will be submitted to US Army Corps of Engineers (USACE) and National Marine Fisheries Service (NMFS).

Beach compaction measurements were taken, and results were submitted to US Army Corps of Engineers and US Fish and Wildlife Service. The beach did not need to be tilled.

Benthic surveys of the beach and offshore were discontinued in 2009 at the suggestion of resource agencies. Results of all surveys to that point were submitted to agencies. The City has fulfilled its obligations regarding benthic surveying associated with the 2008 nourishment project.

With submission of this report, the City will have fulfilled all permit compliance measures associated with the 2008 nourishment project.

Recommendations

CSE recommends that the City move forward with a shoal-management project after receipt of the USACE permit, assuming permit conditions are met prior to construction. Specific volumes and borrow/fill locations will need to be determined based on a new condition survey of the area of concern during final design. As of this writing, the City has a permit from SCDHEC–OCRM and is awaiting a permit from the USACE.

The City should continue monitoring efforts similar to what are presented in this document. As the channel-avulsion event progresses, consideration should be given to increased monitoring of certain affected areas. Quarterly or semi-annual monitoring of the upper and intertidal beach and/or the underwater profile may be warranted if conditions change rapidly along portions of the beach as a result of shoal attachment.

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CSE's data collection and analyses were directed by Steven Traynum with assistance by Philip McKee, Trey Hair, and Tim Kana. Graphics were prepared by Trey Hair and Steven Traynum using AutoCAD®'s Civil 3D®, MATLAB®, and Global Mapper® for digital terrain models. The report was written by Steven Traynum and Dr. Timothy Kana (SC PG 564) with production assistance by Diana Sangster and Trey Hair.