2018 Isle of Palms Restoration Project
Year 3 Monitoring Report

2021
MONITORING REPORT

Prepared for

City of Isle of Palms
Isle of Palms, South Carolina

COASTAL SCIENCE & ENGINEERING

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2018 Isle of Palms Restoration Project

Year 3 (2021) Monitoring Report

Annual Beach and Inshore Surveys

Prepared for:

City of Isle of Palms
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[2492YR3 — Monitoring Year 3]

COVER PHOTO: This image was collected in October 2021 from above the beach access path between 54th Ave and 55th Ave, looking southwest towards the Pier. There is a notable seaward bulge in the water line between 45th Ave and 55th Ave, which is the result of the 2018 renourishment project sand migrating with prevailing waves, winds, and currents. This bulge is known as a sand wave and is a common occurrence along shorelines adjacent to recently-completed nourishment projects. This particular wave is expected to continue moving towards the pier and gradually become smaller.

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1.0 INTRODUCTION

This monitoring report is submitted to the City of Isle of Palms, SC (IOP) by Coastal Science & Engineering (CSE) as part of an ongoing beach monitoring effort which began in 2007 during planning for the 2008 Isle of Palms Beach Restoration Project (P/N 2007–02631–2IG) (CSE 2008). This report follows earlier monitoring reports submitted annually to the City, as well as additional reports and engineering documents related to shoal management and beach nourishment activities (P/N 2010–1041–2IG; 2016–00803 (CSE 2019). The report details the beach condition as surveyed in July 2021 and compares this condition with selected earlier dates, including the pre-2018 project condition. This is the third annual monitoring report following the 2018 nourishment project. Certain portions of this report detail monitoring efforts required by state and federal permit conditions for the 2018 project.

Analyses in this report include detailed beach volume change along the ~7-mile beach, which spans from Breach Inlet to Dewees Inlet. It also includes comparisons of earlier beach conditions with the present condition, calculation of annual erosion rates, and measurements of linear shoreline change. Large-scale morphologic changes occurring in Breach Inlet and Dewees Inlet are also discussed, along with the anticipated impacts of these shifting shoals on the future beach condition. Ground and aerial photographs are included to provide a visual representation of the beach condition. These images document areas with dune escarpments, show dry-beach width, and delineate areas with existing or potential damage due to erosion.

This report also discusses general information about storm events occurring in 2021 and their impact on the beach, as well as updated sea level rise information for the Isle of Palms. Observations of escarpments, vegetation, sand fences, and other beach management considerations are discussed.

2018 Nourishment Project Summary

Sponsor: The beach restoration project was funded by the City of Isle of Palms, the State of South Carolina, Wild Dunes Community Association (including individual property owners and regimes), and Wild Dunes Resort. The City of Isle of Palms served as project owner and administrator.

Engineer: Coastal Science & Engineering (CSE, Columbia, SC)

Contractor: Great Lakes Dredge & Dock Co. (Oak Brook, IL)

Permit: SC048C–OCRM USACE P/N 2016–00803

Scope: Placement of 1,676,518 cubic yards (cy) of sand in the following areas.

Reach 1 (4,400 lf)	Sta 236+00–280+00	942,320 cy	214 cy/ft
Reach 2 (4,400 lf)	Sta 280+00–324+00	734,198 cy	167 cy/ft

Const. Cost: $13,545,585.70

Nourishment Schedule

- 13 December 2017 –Mobilization of equipment and pipe
- 16 January 2018 –First pumping near Beach Club Villas
- 24 February 2018 –Completion of Reach 1
- 23 March 2018 –Completion of Reach 2
- 1 April 2018 –All equipment removed from beach and offshore zone – Project Complete

Monitoring Events

- May 2017 –Pre-Project Annual Survey
- April 2018 –Post-Project Survey
- June 2019 –Year 1 Survey
- June 2020 –Year 2 Survey
- July 2021 –Year 3 Survey

2.0 SETTING

2.1 Project Setting

The Isle of Palms is a ~7-mile-long barrier island located north of Charleston Harbor. It has a southeast-facing shoreline bounded by Breach Inlet and Sullivan's Island to the south, with Dewees Inlet and Dewees Island to the north (Figure 2.1). The northern end of the island is wider due to periodic sand additions through shoal bypass events (Kana 2002, Traynum and Kaczkowski 2015). These events result in a net accumulation of sand over several decades, which builds the updrift end of the island. The downcoast end of the island is narrower and terminates in a recurved spit at Breach Inlet. These characteristic morphologies are typical of "drumstick" barrier islands (Hayes 1979) and occur along mixed energy coasts where both tides and waves influence shoreline evolution (Figure 2.1).

The eastern end of the island is typically more dynamic due to the influence of shoals associated with the Dewees Inlet ebb-tidal delta. Figure 2.2 shows aerial images of the east end of the island from 1944 to 1963. The photos document a large-scale shoal bypass event that impacted the shoreline encompassing the area that is now known as Wild Dunes. The shoal stretched for approximately two miles along the eastern end of the island. It was so large that a new ephemeral barrier beach was established over 1,000 feet (ft) seaward of the previous shoreline. This new beach ridge trapped a tidal lagoon that was flushed by a small channel and the shoal attached to the beach sometime between 1944 and 1949. By 1957, the shoal had merged with the beach, buried the lagoon, and completely attached to the main portion of the island by 1963.

The emergence of this large shoal may be a result of the merging of several shoals in the delta partially visible in the 1944 image, including two visible shoals at the northeastern tip of the island. It is likely these shoals were at one point a trailing ebb spit (see Kana 2002), and the sand from this spit merged with a shoal further west to create the large sand body that formed the lagoon. The shoal ultimately added well over 1,000,000 cubic yards (cy) of sand to the beach.

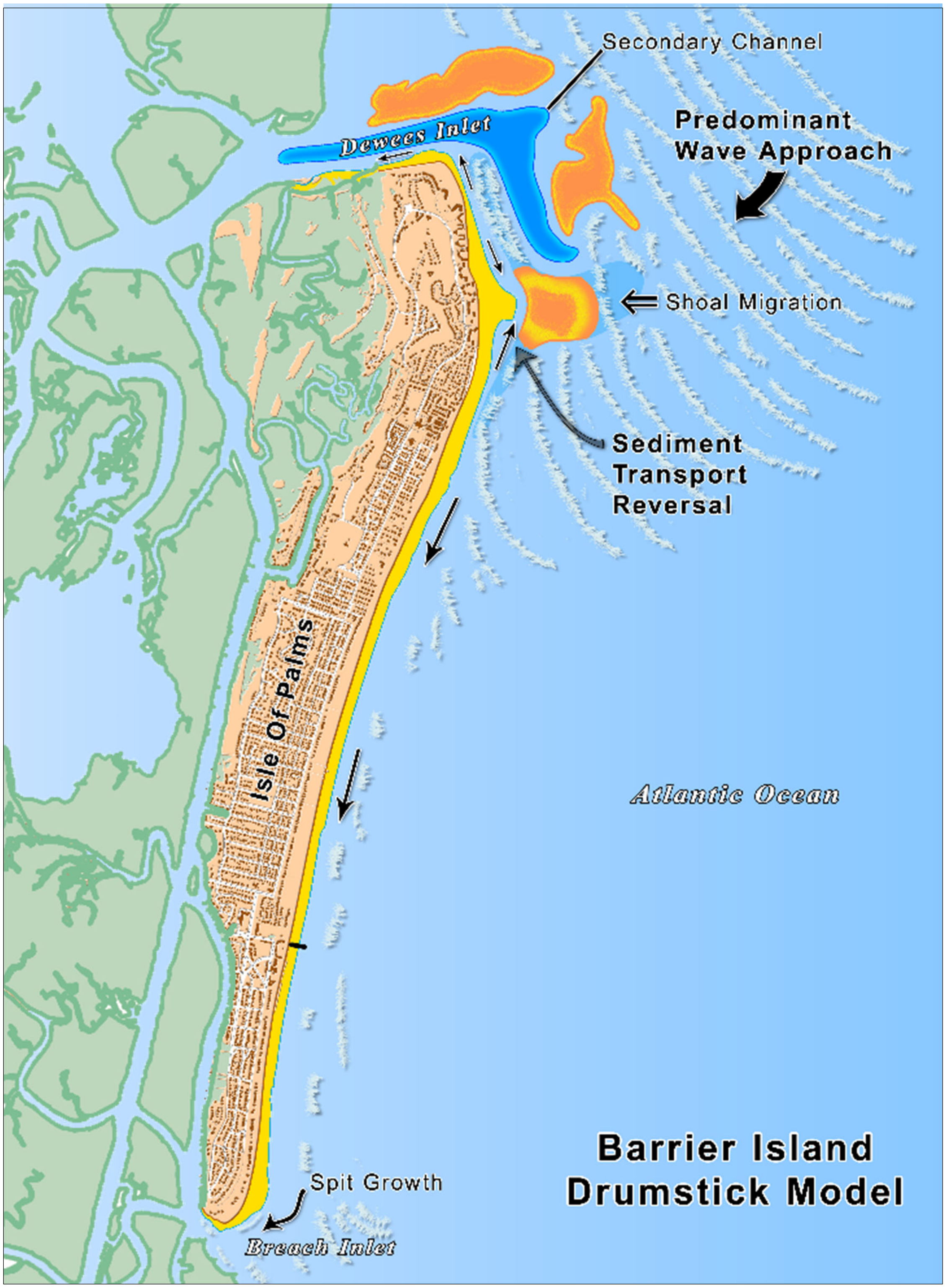

FIGURE 2.1. Schematic of the Isle of Palms showing the wider northeast end characteristic of a "drumstick" barrie island.

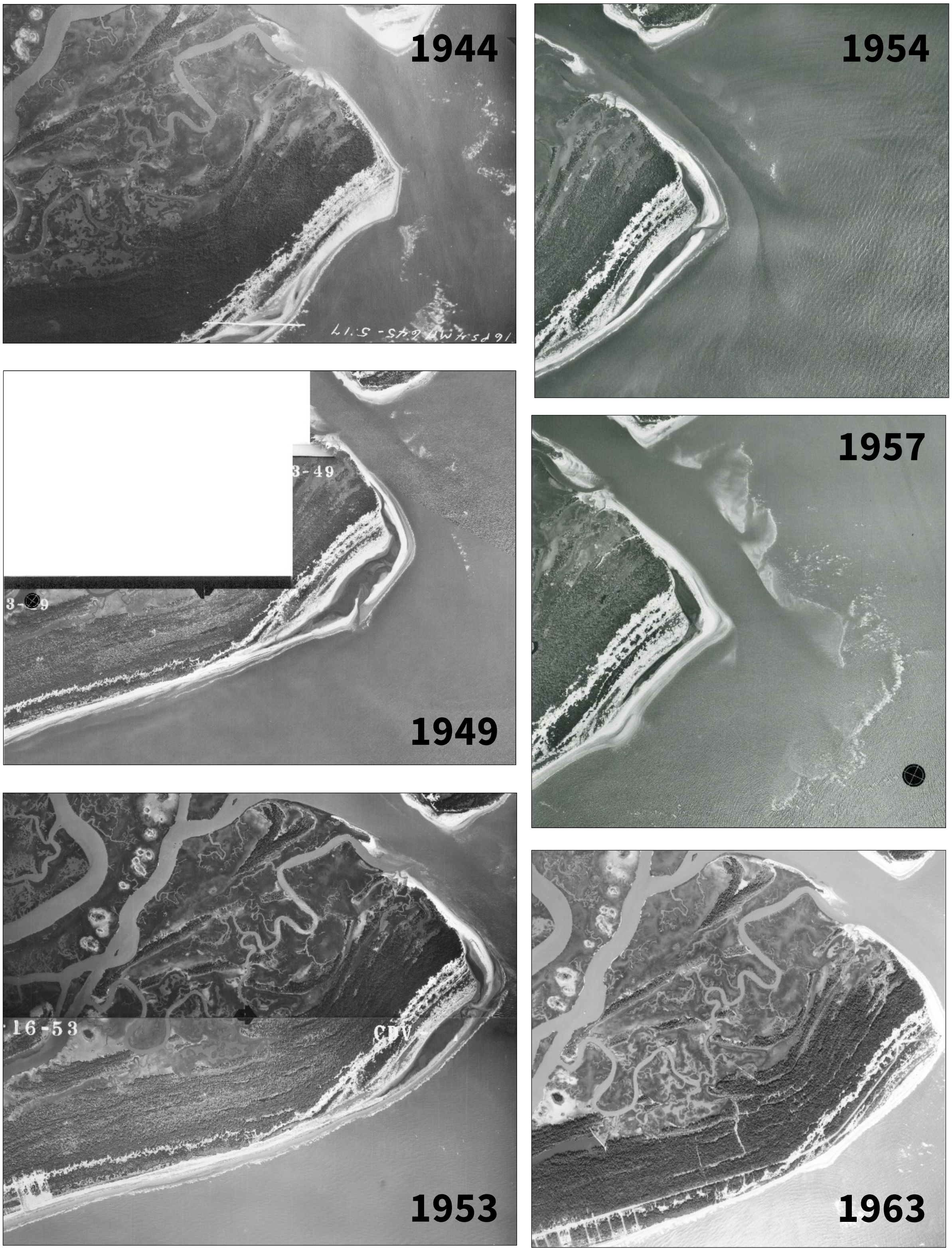

FIGURE 2.2. Historical aerials from CSE 2010 report page 56 (Figure 3.35).

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

This shoal attachment effectively built the shoreline at the northeast end of the island seaward ~500 feet (ft) between 1944 and 1963; however, much of this accreted sand eventually spread to downcoast areas. In short, the eastern end of the island (east of the present-day Beach Club Villas) was developed on sand that recently accreted to the beach and not on the stable upland area that had existed for decades like most of the remainder of the island. Much of the development built in the late 1970s and early 1980s occurred in areas that were likely wet sand beach in the 1930s–1940s.

Following the large-scale event mentioned previously, the eastern end of the island continued to experience shoal-bypass events, though all were substantially smaller in magnitude than the 1940s–1960s event. These events generally attached along the central Wild Dunes area and are more characteristic of shoal-bypass events characterized by Kana (2002), with distinct stages of 1) emergence, 2) migration and attachment, and 3) spreading (Fig 2.3). These events have been responsible for focused erosion along various portions of the Wild Dunes area, including two events in the 1980s, another in the late 1990s, and a large event in the mid-2000s that led to the 2008 beach nourishment project.

