2006 EAST END BEACH RESTORATION PROJECT
KIAWAH ISLAND SOUTH CAROLINA

Survey Report No 8

September 2015

Prepared for:

Town of Kiawah Island
South Carolina

COASTAL SCIENCE & ENGINEERING

2006 EAST END BEACH RESTORATION PROJECT

Kiawah Island – South Carolina

SURVEY REPORT NO 8

Annual Beach and Inshore Surveys

Prepared for:

21 Beachwalker Drive Kiawah Island SC 29455

Prepared by:

Coastal Science & Engineering

PO Box 8056 Columbia SC 29202-8056

[CSE 2392 YR8]
September 2015

COVER PHOTO: View landward into the lagoon on the east end of Kiawah Island (October 2014)

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

SYNOPSIS

This report is the eighth in a series of annual monitoring reports following the 2006 east end beach restoration project. It presents results of detailed surveys encompassing the oceanfront of Kiawah Island with particular focus on the area around the Ocean Course and Stono Inlet.

The Town of Kiawah Island sponsored the east end project at a cost of $3,575,000 for purposes of mitigating encroachment on the Ocean Course and restoring the sand flow to downcoast beaches. The flushing channel was closed and a new channel was opened to the east. About 550,000 cubic yards (cy) of sand were scraped from the new outer beach and were placed along the Ocean Course. [LD Weaver Construction Company was the contractor, and all work was performed by land-based equipment between 8 June and 28 July 2006, a schedule based on recommendations by the US Fish & Wildlife Service.]

In addition to the goal of restoring the flow of sand to downcoast areas of Kiawah Island, the east end project was designed to prolong washover habitat. This was accomplished by removing excess sand in some areas (and transferring it downcoast) before a stable dune line could become established with vegetation. Habitat monitoring showed that washover habitat increased in area by over 50 percent from 2006 to 2011 (CSE 2012).

Kiawah Island remains one of the healthiest beaches in South Carolina (Fig A). The results of shoreline monitoring and tracking the sand supply have provided new insight into the formation of barrier islands and rates of evolution of important habitats. Based on the results herein, the prognosis for the future is favorable for Kiawah's beach.

FIGURE A. Kiawah Island remains one of the healthiest beaches in South Carolina (September 2012 aerial).

TABLE OF CONTENTS

PAGE

— THIS PAGE INTENTIONALLY LEFT BLANK —

1.0 INTRODUCTION

This report is prepared as part of a series of annual beach monitoring reports following the east end restoration project completed in July 2006 (CSE 2005, 2007). The Town of Kiawah Island (SC) is sponsoring annual surveys of the sandy shoreline for purposes of determining the rates of sand movement, accretion, and erosion adjacent to the project area. This eighth report of the series follows over a dozen shoreline erosion reports prepared by Research Planning Institute (RPI) and Coastal Science & Engineering (CSE) for Kiawah Island since the 1980s (eg — Kana et al 1983, CSE 1999). Annual post-project surveys have been conducted in the fall of every year between 2007 and 2014.

The purpose of this report is to describe the current health of Kiawah Island as compared to past conditions. This involves documenting sand volume changes along the entire island (Captain Sams Inlet to Penny's Creek) to identify areas where the beach and dunes may be eroding or accreting. Annual monitoring provides a quantitative account of sand volume changes, which can then be used to infer sediment transport rates along the shoreline and predict future areas of concern before critical situations arise.

The scope of work for the annual monitoring effort includes:

- Ground surveys of the dunes, beach, and inshore zone.
- Oblique aerial photography
- Data analysis and production of a technical report describing beach volume changes.

The next section presents a brief description of Kiawah Island and its historical shoreline changes. A summary of the methods used during surveying and data analyses follows in Section 3. Section 4 includes the results of the survey. Section 5 presents a discussion of CSE's present findings and recommendations.

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

2.0 SETTING AND HISTORY

Kiawah Island continues to be one of the healthiest barrier islands in South Carolina. The addition of sand generated from Stono Inlet has led to stable dunes spanning the beachfront with only minor localized erosion in specific hot spots as sand migrates downcoast from Stono Inlet. The addition of sand through the process of inlet bypassing and the foresight of the island's developers to properly study the processes controlling the morphology of the island (Hayes et al 1975, Hayes 1977) make Kiawah Island an excellent example of beachfront development and a premier community along the South Carolina coast (Fig 2.1).

FIGURE 2.1. View east from Beachwalker Park in January 2014.

2.1 Geologic History of Kiawah Island

Kiawah Island has been studied in detail since 1974, when Professor Miles O. Hayes and colleagues at the University of South Carolina initiated field measurements and review of the geologic history of the island. Using Kiawah Island as a model, Hayes coined the term "drumstick" barrier island, which today commonly describes barrier islands of the South Carolina coast and other "mixed-energy settings" (Fig 2.2) (Hayes 1977, 1994; Hayes & Michel 2008). The oldest part of the island, adjacent to the Kiawah River, was found to be about 4,000 years old. The island's eastern end has prograded several thousand feet seaward since the mid 1800s, leading to the creation of parallel dune ridges, each representing the shoreline at the time it was created.

FIGURE 2.2. Barrier island drumstick model (after Hayes 1977) using Isle of Palms as an example. The upcoast end is wider due to additions of sand from shoal-bypass events in the inlet. Net transport to the south builds a spit at the downcoast end of the island.

The island is roughly 10 miles long, bounded by Stono Inlet to the east and Captain Sams Inlet to the west (Fig 2.3). The eastern end episodically gains sand by way of shoal-bypassing events (Williams & Kana 1986, Gaudiano 1998), and the sand eventually spreads to downcoast parts of the island until reaching Captain Sams Inlet, where it accumulates and forms Kiawah spit. These shoal-bypassing cycles are responsible for the continued growth of Kiawah Island, but can also cause temporary erosion, which will be discussed later. The geologic history of Kiawah and the processes controlling sand movement along the island are discussed in more detail in CSE (1999).

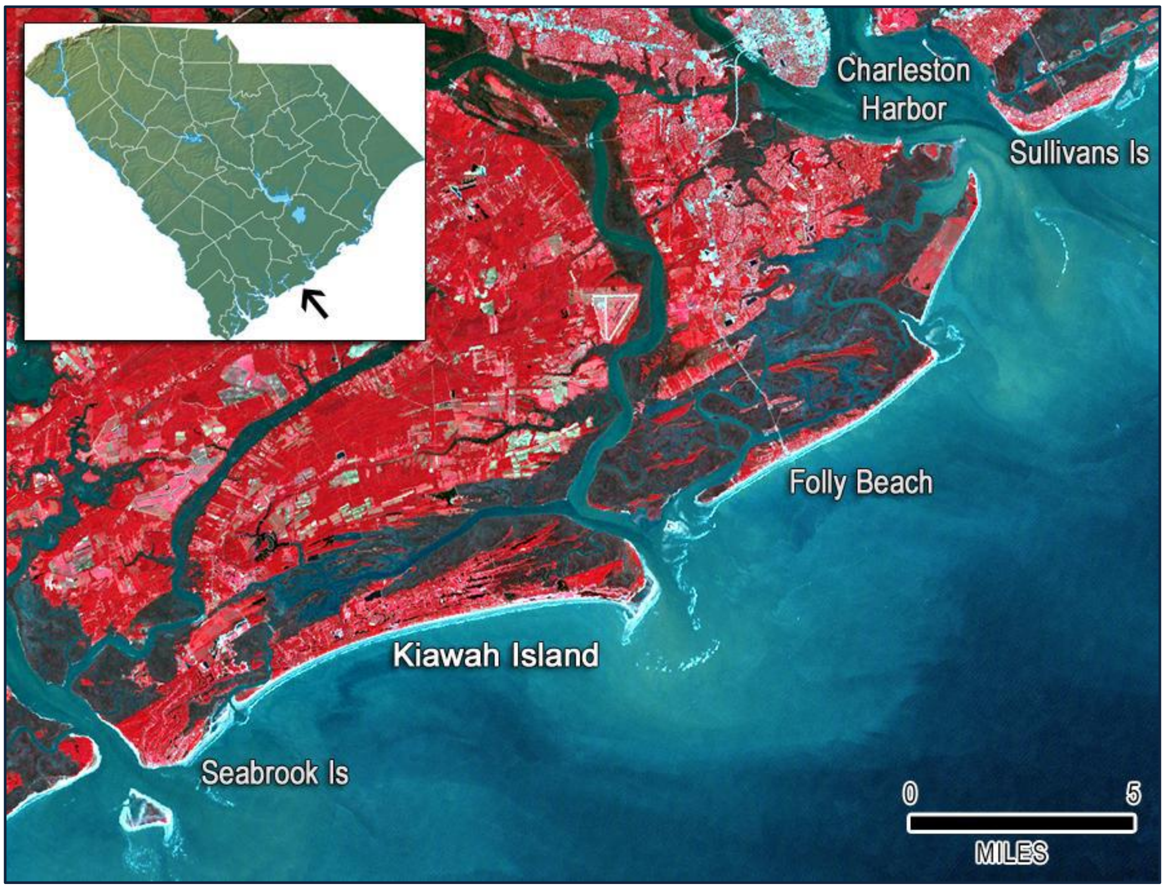


FIGURE 2.3. South Carolina coastline from Seabrook Island to Charleston Harbor. [Image courtesy Research Planning Inc and SCDNR]

2.2 Previous Shoreline Studies

The first shoreline assessment of Kiawah Island was performed by Hayes and his students in the early 1970s (Hayes et al 1975). Based on the geomorphology of the island, Hayes identified five zones along the beach and recommended two middle zones (West Beach and Turtle Point) as being suitable for development landward of the second dune ridge (Fig 2.4). The early development of the island was based on the findings of these studies, and it became one of the first localities in the State to implement rigorous setback lines.

From 1981 to 1987, regular monitoring efforts were conducted by Research Planning Institute Inc (RPI) and CSE (cf – Sexton et al 1981, Williams & Kana 1987). In July 1988, the Beach Management Act (BMA) of South Carolina was enacted, and by 1989, management of the State's beach monitoring programs was taken over by the State, ending CSE's involvement. In 1994, CSE was again contracted by the Town of Kiawah Island and conducted monitoring through 1999.

From 1981 through 1999, Kiawah Island either gained sand or remained stable. Specific areas showed sporadic erosion; however, the magnitude of sand loss was generally small. The West Beach area (encompassing Windswept Villas, Mariners Watch Villas, Eugenia Avenue, West Beach Village, and Kiawah Inn) remained stable, losing only 0.21 cubic yards per foot per year (cy/ft/yr) from 1983 until 1999 (with episodic accretion and erosion events). All other reaches showed gains in sand between 1983 and 1999. Details of volume changes from 1983 to 1999 are given in CSE (1999).

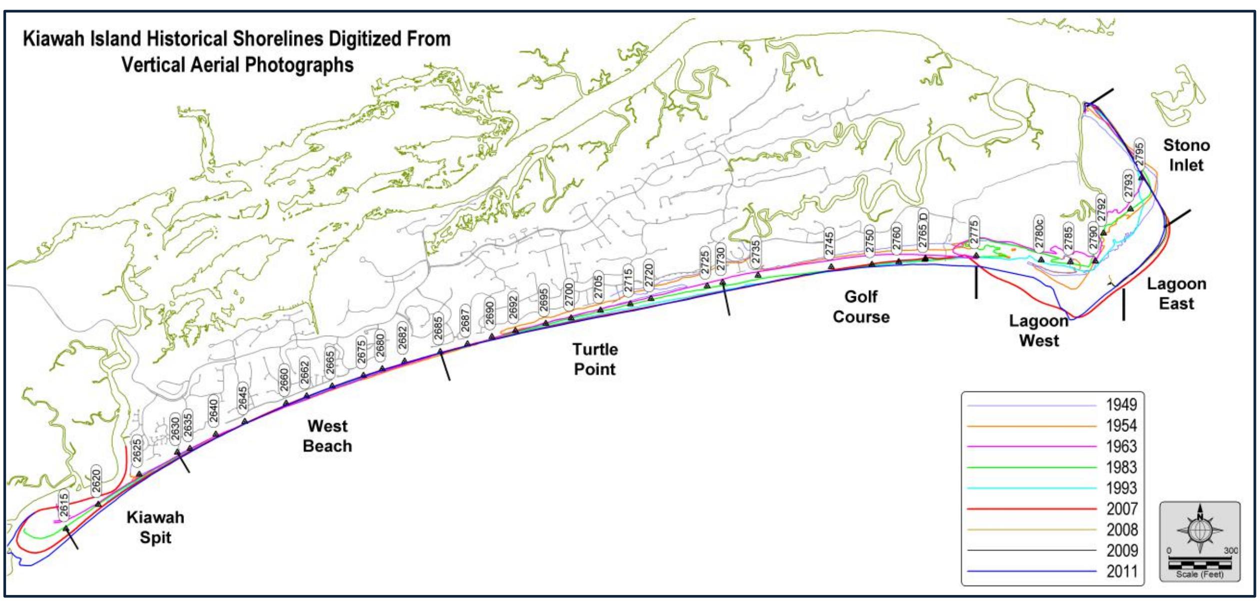


FIGURE 2.4. Historical shorelines (seaward vegetation lines). West Beach has been slightly erosional whereas all other reaches have been accretional since 1949. [Updated from CSE 1995]

Stono Inlet

Sand from Stono Inlet is the major littoral source for Kiawah Island (Kana et al 1981). Inlet ebb-tidal deltas often contain as much or more sand than the adjacent barrier islands along the southern two-thirds of the South Carolina coast (Sexton & Hayes 1996). In this mixed-energy environment (Hayes 1994), waves and tidal currents both have a significant impact on shaping the morphology of the inshore zone (Fig 2.5). Sand is moved seaward by strong ebb-tidal currents at the inlets. Waves then push deposited sand landward in the form of shoals. This produces characteristic features common to much of the central and southern South Carolina coast—such as lobate deltas extending miles offshore, marginal flood channels (small channels near the beach flanking the main channel and dominated by flood currents), and migrating shoals (cf – Figs 2.2 and 2.3).

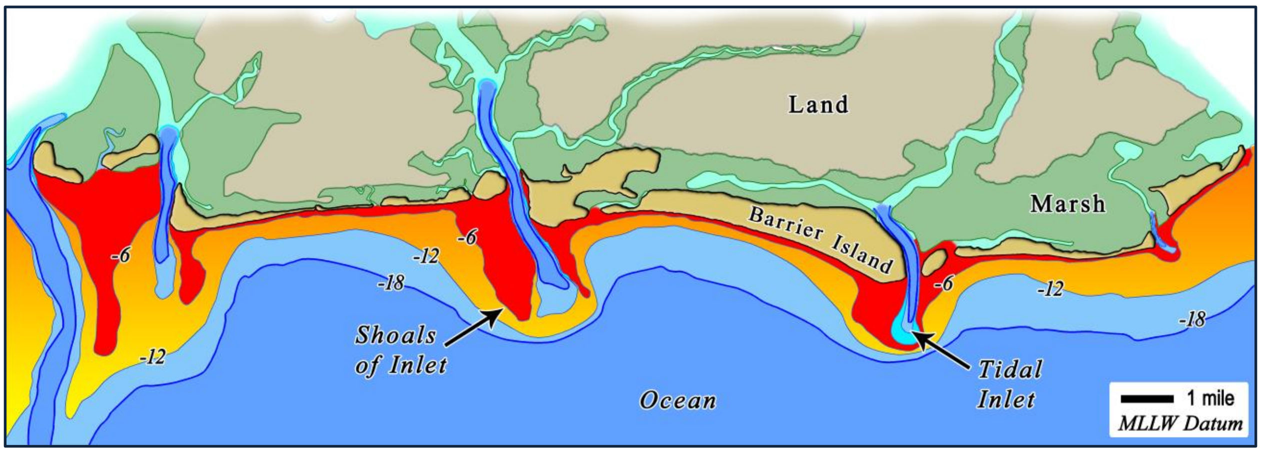


FIGURE 2.5. Nearshore bathymetry for a typical section of the central and southern South Carolina coast. Ebb-tidal deltas contain large amounts of sand, which alter the local bathymetry. This in turn directs wave energy and sediment transport patterns along the adjacent beaches. [From *Coastal Erosion and Solutions — A Primer* (Kana 2011) — CSE]

Periodically, sand stored in the ebb-tidal delta of Stono Inlet is released when the inlet channel shifts position. Shoals on the downcoast (west) side of the channel are freed from the delta and pushed shoreward by wave action. During this process, the beach in the lee of the shoal builds because of decreased wave energy Fig 2.6). Adjacent to the areas of accretion, erosional arcs are formed by changes in the wave patterns due to refraction around the offshore shoal. This process continues until waves have pushed the shoal to the point of attachment along the beach.

Once attached, the shoal is considered to be in Stage 3 of the shoal-bypass cycle (Kana et al 1985, Williams & Kana 1986). Waves continue to push the shoal landward and upward while spreading sand laterally along the beach. Shoal spreading (Stage 3) provides natural nourishment with sand moving downcoast via longshore currents.

THE THREE STAGES OF SHOAL BYPASSING

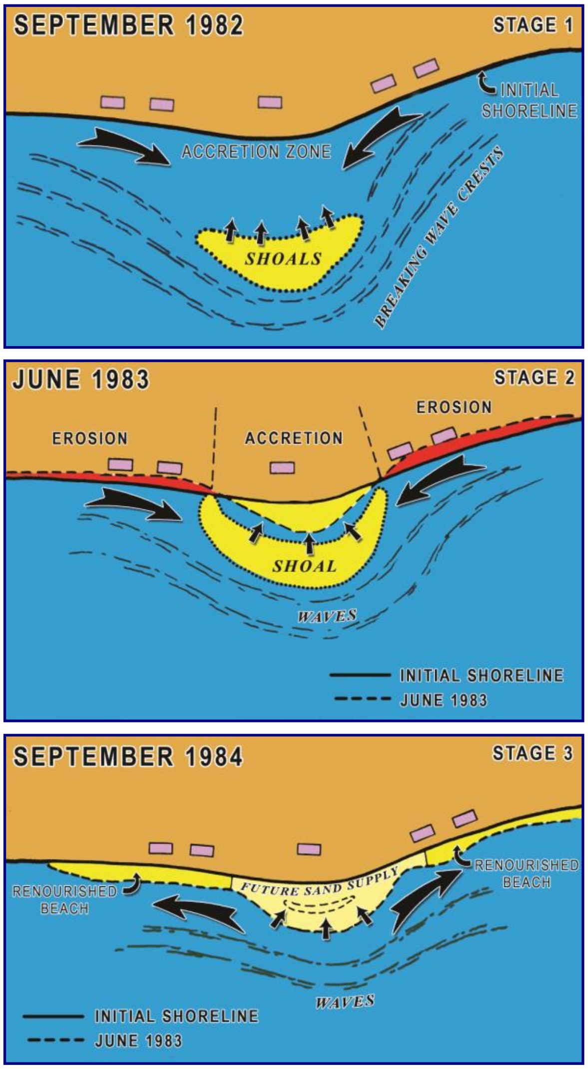


FIGURE 2.6

[LEFT]
Schematic of the shoal-bypass cycle originally modeled from a bypass event at Isle of Palms (SC). 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 bypassing at the east end of Kiawah Island.

Stage 1 in 1977 (upper). Stage 2 in January 1979 (upper middle) (courtesy of Research Planning Institute Inc). Stage 3 in 1983 (lower middle). Stage 1 in 1986 (lower). Note the similarity between the 1977 shoal and the 1986 shoal, but the additional sand accumulated on Kiawah in 1986. [After Kana et al 1999]

The time between release of the shoal by the inlet, and attachment and spreading depends on the size of the inlet and its ebb tidal delta. Large inlets, such as Stono Inlet, tend to initiate shoal-bypassing events every 7–8 years with individual shoal volumes often exceeding 0.5 million cubic yards (Gaudiano & Kana 2001).