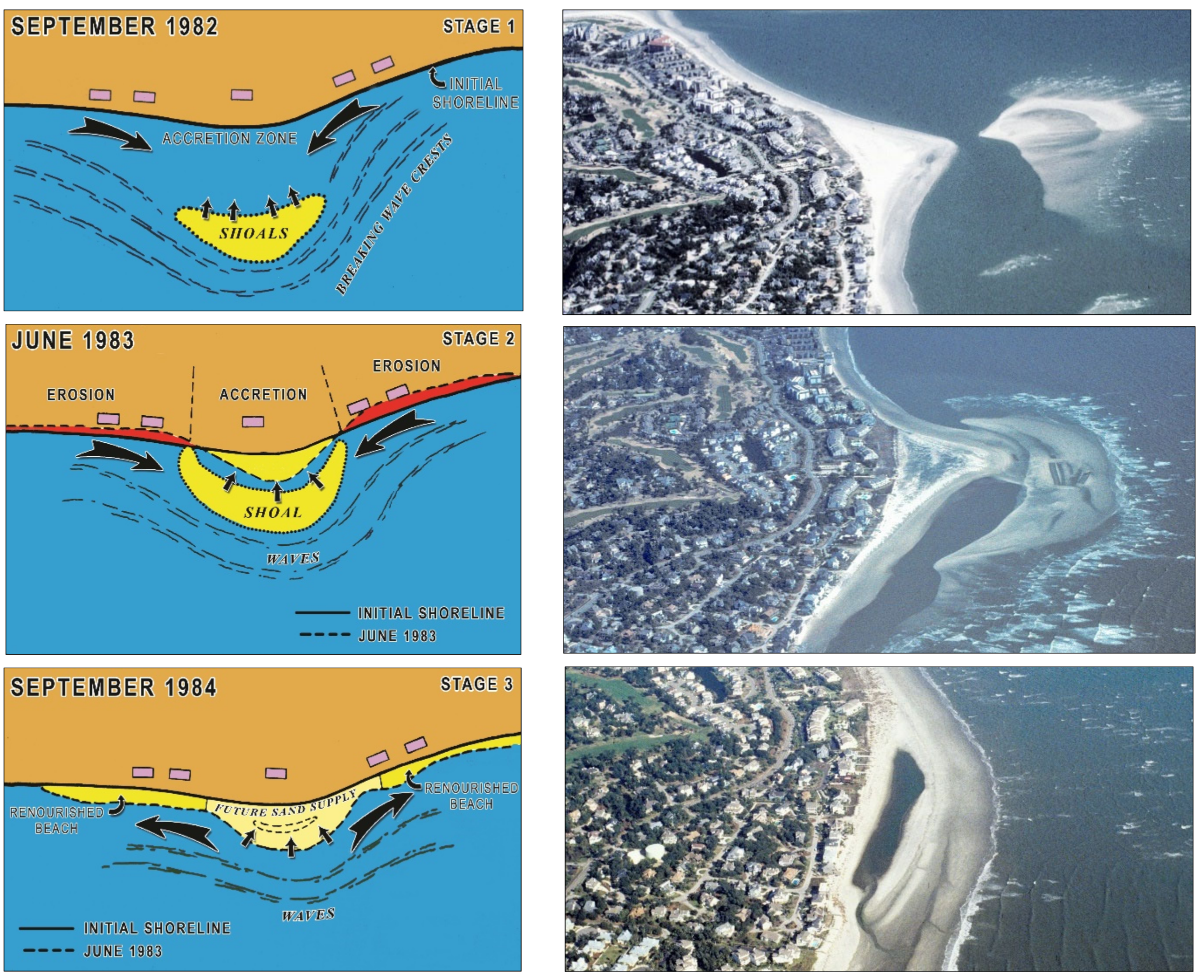

FIGURE 2.3. **[LEFT]** Schematic of the shoal-bypass cycle originally modeled from a bypass event at Isle of Palms. **[RIGHT** A shoal-bypass event at northeastern Isle of Palms corresponding to the schematic. The upper photo shows a shoal i Stage 1 (1996). The middle image illustrates Stage 2 (1997). The bottom photo shows Stage 3 (1998).

The addition of sand from shoal bypassing at the east end of the island has contributed to relatively steady accretion along the central and western ends, resulting in a wide setback for most properties west of 58th Avenue. In the 1970s, properties along 46th Ave to 53rd Ave installed a seawall and several groins by 1984, as shown in Figure 2.4. Since 1984, the beach has accreted rapidly, and all groins and seawalls have been buried.

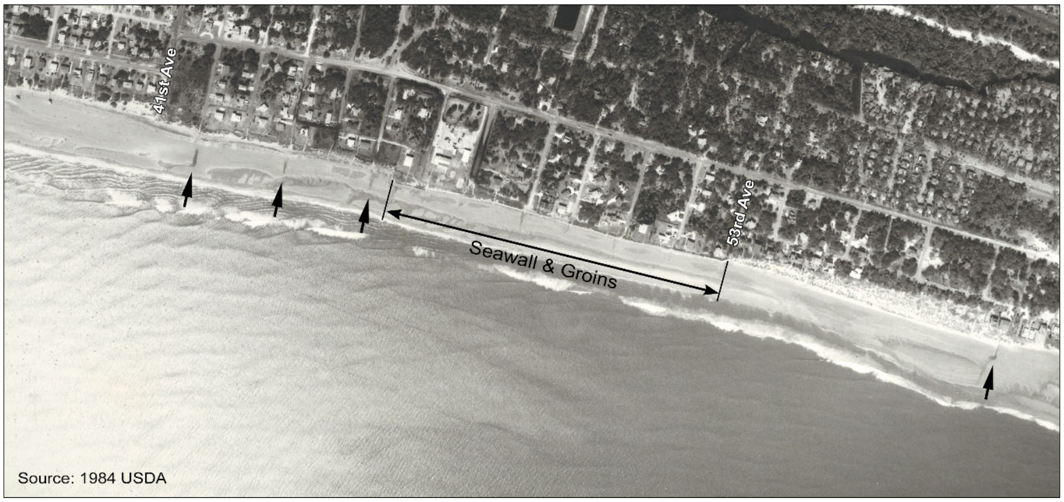

FIGURE 2.4. A seawall and groins were in place in 1984 between 46th Ave to 53rd Ave. Today, due to rapid accretion, these groins and seawalls have been buried.

2.2 Previous Projects

As mentioned in the previous section, erosion mitigation measures at Isle of Palms began in the 1970s with the construction of seawalls and groins in the area between 41st Ave and 53rd Ave. Another groin was visible in 1973 near present-day 58th Avenue. In 1981, a concrete-filled geotextile bag groin was built near the tee of the 17th hole of the Links Course to reduce the erosion threat along the Dewees Inlet shoreline. In 1983, in response to a shoal attachment event, homeowners along Seagrove and Beach Club Villas constructed a rubble mound seawall (Kana, Williams, and Stevens 1985). Sand scraping was also attempted but proved insufficient to maintain a dry sand beach under the extreme erosion pressure. In late 1983, the first nourishment project along Isle of Palms was completed using sand dredged from the new marina at 41st Ave. Approximately 350,000 cy of sand was added to the erosional zones adjacent to the shoal as the shoal was beginning stage three of the bypass cycle. This resulted in a dramatic increase in beach width along Seagrove Villas, Beach Club Villas, and Mariners Walk, where erosion was most severe, augmenting the accretional shoal sand.

From 1984 to 2007, sand scraping from accretional areas was the only mitigation attempted to combat shoal-induced erosion. CSE and its predecessors documented scraping efforts circa 1983, 1987, 1998 (Figure 2.3) which all attempted to move sand from accreting areas to erosional arcs. From 2004–2007, sandbags were installed to protect several structures from Shipwatch to Ocean Club and prevent additional shoreline retreat (Figure 2.5).

FIGURE 2.5. To prevent additional erosion, sandbags were installed along several structures from Shipwatch to Oceai Club from 2004 to 2007.

Erosion reached such a severe condition in 2007 that there was little-to-no beach along portions of the east end of the island, even at low tide (Figure 2.6). The Wild Dunes Community Association contracted with CSE to evaluate the causes of erosion and prepare a feasibility study outlining alternatives for restoration (CSE 2007). CSE recommended nourishing the beach using sand from an offshore borrow area and began the steps to obtain a permit for the work. The City of Isle of Palms then took ownership of the project and served as the applicant for the permits. Permits were obtained (P/N 2007–02631–2IG), and the City contracted with Weeks Marine for a project involving nourishment of 847,000 cy of sand over 10,200 lf (linear feet) of beach. The project extended from 200 ft north of 53rd Avenue to the 17th green of the Links Course.

FIGURE 2.6. Isle of Palms in 2007 prior to beach nourishment.

The 2008 project was completed between 15 May and 15 July 2008 (Figure 2.7). As part of the project, Weeks Marine removed all sandbags from the project area, which totaled ~9,400 bags. Homeowners removed an additional 4,680 bags from under buildings. Averaging ~25,000 cy of sand per day, the dredge *RS Weeks* pumped sand from three borrow areas 2–3 miles from the beach. The nourishment was placed in three reaches and included ~270,000 cy between 53rd Ave and Dune Crest Ln (Reach A), 552,400 cy from Mariners Walk to the 18th Fairway (Reach B), and 25,000 cy from the 18th tee to the 17th fairway (Reach C). Figure 2.8 shows the layout of the 2008 project. Figure 2.9 shows a post-project aerial photo (2008) which compares to the project area before renourishment (2007).

FIGURE 2.7. **[ABOVE]** 2008 beach nourishment projec (completed on 15 July 2008).

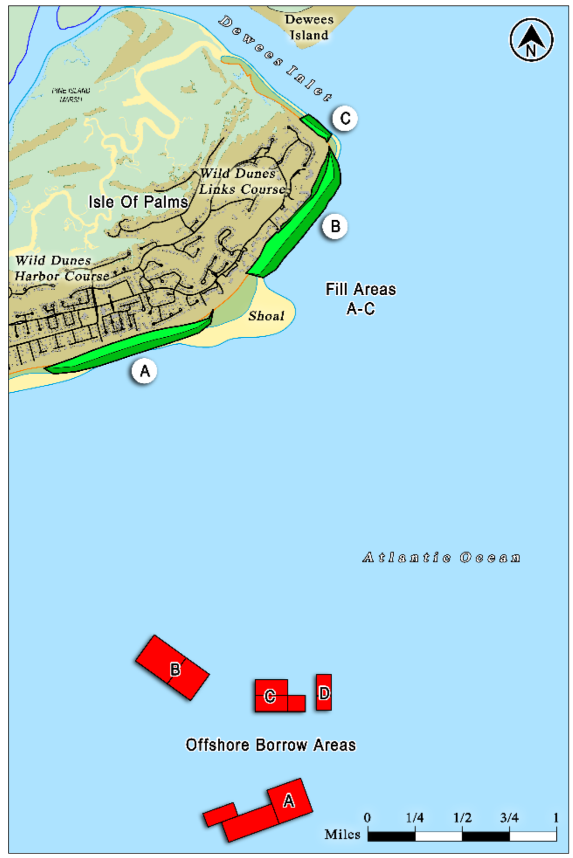

FIGURE 2.8. **[RIGHT]** 2008 nourishment project map.

FIGURE 2.9. **[LEFT]** Isle of Palms in 2007 prior to nourishment. **[RIGHT]** The project area in 2008 following nourishment

Following the 2008 project, CSE monitored the beach at least annually to document beach volume changes and project performance. Two shoal-bypass events occurred in 2009 and 2010, and another larger event was beginning to emerge offshore in 2010. In anticipation of the need for potential remediation (and after observation of an erosional hotspot forming near the Ocean Club/Seascape area), the City sought a permit to manipulate the accretional shoal area, expedite attachment, and move sand to the erosional hotspots. An initial project was completed in 2012 that transferred ~80,000 cy of sand from the central portion of Wild Dunes to the east end near the Ocean Club. A larger project was completed in late 2014 through early 2015, which moved ~280,000 cy from two accretional areas (an attaching shoal centered near Beach Club Villas and from 53rd to 56th Avenues) to the beach fronting Beachwood East (~70,000 cy) and the area fronting Seascape/Ocean Club/18th hole (~210,000 cy). The project sought to transfer as much sand as possible from the shoal to the beach (Figure 2.10).

FIGURE 2.10. January 2015 aerial image of the 2014–2015 shoal management project showing equipment transferring sand from an attaching shoal to the eroded beach.

2.3 2018 Project

From 2015 to 2018, the beach along the eastern end of the island continued to respond to a shoal attachment event. Erosional hotpots were present along Beachwood East and near the 18th hole of the Links Course. In 2016, the City opted to pursue a permit for another large-scale renourishment project. CSE was retained to provide engineering services necessary to complete a permit application package with associated reports and documents. The project design called for the addition of 1,676,000 cy of sand along the eastern end of the island, with maximum fill densities of over 300 cubic yards per foot (cy/ft). The design fill would add over 600 ft of dry sand beach in the largest fill areas.

Engineering for the project began with analyses to determine the volume of sand required to restore the beach to a desired condition. CSE initially prepared a fill plan based on the beach condition as it existed in 2015, when a recent shoal attachment created a bulge in the shoreline near the center of the project area. Following hurricane impacts in 2015, 2016, and 2017, as well as erosion of the attached shoal, CSE modified the fill template to account for erosion occurring in the center of the project area and substantial accretion at the eastern end. The final fill plan is listed in Table 2.1 and shown graphically in Figure 2.11. The data reflect the final design prior to a change order issued during the project that placed additional sand along the center of the project area. The fill density averaged 161.5 cy/ft over the length of the project area, with the maximum fill volume of ~325 cy/ft. The nourishment volume decreased along the center of the project area, with a minimum of 50 cy/ft added.

The fill template ranged in width based on the final design, reaching as much as 600 ft in the highest density areas. The berm width decreased along the central portion of the project area, as the pre-project beach was wider than adjacent areas. At either end of the project, the berm width tapered to the existing dune line (Figs 2.11 and 2.12).

Construction began on 16 January 2018 and was completed by 23 March 2018. Table 2.2 shows the design and actual fill volumes determined by TI Coastal, the independent surveyor retained by Great Lakes Dredge and Dock Company, the nourishment contractor. The "Design Volume" column represents the volume of sand above the before dredge (BD) condition and below the design template. Note that this volume is less than the final contract amount due to accretion between the pre-project design surveys and TI Coastal's BD survey. The "Fill Volume" column represents the total amount of sand placed on the beach. The rows highlighted in yellow represent the area repumped following the Hurricane *Irma* change order. In total, 1,725,942 cy of sand was added to the project area. Of that total, 974,374 cy were pumped west of Station 280+00 (Property Owners Beach House), and 751,568 cy were placed east of Station 280+00. The 49,424 cy of sand placed above the pay quantity of 1,676,518 cy was not paid.

TABLE 2.1. The modified fill schedule designed to account for variable erosion and beach widths along the projec area, as well as substantial accretion at the eastern end of the island.

Station	Pre-Project Unit Volume (cy/ft)	Fill Vol (cy/ft)	Design Fill Vol (cy/ft)	Post-Project Unit Volume (cy/ft)
230	321.6	**0.0**	321.6	351.6
232	338.9	**0.0**	338.9	379.0
234	298.4	**0.0**	298.4	349.0
236	262.7	**0.0**	262.7	329.7
238	258.3	**26.4**	284.8	358.5
240	272.2	**59.0**	331.2	399.6
242	255.7	**73.9**	329.6	415.9
244	295.9	**170.8**	466.7	499.0
246	283.7	**233.3**	517.0	526.5
248	289.5	**277.7**	567.2	562.6
250	306.2	**296.6**	602.8	587.9
252	283.8	**307.5**	591.2	554.5
254	267.2	**315.2**	582.4	539.7
256	228.9	**320.6**	549.6	524.7
258	251.7	**325.8**	577.6	544.6
260	275.5	**314.6**	590.2	547.9
262	306.5	**298.2**	604.7	563.4
264	333.8	**260.0**	593.8	595.7
266	382.5	**240.0**	622.5	620.5
268	376.4	**210.0**	586.4	543.5
270	359.2	**150.0**	509.2	549.8
272	372.9	**120.0**	492.9	537.1
274	355.6	**90.0**	445.6	515.2
276	442.8	**75.0**	517.8	576.2
278	426.6	**60.0**	486.6	587.3
280	534.3	**60.0**	594.3	771.4
282	436.3	**60.0**	496.3	652.7
284	450.9	**50.0**	500.9	746.0
286	520.6	**50.0**	570.6	760.5
288	456.4	**50.0**	506.4	705.7
290	444.9	**60.0**	504.9	657.8
292	479.3	**60.0**	539.3	672.8
294	526.0	**80.0**	606.0	686.2
296	511.1	**110.0**	621.1	655.5
298	498.4	**130.0**	628.4	634.5
300	487.0	**160.0**	647.0	630.9
302	472.4	**190.0**	662.4	622.6
304	436.9	**225.0**	661.9	597.7
306	442.7	**250.0**	692.7	614.1
308	392.2	**250.0**	642.2	571.3
310	376.4	**250.0**	626.4	560.2
312	361.0	**225.0**	586.0	546.5
314	320.2	**180.0**	500.2	488.9
316	415.6	**140.0**	555.6	560.5
318	427.6	**90.0**	517.6	529.7
320	449.0	**30.0**	479.0	526.7
322	449.8	**20.0**	469.8	495.5
324	418.4	**0.0**	418.4	450.9
326	415.0	**0.0**	415.0	434.3
328	420.0	**0.0**	420.0	451.0

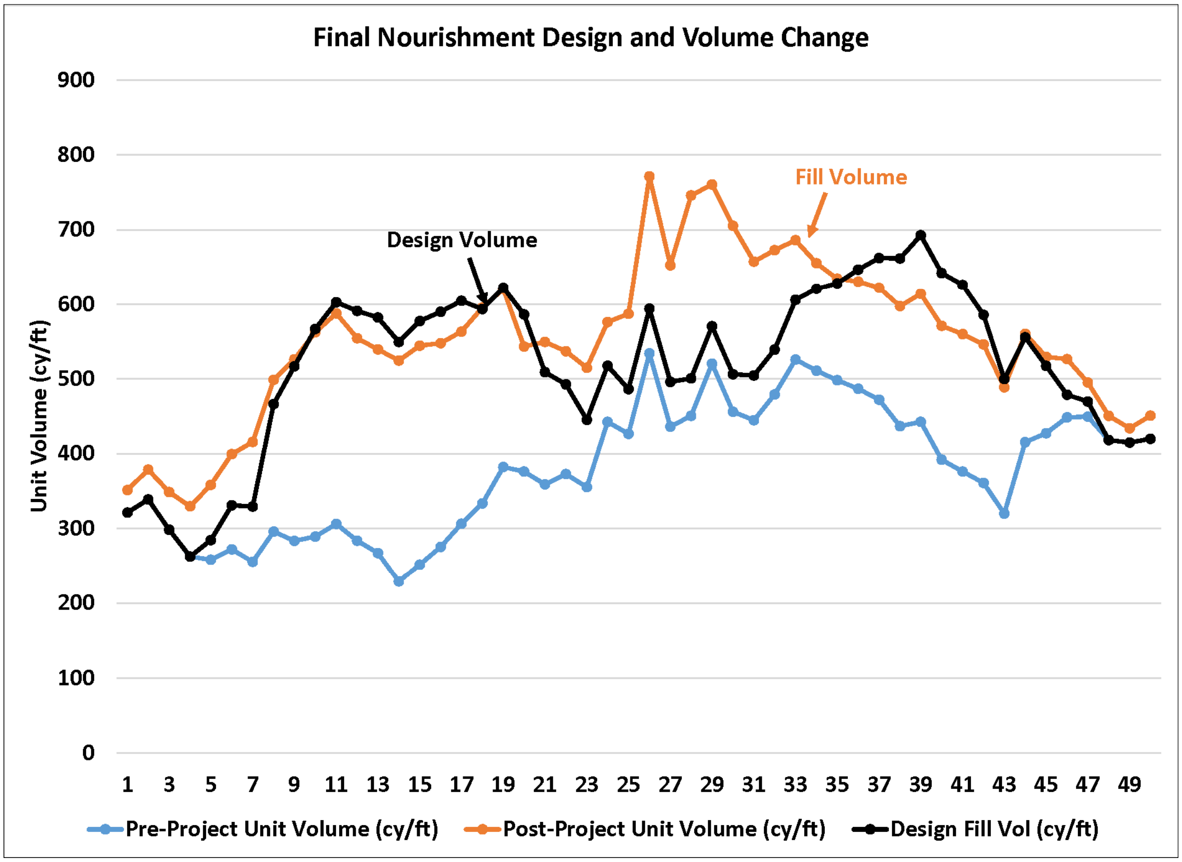

FIGURE 2.11. A graphic representation of the 2018 final fill template (shown in TABLE 2.2).

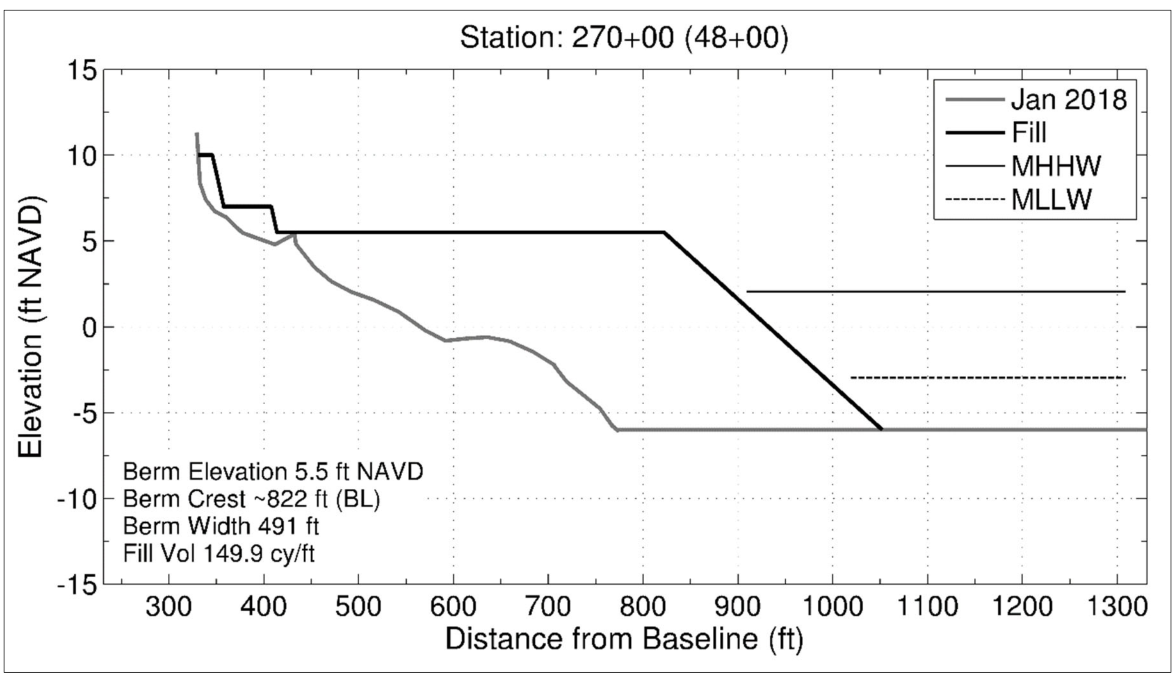

FIGURE 2.12. The 2018 design fill profile incorporated a dune, storm berm, wide fill berm, and sloping section.

TABLE 2.2. Design and actual fill volumes determined by TI Coastal.

Station	Design Volume (cy)	Fill Volume (cy)	Station	Design Volume (cy)	Fill Volume (cy)
236+00	0		289+00	11,105	11,132
237+00	804	884	290+00	11,049	11,207
238+00	2,205	3,896	291+00	11,063	11,254
239+00	3,170	5,926	292+00	11,125	11,402
240+00	4,061	8,310	293+00	11,333	11,170
241+00	6,061	11,356	294+00	11,347	10,909
242+00	9,107	13,518	295+00	11,327	11,444
243+00	12,503	15,683	296+00	11,308	11,948
244+00	16,387	18,628	297+00	11,631	11,995
245+00	19,920	21,625	298+00	12,201	12,333
246+00	22,899	24,474	299+00	12,236	12,523
247+00	25,585	27,183	300+00	12,241	13,075
248+00	27,455	28,754	301+00	12,913	13,281
249+00	28,789	28,239	302+00	13,948	14,104
250+00	30,167	31,479	303+00	15,069	15,477
251+00	31,181	32,451	304+00	16,027	16,373
252+00	31,470	33,976	305+00	16,586	16,906
253+00	31,426	32,359	306+00	17,129	17,478
254+00	32,042	32,369	307+00	17,448	18,473
255+00	32,443	30,318	308+00	17,536	18,527
256+00	33,719	34,416	309+00	17,610	18,244
257+00	34,963	35,931	310+00	17,555	18,307
258+00	33,841	34,875	311+00	17,757	18,698
259+00	32,952	33,558	312+00	17,687	18,582
260+00	32,567	32,868	313+00	17,120	17,922
261+00	31,827	32,428	314+00	16,452	16,991
262+00	30,985	32,027	315+00	15,600	16,329
263+00	29,682	30,800	316+00	13,887	14,910
264+00	27,782	28,388	317+00	11,634	12,404
265+00	26,261	26,810	318+00	9,514	10,179
266+00	25,145	25,880	319+00	7,189	8,952
267+00	23,634	24,314	320+00	5,076	8,638
268+00	22,321	22,946	321+00	3,256	7,093
269+00	21,015	22,001	322+00	1,831	4,643
270+00	18,789	19,955	323+00	1,030	2,780
271+00	16,199	17,330	324+00	631	1,609
272+00	13,753	14,883	279+00	0	0
273+00	11,886	12,419	279+80	1,782	1,812
274+00	10,815	11,146	279+90.404	12,904	14,394
275+00	10,220	10,461	280+00	14,782	16,133
276+00	10,142	10,235	281+00	12,116	12,366
277+00	10,368	10,381	282+00	12,265	12,707
278+00	10,533	10,394	283+00	12,658	13,602
279+00	10,860	10,903	284+00	12,539	13,338
279+80	8,977	9,312	285+00	12,243	12,875
279+90.404	8,459	9,138	286+00	12,229	12,552
280+00	8,460	9,147	287+00	12,153	12,283
281+00	11,040	11,720	288+00	11,948	12,239
282+00	11,006	11,551	289+00	12,056	12,328
283+00	11,091	11,565	290+00	12,171	12,270
284+00	11,120	11,190	291+00	11,992	11,919
285+00	10,931	10,094	292+00	10,418	10,852
286+00	10,903	10,901	293+00	6,838	8,118
287+00	11,171	11,319	294+00	3,503	4,813
288+00	11,218	11,336	**Total**	**1,635,358**	**1,725,942**

3.0 METHODS

Monitoring efforts for the present report were performed in July 2021. Sand volume changes 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 3.1). 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). 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™ R10 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 3.2) and was collected with RTK-GPS coupled with an Odom CV100™ precision echosounder mounted on CSE's survey vessel, the *RV Southern Echo*.

Profiles were collected from the most landward accessible point in the dune system to a minimum of 1,500 ft from the baseline. Profiles along the northeast end of the island extended up to 6,000 ft offshore to encompass the shoals associated with Dewees Inlet. Alongshore spacing of the profiles ranged from 200 ft to 1,000 ft, with the more closely spaced profiles north of 53rd Avenue 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.

To better understand regional sand volume changes, seven reaches were defined along the Isle of Palms. Combining several profiles into a reach makes it easier to identify overall sediment gains and losses over large portions of the beach. In the project area, the reaches differ from those used during construction to encompass areas where no work was performed.

FIGURE 3.1. Baseline map of Isle of Palms showing the reference line used to establish monitoring profiles. Stationing increases to the north from Breach Inlet.

FIGURE 3.2.

Surveying beach profiles involve collection of land-based data at low tide and hydrographic data collectioı overlapping the land-based work.