Kiawah Island has recently experienced two impressively large shoal-bypassing events. The first formed offshore in 1994 and had completely attached to the eastern end of Kiawah by 1997. The second began attaching to Kiawah along its eastern flank in 1998. The western flank of the second shoal overlapped the eastern Kiawah shoreline as it built and migrated west and north between 1998 and 2004 (Fig 2.7). These two events were the largest ever documented on the South Carolina coast (CSE 2005). They contained such a large quantity of sand that wave action was not able to completely push the shoal against the original shoreline, and a new beach line and dune system were formed more than 2,000 feet (ft) seaward of the original shoreline. This created a lagoon between the new and old shorelines, along with a roughly 2-mile-long barrier beach (Fig 2.7). The recent shoal-bypass events showed how rapidly barrier islands can form, even in the presence of sea-level rise and other erosional forcing (Kana 2002).

By 2004, the shoals had completely attached at the eastern end but remained offshore at the western end as sand migrated westward, reaching near the (old) Ocean Course Clubhouse (Fig 2.7). The shoals had not completely attached at the western end due to a natural channel maintained by tidal flushing of the lagoon. CSE (2005) estimated the two shoals added ~5 million cubic yards to Kiawah Island. Due to the overwhelming quantity of sand added at the eastern end, the shoreline near the Ocean Course jumped seaward and changed orientation. This protrusion altered the direction of approaching waves and caused focused erosion along the Ocean Course.

As longshore transport moved the shoal westward, the flushing channel migrated with the shoal, encroaching on the Ocean Course, specifically the 16th and 18th holes. The beach at the original Ocean Course Clubhouse (near OCRM monument 2775) retreated over 500 ft between 2000 and 2005. The magnitude of the bypassing event was so great, it was apparent that severe erosion would continue for several years before the cycle would be complete (Gaudiano & Kana 2001). The Ocean Course remained vulnerable to erosion as the shoal and flushing channel migrated westward. This led to the plan for beach restoration by CSE (2005).

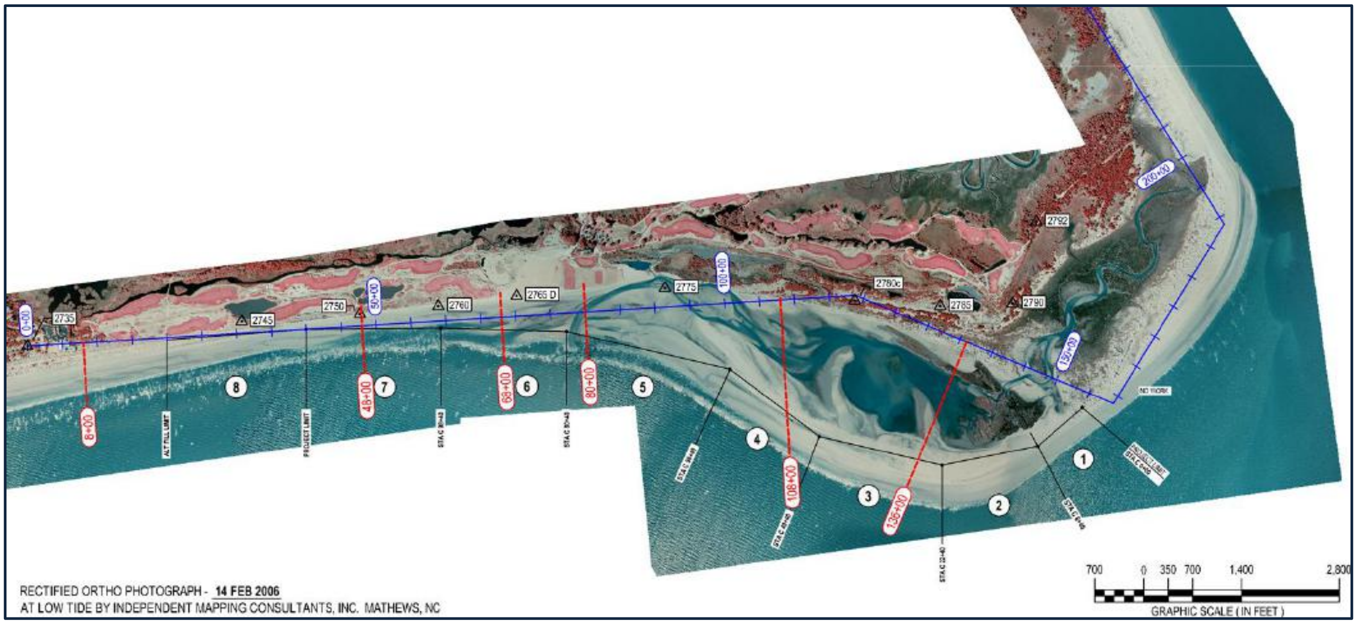
FIGURE 2.7. The eastern end of Kiawah Island in December 1998 (upper) and February 2005 (lower). Note the 1989 shoreline situated well inland from the outer beach. Shoals 1 and 2 added upward of 5 million cubic yards to Kiawah in the 1990s. As waves pushed the new sand shoreward, an incipient barrier island/lagoon/marsh formed. The new lagoon was flushed via a channel at the western end of the accreted beach. [From CSE 2007]

2.3 2006 East End Beach Restoration Project

In June and July of 2006, the east end beach restoration project (SCDHEC–OCRM permit No P/N 2005-1W-310-P, USACE permit No 2005-1W-310) was completed by L. Dean Weaver Company Inc. This project sought to artificially create Stage 3 of the shoal-bypassing cycle and avoid further erosion of the Ocean Course. The details of the project are given in the *2006 East End Erosion and Beach Restoration Project: Kiawah Island Final Report* (CSE 2007). The objectives of the project were to:

- Accelerate the shoal-bypassing cycle so as to restore westerly sand transport along Kiawah Island.
- Eliminate rapid erosion along the Ocean Course, particularly around the 16th, 17th, and 18th fairways and the driving range.
- Maintain viable, piping plover beach habitat along the newly accreted barrier spit east of the Ocean Course, including areas of frequent washovers and the adjacent incipient dune habitat.
- Preserve the environmental, cultural, and aquatic resources of the Town.
- Provide protection to oceanfront recreational facilities and community infrastructure as a resource of tax revenue and income.
- Maintain the economic viability of tourism, the Town's largest industry.
- Make a new source of sand from the accreting shoal more readily available for natural nourishment along downcoast areas.

The project consisted of closure of the existing flushing channel, creation of a new channel to maintain the tidal environment of the lagoon, and excavation and transfer of nourishment sand from the new inlet and accreted shoal areas to eroded downcoast areas. These actions were designed to provide a smoother transition between Kiawah's main beach and the accreted shoal. The contracted volume for the project was 550,000 cubic yards (cy), the majority of which was placed between the new clubhouse and just west of the old flushing channel. The new flushing channel was positioned at the apex of the attached shoal in Reach "1" (Fig 2.8).



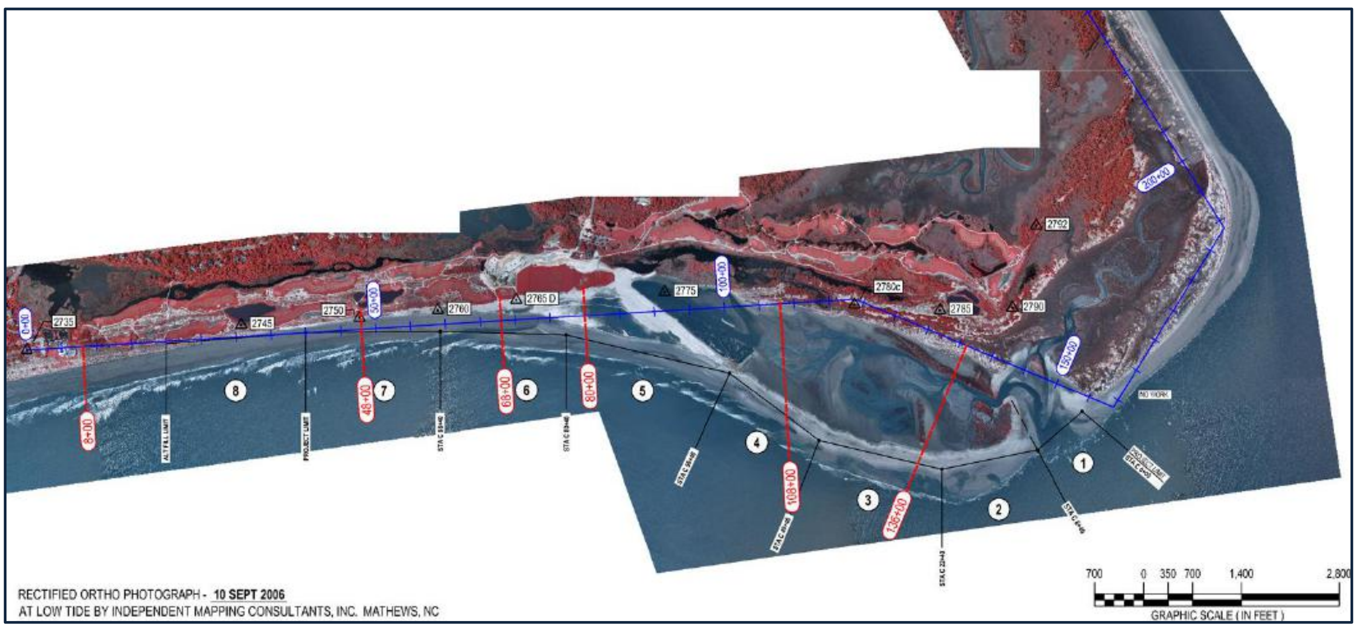


FIGURE 2.8. Rectified aerial photos of the project area showing pre-construction (February 2006, upper) and post-construction (September 2006, lower). The channel in Reach 5 was closed, and a new channel was constructed in Reach 1. Sand from Reach 1 to Reach 4 was excavated and transferred to Reaches 5–7.

A major goal of the project was to maintain habitat for piping plovers, which migrate to the area in early fall and utilize the area for foraging through the spring. Piping plovers make use of washover areas with little vegetation, particularly where the habitat is adjacent to sheltered tidal flats (M Bimbi, pers comm, April 2006). To maximize habitat, elevations along the new outer beach were maintained below +4.5 ft NAVD. This elevation allows frequent overtopping by waves during minor storm events. As recommended by the US Fish & Wildlife Service (USFWS), yearly monitoring of critical habitat for piping plovers was incorporated into the project and is being supervised by staff biologists for the Town of Kiawah Island.

In 2007, the constructed flushing channel naturally closed while a new flushing channel opened in Reach 4 (Fig 2.9). Several factors potentially led to the closure of the original flushing channel. The emergence of an offshore shoal to the west of the channel caused wave-focusing and significant erosion to the shoreline in the vicinity of the constructed channel. Sand lost from the dunes adjacent to the channel was deposited in and behind the channel. By September 2007, the constructed channel had completely infilled, and a new flushing channel had opened in Reach 4 (see Fig 2.8 for construction reach boundaries). The low elevations of the outer beach in Reaches 2–4 (intended to maintain washover habitat) left that reach susceptible to a breach. The new channel location provided a more efficient path for tidal flow. The emergent shoal off Reach 2 also increased the likelihood of a breach in Reach 4 because of wave-focusing around the sand bar.

The opening of the breach channel in Reach 4 was not surprising given that the goal of the project was to maintain washover habitat. By limiting the outer beach to a height less than storm tides and reducing the volume of sand in the profile so as to prolong the washover habitat, the project allowed the system to develop a channel in a more efficient location. The inlet of the new channel intersected monitoring station 104+00. It was ~75 ft wide at mean low water (MLW) at its narrowest point, and ~600 ft wide at mean higher high water (MHHW); however, at high tide, much of the area was subject to washover, and flow was not restricted through the inlet.

Between August 2009 and April 2010, the flushing channel had relocated ~2,500 ft to the east. This was facilitated by erosion of the outer barrier due to the most recent shoal-bypass event. This erosion left relatively little sand volume on the outer beach, making it susceptible to breaching. Southerly migration of the old channel was also inhibited by large sand volumes in the closure dike area. Section 4 contains details of the evolution of the lagoon along with pre-project and post-project changes in sand volumes and habitat areas.

FIGURE 2.9.

[UPPER]
Aerial view of the outer beach in the project area between Reaches 1 and 4 on 17 February 2007. Note shoaled flushing channel at right side of image (Reach 1).

[LOWER]
The same area at low tide on 5 December 2007 after formation of a breach channel in Reach 4 and natural closure of the constructed channel.

3.0 METHODOLOGY

This section describes the methodologies of the topographic survey and habitat mapping used by CSE to monitor changes at Kiawah Island.

3.1 Survey

The present survey was conducted by RTK-GPS* (Trimble™ R8 GNSS system) in early October 2014. Profiles along Kiawah Island were surveyed perpendicular to the local shoreline (CSE baseline) azimuth from the control points to a minimum of −12 ft NAVD (the depth equal to the normal limit of sand movement in this setting) or at least 3,000 ft from the dune. Surveys were conducted by combining a land-based survey and a bathymetric survey (Fig 3.1). Land surveys were accomplished using an RTK-GPS between the foredune and low-tide wading depth [(~)−6 ft NAVD], whereas overwater work was accomplished via RTK-GPS combined with a precision echo-sounder mounted on CSE's shallow-draft boat, the *RV Southern Echo*.

*[*Real-time kinematic global positioning system]*

FIGURE 3.1.

CSE's monitoring methods include land-based data collection via RTK-GPS (upper left) and hydrographic data collection via RTK-GPS linked to a precision echo-sounder.

CSE's shallow-draft vessel the *R/V Southern Echo* is shown in the lower image.

Working around the tidal cycle, data collected on land were extended into shallow depths in the surf zone at low tide. Then data were collected from the boat at high tide such that overlap of the two surveys occurred close to shore (Fig 3.2). Appendix A includes profiles for the most recent survey compared to earlier surveys. CSE has updated profile sheets to include profile volume and aerial images showing profile locations.

The 2014 survey represents the third survey of the Kiawah Island beach since satisfactory completion of project-required monitoring in 2011. At the request of the Town, CSE modified the scope of services for the 2012 and future monitoring to reduce overall costs while providing more detail of the beach condition west of the project area. Surveys conducted from 2007 to 2011 involved 23 stations west of the project area (using existing OCRM monuments spaced ~1,000 to 2,500 ft apart) and 64 stations in the project area spaced 400 ft apart. The present baseline reduces the maximum spacing in the downcoast profiles to ~1,000 ft. CSE also reduced the total number of lines in the project area from 64 to 24 by increasing the spacing from 400 ft to 1,000–1,200 ft. The baseline was also modified at the east end to reduce the number of turns in the baseline and to simplify volume calculations.

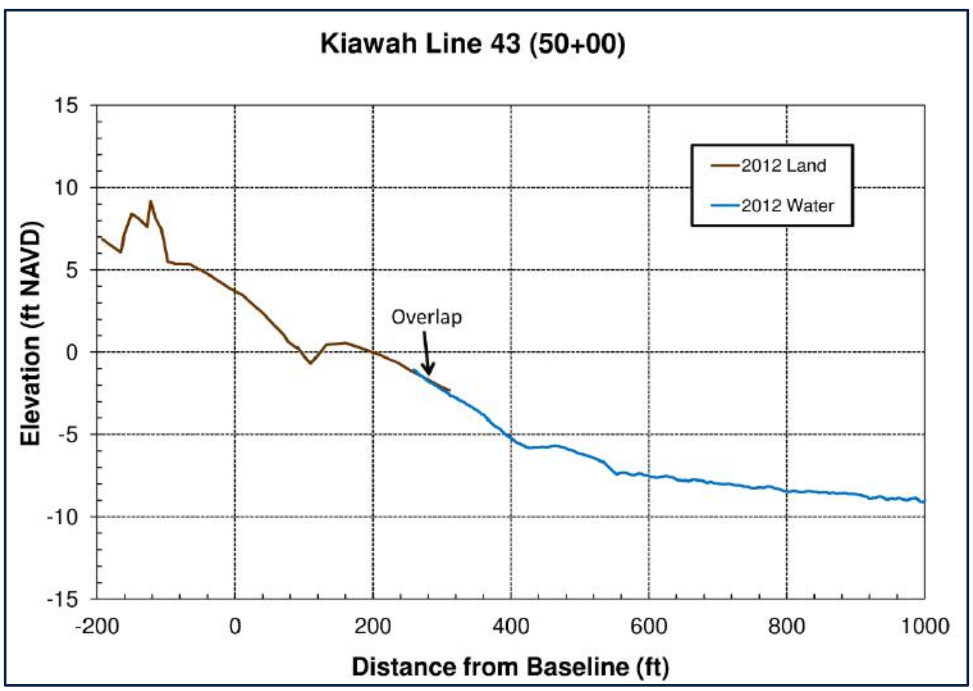


FIGURE 3.2. CSE combines land-based and hydrographic data collection to produce continuous profiles of the beach. Land-based work is accomplished at low tide, while hydrographic work is performed at high tide. This allows for overlap of the two data collection methods and ensures quality data and a complete profile.

The present baseline is comprised of 61 profiles with lines 1–37 representing the shoreline west of the 2006 project area and lines 38–61 representing the project area and east end of the island (Table 3.1). The baseline is shown in Figure 3.3. Line numbering increases from west to east—Line 1 is at Captain Sams Inlet ~1.2 miles southwest of the Beachwalker Park vehicle access. Line 61 is at the tip of the sand spit at the junction of the Stono River and Penny's Creek. OCRM monument names and CSE project stationing are indicated where the new profile lines coincide with previous stations (ie — Line 35 is OCRM station 2725). The current reaches (Fig 3.3) are defined in Table 3.2.

Volume calculations for the lagoon were obtained via digital terrain models (DTMs) produced from CSE survey data. This eliminates the need for volume adjustments due to differing baseline and beach configurations, but does not provide the detailed comparative profiles between earlier surveys and the new data. Rather than comparing repetitive survey lines, the DTMs allow for generation of "sections," which are interpolated depictions of the beach profiles. These can be produced for multiple surveys to determine beach condition changes.

3.2 Volume Calculations

To estimate changes in the sand volume along Kiawah Island, survey data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which calculates volumes based on 2-D profile data (in x–y format) and distances between subsequent lines. The resulting volumes provide a more quantitative and objective way of determining beach condition, including the ideal minimum beach profile and how sand quantities at a site (volume per unit length of shoreline) compare with the desired condition (Kana 1993). Volume results calculated via this method integrate all the small-scale perturbations across the beach and yield a simple measure of its condition which is less susceptible to seasonal fluctuations in the profile, a problem with shoreline change studies that are based on movement of a single contour.

Unit-volume calculations allow for distinguishing 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 3.4 depicts the profile volume concept. The reference boundaries are site-specific but ideally encompass the entire zone over which sand moves each year—dune to the depth of closure (DOC*), which is the depth of water where little sand movement to or from the beach occurs. [**DOC is the depth beyond which there is negligible change in bottom elevation.*]

TABLE 3.1. Kiawah Island beach monitoring stations referenced in the present report. Order is generally west to east. Offset and cutoff refer to distances from the benchmark/baseline for the start and end of beach volume calculations.

Line	Reach	Name	Offset	Cutoff	Distance to Next	Easting	Northing	Line	Reach	Name	Offset	Cutoff	Distance to Next	Easting	Northing
1			-200	2,500	1,000	2262721.7	271034.2	32		OCRM 2720	208	1,500	645	2289526.0	282752.7
2			300	2,500	997	2263451.4	271718.0	33			309	1,700	646	2290143.9	282937.6
3			250	2,500	1,153	2264178.6	272399.3	34	3	OCRM 2722	436	1,600	1,125	2290763.1	283122.9
4		OCRM 2615	140	1,500	844	2265064.0	273138.6	35		OCRM 2725	322	1,600	666	2291875.6	283288.9
5	1		93	2,500	845	2265739.8	273644.8	36		OCRM 2730	316	1,600	666	2292526.8	283430.6
6		OCRM 2620	86	1,500	1,157	2266414.9	274152.4	37			319	1,700	752	2293263.8	283580.0
7			28	2,500	978	2267397.7	274763.4	38		0+00	320	1,600	1,000	2294001.1	283729.5
8		OCRM 2625	189	1,500	1,040	2268125.0	275417.0	39		10+00	165	1,700	1,000	2294999.2	283790.2
9			92	1,500	806	2269055.6	275882.0	40		20+00	30	1,500	1,000	2295997.4	283850.9
10		OCRM 2630	152	1,500	547	2269723.8	276332.8	41		30+00	-55	1,500	1,000	2296995.5	283911.6
11		OCRM 2635	41	1,500	1,232	2270247.2	276490.7	42	4	40+00	-120	1,500	1,000	2297993.6	283972.3
12		OCRM 2640	94	1,500	665	2271326.8	277083.3	43		50+00	-219	1,500	1,000	2298991.7	284033.0
13			67	1,400	665	2271935.3	277351.5	44		60+00	-295	1,500	1,000	2299989.8	284093.8
14		OCRM 2645	47	1,200	945	2272543.9	277619.7	45		70+00	-370	1,500	1,000	2300988.0	284154.5
15			27	1,400	946	2273408.4	278001.2	46		80+00	-300	1,500	1,000	2301986.1	284215.2
16	2	OCRM 2660	28	1,100	1,025	2274273.9	278383.2	47		90+00	-374	1,800	1,000	2302984.2	284275.9
17			15	1,400	1,026	2275234.5	278740.9	48		100+00	-250	2,000	1,000	2303982.3	284336.6
18		OCRM 2665	22	1,000	691	2276196.1	279099.0	49		110+00	0	2,500	1,000	2304980.4	284397.3
19			12	1,400	692	2276850.6	279320.6	50		120+00	350	3,200	1,000	2305978.6	284458.0
20		OCRM 2675	0	1,100	831	2277505.6	279542.3	51	5	130+00	780	3,500	1,000	2306976.7	284518.8
21		OCRM 2680	46	1,300	1,266	2278288.1	279822.4	52		140+00	615	3,500	1,000	2307974.8	284579.5
22			16	1,400	1,627	2279502.6	280179.9	53		150+00	0	2,800	1,000	2308972.9	284640.2
23		OCRM 2685	10	1,200	1,033	2280718.1	280537.6	54		160+00	0	1,500	1,000	2309971.0	284700.9
24		OCRM 2687	40	1,500	1,215	2281707.1	280837.2	55		170+00	-775	1,000	0	2310969.2	284761.6
25		OCRM 2690	93	1,300	1,145	2282876.3	281167.0	56		Inlet 0+00	540	1,300	1,200	2310528.3	285452.3
26		OCRM 2692	279	1,500	1,205	2283935.3	281602.5	57		Inlet 12+00	805	1,420	1,200	2309882.6	286463.7
27	3	OCRM 2695	119	1,400	1,080	2285131.1	281719.2	58	6	Inlet 24+00	920	1,420	1,200	2309237.0	287475.2
28		OCRM 2700	100	1,400	1,269	2286187.8	281943.8	59		Inlet 36+00	920	1,420	1,200	2308591.3	288486.6
29		OCRM 2705	130	1,500	635	2287413.8	282268.9	60		Inlet 48+00	912	1,720	1,200	2307945.7	289498.1
30			143	1,500	643	2288034.7	282401.8	61		Inlet 60+00	640	1,520	1,200	2307300.1	290509.5
31		OCRM 2715	145	1,500	889	2288663.4	282536.4								

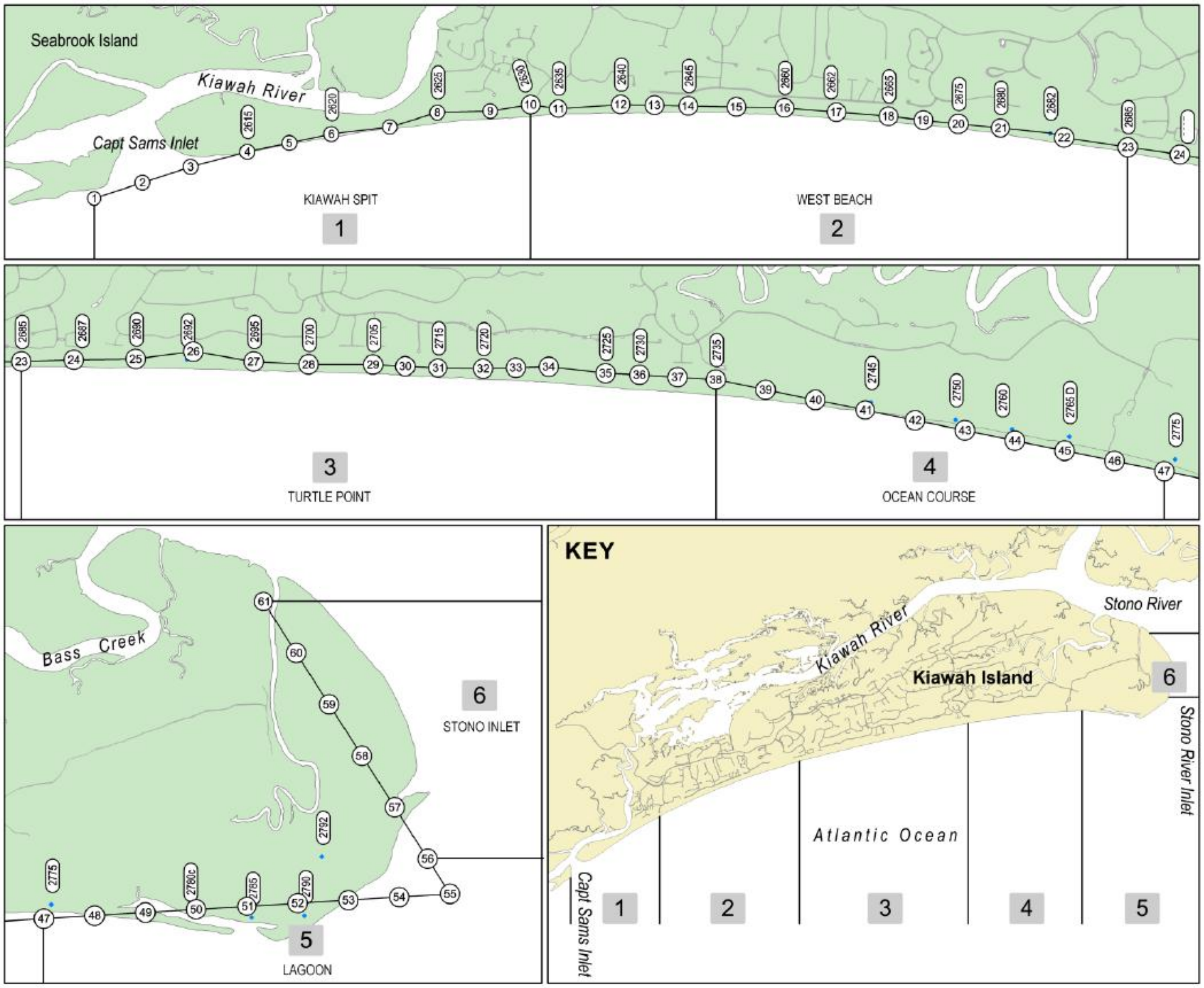


FIGURE 3.3. General location of beach stations and reaches monitored for the present report. Line numbers are shown in circles.

TABLE 3.2. Kiawah Island reaches referenced in the present report. Figure 3.3 shows reach boundaries.

Reach	Approximate Geographic Boundaries	Line Numbers	Reach Length (ft)
Kiawah Spit	West end of Kiawah Island to Beachwalker Park	1–10	8,820
West Beach	Beachwalker Park to Turtle Point	10–23	11,798
Turtle Point	Turtle Point Area	23–38	13,614
Ocean Course	Ocean Course Area	38–47	9,000
Lagoon	Lagoon Area	47–55	8,000
Stono Inlet	Stono Inlet Shoreline	56–61	6,000

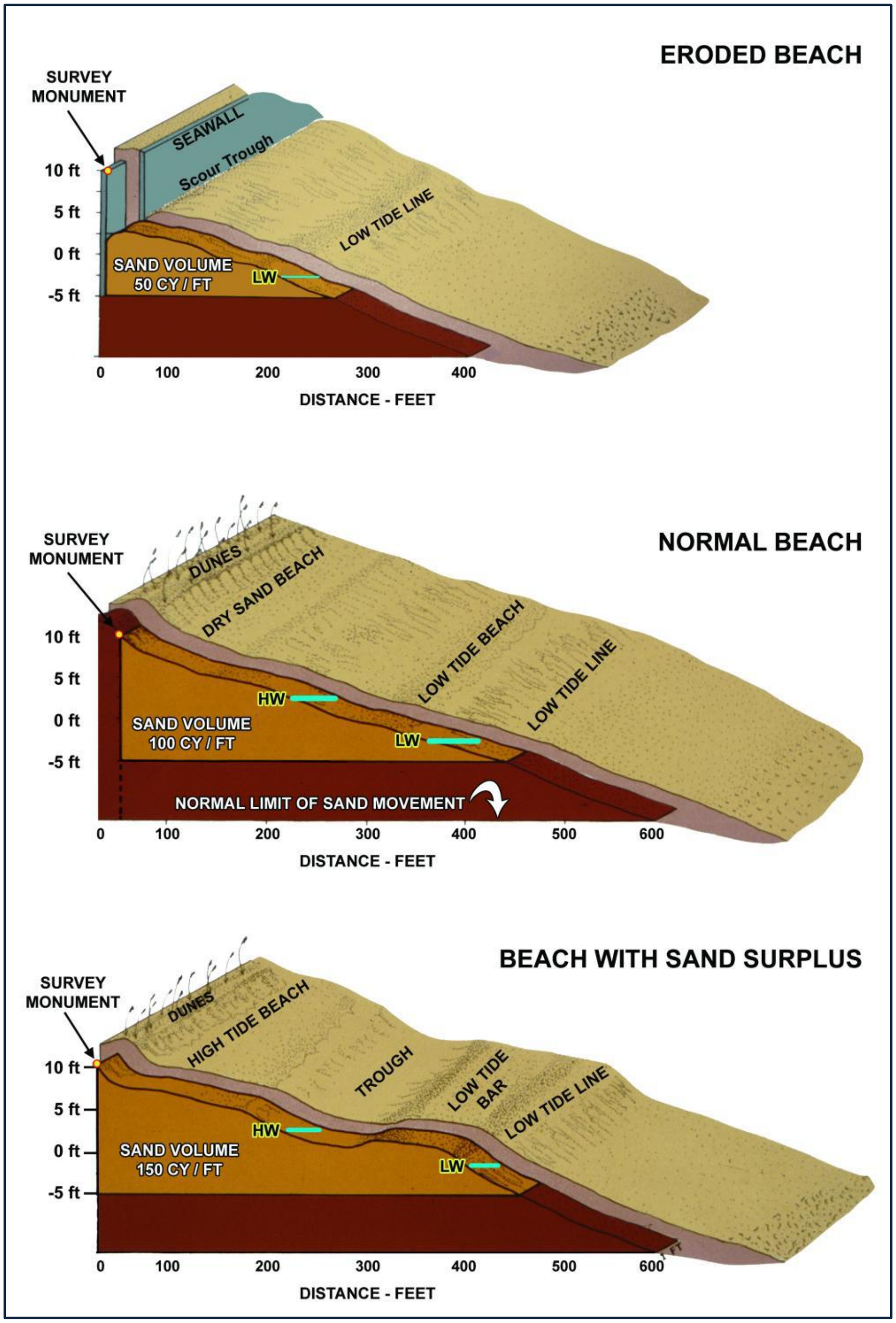


FIGURE 3.4. The concept of profile volumes – the volume of sand between defined contours over a 1-ft (unit) length of beach. [After Kana 1990]

For the present survey (2014), sand volume was calculated between the primary dune and −10 ft NAVD. The −6 ft NAVD contour has been used in past reports for consistency with earlier studies and limitations of pre-2007 data. While most sand movement occurs above −6 ft NAVD, some profile changes do occur between −6 ft and −10 ft NAVD. Significant changes can occur within this lens when underwater bars form or change and as shoals move onshore and alter morphology. Especially at the northeastern end, volume calculations were cut off at a set distance (profile specific) due to data coverage or morphological considerations (ie – the profile flattens over the ebb-tidal delta before reaching −10 ft NAVD). Profiles and calculation limits are shown in Appendix A.

Figure 3.5 shows representative profiles from two reaches over an approximate five-year period. The lower portion of each graph tracks the standard deviation in elevation based on the mean profile elevation of the set of profiles at a station. A standard deviation of <0.25 ft over several hundred feet at the outer end of a profile is evidence of little change in bottom elevation over the period encompassed by the data. This analysis confirms that nearly all measurable volume change along Kiawah's beach occurs above −10 ft NAVD and that a realistic value for DOC at decadal scales is <10 ft.

Comparative volumes and volume changes were computed using standard procedures. [CSE incorporates the 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.] Volume results at each profile line were extrapolated to the next line. Net volumes were calculated for each profile as well as for project reaches (see Tables 3.1 and 3.2).

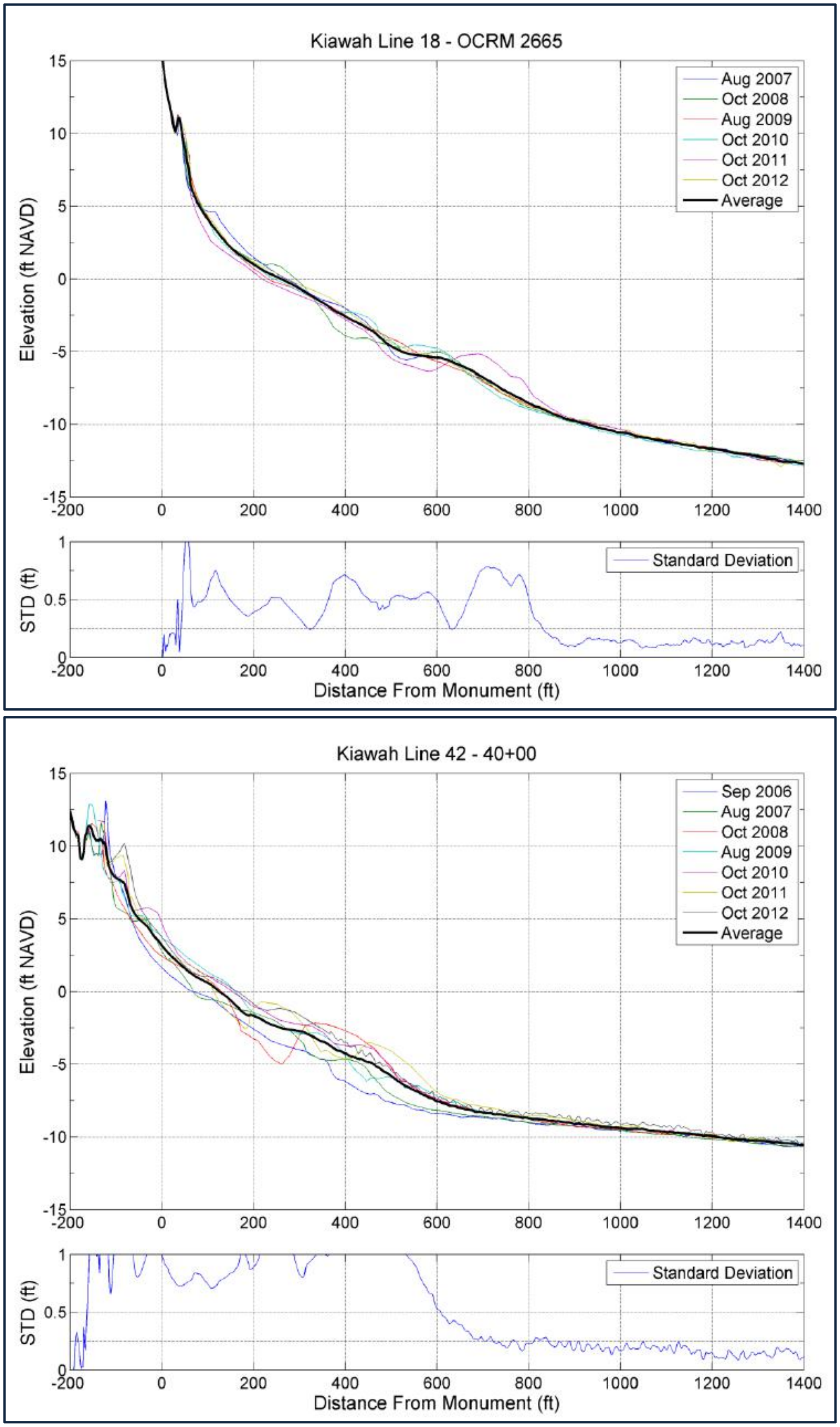


FIGURE 3.5. The lower portion of each graph tracks the standard deviation (variation from the average elevation) at any given point along a set of profiles. A standard deviation of <0.25 ft over several hundred feet is evidence of little change (ie – approximate depth of closure).

4.0 RESULTS

Results from the 2014 monitoring survey are given in the following sections. The first section generally describes changes in the project area. Section 4.2 presents the volume change calculations within the project area. Section 4.3 provides detailed sand volumes for the length of Kiawah west of the 2006 project site. The 2014 data are compared with 1999 volumes to quantify changes over the last 15 years.

4.1 Project Area Observations

CSE has monitored the 2006 project yearly for the Town of Kiawah Island. CSE expected the project area (west lagoon) to evolve into a similar system as the eastern lagoon with dense marsh and incised tidal channels (CSE 2005). This process is facilitated by sand overtopping the outer beach during high tides and storm events. Erosion and washovers shift the beach landward and deposit sand in the lagoon, building up intertidal areas and creating suitable elevations for marsh propagation.

Two significant, but related, events have occurred in the project area since construction. The first was formation and emergence of an inlet shoal near the southern apex of the bulge created by the previous bypassing events (Fig 4.1). This shoal followed the typical shoal-bypass progression, reaching Stage 3 in 2010. While in Stage 2, the breakwater effect of the shoal contributed to severe erosion of portions of the outer beach adjacent to the shoal while accretion occurred in its lee. The attachment site eroded after attachment in 2010, contributing to gains in adjacent areas consistent with Stage 3 of the bypassing cycle (cf — Fig 2.6). A new shoal is nearly attached to the beach (Fig 4.2) in a similar location as the 2010 shoal.

Rapid and large-scale volume changes led to closure of the original (constructed) flushing channel and the opening of a new channel in the summer of 2007 (cf — Fig 2.6). The new flushing channel was located near the center of the west lagoon and migrated west between 2007 and 2009. It began to encroach on the constructed dike as it continued to migrate west. During this time (2007–2009), the outer barrier eroded via overtopping and sand spreading to the lee of the shoal, leaving it low, narrow, and susceptible to another breach. A new breach occurred between August 2009 and April 2010, and the old channel closed naturally. The new inlet was again located near the central portion of the west lagoon near the attachment site of the western edge of the incipient shoal. The seaward end of the channel meandered between 2010 and 2012; however, the channel throat remained in the same general location. The channel migrated further west from 2012 to 2014, encroaching on the 2006 closure dike and emptying in front of the Ocean Course clubhouse. Migration of the channel accelerated in late 2014.

FIGURE 4.1. Oblique aerial photos of the west lagoon at the northeastern end of Kiawah Island. In December 2006 (upper left), an incipient shoal was present offshore of the eastern end of the lagoon. By May 2008 (upper right), the shoal was nearing attachment. A shoreline salient had formed on the outer barrier, as sand eroded from adjacent areas was deposited behind the shoal. The flushing channel had also relocated to the west and migrated westerly into the closure dike. The shoal had attached by April 2010 (middle), creating a small lagoon (black arrow) seaward of the original outer barrier. The flushing channel again relocated from the closure dike area (red arrow) to the central portion of the lagoon. Erosion of the shoal attachment site and downcoast spreading of sand rounded off the point of land from 2010 to November 2013 (bottom). A new shoal has emerged and was nearly attached to the beach in October 2014 in a similar location as the previous shoal (see Fig 4.2). Note formation and expansion of salt marsh in the west lagoon over the seven-year period represented by the photos.