The reaches used for monitoring purposes are shown in Figure 2.3 and are defined as follows:

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

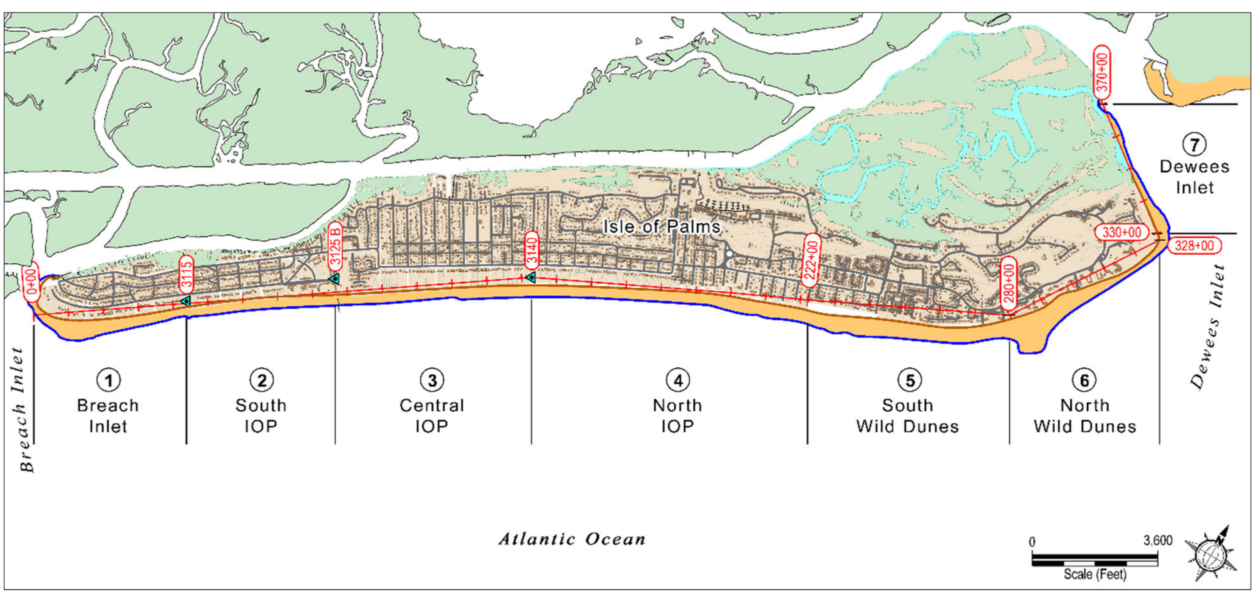

FIGURE 3.3. Reach limits used in the present monitoring report.

To determine changes in beach volume along Isle of Palms, beach profile data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which converts 2D profile data in x–z (distance–elevation) 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 (closure depth).

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. Sand volume was calculated between the primary dune and between −10 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.

Note that for the present report, several adjustments were made to the calculation limits for profiles showing significant erosion in recent years. The erosion has resulted in the active beach moving landward into areas not previously included in volume measures. Profile volumes for all previous surveys were recomputed using these new limits to provide accurate comparisons. This results in report volumes for a given year being slightly different than volumes reported in earlier reports.

Sand volumes for offshore areas were calculated from digital terrain models (DTMs) produced from MATLAB® and GlobalMapper®. 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 are compared with earlier collections to determine changes in shoal positions and volumes.

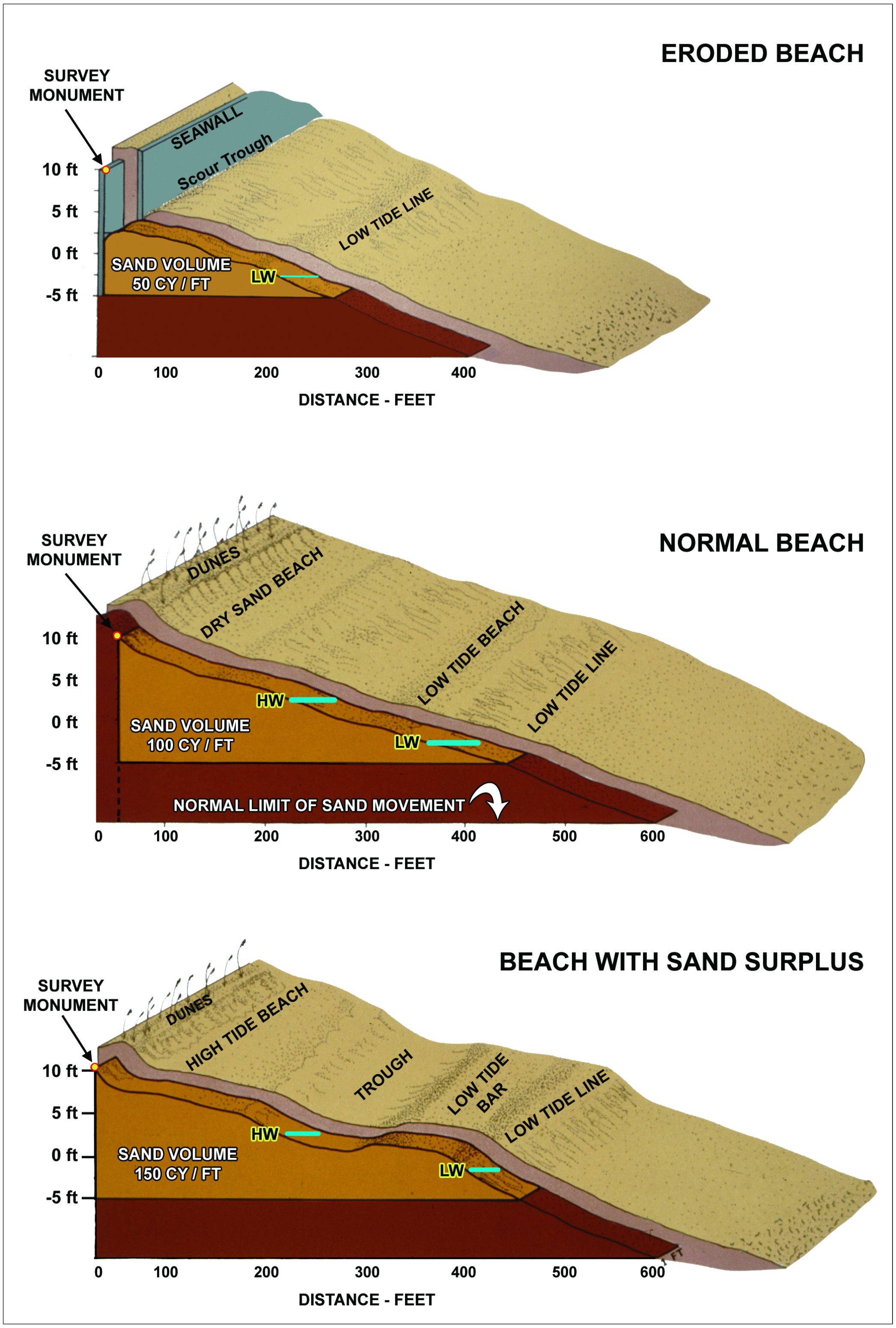

FIGURE 3.4. Illustration of the profile volume concept.

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4.0 RESULTS

Results of the beach monitoring effort presented in the following sections focus on changes occurring since the 2018 project but also address the condition relative to earlier periods, such as the pre-2008 project condition. CSE attempts to simplify the discussion of beach changes by focusing on larger reaches or areas rather than change occurring at a single profile. However, individual profiles are useful in visualizing how the shape of the beach changes over time, how shoals migrate onshore, and how the beach condition is in front of specific properties or features. Volume change is first reported for the entire island and will identify overall trends occurring between 2020 and 2021. The following sections focus on changes occurring in Dewees and Breach Inlets, followed by localized changes in reaches 1–7.

4.1 Island-wide Changes

The Isle of Palms beach lost ~191,200 cy of sand between June 2020 and July 2021. This compares to a loss of 59,605 cy of sand between June 2019 and June 2020. Figure 4.1 shows a map of the island with the distribution of volume change as colored lines. In the figure, warmer colors indicate erosion, while cooler colors show areas that gained sand. Erosion dominated the east end of the island (2018 project area), while much of the beach south of 53rd Ave gained volume. As observed in the past several surveys, erosion was most severe along Dunecrest Lane and Beach Club Villas. Accretion was most pronounced between 31st and 53rd Ave. Figure 4.2 graphs the beach volume change for each surveyed profile. Across the entire island, the beach holds ~1,159,900 cy more sand than the 2017 pre-nourishment condition and ~914,300 cy more sand than in 2009 (Figure 4.3). Details of beach volume change for each reach of the island are discussed in the following sections.

Tables 4.1 and 4.2 provide beach volume data for selected dates since 2008 for each project reach and each monitoring profile. Table 4.1 shows the beach volume change over the past year ranged from losses of ~22–36 cy/ft per year in reaches 5 and 6 to an increase of ~17 cy/ft per year in Reach 4 (just downcoast of the project area). Table 4.2 provides unit volumes for each line, with the 2018 project area highlighted.

FIGURE 4.1. Line map showing erosion and accretion patterns over Isle of Palms from April 2019 – July 2021.

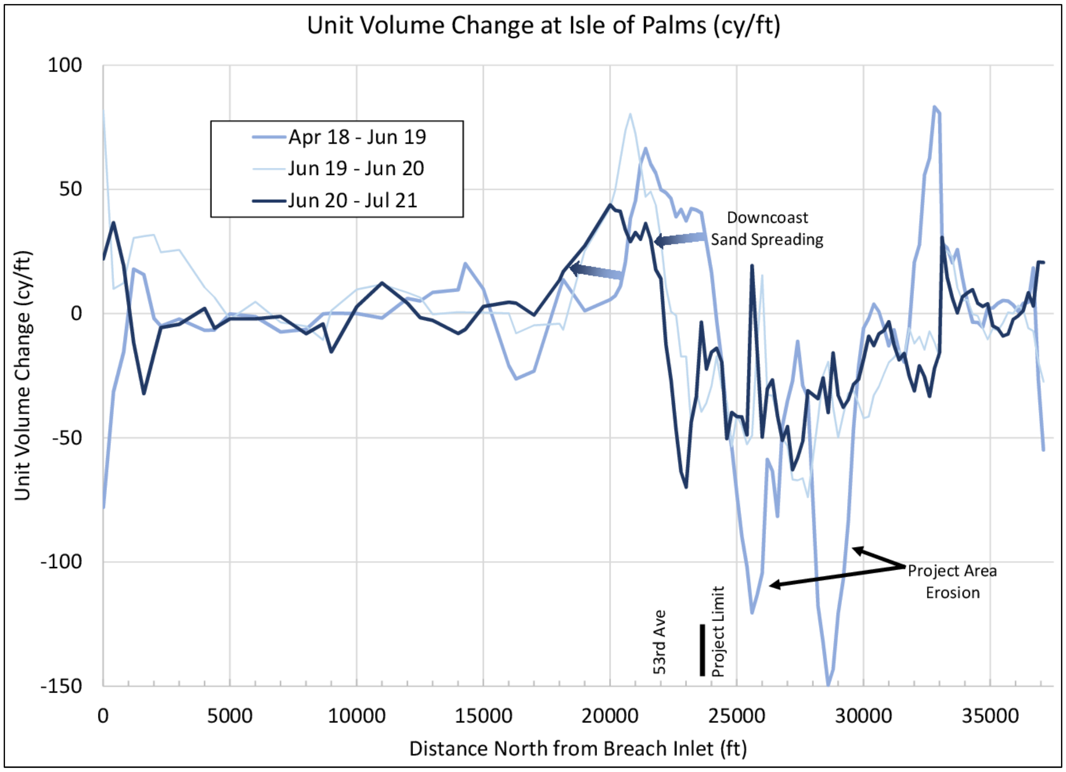


FIGURE 4.2. Beach unit volume change from 2018–2019, 2019–2020, and 2020–2021 for each monitoring line at Isle of Palms. The X axis represents distance from Breach Inlet in feet. This graph highlights the erosion occurring in the project area and accumulation of spreading sand adjacent to the project area.

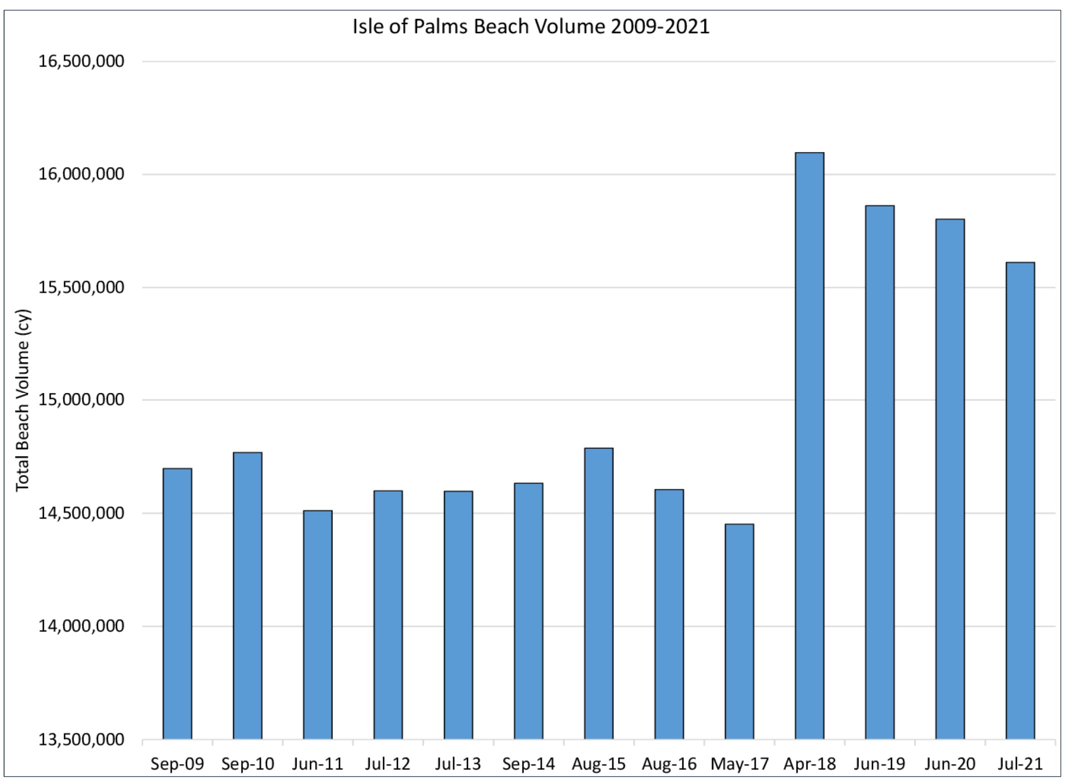


FIGURE 4.3. Total beach volume at Isle of Palms from 2009 to 2021. Effects of the 2018 project are seen in the rapid increase in the April 2018 island-wide beach volume.