FIGURE 4.2. Seaward aerial view of the Stono Inlet delta in November 2013 (upper) and landward aerial view in October 2014 (lower).

Notable changes in the 2006 project area between 2013 and 2014 included:

- Variable erosion between lines 44 and 50; erosion from line 51 to 57 along the eastern lagoon.
- Increased westward and landward migration of the lagoon flushing channel into the driving range and buildup of the intertidal flats seaward of the channel.
- Approximately 500 ft of landward migration of the offshore shoal (at line 50). The shoal was ~400 ft from the beach in October 2014.

4.2 East End Sand Volumes

Shoal-bypassing events are dynamic; therefore, typical volume analysis in the vicinity of by-passing events can often be misleading. Large volumes of sand can move quickly from one location to another in both the exposed and sheltered areas of the attachment site. Comparing sand volumes for individual profile lines from one year to the next may not fully represent the processes controlling morphologic change in the system.

For this report, volume changes are reported for all profiles surveyed in the project area as well as for the entire beach to Kiawah spit. [The reaches used in this report are illustrated in Figure 3.3.] In the project area, reach-wide volume changes yield a better representation of actual changes in the system. In most cases, local changes observed in individual profiles are due to evolution of the lagoon and recent shoal-bypass events, and general trends are not easily interpreted via volume change at individual lines. Volume changes are reported in Tables 4.1 and 4.2. Figure 4.3 shows reach unit volumes in the downcoast area since 1999 and in the project area since 2006. Profiles are given in Appendix A.

Volumes for the present report were calculated to −10 ft NAVD'88. Cross-shore calculation limits (offset and cutoff distances) were also adjusted as necessary to match available data. Total and unit volumes were recalculated using these new limits for all available surveys (see Table 3.1 for station-by-station limits). CSE computed volumes for the Lagoon Reach via Digital Elevation Models (DEMs). This was necessary due to the large fluctuations of the shoreline in response to the 2007 shoal-bypass event and data availability.

TABLE 4.1. Unit volumes and unit volume changes (cy/ft) for Kiawah Island monitoring stations from April 1999 to October 2014.

Kiawah Island 2014 Monitoring Survey			Unit Volume (cy/ft)										Unit Volume Change Since Previous (cy/ft)							
Reach	Line	Distance to Next (ft)	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14
1 - Kiawah Spit	1	1,000								601.9	577.7	576.6	-	-	-	-	-	-	-24.2	-1.1
	2	997								319.8	320.2	304.2	-	-	-	-	-	-	0.4	-16.0
	3	1,153								339.7	346.1	337.0	-	-	-	-	-	-	6.4	-9.1
	4	844	300.2		392.4	392.4	391.9	406.7	392.1	388.2	384.7	387.0	92.2	-	-0.5	14.8	-14.6	-3.9	-3.5	2.3
	5	845								384.3	384.5	386.4	-	-	-	-	-	-	0.2	1.8
	6	1,157	252.5		361.9	361.1	375.2	384.1	380.9	381.9	381.4	383.5	109.3	-0.8	14.2	8.9	-3.2	1.0	-0.5	2.0
	7	978								364.0	362.0	359.4	-	-	-	-	-	-	-2.0	-2.6
	8	1,040	240.6		309.0	309.9	321.6	334.7	331.0	347.6	353.8	346.8	68.4	0.9	11.7	13.1	-3.7	16.7	6.2	-7.1
	9	806								340.9	341.1	340.1	-	-	-	-	-	-	0.2	-1.0
2 - West Beach	10	547	268.3		300.9	299.1	303.6	318.5	317.1	335.8	339.8	339.1	32.6	-1.7	4.5	14.9	-1.3	18.7	3.9	-0.6
	11	1,232	255.0		289.3	290.4	300.2	307.1	312.3	323.8	327.7	325.1	34.4	1.0	9.9	6.9	5.1	11.5	3.9	-2.6
	12	665	232.9		261.1	257.9	273.1	273.1	275.4	284.8	293.0	294.6	28.2	-3.2	15.1	0.1	2.2	9.4	8.2	1.5
	13	665								277.8	281.6	287.8	-	-	-	-	-	-	3.8	6.1
	14	945	251.9		252.3	248.5	257.7	258.2	259.3	270.7	278.3	280.9	0.4	-3.8	9.2	0.5	1.1	11.5	7.5	2.6
	15	946								267.5	273.3	279.5	-	-	-	-	-	-	5.9	6.2
	16	1,025	235.6		254.5	252.8	258.3	260.3	253.0	265.4	269.6	278.3	19.0	-1.8	5.5	2.0	-7.3	12.4	4.2	8.7
	17	1,026								251.6	256.6	261.8	-	-	-	-	-	-	5.0	5.2
	18	691	228.6		236.9	229.7	231.1	232.6	229.9	237.9	247.9	253.2	8.3	-7.3	1.5	1.5	-2.6	8.0	10.0	5.3
	19	692								242.8	245.5	248.4	-	-	-	-	-	-	2.7	2.9
	20	831	273.3		243.8	239.0	239.3	237.4	239.2	247.5	252.7	260.2	-29.5	-4.8	0.3	-1.9	1.8	8.3	5.2	7.5
	21	1,266					222.0	220.0	226.8	234.1	238.9	235.1	-	-	-	-2.0	6.9	7.2	4.8	-3.7
	22	1,627								246.0	246.4	254.5	-	-	-	-	-	-	0.4	8.1
3 - Turtle Point	23	1,033	234.3		253.9	249.0	252.2	253.0	257.3	261.3	271.2	270.5	19.6	-4.8	3.2	0.7	4.4	4.0	10.0	-0.8
	24	1,215					257.1	255.3	259.0	265.4	274.7	285.8	-	-	-	-1.8	3.7	6.4	9.3	11.1
	25	1,145	219.7		250.7	244.3	248.7	245.3	248.4	262.3	270.9	282.1	30.9	-6.4	4.4	-3.4	3.1	13.9	8.6	11.2
	26	1,205					259.9	251.7	258.3	265.2	278.2	294.2	-	-	-	-8.2	6.6	6.9	13.0	16.0
	27	1,080	266.2		262.7	274.3	279.7	270.2	277.2	287.6	304.5	314.5	-3.5	11.6	5.4	-9.5	7.0	10.5	16.9	9.9
	28	1,269	299.2		278.2	291.8	295.2	292.3	300.8	307.4	324.3	337.0	-21.0	13.6	3.4	-3.0	8.5	6.7	16.9	12.6
	29	635	268.3		321.9	313.4	325.8	323.1	322.1	344.5	360.4	370.5	53.6	-8.5	12.3	-2.7	-1.0	22.4	15.9	10.2
	30	643								345.7	354.7	369.1	-	-	-	-	-	-	9.0	14.4
	31	889	265.3		322.6	325.1	326.4	331.6	326.8	347.1	353.9	374.1	57.3	2.5	1.3	5.2	-4.8	20.3	6.8	20.1
	32	645	286.4		306.2	302.0	306.9	309.3	305.3	323.3	330.2	351.9	19.8	-4.1	4.9	2.3	-4.0	18.0	6.9	21.7
	33	646								282.4	299.6	310.3	-	-	-	-	-	-	17.2	10.7
	34	1,125					224.2	229.8	225.6	241.8	249.5	255.3	-	-	-	5.6	-4.1	16.2	7.6	5.8
	35	666	217.0		252.1	250.3	253.3	254.5	245.4	269.3	267.0	273.8	35.1	-1.8	3.0	1.2	-9.0	23.9	-2.3	6.8
	36	666	252.2		257.4	204.2	259.9	263.7	257.8	275.8	275.7	276.7	5.2	-53.2	55.7	3.7	-5.8	18.0	-0.1	1.0
	37	752								271.7	274.2	271.6	-	-	-	-	-	-	2.6	-2.6
4 - Ocean Course	38	1,000		241.6	247.0	247.8	251.4	256.6	251.2	266.7	266.2	269.4	5.5	0.8	3.6	5.2	-5.4	15.6	-0.5	3.1
	39	1,000								277.5	276.9	271.5	-	-	-	-	-	-	-0.7	-5.4
	40	1,000		251.1	251.6	257.3	276.6	279.3	276.4	288.9	291.4	286.3	0.4	5.7	19.3	2.7	-2.9	12.5	2.4	-5.1
	41	1,000								285.1	274.2	289.1	-	-	-	-	-	-	-10.9	14.9
	42	1,000		216.1	232.2	248.2	259.7	271.1	272.1	281.1	282.4	276.0	16.0	16.0	11.5	11.4	1.0	9.0	1.2	-6.3
	43	1,000								325.7	310.4	324.1	-	-	-	-	-	-	-15.3	13.8
	44	1,000		294.9	355.1	346.9	351.5	362.9	356.3	371.2	364.1	424.1	60.3	-8.2	4.5	11.4	-6.6	15.0	-7.2	60.1
	45	1,000								454.2	527.4	526.0	-	-	-	-	-	-	73.2	-1.4
	46	1,000		505.6	500.1	453.5	465.3	441.4	486.7	537.7	572.5	543.9	-5.5	-46.7	11.8	-23.9	45.3	51.0	34.7	-28.5
5 - Lagoon	47	1,000								647.9	696.4	840.0	-	-	-	-	-	-	48.5	143.6
	48	1,000		617.4	578.8	541.8	561.5	562.6	689.5	758.3	839.2	879.5	-38.6	-37.1	19.7	1.1	126.9	68.8	80.9	40.3
	49	1,000								980.9	978.9	960.1	-	-	-	-	-	-	-2.0	-18.8
	50	1,000								1012.4	1005.7	1025.4	-	-	-	-	-	-	-6.7	19.7
	51	1,000								929.1	838.9	799.5	-	-	-	-	-	-	-90.2	-39.4
	52	1,000								967.5	881.7	821.2	-	-	-	-	-	-	-85.8	-60.5
	53	1,000								984.6	934.2	859.6	-	-	-	-	-	-	-50.4	-74.6
	54	1,000								604.7	593.3	548.7	-	-	-	-	-	-	-11.4	-44.6
	55	0								588.4	621.0	602.3	-	-	-	-	-	-	32.6	-18.7
6 - Stono Inlet	56	1,200		322.0	312.4	269.6	219.4	187.0	220.3	237.2	229.9	208.7	-9.6	-42.8	-50.2	-32.4	33.2	16.9	-7.3	-21.2
	57	1,200		169.0	168.2	186.0	184.6	176.3	154.5	163.2	165.7	168.3	-0.8	17.7	-1.3	-8.3	-21.8	8.7	2.5	2.6
	58	1,200		146.2	143.4	140.7	137.1	156.6	163.7	169.4	158.5	141.5	-2.8	-2.7	-3.5	19.5	7.1	5.7	-10.9	-16.9
	59	1,200		167.6	166.9	165.4	168.1	180.7	178.6	173.7	162.1	145.3	-0.8	-1.4	2.6	12.7	-2.1	-4.9	-11.6	-16.7
	60	1,200		150.0	156.8	154.8	157.1	173.5	173.1	161.2	147.4	131.3	6.8	-2.0	2.3	16.4	-0.4	-11.9	-13.8	-16.1
	61	1,200		108.9	111.3	123.7	137.5	146.2	144.4	146.2	159.6	163.2	2.4	12.4	13.7	8.7	-1.8	1.9	13.4	3.6

TABLE 4.2. Beach volume and volume changes for monitoring reaches from April 1999 to October 2014. Depth limit of calculations is −10 ft NAVD. These data show Kiawah Island has gained over 1.8 million cubic yards since 2007.

			Reach Total Volume (cy)									
Reach	**Name**	**Length**	**Apr-99**	**Sep-06**	**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**
1	Kiawah Spit	8,820	2,328,514		3,097,296	3,094,685	3,181,691	3,276,726	3,221,628	3,269,265	3,266,644	3,235,096
2	West Beach	11,798	2,903,774		2,994,556	2,949,260	2,978,605	2,991,545	3,000,541	3,108,310	3,170,302	3,213,238
3	Turtle Point	13,614	3,097,370		3,736,350	3,679,389	3,734,117	3,724,681	3,726,666	3,921,035	4,049,840	4,189,161
4	Ocean Course	9,000		2,832,947	2,964,385	2,903,690	3,005,533	3,026,626	3,135,711	3,278,923	3,380,461	3,495,840
5	Lagoon	8,000		6,559,380	6,499,468	6,763,197	7,090,470	7,385,476	7,175,787	7,156,897	7,056,459	7,089,847
6	Stono Inlet	6,000		1,219,056	1,213,419	1,198,757	1,155,841	1,173,275	1,176,151	1,195,114	1,156,125	1,081,375
1-6	**All**	**57,232**			**20,505,475**	**20,588,979**	**21,146,257**	**21,578,329**	**21,436,484**	**21,929,544**	**22,079,831**	**22,304,557**

			Reach Unit Volume (cy/ft)									
Reach	**Name**	**Length**	**Apr-99**	**Sep-06**	**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**
1	Kiawah Spit	8,820	264.0		351.2	350.9	360.7	371.5	365.3	370.7	370.4	366.8
2	West Beach	11,798	246.1		253.8	250.0	252.5	253.6	254.3	263.5	268.7	272.4
3	Turtle Point	13,614	227.5		274.4	270.3	274.3	273.6	273.7	288.0	297.5	307.7
4	Ocean Course	9,000		314.8	329.4	322.6	333.9	336.3	348.4	364.3	375.6	388.4
5	Lagoon	8,000		819.9	812.4	845.4	886.3	923.2	897.0	894.6	882.1	886.2
6	Stono Inlet	6,000		203.2	202.2	199.8	192.6	195.5	196.0	199.2	192.7	180.2
1-6	**All**	**57,232**			**358.3**	**359.7**	**369.5**	**377.0**	**374.6**	**383.2**	**385.8**	**389.7**

			Reach Volume Change Since Previous (cy)									
Reach	**Name**	**Length**			**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**
1	Kiawah Spit	8,820				-2,611	87,006	95,035	-55,098	47,637	-2,622	-31,548
2	West Beach	11,798				-45,296	29,345	12,940	8,996	107,769	61,992	42,936
3	Turtle Point	13,614				-56,961	54,728	-9,437	1,986	194,369	128,805	139,320
4	Ocean Course	9,000			131,439	-60,695	101,843	21,093	109,085	143,212	101,538	115,379
5	Lagoon	8,000			-59,912	263,729	327,273	295,006	-209,689	-18,890	-100,438	33,388
6	Stono Inlet	6,000			-5,637	-14,662	-42,916	17,434	2,875	18,963	-38,989	-74,750
1-6	**All**	**57,232**				**83,504**	**557,279**	**432,072**	**-141,844**	**493,060**	**150,287**	**224,726**

			Reach Unit Volume Change Since Previous (cy/ft)									
Reach	**Name**	**Length**			**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**
1	Kiawah Spit	8,820				-0.3	9.9	10.8	-6.2	5.4	-0.3	-3.6
2	West Beach	11,798				-3.8	2.5	1.1	0.8	9.1	5.3	3.6
3	Turtle Point	13,614				-4.2	4.0	-0.7	0.1	14.3	9.5	10.2
4	Ocean Course	9,000			14.6	-6.7	11.3	2.3	12.1	15.9	11.3	12.8
5	Lagoon	8,000			-7.5	33.0	40.9	36.9	-26.2	-2.4	-12.6	4.2
6	Stono Inlet	6,000			-0.9	-2.4	-7.2	2.9	0.5	3.2	-6.5	-12.5
1-6	**All**	**57,232**				**1.5**	**9.7**	**7.5**	**-2.5**	**8.6**	**2.6**	**3.9**

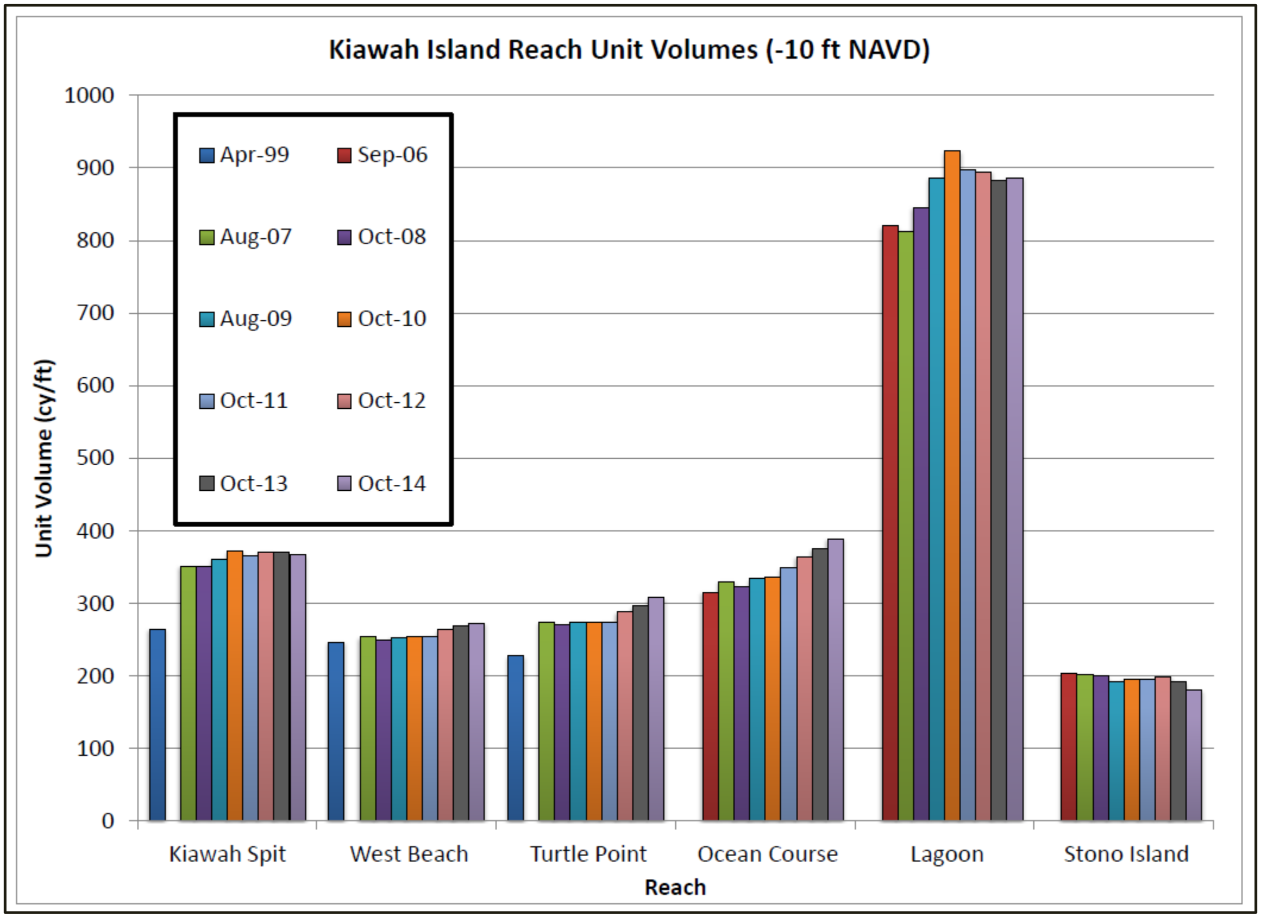


FIGURE 4.3. Reach unit volumes at Kiawah Island since 1999 measured to −10 ft NAVD.

Data in the lagoon area is limited because it is becoming difficult to conduct land-based surveys through the expanding marsh in the west lagoon. Elevation models were produced for all surveys since September 2006. LIDAR data from 2012 provided by NOAA were used to fill in gaps in the landward portion of the lagoon. The area covered by the LIDAR data has remained fairly stable since 2010. An area encompassing the outer beach ridge (berm) and subtidal zone was selected to compute volumes to −10 ft NAVD for each survey date (Fig 4.4). This allows for a simple and consistent approach to measuring beach volume. The remaining reaches were characterized by more typical shoreline changes, and volumes were computed via traditional average-end-area methods.

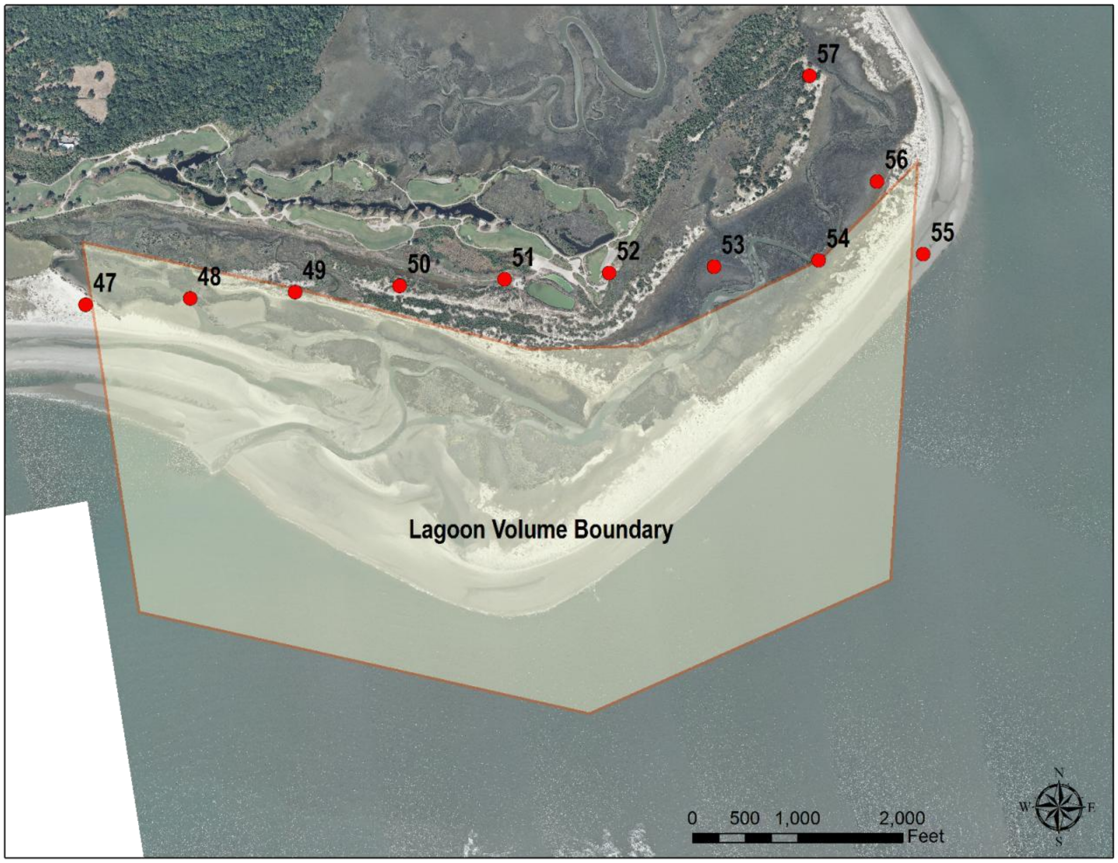


FIGURE 4.4. Boundary for the Lagoon Reach used to compute beach volumes for the present report. Elevation models were produced for surveys between 2006 and 2014, and total beach volume within the boundary was calculated to −10 ft NAVD. Coordinates below are in SC State Plane 3900 (ft).

Kiawah Island — Lagoon Volume Boundary		
Vertex Number	X	Y
1	2302949.72	284877.32
2	2304169.62	284601.84
3	2304963.51	284436.43
4	2307218.36	283850.98
5	2308259.76	283884.69
6	2309971.04	284700.91
7	2310912.68	285639.28
8	2310652.94	281648.20
9	2307785.75	280369.45
10	2303489.97	281338.50
11	2302949.72	284877.32

Stono Inlet Reach

Stono Inlet Reach spans ~6,000 ft from Line 56 (at the easternmost point of the island) to Line 61 near Penny's Creek. Beach profiles in this reach are steeper than the front-beach reaches due to the presence of Stono Inlet and reduced wave energy along the inlet. Unit volumes for Stono Inlet Reach are shown in Figure 4.5.

The reach has been relatively stable since 2007, with individual profiles within the reach showing variable periods of erosion or accretion. However, erosion has increased over the past two years, with the reach losing ~39,000 cy (6.5 cy/ft) from 2012 to 2013 and ~75,000 cy (12.5 cy/ft) from 2013 to 2014. Stono Inlet is the only monitoring reach showing net erosion since 2007, losing 132,000 cy over that time. This equals an average annual erosion rate of 18,400 cy/ft/yr (3.1 cy/ft) between 2007 and 2014.

The majority of erosion has occurred at the seaward end of the reach (Line 55), which eroded rapidly between 2006 and 2010, accreted from 2010 to 2012, and has eroded since 2012. Lines 57 and 58 remain in similar condition to the 2007 condition, while Lines 59 and 60 have lost 22-25 cy/ft since 2007. Line 61, at the inland extreme of the sandy beach, has consistently accreted since 2007, gaining 51.9 cy/ft since 2007. Over the past year, lines 57 and 61 gained 2.6 cy/ft and 3.6 cy/ft of sand (respectively), and lines 56 and 58–60 each lost between 16.1 cy/ft and 21.2 cy/ft.

Aerial images from October 2014 are shown in Figure 4.6. Along the majority of the reach, there is little stable dry beach and evidence of a recent escarpment. The escarpment is visible in the distinct vegetation line in the photographs. The condition of the shoreline along Stono Inlet Reach is mostly influenced by sand moving landward from the area fronting the lagoon further west. Insufficient sand supply is coming from the eastern lagoon area (seaward of the Stono River shoreline), which was highly erosional over the past year. The erosion is caused by sand overwashing into the lagoon as well and sand moving to the west due to a shoal-bypass event presently occurring. This will be discussed in detail in the next section.

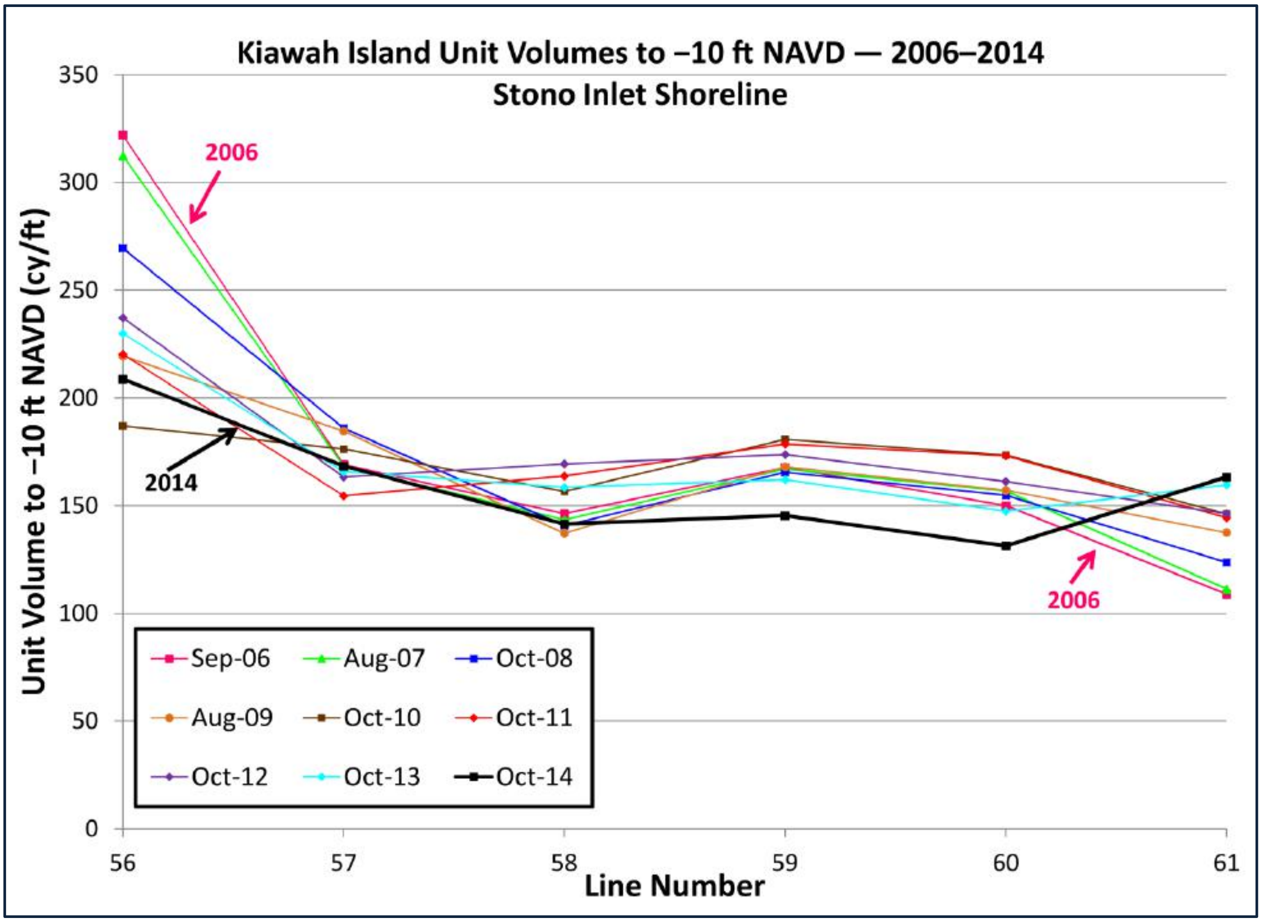


FIGURE 4.5. Unit volumes along the Stono Inlet Reach. The seaward end of this reach (left side of graph) eroded from 2006 to 2010, accreted from 2010 to 2012, then eroded through 2014. The central and inland areas have been more stable.

FIGURE 4.6. October 2014 aerial images of the Stono Inlet reach which eroded mover over the past year than during any other interval since 2007. This has led to escarpments along most of the reach.

Lagoon Reach

The Lagoon Reach spans 8,000 ft from the 2006 closure dike (Line 47 near the east end of the Ocean Course Driving Range) to Line 55 at the eastern point of the island (Fig 4.7). Monitoring reports for the 2007–2011 surveys subdivided this reach into the eastern and western lagoons. The 2012 report combined these reaches and adjusted the baseline to simplify data collection and reporting, and the present report continues this method. This reach encompasses the area of the island most influenced by shoal-bypass events (see Section 1).

Due to the rapid shoreline fluctuations and varying shoreline directions in this reach, CSE has elected to compute beach volumes using DTMs created from survey data. These volumes represent the volume of sand within the established boundaries and to a set depth. The analogy of a sandbox is often used, where the volume of sand is measured within the same sandbox each year. DTMs are also used to create contours at specified elevations for each survey, which can then be compared to provide a visual representation of the linear shoreline change.

A shoal-bypass event occurred in the lagoon reach between 2007 and 2009, attaching in late 2009 at the southern apex of the lagoon. During the attachment process, the beach in the lee of the shoal accreted, gaining sand from adjacent areas nearby and creating a large protrusion in the shoreline (see Fig 4.1). Once attached, sand spread rapidly from the attachment site, contributing to gains along the western lagoon and Stono Inlet shoreline between 2009 and 2012. Beginning in 2012, another shoal-bypass event became visible in a similar location as the previous event.

In 2012, the incoming shoal was positioned ~1,700 ft from the beach and was still far enough offshore to only have limited impacts to the beach. Between 2012 and 2013, the shoal migrated ~700 ft (Fig 4.) landward. At the same time, the low-tide beach (at 0 ft NAVD elevation) in the lee of the shoal built out ~100 ft. Between October 2013 and October 2014, the shoal migrated ~500 ft landward. The elevation of the shoal grew to approximately −4 ft NAVD, compared to −6 ft in 2012 and 2013. The leading edge of the shoal is closest to the beach near Line 50, where it was ~450 ft from the beach in 2014 (see Fig 4.7, lower).

FIGURE 4.7. October 2014 aerial images of the Lagoon Reach. The lower photo shows the position of the approaching shoal.

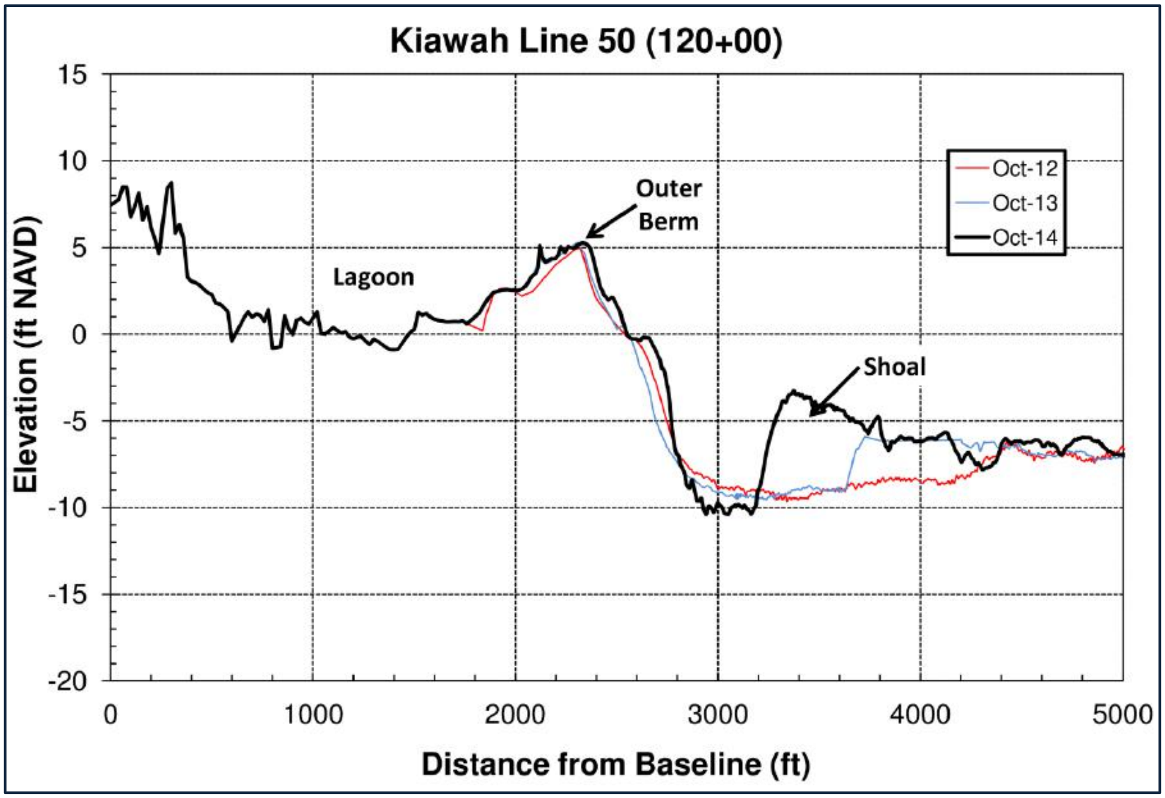


FIGURE 4.8. Line 50 (near the southern apex of the east end) shows migration of the current shoal-bypass event which moved ~500 ft landward over the past year.

As the shoal nears the beach, the breakwater effect increases and produces the characteristic accretion of the beach in the lee of the shoal (and erosion on the flanking beach). Following the 2013 monitoring effort, CSE anticipated that the shoal would attach to the beach in late 2014 or in 2015 (based on a ~700 ft/yr migration rate observed from 2012 to 2013). A slower migration rate over the past year has delayed the attachment into later 2015. The magnitude of shoreline change will continue to increase over this upcoming year as sand will build in the lee of the shoal (Lines 50–51) and adjacent areas are likely to erode until the shoal attaches.

As discussed in the previous monitoring report, the lagoon flushing channel has migrated westward to the point where it is threatening dunes and infrastructure of the Ocean Course. Between October 2013 and October 2014, the seaward end of the flushing channel migrated westward, paralleling the beach along the east end of the driving range before deflecting seaward just east of the driving range tee box (Fig 4.9). At line 46, near the center of the driving range, the channel migration resulted in ~250 ft of dune erosion from 2013 to 2014, the majority of which occurred between October 2013 and April 2014 (Fig 4.10).

FIGURE 4.9. October 2014 aerial images of the lagoon flushing channel. The channel rapidly migrated into the dune area and driving range after these images were taken.

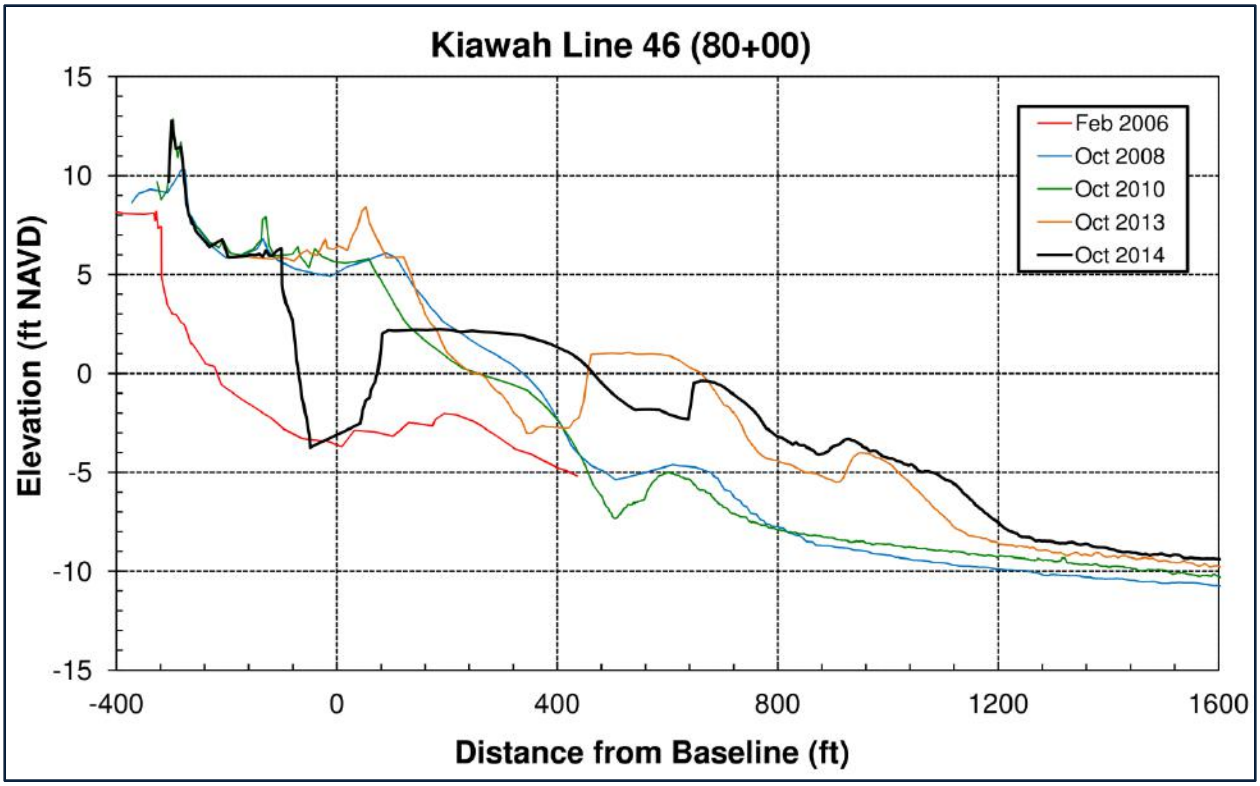


FIGURE 4.10. Profiles from Line 46 near the center of the Ocean Course Driving Range. The migration is visible in the comparison between the black and orange lines.