TABLE 4.1. Beach volume data for selected dates since 2008 for each project reach and each monitoring profile. Beach volume change over the past year ranged from losses of 22-36 cy/ft per year in reaches 5 and 6 to gains of 17 cy/ft per year in reach 4.

								Total Volume (cy)									
	Length (ft)	Jul-07	Mar-08	Jul-08	Sep-09	Sep-10	Jun-11	Jul-12	Jul-13	Sep-14	Aug-15	Aug-16	May-17	Apr-18	Jun-19	Jun-20	Jul-21
Reach 1	4,390				1,940,588	1,993,636	1,942,143	1,881,244	1,816,322	1,881,462	1,872,947	1,775,416	1,757,549	1,791,525	1,759,618	1,863,247	1,860,783
Reach 2	4,280				1,459,694	1,482,997	1,415,263	1,531,348	1,552,061	1,528,779	1,494,240	1,517,129	1,493,822	1,502,877	1,486,790	1,480,475	1,465,678
Reach 3	5,620				1,810,569	1,876,440	1,828,257	1,896,808	1,967,693	1,970,583	2,007,460	2,016,198	2,012,752	2,019,758	2,040,749	2,071,086	2,069,438
Reach 4	7,910				2,596,737	2,631,739	2,651,113	2,803,737	2,921,254	2,934,335	3,002,074	2,980,044	2,987,522	3,032,547	3,106,339	3,257,028	3,389,472
Reach 5	6,000	2,629,327	2,549,937	2,861,693	2,786,313	2,745,765	2,661,727	2,512,657	2,406,324	2,362,329	2,293,119	2,129,726	2,063,023	2,972,774	2,796,544	2,577,463	2,361,302
Reach 6	4,900	1,683,637	1,693,074	2,315,187	2,323,458	2,239,921	2,182,964	2,119,653	2,053,612	2,048,008	2,206,134	2,267,962	2,249,140	2,919,450	2,796,471	2,676,289	2,570,853
Reach 7	4,000	1,686,112	1,734,455	1,747,799	1,779,401	1,796,965	1,829,702	1,852,674	1,879,955	1,906,471	1,911,566	1,918,296	1,887,345	1,857,506	1,875,343	1,876,662	1,893,570
Reaches 5-6	10,900	4,312,963	4,243,011	5,176,880	5,109,772	4,985,687	4,844,691	4,632,311	4,459,936	4,410,336	4,499,253	4,397,688	4,312,163	5,892,224	5,593,015	5,253,751	4,932,155
Total Island Volume	37,100				14,696,761	14,767,463	14,511,169	14,598,121	14,597,222	14,631,967	14,787,541	14,604,770	14,451,155	16,096,437	15,861,854	15,802,249	15,611,096
								Unit Volume (cy/ft)									
	Length (ft)	Jul-07	Mar-08	Jul-08	Sep-09	Sep-10	Jun-11	Jul-12	Jul-13	Sep-14	Aug-15	Aug-16	May-17	Apr-18	Jun-19	Jun-20	Jul-21
Reach 1	4,390				442.0	454.1	442.4	428.5	413.7	428.6	426.6	404.4	400.4	408.1	400.8	424.4	423.9
Reach 2	4,280				341.1	346.5	330.7	357.8	362.6	357.2	349.1	354.5	349.0	351.1	347.4	345.9	342.4
Reach 3	5,620				322.2	333.9	325.3	337.5	350.1	350.6	357.2	358.8	358.1	359.4	363.1	368.5	368.2
Reach 4	7,910				328.3	332.7	335.2	354.5	369.3	371.0	379.5	376.7	377.7	383.4	392.7	411.8	428.5
Reach 5	6,000	438.2	425.0	476.9	464.4	457.6	443.6	418.8	401.1	393.7	382.2	355.0	343.8	495.5	466.1	429.6	393.6
Reach 6	4,900	343.6	345.5	472.5	474.2	457.1	445.5	432.6	419.1	418.0	450.2	462.8	459.0	595.8	570.7	546.2	524.7
Reach 7	4,000	421.5	433.6	436.9	444.9	449.2	457.4	463.2	470.0	476.6	477.9	479.6	471.8	464.4	468.8	469.2	473.4
Reaches 1-7	37,100				396.1	398.0	391.1	393.5	393.5	394.4	398.6	393.7	389.5	433.9	427.5	425.9	420.8
								Profile Volume Change Since Last Survey (cy)									
	Length (ft)		Mar-08	Jul-08	Sep-09	Sep-10	Jun-11	Jul-12	Jul-13	Sep-14	Aug-15	Aug-16	May-17	Apr-18	Jun-19	Jun-20	Jul-21
Reach 1	4,390					53,048	-51,492	-60,899	-64,922	65,140	-8,515	-97,531	-17,867	33,975	-31,907	103,629	-2,463
Reach 2	4,280					23,303	-67,734	116,085	20,713	-23,282	-34,539	22,888	-23,306	9,054	-16,086	-6,315	-14,797
Reach 3	5,620					65,871	-48,183	68,550	70,886	2,889	36,877	8,738	-3,446	7,007	20,990	30,337	-1,647
Reach 4	7,910					35,002	19,374	152,624	117,518	13,081	67,739	-22,030	7,478	45,025	73,792	150,689	132,444
Reach 5	6,000		-79,389.26	311,755.42	-75,379.47	-40,548	-84,038	-149,070	-106,333	-43,996	-69,210	-163,393	-66,703	909,751	-176,230	-219,081	-216,160
Reach 6	4,900		9,437.24	622,112.95	8,271.32	-83,537	-56,958	-63,310	-66,042	-5,604	158,126	61,828	-18,821	670,309	-122,978	-120,183	-105,436
Reach 7	4,000		48,342.72	13,344.27	31,601.55	17,565	32,736	22,972	27,282	26,516	5,095	6,729	-30,950	-29,839	17,837	1,319	16,908
Reaches 1-7	37,100					70,703	-256,294	86,951	-898	34,744	155,574	-182,770	-153,616	1,645,283	-234,583	-59,605	-191,152
								Unit Volume Change Since Last Survey (cy/ft)									
	Length (ft)		Mar-08	Jul-08	Sep-09	Sep-10	Jun-11	Jul-12	Jul-13	Sep-14	Aug-15	Aug-16	May-17	Apr-18	Jun-19	Jun-20	Jul-21
Reach 1	4,390					12.1	-11.7	-13.9	-14.8	14.8	-1.9	-22.2	-4.1	7.7	-7.3	23.6	-0.6
Reach 2	4,280					5.4	-15.8	27.1	4.8	-5.4	-8.1	5.3	-5.4	2.1	-3.8	-1.5	-3.5
Reach 3	5,620					11.7	-8.6	12.2	12.6	0.5	6.6	1.6	-0.6	1.2	3.7	5.4	-0.3
Reach 4	7,910					4.4	2.4	19.3	14.9	1.7	8.6	-2.8	0.9	5.7	9.3	19.1	16.7
Reach 5	6,000		-13.2	52.0	-12.6	-6.8	-14.0	-24.8	-17.7	-7.3	-11.5	-27.2	-11.1	151.6	-29.4	-36.5	-36.0
Reach 6	4,900		1.9	127.0	1.7	-17.0	-11.6	-12.9	-13.5	-1.1	32.3	12.6	-3.8	136.8	-25.1	-24.5	-21.5
Reach 7	4,000		12.1	3.3	7.9	4.4	8.2	5.7	6.8	6.6	1.3	1.7	-7.7	-7.5	4.5	0.3	4.2
Reaches 1-7	37,100					1.9	-6.9	2.3	0.0	0.9	4.2	-4.9	-4.1	44.3	-6.3	-1.6	-5.2

TABLE 4.2. Beach volume data for selected dates since 2008 for each project reach and each monitoring profile. Unit volumes for each line are provided below, with the 2018 project area highlighted.