As of October 2014, a fairly wide dune area remained in front of the Ocean Course driving range and practice green; however, in late 2014 and early 2015 (after the monitoring survey), the channel migrated rapidly landward and to the west, encroaching into the dunes and eliminating most of the dune area fronting the driving range. The distal bend in the channel neared the driving range tee box and the channel induced erosion resulted in escarpments, exposure of the golf course irrigation system, and loss of all the dry beach and dune area over an ~800-ft length of beach (Fig 4.11).

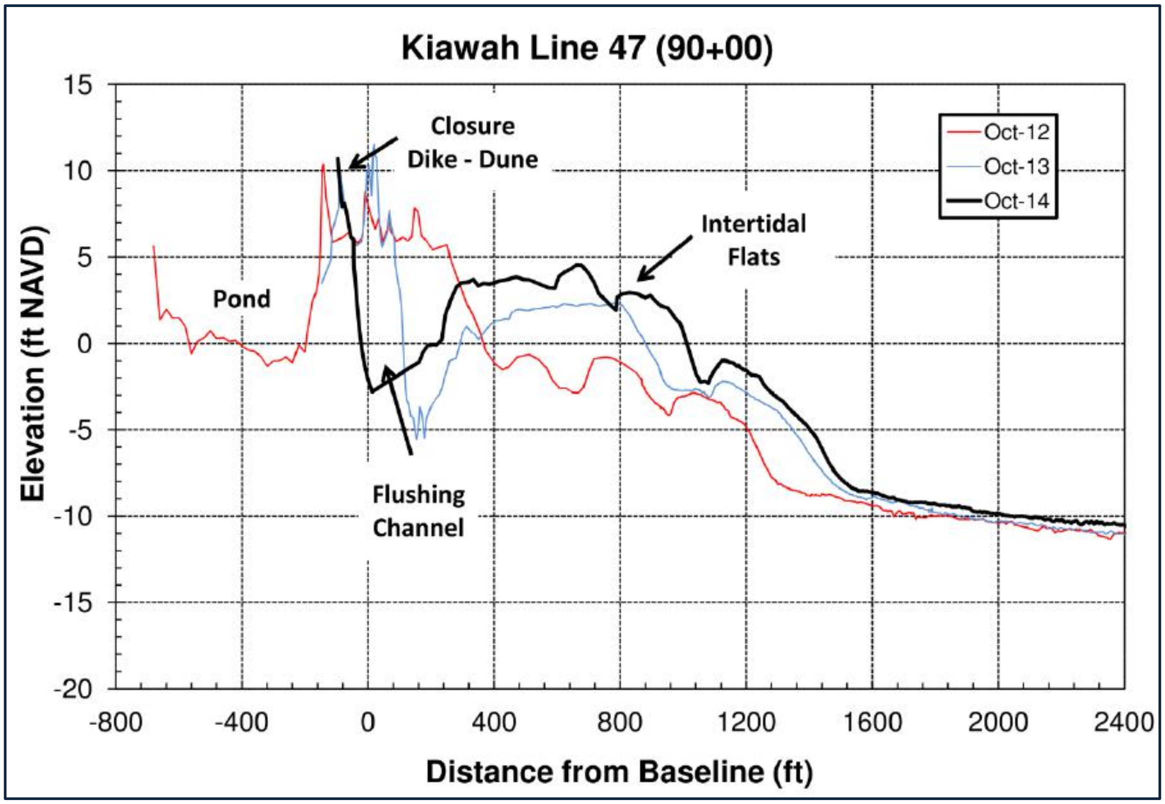
At the same time, intertidal shoals seaward of the channel continued to build, reaching over 1,000 ft in width seaward of the channel near line 45. Sandbags were installed by the Kiawah Island Golf Resort in February 2015 to prevent further migration of the channel into the golf course.

FIGURE 4.11. Aerial image from January 2015 showing additional encroachment of the flushing channel.

Despite the erosion occurring along the dunes in the western portion of the reach, overall the Lagoon Reach gained 33,400 cy (4.2 cy/ft) of sand between October 2013 and October 2014. Since 2007, the reach has gained 590,400 cy which is equivalent to an annual accretion rate of 82,300 cy/yr (10.3 cy/ft/yr). The reach gained 886,000 cy between 2007 and 2010, then lost 329,000 cy between 2010 and 2013. The majority of the gains in the reach (defined by the boundary area in Fig 4.4) were confined to the intertidal flats along the western end of the reach, and the offshore zone where the shoal bypass event is occurring. Unit volumes provided in Table 4.1 and Appendix A along the central and eastern portion of the reach show net sand loss, as the volume calculation limits do not include the sand volume in the approaching shoal.

At Line 47, which intersects the 2006 closure dike, the channel migration eroded nearly 200 ft of dunes, however, the intertidal area built higher and wider resulting in a net gain of 144 cy/ft. The position of the outer berm was stable or accretional between Lines 47 and 50 (Fig 4.12), and erosional east of Line 50 with retreat of up to 200 ft at Line 52 (Fig 4.13).

[A channel realignment project was completed in May–June 2015 to relocate the flushing channel to a position near Line 50 and eliminate the erosion occurring in the dune area fronting the Ocean Course. The details of this project will be provided in an independent report to the Town in the fall of 2015.]



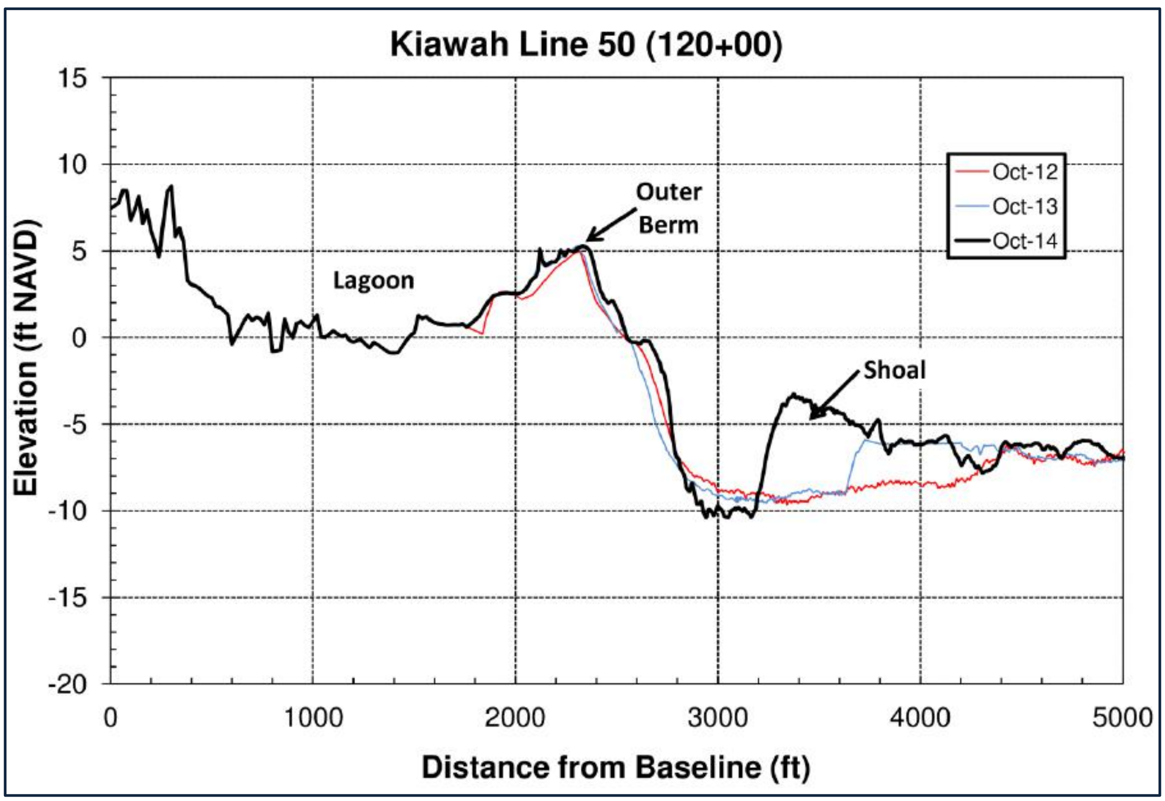


FIGURE 4.12. **[UPPER]** Profiles from Line 47 showing encroachment of the dune by the migrating flushing channel. **[LOWER]** Line 50 (near the southern apex of the east end) shows migration of the current shoal-bypass event which moved ~500 ft landward over the past year.

FIGURE 4.13.

October 2014 ground photos.

[UPPER] This image of Line 47 shows the flushing channel eroding the 2006 constructed dike.

[MIDDLE] View west from Line 49. Note the washover habitat separating the lagoon and ocean.

[LOWER] View landward from Line 51 showing washover into the marsh and an erosional low beach.

Ocean Course Reach

Ocean Course Reach is the most westward reach in the project area. This transition zone, between the washover/lagoon reaches in the project area and the developed sections of Kiawah Island, contains a more typical beach profile away from the influence of Stono Inlet. Comparative profiles are, therefore, more applicable for estimating volume changes at specific locations. The reach spans 9,000 ft of shoreline, fronting the Ocean Course from Line 38 (project station 0+00) to Line 47 (project station 92+00) (Fig 4.14). It received the majority of the nourishment fill in the 2006 project.

Ocean Course Reach has been accretional since completion of the 2006 project, gaining sand during every monitoring event since 2006 except for the 2007–2008 period. The reach has gained a total of 662,894 cy (73.7 cy/ft) since 2006, including 115,379 cy (12.8 cy/ft) over the past year. Accretion has averaged 8.2 cy/ft/yr since 2007 (Fig 4.15, upper). Individual stations show net gains of 25–130 cy/ft since 2006 generally increasing from west to east.

Unit volume change within the reach was variable between profiles and ranged from −28.5 cy/ft to +60.1 cy/ft. The eastern end of the reach was the most dynamic due to the encroachment of the lagoon flushing channel (Fig 4.15, lower). Lines 45 and 46 lost dune area or upper beach area but gained sand in the intertidal area. Line 44 was just west of the channel, in the accretional downdrift bulge typical of migrating inlets, and gained the most sand between 2013 and 2014. The remainder of the reach west of the Ocean Course Clubhouse was more stable and was out of the influence of the channel.

FIGURE 4.14.

The Ocean Course Reach in October 2014.

The dune field fronting the Ocean Course west of the clubhouse has continued to grow since the 2006 project.

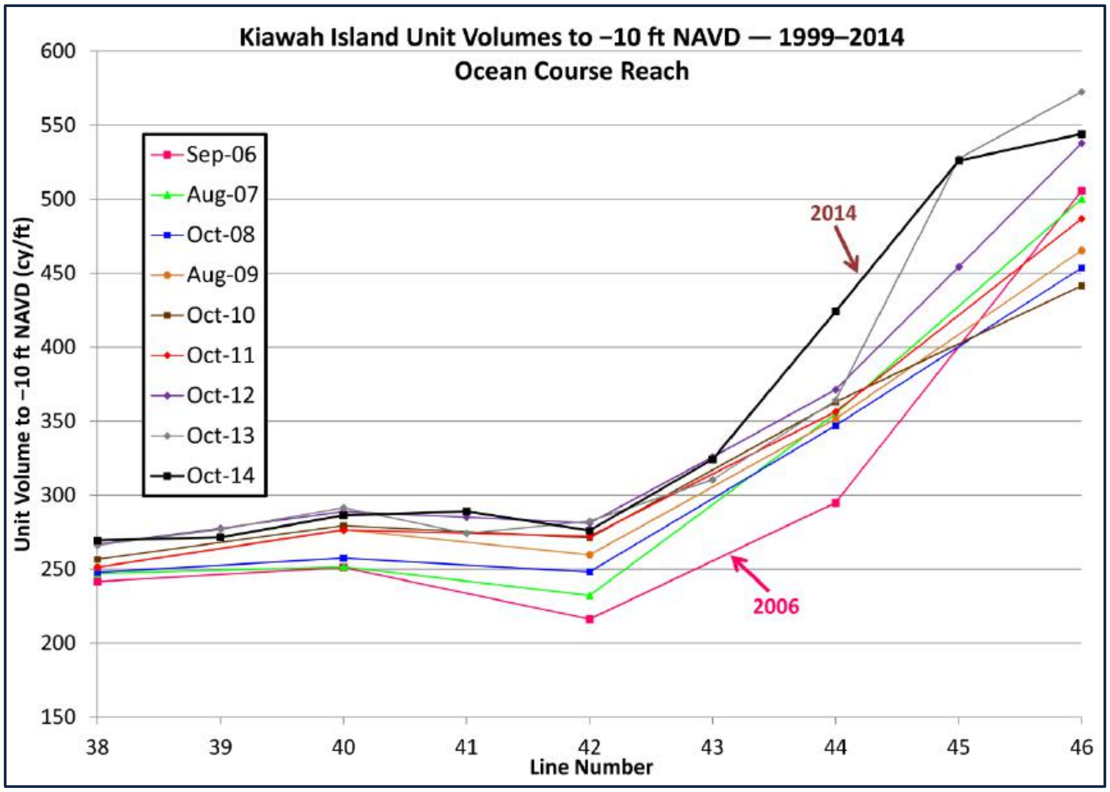


FIGURE 4.15.

Graph presents unit volumes for profiles in the Ocean Course Reach. All stations who higher volumes in 2013 than at any other time since 2006.

Photos showing Ocean Course Reach in October 2014.

[UPPER LEFT] Looking east from Line 39 (Hole 14).

[UPPER RIGHT] View west from Line 43 (Hole 17)–note escarpment.

[LOWER RIGHT] View west from Line 45 (Club House).

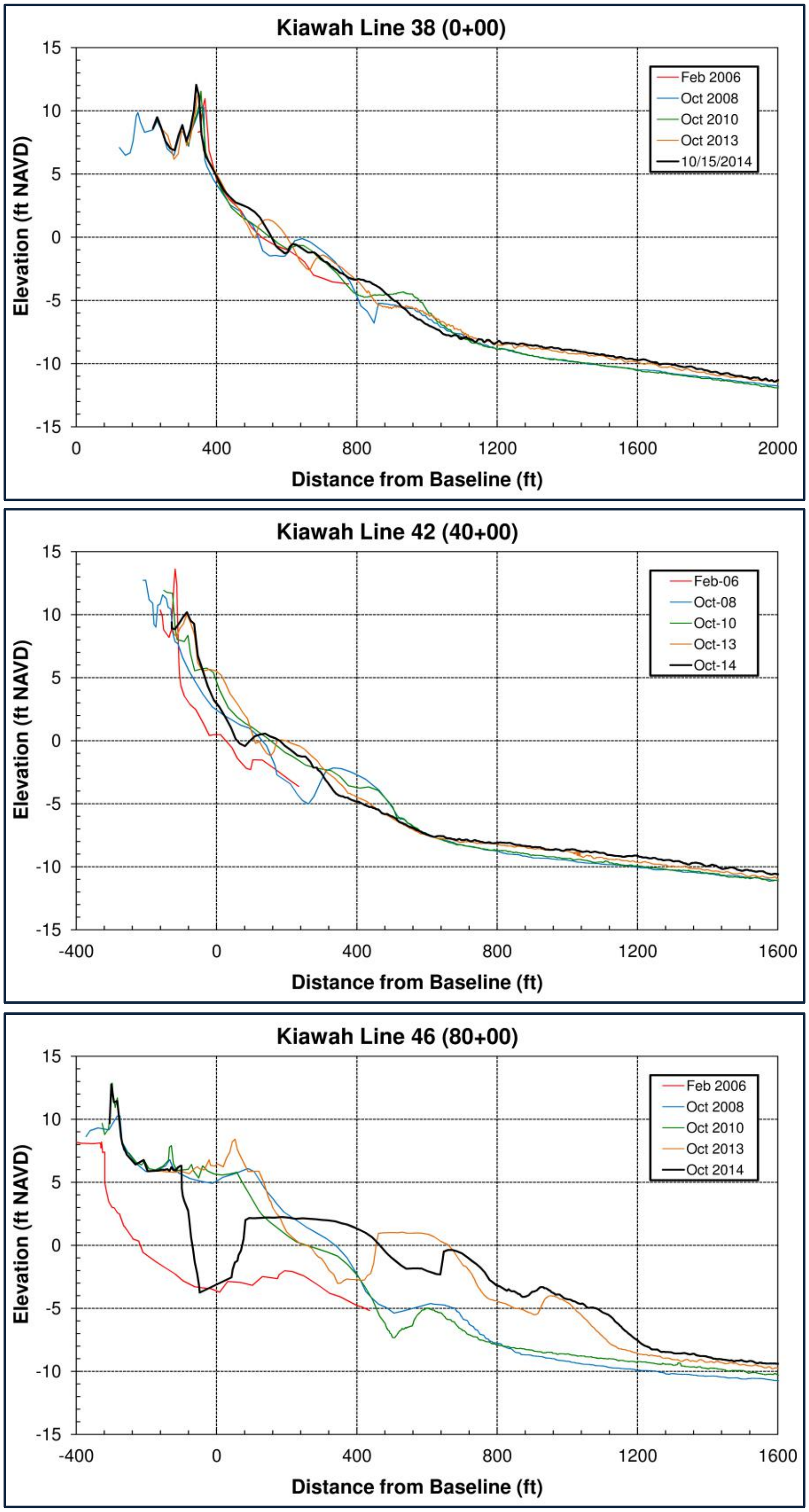


FIGURE 4.16. Beach profiles from Ocean Course Reach. Line 38 is at the western end of the reach (Kiawah Beach Club) and has been stable since 2006. Accretion increases moving east to Line 42 (16th hole) and Line 46 (Ocean Course Driving Range).

Summary of East-End Changes

Kiawah Island's eastern end gained ~74,000 cy (3.2 cy/ft) of sand between October 2013 and October 2014. This compares to a loss of 39,000 cy the previous year. The three east-end reaches have gained over one million cubic yards since completion of the 2006 project, all by way of natural migration of sand onto the beach. The gain equals an average annual accretion rate of 6.0 cy/ft/yr over the 23,000-ft east-end shoreline. Marsh continues to propagate and mature in the western lagoon. The outer berm of the western lagoon continues to be a washover-type beach in some areas while others are becoming stabilized with vegetation and dunes.

The channel migrated into the dune area east of the Ocean Course clubhouse, resulting in loss of dunes and encroachment into the driving range. By February 2015, sandbags had been installed to prevent additional loss of upland. A channel realignment project was completed in late spring of 2015 to eliminate the erosion pressure on the Ocean Course and prevent additional loss of dune area. The project moved 100,000 cy of sand between 18 May and 11 June 2015.

4.3 Downcoast Reaches

The 2014 monitoring data for reaches downcoast of the east end project area were compared to 1999 and 2006–2013 data. Profiles in these areas use OCRM monuments and newly (2012) created profiles so that profile spacing does not exceed 1,267 ft. CSE added new lines for the present monitoring agreement with the Town to better monitor local beach changes along the "populated" beach. CSE has collected data at certain downcoast stations since the early 1980s. Historically, West Beach Reach has been stable, while the Turtle Point Reach and Kiawah Spit Reach have been accretional. Profiles are given in Appendix A.

At several of the downcoast stations, the 1999 profile lines terminate before reaching −10 ft NAVD. At these stations, volumes were computed to −6 ft NAVD and then adjusted by a factor of 1.95 to produce a representative volume to −10 ft. This scale factor was computed from volume analysis of the 1999 profiles which did extend to −10 ft NAVD. The importance of collecting and analyzing data to the depth of closure is evident in the volume changes between 2010 and 2011.