	Station	Distance to Next	Mar-08	Jul-08	Sep-10	Jul-12	Sep-14	May-17	Apr-18	Jun-19	Jun-20	Jul-21	Apr 18 - Jun 19	Jun 19 - Jun 20	Jun 20 - Jul 21	Change Since 2018
Reach 1	0	400			278.7	290.5	254.8	278.5	266.3	188.3	270.1	292.1	-78.0	81.8	22.0	25.8
	4	400			458.6	412.0	393.2	409.8	425.1	393.6	403.6	440.2	-31.4	9.9	36.6	15.1
	8	400			449.6	423.2	436.9	411.7	424.9	409.5	421.8	441.1	-15.4	12.3	19.3	16.2
	12	400			610.8	543.2	582.7	527.7	514.8	532.7	563.1	551.5	17.9	30.4	-11.7	36.7
	16	400			567.0	485.1	541.3	484.3	480.4	496.1	527.3	495.1	15.7	31.2	-32.2	14.7
	20	270			492.0	437.0	458.8	402.8	418.6	416.7	448.5	432.3	-1.9	31.8	-16.1	13.7
	3110	730			454.4	422.9	418.7	384.9	398.8	393.8	418.5	412.9	-5.0	24.7	-5.7	14.0
	30	1000			425.9	422.8	408.9	374.5	388.5	386.3	411.9	407.6	-2.2	25.6	-4.3	19.1
	40	390			390.1	401.1	375.9	359.7	367.1	360.4	370.9	372.9	-6.8	10.5	2.1	5.8
Reach 2	3115	610			369.2	386.8	363.4	344.1	355.6	349.0	355.6	349.7	-6.6	6.5	-5.8	-5.9
	50	1000			379.7	382.2	360.1	359.1	357.1	357.0	354.7	352.7	-0.2	-2.2	-2.1	-4.4
	60	1000			347.7	360.2	353.7	352.6	343.4	342.2	346.9	344.8	-1.2	4.8	-2.1	1.5
	70	1000			340.9	358.9	364.9	354.5	358.7	351.3	347.8	346.6	-7.4	-3.5	-1.2	-12.0
	80	670			310.0	318.7	336.0	321.0	330.1	323.7	318.6	310.6	-6.4	-5.1	-8.1	-19.5
Reach 3	3125	330			350.1	359.6	384.7	372.1	385.9	385.8	375.1	371.0	-0.1	-10.6	-4.1	-14.9
	90	1000			316.1	330.5	350.8	342.9	345.8	346.0	347.2	331.8	0.2	1.2	-15.4	-14.0
	100	1000			344.3	339.6	363.7	365.1	362.7	362.8	372.5	375.3	0.1	9.7	2.8	12.6
	110	1000			316.5	321.6	332.3	343.2	338.6	336.8	348.6	360.9	-1.8	11.8	12.3	22.3
	120	500			346.4	358.9	358.5	374.5	375.3	381.4	389.9	394.1	6.1	8.5	4.2	18.8
	3135	500			355.8	360.9	364.6	377.2	389.0	394.1	400.7	399.0	5.1	6.5	-1.6	10.0
	130	1000			329.3	328.4	335.5	352.7	356.9	365.4	365.2	362.4	8.6	-0.3	-2.7	5.6
	140	290			330.6	328.5	346.1	353.7	354.5	364.0	364.5	356.5	9.5	0.6	-8.0	2.1
Reach 4	3140	710			342.7	335.8	357.4	364.7	362.3	382.5	383.0	376.6	20.2	0.5	-6.4	14.3
	150	1000			309.7	313.0	337.9	346.6	350.6	360.5	361.0	363.9	9.9	0.4	2.9	13.2
	160	290			283.1	305.0	328.2	347.2	377.0	356.1	356.2	360.8	-21.0	0.1	4.6	-16.3
	3145	710			285.0	321.9	345.3	367.9	399.3	373.0	365.0	369.2	-26.3	-8.0	4.2	-30.1
	170	1000			293.4	317.0	339.3	366.0	388.0	364.8	360.1	359.6	-23.2	-4.7	-0.6	-28.4
	180	150			336.2	354.6	375.4	407.6	395.6	404.9	400.8	414.3	9.3	-4.0	13.5	18.8
	3150	850			274.4	317.7	393.6	413.5	406.2	419.8	413.3	430.1	13.6	-6.5	16.9	24.0
	190	1000			336.5	370.6	366.8	378.1	372.3	373.5	398.7	426.0	1.2	25.3	27.3	53.7
	200	200			362.5	383.1	388.9	373.7	375.8	381.5	424.1	467.9	5.6	42.6	43.8	92.0
	202	200		320.6	377.3	391.4	396.9	389.0	386.4	393.6	443.4	484.9	7.2	49.8	41.6	98.5
	204	200		339.9	396.1	405.7	410.8	393.4	400.3	411.3	473.3	514.5	11.0	62.0	41.1	114.2
	206	200		327.6	383.6	392.3	400.6	388.9	389.1	409.9	483.6	517.4	20.8	73.7	33.8	128.4
	208	200		328.8	381.7	400.8	406.1	393.4	386.5	424.6	505.0	534.0	38.1	80.4	29.0	147.5
	210	200		354.1	407.9	421.1	438.8	415.9	413.6	458.9	531.4	564.1	45.3	72.5	32.7	150.5
	212	200		333.8	386.7	411.1	411.7	389.5	385.2	445.4	505.6	535.5	60.2	60.2	29.9	150.4
	214	200		326.9	381.8	410.3	391.2	382.2	388.6	455.1	502.1	538.5	66.5	47.0	36.3	149.8
	216	200		327.4	377.2	406.5	394.4	387.2	391.5	451.7	500.8	530.7	60.2	49.1	29.9	139.2
	218	200		349.3	393.6	417.6	419.3	406.5	409.2	465.7	509.4	527.1	56.5	43.7	17.7	117.9
	220	200		342.5	388.1	416.4	430.0	403.1	412.5	462.4	492.2	506.3	49.9	29.8	14.1	93.8
Reach 5	222	200	302.4	310.3	352.6	382.3	388.2	360.2	366.0	414.6	425.4	412.9	48.6	10.7	-12.5	46.9
	224	200	323.2	335.2	373.5	411.2	409.6	379.8	382.1	428.3	429.1	402.4	46.3	0.8	-26.7	20.3
	226	200	303.2	310.8	362.8	386.4	383.6	345.7	342.3	381.3	380.5	333.5	39.0	-0.7	-47.0	-8.8
	228	200	328.1	357.6	383.2	396.4	392.6	340.4	343.0	384.9	367.7	304.0	41.9	-17.2	-63.7	-39.0
	230	200	370.4	422.4	414.5	399.9	406.1	349.9	354.8	392.1	374.7	304.8	37.3	-17.3	-69.9	-50.0
	232	200	400.4	436.9	452.3	445.8	427.0	366.8	379.0	421.3	376.2	332.4	42.3	-45.1	-43.7	-46.5
	234	200	342.6	417.1	416.4	398.4	378.7	318.6	348.6	390.4	359.1	325.7	41.7	-31.3	-33.5	-23.0
	236	200	307.8	388.7	391.4	378.3	345.9	285.5	329.7	370.2	330.7	327.2	40.5	-39.6	-3.5	-2.5
	238	200	299.2	389.0	392.4	374.4	343.8	286.3	358.5	386.9	351.0	328.6	28.4	-35.9	-22.3	-29.8
	240	200	306.6	400.9	407.0	392.5	355.4	300.4	399.6	416.0	386.8	371.3	16.4	-29.2	-15.5	-28.3
	242	200	292.4	385.7	394.8	372.4	336.6	282.2	415.9	413.2	396.1	382.1	-2.7	-17.2	-13.9	-33.8
	244	200	339.5	433.3	441.5	419.2	383.5	318.7	499.0	479.7	449.9	430.3	-19.3	-29.8	-19.5	-68.7
	246	200	355.9	444.8	439.1	413.0	386.1	315.9	526.5	484.5	448.8	398.5	-42.0	-35.7	-50.4	-128.1
	248	200	387.0	469.0	451.5	421.9	420.6	316.6	562.6	508.9	455.4	415.6	-53.7	-53.5	-39.8	-147.0
	250	200	391.8	484.0	465.2	420.7	436.8	318.5	587.9	515.6	474.6	433.1	-72.3	-41.0	-41.5	-154.7
	252	200	365.7	458.7	418.2	389.7	369.1	268.3	554.5	464.7	419.5	377.9	-89.8	-45.2	-41.6	-176.7
	254	200	346.4	447.1	390.2	372.1	326.8	243.9	539.7	437.8	385.2	336.4	-101.9	-52.6	-48.9	-203.3
Reach 5 (Continued)	256	200	351.5	450.2	373.2	381.1	291.4	226.4	524.7	404.2	355.1	374.4	-120.5	-49.1	19.3	-150.3
	258	200	390.9	484.6	399.7	421.4	321.9	250.1	544.6	431.3	419.4	404.5	-113.4	-11.9	-14.9	-140.2
	260	200	432.0	502.2	414.9	415.9	308.6	264.4	547.9	443.5	458.9	409.2	-104.4	15.4	-49.7	-138.7
	262	200	464.2	529.3	457.9	417.1	293.5	288.8	563.4	504.8	472.0	441.7	-58.7	-32.8	-30.3	-121.8
	264	200	525.0	575.4	504.4	444.6	349.6	328.6	595.7	532.2	499.3	472.6	-63.5	-33.0	-26.7	-123.2
	266	200	538.0	599.6	521.8	459.8	377.5	347.8	620.5	538.8	496.9	455.7	-81.7	-41.9	-41.2	-164.8
	268	200	521.0	566.2	478.2	438.2	366.3	353.1	543.5	498.2	448.1	397.1	-45.2	-50.1	-51.1	-146.4
	270	200	550.5	582.7	501.4	400.2	412.7	417.0	550.1	514.9	461.6	416.2	-35.1	-53.3	-45.4	-133.9
	272	200	555.0	569.4	503.4	416.0	416.2	388.2	537.1	510.1	443.3	380.4	-27.0	-66.8	-62.9	-156.7
	274	200	518.1	526.2	490.7	402.0	398.1	387.0	509.0	497.9	430.8	372.7	-11.1	-67.2	-58.0	-136.3
	276	200	622.6	619.9	594.1	492.4	527.9	472.1	576.2	547.2	481.0	429.6	-28.9	-66.3	-51.4	-146.6
	278	400	642.3	593.3	616.4	475.2	524.2	492.7	585.4	551.8	477.9	446.8	-33.6	-73.9	-31.1	-138.6
Reach 6	280	200	706.1	676.2	794.7	578.3	665.6	634.8	766.3	648.6	606.3	572.0	-117.7	-42.3	-34.3	-194.3
	282	200	631.7	568.1	683.5	480.2	556.7	516.6	652.7	520.2	495.4	469.5	-132.5	-24.8	-25.9	-183.2
	284	200	676.3	671.0	737.7	575.3	672.3	608.4	757.8	608.2	588.8	548.9	-149.6	-19.4	-39.9	-208.9
	286	200	651.2	666.9	709.0	590.8	700.8	633.9	760.5	617.3	579.6	563.8	-143.2	-37.7	-15.8	-196.7
	288	200	487.2	577.8	599.8	536.5	608.0	546.1	705.7	585.0	535.2	502.2	-120.7	-49.8	-32.9	-203.4
	290	200	382.0	486.4	524.9	498.9	573.6	506.7	657.8	550.8	510.0	472.3	-107.0	-40.7	-37.7	-185.5
	292	200	377.4	486.6	511.3	538.4	608.3	534.8	672.8	589.4	557.3	522.7	-83.3	-32.1	-34.7	-150.1
	294	200	385.8	514.9	527.6	571.9	585.9	576.9	686.2	639.5	608.4	579.9	-46.7	-31.1	-28.5	-106.4
	296	200	356.5	496.5	495.8	539.7	518.2	538.3	655.5	634.1	597.8	571.3	-21.4	-36.3	-26.5	-84.2
	298	200	320.0	483.9	467.6	490.9	446.3	512.2	634.5	628.7	586.6	568.4	-5.8	-42.1	-18.2	-66.2
	300	200	308.2	483.5	457.4	491.4	433.8	499.1	630.9	629.0	587.4	578.3	-1.9	-41.5	-9.1	-52.6
	302	200	279.5	474.9	436.7	463.0	405.7	478.6	622.6	626.4	593.5	580.6	3.8	-32.9	-12.9	-42.0
	304	200	259.8	451.5	399.8	429.3	355.4	430.9	597.7	598.5	569.2	561.0	0.8	-29.4	-8.2	-36.7
	306	200	270.1	460.1	400.2	421.7	364.6	428.1	614.1	608.7	584.3	577.4	-5.4	-24.4	-6.9	-36.7
	308	200	246.1	428.0	346.3	366.0	287.4	372.1	571.3	558.4	538.8	535.5	-12.9	-19.6	-3.3	-35.8
	310	200	252.2	412.0	333.4	336.9	247.0	351.3	560.2	553.7	536.0	523.4	-6.5	-17.7	-12.6	-36.8
	312	200	232.0	398.1	310.3	322.9	235.8	331.7	546.5	531.1	516.2	497.6	-15.4	-14.9	-18.6	-48.9
	314	200	192.1	349.8	274.0	279.6	208.0	286.2	488.9	469.4	451.8	435.7	-19.5	-17.7	-16.0	-53.2
	316	200	261.7	432.8	371.6	348.4	286.4	380.7	560.5	554.6	548.9	523.7	-5.9	-5.8	-25.1	-36.8
	318	200	246.7	428.2	358.9	355.4	275.1	393.3	529.7	550.2	538.2	507.1	20.5	-12.1	-31.1	-22.6
	320	200	261.3	440.4	375.6	361.3	297.4	416.2	526.7	554.2	544.9	523.9	27.6	-9.3	-21.1	-2.8
	322	200	267.0	435.2	379.2	334.4	297.3	416.2	495.5	551.2	536.6	511.2	55.6	-14.5	-25.4	15.7
	324	200	246.4	407.1	370.1	316.7	291.6	394.0	450.9	513.4	506.3	473.0	62.5	-7.2	-33.3	22.0
	326	200	248.7	365.9	369.7	325.7	323.2	398.5	434.3	517.5	506.0	483.9	83.2	-11.6	-22.0	49.7
	328	100	303.2	354.4	388.6	344.2	344.3	415.3	451.0	531.6	514.1	498.3	80.7	-17.6	-15.7	47.4
Reach 7	330	200	180.0	209.7	281.7	302.3	280.4	263.7	250.3	278.6	302.1	332.8	28.3	23.5	30.7	82.5
	332	200	507.1	560.5	619.8	650.7	685.0	665.3	630.3	656.8	681.9	696.6	26.5	25.1	14.6	66.2
	334	200	473.1	528.3	573.4	611.3	652.3	633.1	605.6	626.0	648.9	655.3	20.4	22.9	6.3	49.7
	336	200	459.8	519.2	524.7	567.2	612.2	609.7	584.2	609.9	620.4	620.6	25.8	10.4	0.3	36.5
	338	200	444.2	500.0	467.4	504.7	551.0	563.4	546.9	561.2	566.5	573.2	14.3	5.2	6.7	26.2
	340	200	438.0	495.3	441.8	472.8	514.8	521.5	509.3	513.6	519.2	527.6	4.4	5.6	8.4	18.4
	342	200	481.5	505.0	470.4	506.3	530.0	530.3	521.2	517.8	517.6	527.2	-3.5	-0.2	9.7	6.0
	344	200	444.6	456.2	431.6	459.1	479.0	473.7	462.9	459.3	458.3	462.5	-3.6	-0.9	4.1	-0.4
	346	200	437.6	438.2	421.3	440.1	454.6	448.2	443.1	437.6	431.9	434.7	-5.5	-5.8	2.8	-8.4
	348	200	380.9	378.1	364.8	376.9	384.5	393.9	388.8	391.1	380.7	384.7	2.2	-10.3	4.0	-4.1
	350	200	429.8	430.5	424.2	432.6	446.1	453.7	453.3	455.6	449.5	444.6	2.3	-6.0	-4.9	-8.7
	352	200	422.4	423.1	417.6	421.9	437.4	442.1	444.9	449.0	442.2	436.1	4.1	-6.8	-6.1	-8.8
	354	200	436.8	438.7	437.0	445.0	453.9	448.7	450.9	456.2	452.5	443.4	5.3	-3.7	-9.0	-7.4
	356	200	447.7	447.2	444.1	453.3	454.9	443.1	443.0	448.1	448.6	440.4	5.1	0.5	-8.2	-2.6
	358	200	413.8	411.0	412.2	422.4	402.8	384.9	384.2	387.7	387.8	385.4	3.5	0.1	-2.3	1.2
	360	200	405.8	402.9	402.3	413.2	380.7	359.6	360.5	361.5	364.7	363.8	0.9	3.3	-0.9	3.2
	362	200	394.5	392.3	400.4	402.3	360.4	339.0	340.4	344.5	346.1	347.4	4.2	1.6	1.2	7.0
	364	200	352.4	352.7	362.2	337.8	311.6	297.8	296.3	300.8	294.9	303.3	4.6	-5.9	8.4	7.1
	366	200	413.5	410.9	402.6	405.0	408.5	397.7	379.3	397.7	390.7	393.8	18.4	-7.0	3.1	14.5
	368	200	538.8	544.3	534.6	538.0	566.5	575.5	584.1	557.1	537.6	558.4	-27.0	-19.5	20.8	-25.6
	370	0	520.1	0.0	583.1	503.3	611.5	647.1	666.6	611.7	584.3	604.9	-54.9	-27.4	20.6	-61.7

4.2 Project Area Reaches

The 2018 nourishment project placed sand along most of reaches 5 and 6 at the eastern end of the island. Reach 7 is included in this section as a portion of it was nourished in the 2008 project. The entire length of the beach along these reaches is affected by morphological changes occurring in Dewees Inlet, as discussed in earlier sections.

4.2.1 Reach 7

Reach 7 encompasses the length of beach between lines 330 and 370 that span the shoreline fronting the Dewees Inlet channel (Figure 4.4). The inlet shoals shelter large waves from impacting this portion of beach, resulting in the profile generally showing a narrow dry sand berm and a steep beach face. The steep beach face reduces the total profile volume needed for a stable profile compared to oceanfront areas. The seaward end of the reach was included in the 2008 nourishment project and remained relatively stable in the following years. The healthy condition in 2018 did not require nourishment as part of the last project, and this condition has persisted through the 2021 survey.

FIGURE 4.4. Baseline stationing along Reach 7 encompassing the length of beach between lines 330 and 370.

Except for an erosional period from 2017 to 2018, Reach 7 has remained stable or accretional since 2009 (Fig 4.5) and gained ~16,900 cy (4.2 cy/ft) from June 2020 to July 2021. Similar to 2018–2019 monitoring results, the ends of the reach were highly accretional, with profiles gaining 20 to 30 cy/ft of sand due to spreading from the front beach. Some profiles located along the 17th hole lost volume, but these losses were relatively minor (eg – 0 to 5 cy/ft, generally). Figure 4.5 shows the beach volume trends for the reach since 2007, with the upper figure showing the total reach volume and the lower figure showing the volume history for each monitoring line. Figure 4.6 provides beach profiles and representative photos of the reach in 2021. Profiles from the seaward end of the reach (ie – Station 332) to the 17th tee (Station 336) show an increase in sand volumes from 2018 to 2021, with the area gaining approximately 150 ft in width and increasing in elevation. Stations further inland were more stable, as shown in the profiles from Station 334. Ground photos from Station 334 show unvegetated dry sand with scattered beach wrack and grasses, indicating stability and colonization of dune-building species. Photos from further inland also show a very healthy dry sand beach with a vegetated dune well landward of the typical high tide line (Fig 4.6).

Overall, Reach 7 has gained ~207,500 cy of sand since 2007, which is an average annual increase of 3.7 cy/ft per year. CSE expects the accretional trend to slow over the next few years as most of the post-nourishment sand spreading from Reach 6 has already taken place. Erosion is likely along the seaward end of the reach in the next few years.

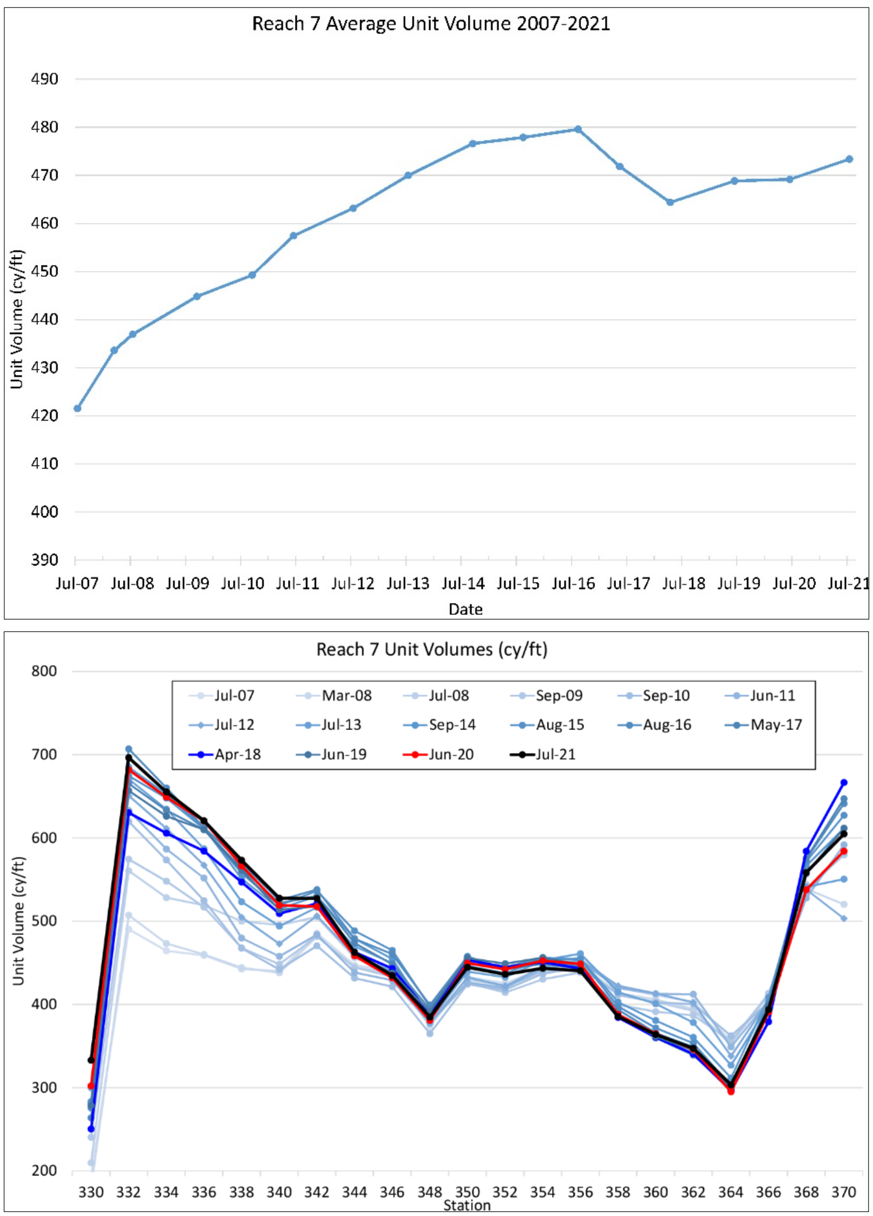
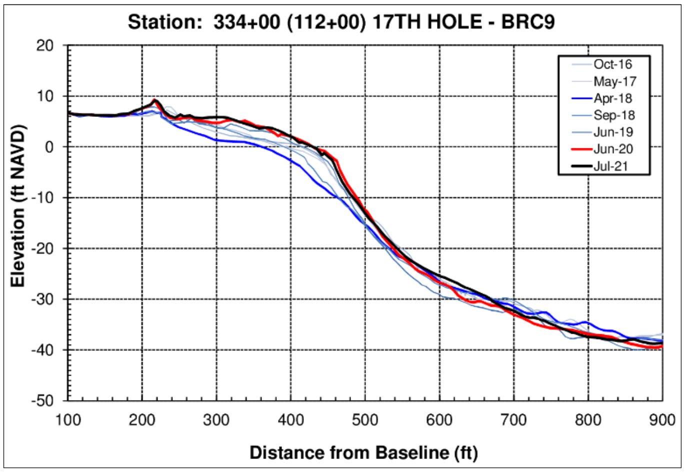


FIGURE 4.5. **[UPPER]** Average beach volume in Reach 7 since 2007. **[LOWER]** Profile unit volumes for each monitoring line in Reach 7.



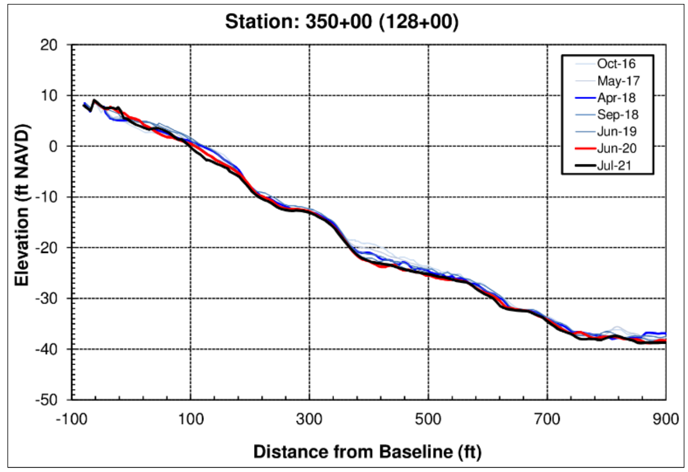


FIGURE 4.6.
[UPPER] Beach profiles from Reach 7.

[MIDDLE] Aerial photo of Reach 7 collected July 2021.

[LOWER] Ground photos from Station 334 **[LEFT]** looking landward and Station 350 looking seaward **[RIGHT]** in July 2021.

4.2.2 Reach 6

Reach 6 encompasses ~4,900 linear feet of beach between the Wild Dunes Property Owners Beach House (Station 280) and the 18th Hole of the Links Course (Station 328+00) (Figure 4.7). Along with Reach 5, shoal bypass events directly impact this length of beach. Depending on the location of bypass events, the shoreline can move hundreds of feet over a few months (Kana et al 1985, Gaudiano 1998). As a result, the waterline periodically encroaches on properties along this reach.

FIGURE 4.7. Baseline stationing along Reach 6 encompassing ~4,900 lf of beach between Wild Dunes Property Owners Beach House and the 18th Hole of the Links Course.

Details of beach volume changes occurring in the reach from 2007 to 2015 are in the 2015 annual beach monitoring report (CSE 2016). In summary, following nourishment in 2008, this reach experienced variable erosion and accretion, with one part of the reach gaining sand while the other lost sand. The area along the western end of the reach near Beach Club Villas was highly erosional following the 2008 project, requiring additions of sand via shoal-management projects in 2012 and late 2014. The eastern end of the reach fluctuated in volume based on attaching shoals; however, it always maintained a sufficient width to protect property. By 2018, the eastern end of the reach was accreting from a prior shoal attachment while the western end was eroding. The erosion pattern prior to nourishment necessitated an adjustment to the fill design, with less sand being placed at the east of the reach and additional sand being placed at the west end. The reach gained ~670,000 cy of sand via nourishment in 2018.

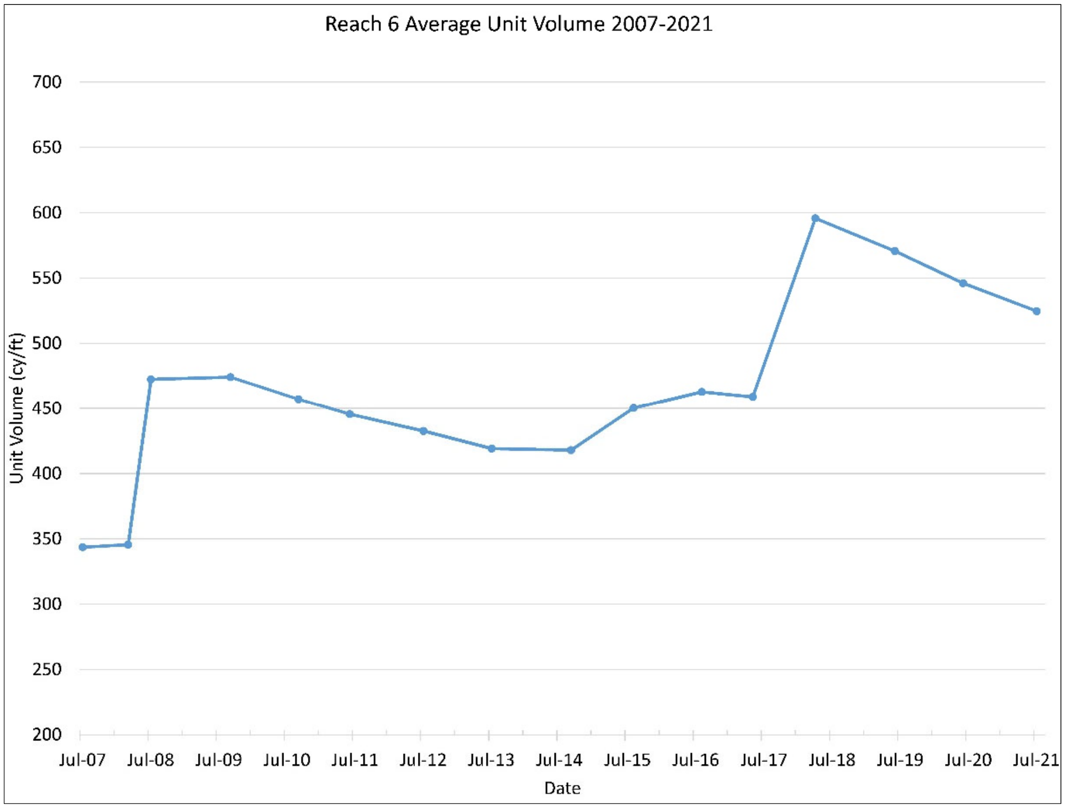
Reach 6 has exhibited similar erosion rates in each survey period following project completion in 2018. The western end of the reach (Beach Club Villas, Mariners Walk) has generally lost sand since the 2018 project, while the eastern end (closer to Dewees Inlet) has generally gained sand over the same period. The reach lost ~123,000 cy (25.1 cy/ft) from April 2018 to June 2019, and lost ~120,200 cy (24.5 cy/ft) from June 2019 to June 2020. From June 2020 to July 2021, Reach 6 lost ~105,400 cy (21.5 cy/ft).

While the measured loss within the reach is significant, erosion rates along the western half of the reach have generally declined since April 2018. That area had eroded rapidly before the 2018 project and continued through 2019, averaging losses of ~128 cy/ft between stations 280 and 290 from 2018 to 2019 and ~36 cy/ft from 2019 to 2020. From 2020 to 2021, this portion of the reach lost ~31 cy/ft. The reduction in erosion rates along the western half of Reach 6 has meant that erosion rates along the entire reach are now more uniform than since before the 2018 renourishment; between June 2020 and July 2021, erosion rates at individual stations ranged from –3.3 cy/ft (Station 308) to –39.9 cy/ft (Station 284).

Beach profiles from within the reach reflect volume trends measured from June 2020 to July 2021, with areas along the west end losing up to 40 cy/ft and the east end losing ~25 cy/ft (Figure 4.8). Throughout the reach, the berm elevation remains close to the +6 ft design elevation; however, along the seaward edge of the berm, the elevation tends to increase as a result of storm waves reworking the beach face. Dune growth is evident along the landward end of the nourishment berm at many stations within the reach. While some stations near Beach Club Villas (stations 280–290) show a net reduction in volume compared to the pre-project (2017) condition, the beach remains wider than in 2017.

Details of changes occurring within the Dewees Inlet delta will be discussed in more detail in Section 6.0. Shoals often attach to the northeast end of the island and are oriented parallel to and on the landward side of the Dewees Inlet channel. This shoal is called a trailing ebb spit and is beneficial in sheltering wave energy along the northeast corner of the island and backing up sand along the beach. Trailing ebb spits are a constituent part of ebb-tidal deltas like that of Dewees Inlet.

A full shoal bypass event requires portions of an ebb-tidal delta to migrate across the main inlet channel and attach to the dry beach, which often triggers large-scale accretion along adjacent beaches. However, a trailing ebb spit does not have to traverse an inlet channel to attach to the dry beach. So, these smaller features will accrete onto adjacent beaches more often than the full ebb-tidal delta. As a result, the volumes of sand associated with trailing ebb spits are small compared to large-scale bypassing events like those observed on Isle of Palms in the 1950s, 1980s, 1990s, and 2000s. At the same time, the trailing ebb spits along Reach 6 periodically deliver sand volumes on the order of tens of thousands of cubic yards of beach sand. Depending on wave conditions and the tidal cycle during one of these attachment episodes, the additional beach volume may not be discernable without a comprehensive survey before and after the event.



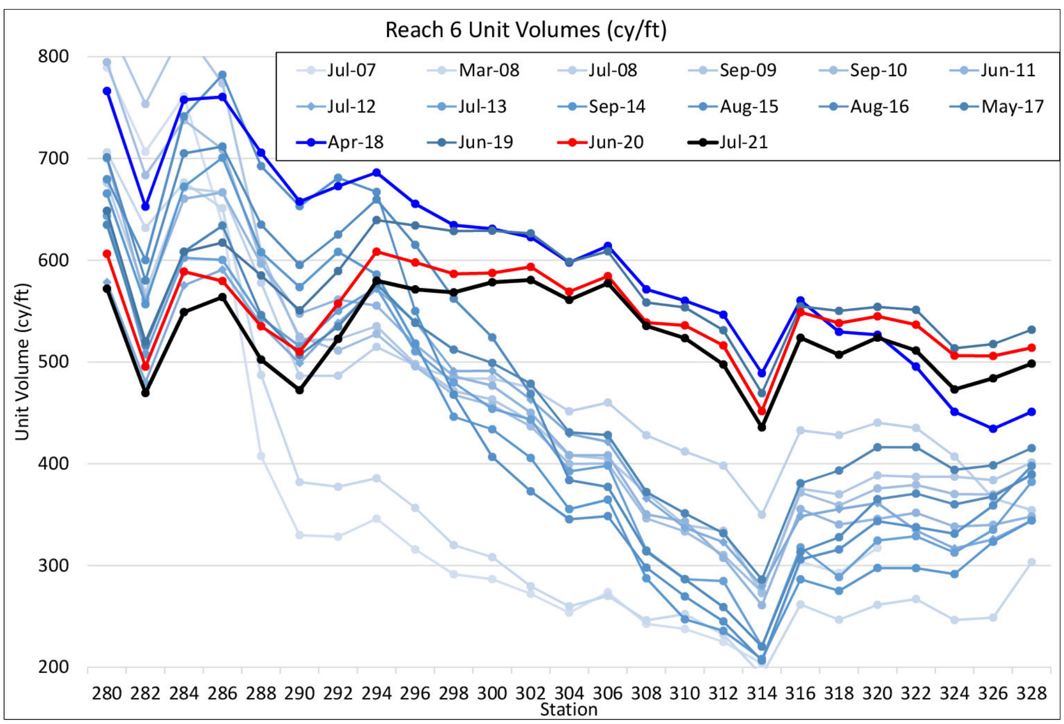


FIGURE 4.8. **[UPPER]** Average beach volume in Reach 6 since 2007. **[LOWER]** Profile unit volumes for each monitoring line in Reach 6.