In 2011, a significant underwater bar was present at most of the profiles in the downcoast reaches. Most of the sand volume associated with the bar was positioned vertically between −6 ft and −10 ft NAVD. Thus, volume change calculations to −6 ft NAVD miss the volume in the bar and do not provide a full accounting of beach condition. For example, at station 2695, the unit volume change to −6 ft NAVD (low-tide wading depth) was −4.7 cy/ft from 2010 to 2011. However, the volume change between −6 ft and −10 ft NAVD was +11.7 cy/ft, yielding a more realistic total volume change of +7.0 cy/ft. While the underwater volumes in bars may not provide immediate benefit to the visible beach, they indicate the likelihood of future beach buildup. Future monitoring should strive for a full accounting of sand volumes into deeper water because the resulting data provide the most objective measure of beach condition.

Figure 4.17 shows unit volumes for each station in the downcoast reaches. It is apparent that the present condition along the majority of the beach is much healthier than it was in 1999. Only at Line 20 (OCRM 2675 near Sea Forest Drive) does the current condition have less volume than in 1999. Overall, the downcoast reaches have gained 2.3 million cubic yards of sand since 1999, equivalent to an average annual accretion rate of 4.34 cy/ft/yr***** over the ~6-mile beach length. Over the past year, the downcoast beach was accretional, gaining a total of 150,709 cy (4.4 cy/ft) of sand. This compares to a gain of ~188,000 cy over the previous year. Over the past year, 24 of the 37 profiles in the downcoast reaches gained sand.

*[*A gain of 4.3 cy/ft/yr is roughly equivalent to a beach widening of 6–7 ft/yr in settings like Kiawah Island, where DOC is relatively shallow (Kana et al 2013). Over the 15-year period (1999–2014), this rate of sand accumulation has widened Kiawah's beach by an average of roughly 100 ft.]*

Turtle Point Reach

Turtle Point Reach (Fig 4.18) extends 13,614 ft from Line 23 (OCRM 2685 at the 16th hole of Turtle Point Golf Course) to Line 38 (OCRM 2735 at Kiawah Beach Club). The reach was fairly stable from 2007 to 2011, showing yearly unit volume changes ranging from −4.2 cy/ft to +4.0 cy/ft. The reach was much more accretional from 2011 to 2013, gaining an average of 11.9 cy/ft, and continued the higher accretion trend between 2013 and 2014 as the reach gained 10.2 cy/ft (139,320 cy). Individual stations ranged between 2.6 cy/ft erosion to 21.7 cy/ft accretion. The west and central portions of the reach were more accretional than the east stations. Stations with data from 1999 show between 24.5 cy/ft and 108.8 cy/ft more sand than the 1999 conditions with the larger gains at stations 29–31.

Beach profiles (Fig 4.19) show dune heights range between +10 ft NAVD and +15 ft NAVD (note data may not extend to the highest dune due to vegetative cover or difficulty accessing densely vegetated areas). In the central portion of the reach, the dune line has moved over 100 ft seaward since 1999. At the east and west ends of the reach, the dune line has grown ~50 ft seaward since 1999. A wide and relatively-low-elevation dune field exists throughout the reach (Fig 4. 20).

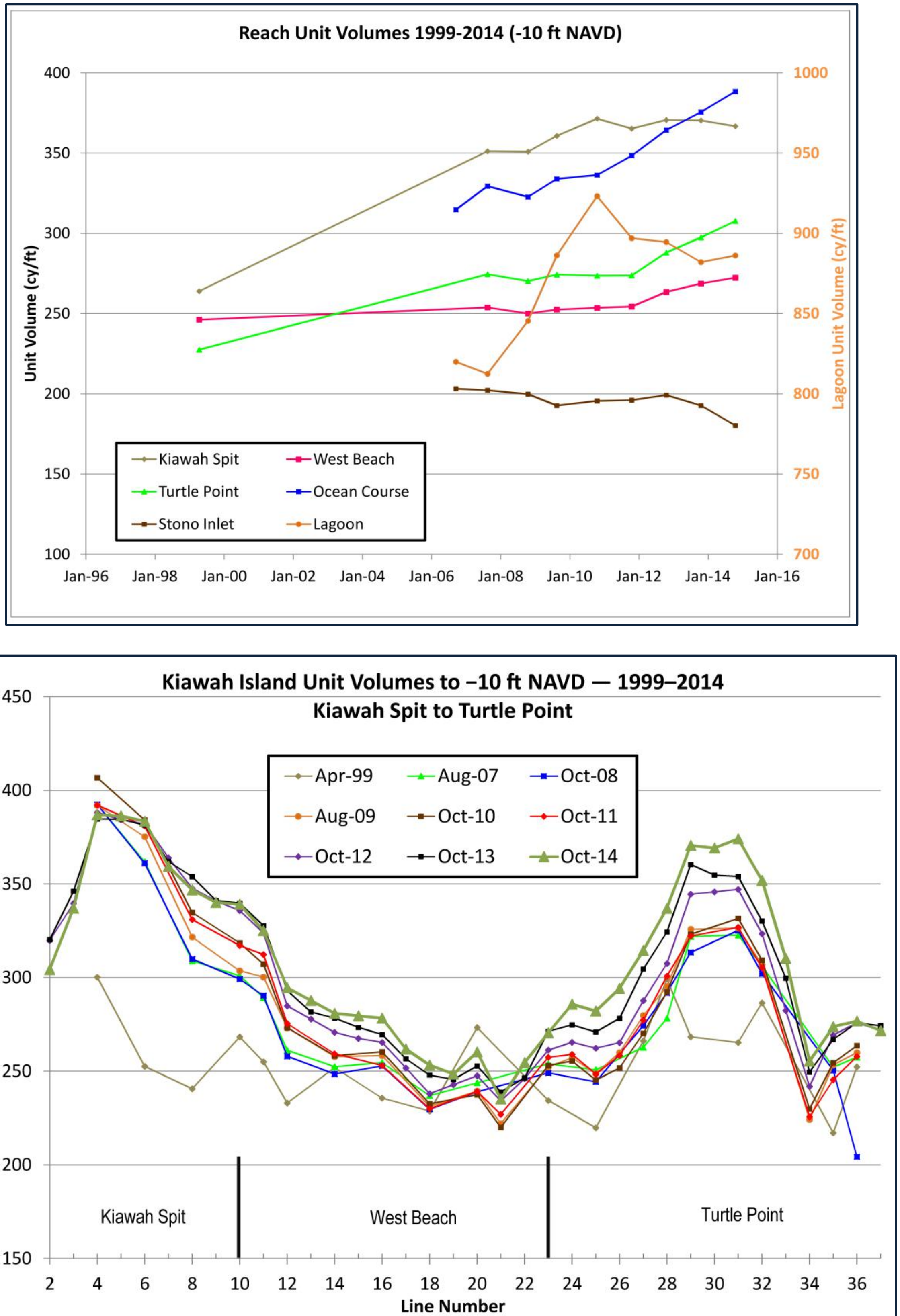


FIGURE 4.17. Unit volumes for each station in the downcoast reaches.

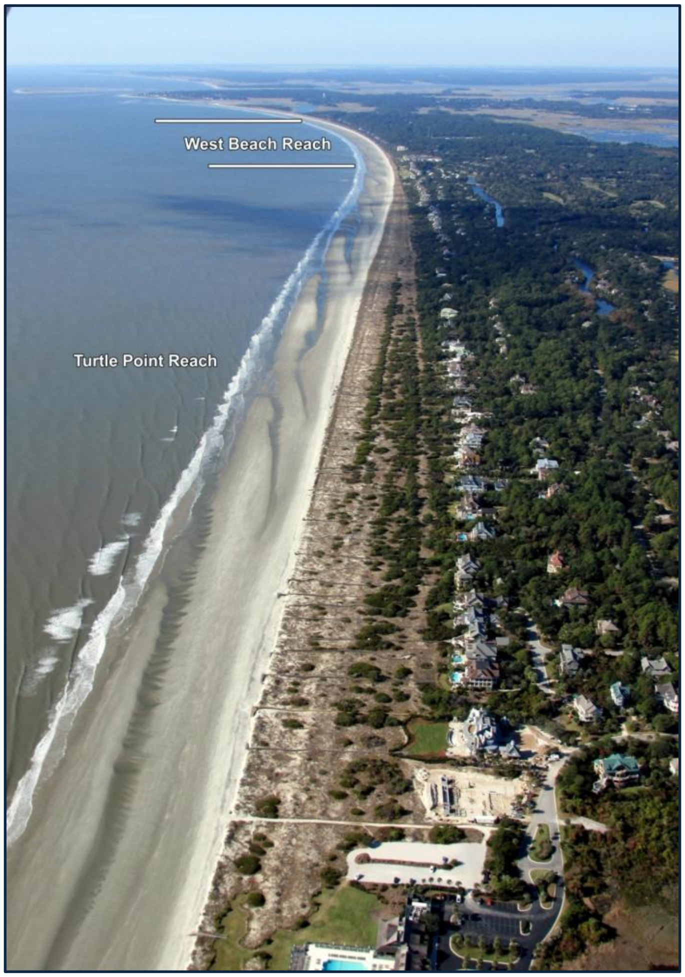
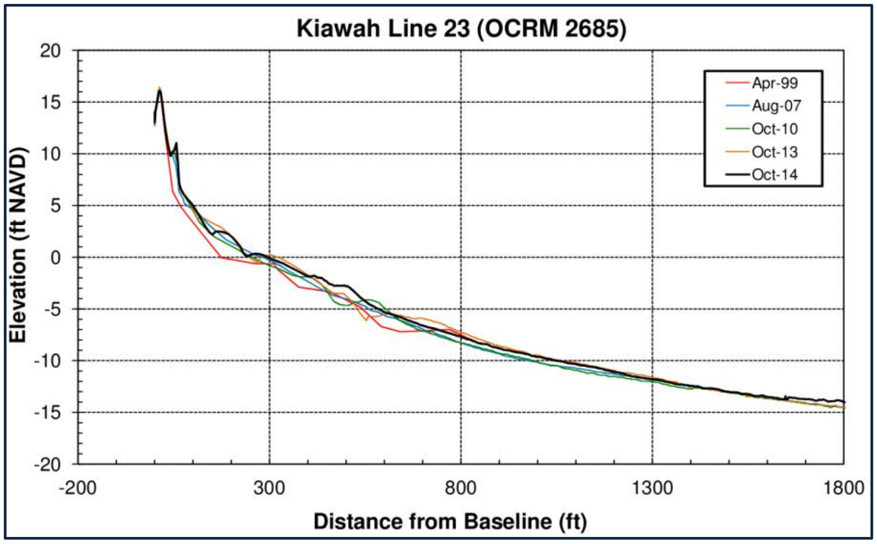
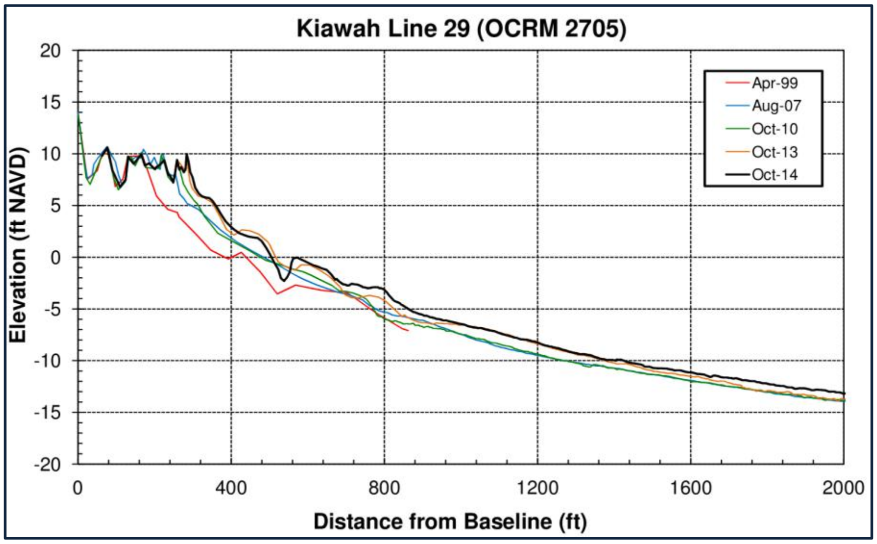


FIGURE 4.18. [UPPER] November 2013 aerial image of Turtle Point Reach. Shrub vegetation (typically waxed myrtle) continues to propagate between sparsely vegetated foredunes. CSE expects the shrub zone to expand and eventually be transformed to forest vegetation. **[LOWER]** October 2014 aerial image.





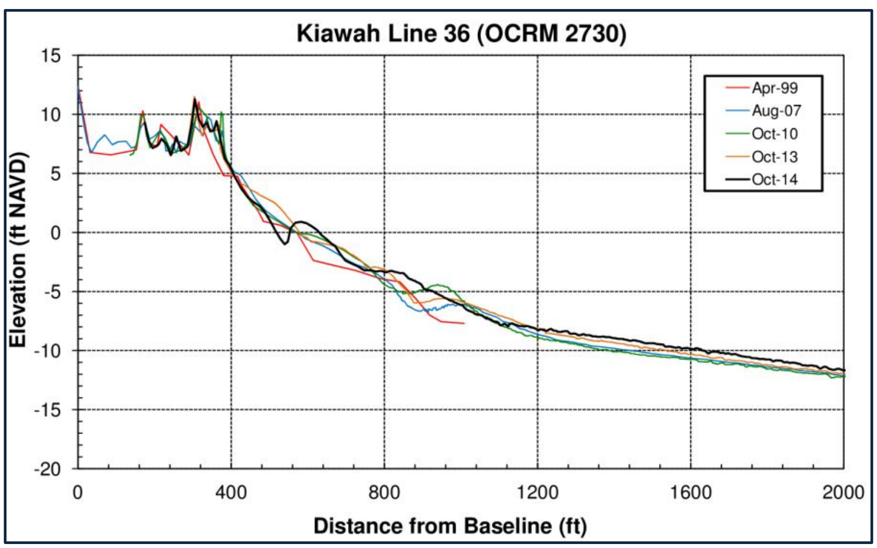


FIGURE 4.19. Beach profiles from the Turtle Point Reach. Line 23 is located ~1,000 ft east of The Sanctuary. Line 29 is near Jackstay Court. Line 36 is near Bally Bunion Drive.

FIGURE 4.20. October 2014 ground photos of Turtle Point Reach. Note the low, wide dune field and narrow dry berm.

[UPPER LEFT] Line 36 near Bally Bunion Drive.

[MIDDLE RIGHT] Line 32 east of Royal Beach Drive.

[MIDDLE LEFT] Line 28 west of Forestay Court.

[LOWER RIGHT] Line 23 near Turtle Point's 16th hole (east of The Sanctuary).

At the eastern end of Turtle Point Reach, mature dune vegetation (typically wax myrtle) is propagating. Expectations are that the central and western ends of the reach will continue to mature (if left alone) with vegetation into a thicket of wax myrtle 12–15 ft above existing ground level. A couple of decades from now, large trees will emerge through the thicket, creating a climax forest of palmetto, loblolly pine, cedar, and live oak trees.

West Beach Reach

West Beach Reach encompasses the beach between Lines 10 and 23 (Sand Alley to the 16th tee of Turtle Point Golf Club) (Fig 4.21). Historically, this reach has been fairly stable compared to remaining reaches. Although the reach has experienced periods of erosion, properties within the reach are sufficiently set back to allow for a substantial vegetated buffer between the ocean and the structures. The reach lost 3.8 cy/ft of sand from 2007 to 2008, but has accreted during every monitoring interval since then, including a gain of 3.6 cy/ft (43,000 cy) from 2013 to 2014. Lines 10, 11, and 21 lost sand over the past year, while the other ten stations gained sand. Individual stations ranged between 3.7 cy/ft erosion to 8.7 cy/ft accretion. There was no distinct trend of volume change for the various areas within the reach, but the middle portion of the reach tended to accrete more sand than the edges of the reach. Profiles show the high dune was fairly stable over the past year, and accretion was generally observed along the intertidal beach (Fig 4.22).

FIGURE 4.21. October 2014 aerial view of West Beach Reach.

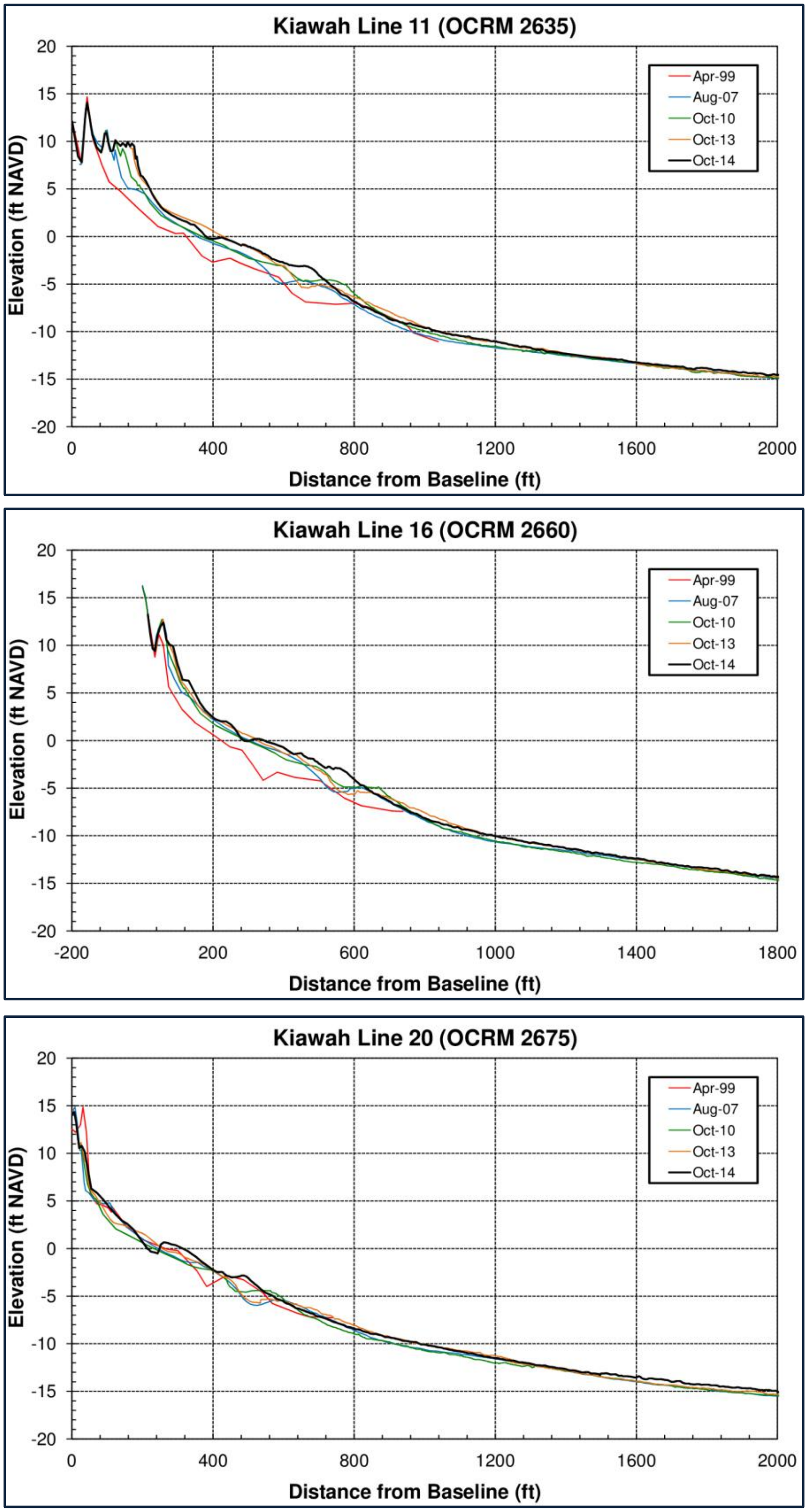


FIGURE 4.22. Profiles from West Beach Reach. The western end has been more accretional than the rest of the reach. Line 20 is the only profile on the island showing less volume than the 1999 condition.

Ground photos (Fig 4.23) show that the beach was stable to accretional over the past year with no escarpments present and expanding dune vegetation along the majority of the reach. West Beach Reach has historically been an area of long-term stability, with periods of erosion and accretion balancing the net sand volume change. As shown in the photos, a typical beach condition along a stable stretch of beach is a narrow dry beach fronting a growing dune. The width of the dry beach changes with the magnitude of the tide becoming smaller during spring tides and wider during neap tide cycles.

West Beach Reach averaged 0.1 cy/ft/yr accretion from 2007 to 2011. Over the past three years, the accretion rate has increased to 6.0 cy/ft/yr. The reach has gained 309,500 cy since 1999, which is an average annual accretion rate of 1.7 cy/ft/yr. The western end of the reach has been more accretional than the eastern end, showing up to 70 cy/ft more sand and an additional 100 ft of dune width compared to the 1999 condition.

Kiawah Spit Reach

Kiawah Spit Reach encompasses the downcoast end of the island (Fig 4.24). It acts as a collection site for sand transported by longshore currents from upcoast areas. As wave action transports sand to the west, it feeds the spit, causing growth into Captain Sams Inlet and forcing the inlet to migrate toward Seabrook Island.

Previous shoreline monitoring reports by CSE referenced three OCRM monuments in this reach. CSE has added six additional lines to better account for beach changes along the spit with the most westward line located near the current position of Captain Sams Inlet. To compare equivalent shoreline segments, CSE extrapolated volume to the western end of the spit for the lines without 1999–2011 data. This was accomplished by applying the percent of volume change at the most westward line with data (Line 4) to the lines without data, beginning at the 2011–2012 change and working back in time.

For example, the 2011–2012 volume change at Line 4 was −390 cy, which is −0.03 percent of the 2011 volume. This percentage was applied to the 2012 volume at Lines 1–3 to obtain 2011 volumes for each of those lines. The 2010–2011 volume change at Line 4 was then applied to these new 2011 volumes for Lines 1–3 to provide new 2010 volumes, and so on. While the method is obviously limited in accuracy, it does provide a rough volume estimate of the lines west of Line 4 to compare with more recent results.

FIGURE 4.23.

October 2014 ground photos of West Beach Reach.

[UPPER LEFT] Line 21 looking east with The Sanctuary visible.

[MIDDLE RIGHT] Line 19 looking west. The image shows a recent dune escarpment is healing with sparse new vegetation at the toe of the foredune.

[MIDDLE LEFT] View east from Line 15 near the center of Eugenia Avenue.

[LOWER RIGHT] View east from Line 11. The western end of the reach has a much wider, but low, dune field.

FIGURE 4.24. October 2014 aerial images of the Kiawah Spit Reach. The spit has grown seaward ~200 ft since 1999.

Over the past year, Kiawah Spit Reach lost ~31,500 cy (−3.6 cy/ft), which is the most erosion that has occurred in the reach since 2011. Erosion over the past year occurred along the east and west ends of the reach, while the center portion of the reach accreted (Fig 4.25). Stations 1–3 lost an average of 8.7 cy/ft; stations 7–9 lost an average of 3.6 cy/ft, and stations 4–6 gained an average of 2.0 cy/ft. Since 2007, the beach has remained fairly stable while dune height has increased by ~5 ft. The eastern end of the reach, near Beachwalker Park, has been consistently accretional since 1999 and is also ~200 ft wider than the 1999 condition. Ground photos are shown in Figure 4.26.

The long-term accretion occurring along the spit results in westward migration of Captain Sams Inlet at a rate of 200–300 ft/yr. As it migrates, the newly created beach at the western tip of Kiawah Island evolves from a washover intertidal area to a dry barren beach area with sparse vegetation and finally to a stable beach area with vegetated dunes. The ever-changing beach creates several areas of habitat preferred by shorebirds, including Wilson's plovers, least terns, and piping plovers.

NOTE: In late spring of 2015, Captain Sams Inlet was relocated ~3,000 ft east to its 1960 position, just west of Line 3. This was the third inlet relocation event, following similar projects in 1983 and 1996. The project moved ~160,000 cy of sand between 18 May and 18 June 2015. The project was sponsored by the Seabrook Island Property Owners Association. Additional details will be provided in the next Kiawah Island monitoring report (2015 survey).

Overall since 1999, Kiawah Spit Reach has gained 906,000 cy (102.8 cy/ft) of sand which translates into an average annual accretion rate of 6.6 cy/ft/yr.

Island wide from October 2013 to October 2014, Kiawah gained 225,000 cy (3.9 cy/ft) of sand. Since 2007, the island has gained nearly 1.8 million cubic yards, measured to −10 ft NAVD. This is an average annual accretion rate of 4.4 cy/ft/yr since 2007. Kiawah continues to be one of the healthiest beaches on the South Carolina coast, and monitoring results continue to suggest that this trend will continue in the near future.

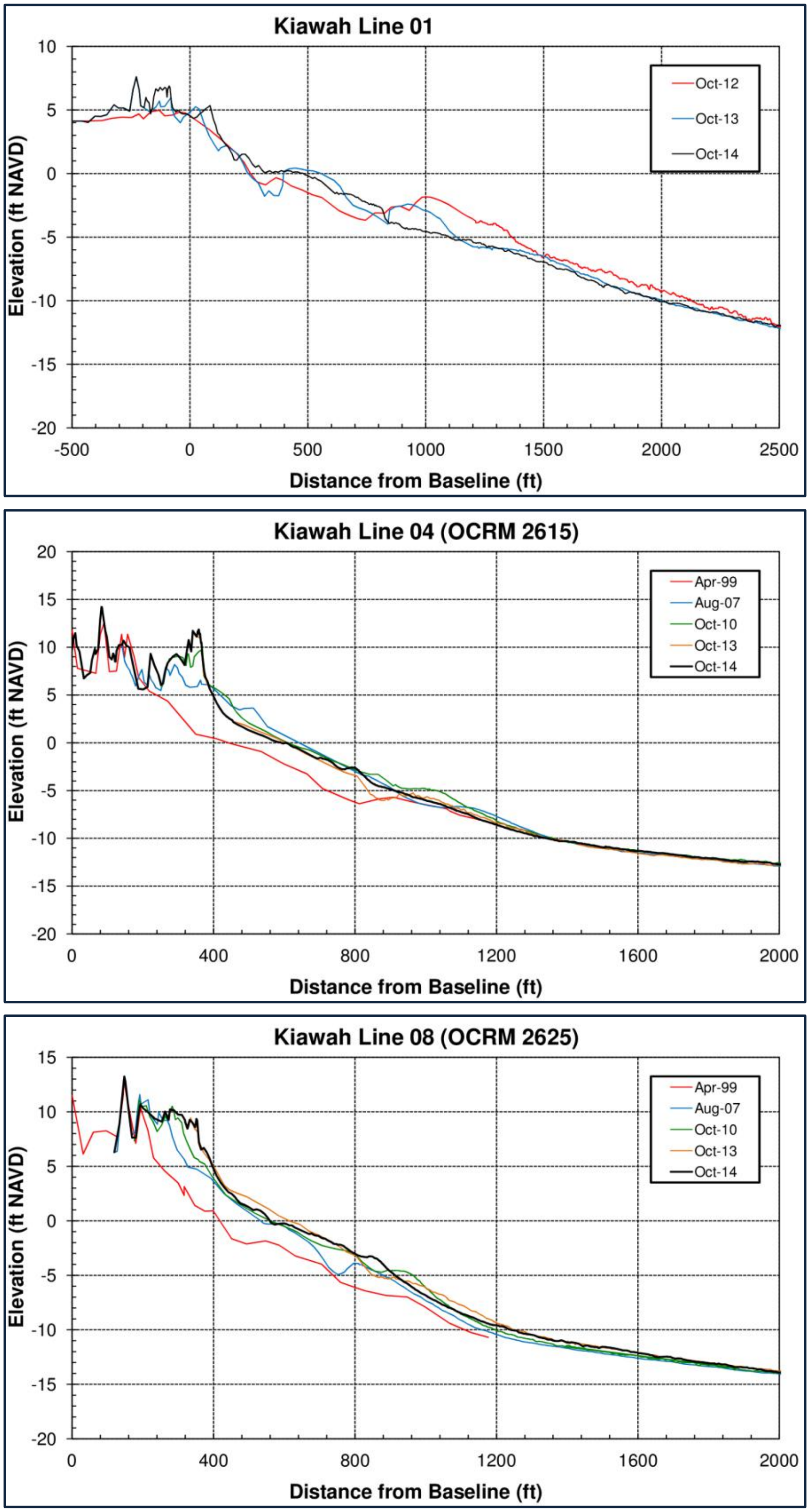


FIGURE 4.25. Profiles from Kiawah Spit Reach. The dune line in this reach has built nearly 200 ft seaward since 1999. The sand volume gain from 1999 to 2014 between the original foredune and −10 ft NAVD is 106.2 cy/ft at station 2625.

FIGURE 4.26. October 2014 ground photos of Kiawah Spit Reach. **[UPPER LEFT]** Line 8 looking west (new Beachwalker vehicle access). **[MIDDLE RIGHT]** Line 4 looking west. **[MIDDLE LEFT]** Looking east near the end of the spit. **[LOWER]** January 2014 image of the dune field just west of Beachwalker Park.

— THIS PAGE INTENTIONALLY LEFT BLANK —

5.0 SUMMARY OF FINDINGS

The 2014 monitoring survey, conducted in early October, is the eighth annual monitoring event since completion of the 2006 beach restoration project at the eastern end of Kiawah Island. Data show that the eastern end continues to evolve in response to the large shoal-bypass events of 1990 to 2005, which have added over 6 million cubic yards of sand to the beach in recent decades. The lagoon that was present during the 2006 restoration project is developing into a mature marsh system, while the new outer beach is constantly moving in response to local sediment supply and wave conditions. The most evident changes over the past year were westward and landward migration of the lagoon flushing channel into the driving range of the Ocean Course, onshore migration of a shoal, and westward accretion of the front beach area.

The island was accretional from 2013 to 2014. Kiawah Spit Reach and Stono Inlet Reach lost sand, while Lagoon Reach, West Beach Reach, Turtle Point Reach, and Ocean Course Reach accreted. The most significant erosion was observed at the east end of Lagoon Reach with over 100 ft of recession of the outer berm observed. Lagoon Reach, as a whole, accreted due to volume gains in the attaching shoal. The majority of the profiles along the developed front beach gained sand. Overall, the east end (Ocean Course to the east) gained ~74,000 cy over the past year, while the remainder of the island gained ~150,709 cy.

Overall, the island gained 225,000 cy (3.9 cy/ft) of sand over the past year, which is equivalent to an average beach widening of ~6 ft. Beach profiles show increasing dune heights or seaward movement of the dune line. Kiawah Island has gained nearly 1.8 million cubic yards of sand since 2007, which is an average accretion rate of 4.4 cy/ft/yr. As of October 2014, the lagoon flushing channel was meandering across the active beach east of the Ocean Course and encroached on the dune area, the 2006 closure dike, and the nourishment berm. Erosion accelerated after October 2014, leading to a channel realignment project in late spring of 2015.

Kiawah Island represents one of the healthiest beaches along the U.S. East Coast and offers an unparalleled example of the accretionary dynamics which maintain mixed-energy barrier islands. While monitoring of any kind entails some cost, its value lies in prediction of localized problems such as the events that led to the 2006 project. CSE is scheduled to repeat annual monitoring in the fall of 2015.

— THIS PAGE INTENTIONALLY LEFT BLANK —

REFERENCES & BIBLIOGRAPHY

CSE. 1995. Shoreline assessment and recommendations for dune/beach restoration, Kiawah Island, South Carolina. Final Report for Town of Kiawah Island; Coastal Science & Engineering (CSE), Columbia, South Carolina, 42 pp. + appendices.

CSE. 1996. Kiawah Island — 1996 beach scraping. Final survey report to Town of Kiawah Island, South Carolina. CSE, Columbia, SC, 6 pp + app.

CSE. 1997. Kiawah Island — state of the beach — winter 1997, Kiawah Island, South Carolina. Memorandum Report to Town of Kiawah Island, South Carolina. CSE, Columbia, SC, 14 pp + app.

CSE. 1999. Updated shoreline assessment and condition of the beach, Kiawah Island, South Carolina. Final Report for Town of Kiawah Island. CSE, Columbia, South Carolina, 81 pp + appendices.

CSE. 2005. Kiawah Island east end erosion – opinion of probable causes and alternative strategies for management mitigation. Memorandum Report for Town of Kiawah Island, SC. CSE, Columbia, South Carolina, 31 pp.

CSE. 2007. East end erosion and beach restoration project, Kiawah Island, Charleston County, SC. Final Report for Town of Kiawah Island, SC. CSE, Columbia, South Carolina, 54 pp + appendices.

CSE. 2008. 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 1. CSE. Columbia, South Carolina, 38 pp + appendicies.

CSE. 2009 (February). 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 2. CSE. Columbia, South Carolina, 50 pp + appendicies.

CSE. 2009 (December). 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 3. CSE. Columbia, South Carolina, 55 pp + appendices.

CSE. 2011. 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 4. CSE. Columbia, South Carolina, 69 pp + appendices.

CSE. 2012. 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 5. CSE. Columbia, South Carolina, 83 pp + appendices.

CSE. 2013. 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 6. CSE. Columbia, South Carolina, 71 pp + appendices.

CSE. 2014. 2006 East end beach restoration project, Kiawah Island South Carolina, Survey Report No 7. CSE. Columbia, South Carolina, 69 pp + appendices.

Duc, AW, and RS Tye. 1987. Evolution and stratigraphy of a regressive barrier/back-barrier complex: Kiawah Island, South Carolina. Sedimentology, Vol 34, pp 237-251.

Eiser, WC, and TW Kana. 1987. Summary of shoreline changes along Kiawah Island between September 1986 and October 1987. Report to Kiawah Island Company, Kiawah Island, SC. CSE, Columbia, SC, 12 pp + appendices.

Gaudiano, DJ. 1998. Shoal bypassing in South Carolina inlets: geomorphic variables and empirical predictions for nine inlets. Tech. Rept., Dept. Geological Sciences, Univ. South Carolina, Columbia, 182 pp.

Gaudiano, DJ, and TW Kana. 2001. Shoal bypassing in South Carolina tidal inlets: geomorphic variables and empirical predictions for nine mesotidal inlets. Jour Coastal Research, Vol 17, pp 280-291.

Hayes, MO. 1977. Development of Kiawah Island, SC. In Proc Coastal Sediments '77, ASCE, New York, NY, pp 828-847.

Hayes, MO. 1994. Georgia Bight. Chapter 7 in RA Davis, Jr (ed), *Geology of the Holocene Barrier Island System*, Springer-Verlag, Berlin, pp 233-304.

Hayes, MO, SJ Wilson, DM FitzGerald, LJ Hulmes, and DK Hubbard. 1975. Coastal processes and geomorphology. In *Environmental Inventory of Kiawah Island*, Environmental Research Cntr Inc, Columbia, SC, 165 pp.

Hayes, MO, and J Michel. 2008. *A Coast for All Seasons — A Naturalist's Guide to the Coast of South Carolina*. Pandion Books, a division of Research Planning, Columbia, SC, 285 pp.

Jones, CP. 1989. Summary of proposed revisions to interim baseline and setback line at Kiawah Island. Final Report, Kiawah Resort Associates, Charleston, SC. CSE, Columbia, SC, 31 pp., appendix, attachment.

Kana, TW. 1993. The profile volume approach to Beach Renourishment. In DK Stauble, and NC Kraus (eds.), Beach Nourishment Engineering and Management Considerations, Association of Civil Engineers, New York, NY, p. 176-190.

Kana, TW. 2002. Barrier island formation via channel avulsion and shoal bypassing. In Proc 28th Intl Conf Coastal Engineering (Cardiff), pp 3438–3448.

Kana, TW. 2011. *Coastal Erosion and Solutions – A Primer*. Second Edition, Coastal Science & Engineering, Columbia, SC, 38 pp.

Kana, TW, SP Dinnel, and WJ Sexton. 1981. Bathymetry of Kiawah River, Stono River, and historical changes in Stono Inlet, South Carolina. Tech Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 71 pp.

Kana, TW, E.J. Hayter, and P.A. Work. 1999. Mesoscale sediment transport at southeastern U.S. tidal inlets: conceptual model applicable to mixed energy settings. Jour. Coastal Research, Vol 15(2), pp 303-313.

Kana, TW, ML Williams, and SJ Siah. 1984. Shoreline changes along Kiawah Island, May 1983 — May 1984. Final Report to Kiawah Island Company, Charleston, SC. RPI, Columbia, SC, 34 pp. + app.

Kana, TW, ML Williams, and FD Stevens. 1985. Managing shoreline changes in the presence of nearshore shoal migration and attachment. In Proc. Coastal Zone '85, Vol. 1, ASCE, New York, NY, pp. 1277-1294.

Kana, TW, MJ Vogel, WJ Sexton, and MO Hayes. 1983. Shoreline changes along Kiawah Island, May 1872 through May 1983. Final Report for Kiawah Island Company, Charleston, SC. Research Planning Institute Inc, Columbia, SC, 33 pp + appendices.

Kana, TW, SB Traynum, D Gaudiano, HL Kaczkowski, and T Hair. 2013. The physical condition of South Carolina beaches 1980–2010. Jour Coastal Research, Special Issue 69, pp 61-82.

Katmarian, E, and TW Kana. 1996. Shoreline assessment and recommendations for dune/beach restoration, Kiawah Island, South Carolina. Final Report to Town of Kiawah Island, SC. CSE, Columbia, SC, 44 pp + appendices.

Levisen, MV, and RF Van Dolah. 1996. Environmental evaluation of the Kiawah Island beach scraping project. Final Report to Town of Kiawah Island, SC. SCDNR Marine Resources Division, Charleston, SC, 16 pp + app.

SCDHEC–OCRM. 2009. Adapting to shoreline change: a foundation for improved management and planning in South Carolina. Draft Report of the Shoreline Change Advisory Committee, South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resources Management, Charleston, SC, 151 pp.

Sexton, WJ, and MO Hayes. 1996. Holocene deposits of reservoir quality sand along the central South Carolina coast. American Association Petroleum Geologists, Bulletin 80(6), pp 831-855.

Sexton, WJ, MO Hayes, and SP Dinnel. 1981. Shoreline stability of Kiawah Island, SC, October 1975 through July 1981. Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 22 pp.

Sexton, WJ, MO Hayes, TW Kana, MG Muthig. 1982. Shoreline stability of Kiawah Island, South Carolina (March 1981 through January 1982). Final Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 30 pp.

USFWS. 2006. Biological opinion: Kiawah Island beach nourishment (P/N 2005-1W-310-P). US Department of the Interior, Fish and Wildlife Service, Charleston, SC, 51 pp + app.

Ward, GW. 1978. Physical and sedimentological processes in a salt marsh tidal channel: Kiawah Island, South Carolina. Dissertation, Department of Geology, University of South Carolina, Columbia, 180 pp.

Williams, ML, and TW Kana. 1985. Shoreline changes along Kiawah Island, June 1984 — June 1985. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 76 pp.

Williams, ML, and TW Kana. 1986. Shoreline changes along Kiawah Island, June 1985 to September 1986. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 48 pp. + app.

Williams, ML, and TW Kana. 1987. Summary of shoreline changes along Kiawah Island between September 1986 and May 1987. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 11 pp + app.

ACKNOWLEDGMENTS

This report is the eighth in a series of annual beach monitoring reports following the 2006 east end beach restoration project, which was sponsored by the Town of Kiawah Island.

We thank Charles Lupima (mayor) and Jim Jordan (town wildlife biologist) for coordinating CSE's work and for providing access to the project site and related information on natural changes at the eastern end.

CSE's field surveys were directed by Drew Giles with assistance by Luke Fleniken, Steven Traynum, and Trey Hair. Data reduction and analysis were accomplished by Steven Traynum and Drew Giles with assistance by Trey Hair and Dr. Tim Kana. The report was written by Steven Traynum and Tim Kana with production assistance by Diana Sangster and Trey Hair.