Figures 4.9 and 4.10 show aerial and ground photos of the reach in 2021. The images generally show a wide dry sand beach with incipient vegetation sprouting over the berm. There is a distinct even curvature of the shoreline spanning the east end, which is somewhat atypical of the area due to the influence of attaching shoals. Presently, no ongoing shoal-bypass events are close enough to the shore to result in significant variations in the shoreline geometry.

Overall, the reach holds ~887,200 cy more sand than the 2007 condition. Nourishment projects in 2008 and 2018 have resulted in an average annual volume increase of 12.9 cy/ft per year along Reach 6. While the volume totals are very positive, the reach is subject to dynamic localized volume changes and should be monitored closely.

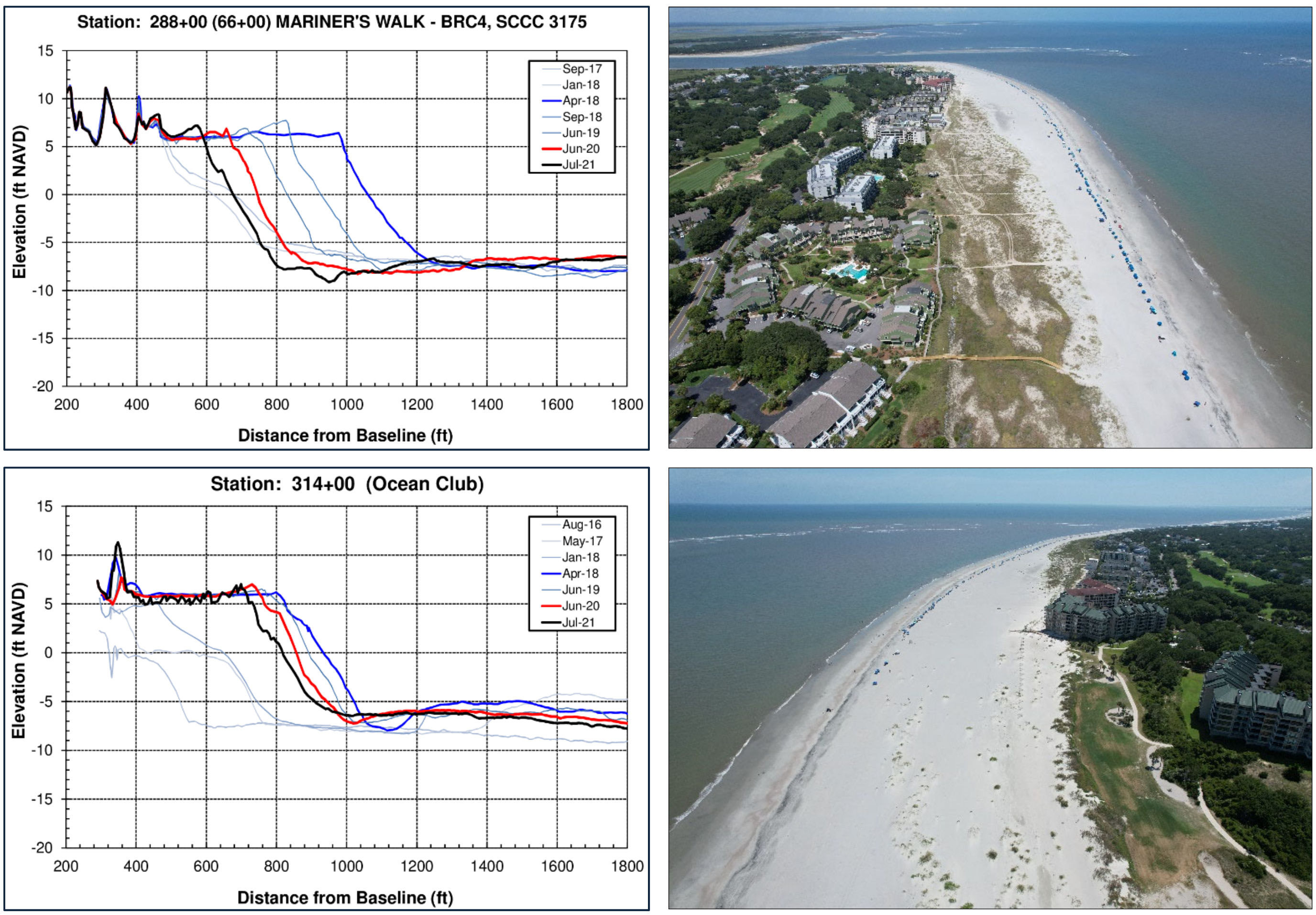


FIGURE 4.9. **[LEFT]** Reach 6 profiles. The rapid erosion in this area is suspected to be a continuation of the higher erosion trend observed prior to the 2018 project. **[RIGHT]** Aerial photos collected in July 2021.

FIGURE 4.10. Ground photos from Station 284 **[UPPER]** and Station 320 **[LOWER]** in July 2021. As of July 2021, the seawardmost Ocean Club units were >400 ft from the normal high tide line.

4.2.3 Reach 5

Reach 5 spans ~5,800 lf of beach between 53rd Avenue and the Wild Dunes Property Owners Beach House (stations 222–280 – Figure 4.11). Similar to Reach 6, this area of the beach is highly influenced by shoal-bypass events, especially along the central and eastern portion of the reach. The 2008 nourishment project added ~318,000 cy of sand to the reach; however, by 2015, the area fronting Beachwood East and Dunecrest Lane was highly erosional. Reach 5 has lost the most volume of any reach on Isle of Palms from 2008 to 2021.

FIGURE 4.11. Baseline stationing along Reach 5 which spans ~5,800 lf of beach between 53rd Avenue and Wild Dunes Property Owners Beach House.

Reach 5 gained 909,000 cy of sand (151 cy/ft) from 2017 to 2018 (including nourishment and background changes – Figure 4.12). This was nearly three times the volume added during the 2008 project. Beach width increased by over 500 ft in some locations, and like Reach 6, a dune was constructed as part of the nourishment design. The City installed dune vegetation and sand fencing to promote natural dune building.

Since project completion, Reach 5 has steadily lost ~30 to 40 cy/ft between each survey. The reach lost 176,000 cy (29.4 cy/ft) of sand between April 2018 and June 2019 and an additional 219,000 cy (36.5 cy/ft) from 2019–2020. From June 2020 to July 2021, Reach 5 lost ~216,200 cy (36.0 cy/ft). The magnitude of losses in recent years has been higher along the eastern part of the reach, with stations 244–278 all losing more than 50 cy/ft between 2018 and 2021. No station between 222 and 244 has lost more than 50 cy/ft over the same period. Figure 4.12 (lower) shows the profile volume record for Reach 5 since 2007. The red and black lines represent changes observed in 2020 and 2021, while the difference between the blue and black lines represents changes from 2018 to 2021. At the very eastern end of the reach, near Beach Club Villas, the beach volume is near the lowest observed condition; however, as mentioned previously, the beach width is greater compared to conditions before the 2018 nourishment.

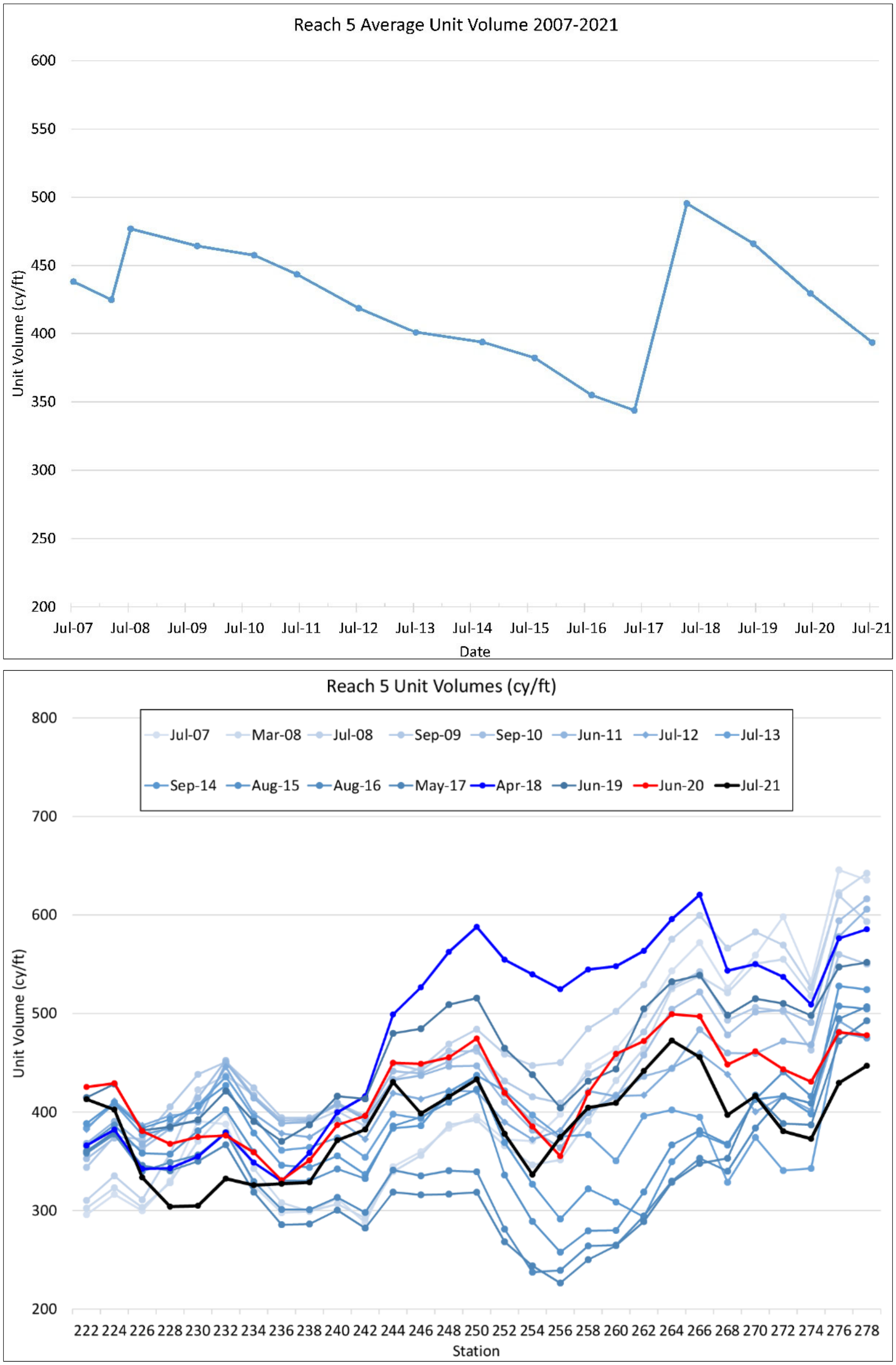


FIGURE 4.12. [UPPER] Average beach volume in Reach 5 since 2007. [LOWER] Profile unit volumes for each monitoring line in Reach 5.

Similar to Reach 6, there were some positive trends in the erosion rates compared to the previous year. Between stations 250–266 (eastern Grand Pavilion, Seagrove, and Beachwood East), erosion averaged ~90 cy/ft from 2018 to 2019 but has decreased to ~35 to 40 cy/ft since June 2019. Profiles from within the reach (Figure 4.13) show the berm west of the Grand Pavilion boardwalk is ~100 ft narrower than the 2020 condition but over 200 ft wider than the pre-project condition. Along the central portions of the reach (stations 236 to 268), the berm is wider than pre-nourishment, and the dune remains healthy. Around Beachwood East, the berm is still more than 100 ft wider than the pre-project condition, despite rapid erosion over the past two years. There remains a low swale on the landward side of the berm, seaward of the pre-project dune line (Figure 4.14).

CSE expects the volume changes along Reach 5 to continue to reduce in magnitude over the next 1–2 years. Presently, there is a low shoal located ~1,500 ft offshore around Beachwood East. As the shoal moves ashore, it may trigger localized erosion of the dry beach even though profile-wide volumes are increasing.

4.2.4 Summary of East End Changes

Overall, the 2018 project area reaches (5 and 6) have lost ~960,000 cy of sand from April 2018 to July 2021. This represents ~57% of the nourishment pay quantity. While this value is higher than desired, not all of these losses indicate sand moving away from the dry beach. Much of the losses can be accounted for in gains in adjacent areas or losses occurring in the submerged offshore zone. To this point, the position of the +4 ft (NAVD) contour was relatively static from 2020 to 2021, compared to volume changes along the submerged portion of the profile (Fig 4.15)

Figure 4.16 provides the beach volume history of the eastern end of the island since 2007, with dates following nourishment indicated. The overall erosional trend is evident along reaches 5 and 6 between nourishment projects, each of which restores sand volumes to maintain a dry beach and protective dune. Sand lost from reaches 5 and 6 either moves south to provide sediment to the rest of Isle of Palms, or recycles to Dewees Inlet, where it will eventually form a shoal and recycle back to the beach. The increases in volume along Reach 7 observed in recent years, as well as the buildup of sand within the delta at the northeast corner of the island, document the transfers of sand from reaches 5 and 6 into the inlet system (see Fig 4.16).

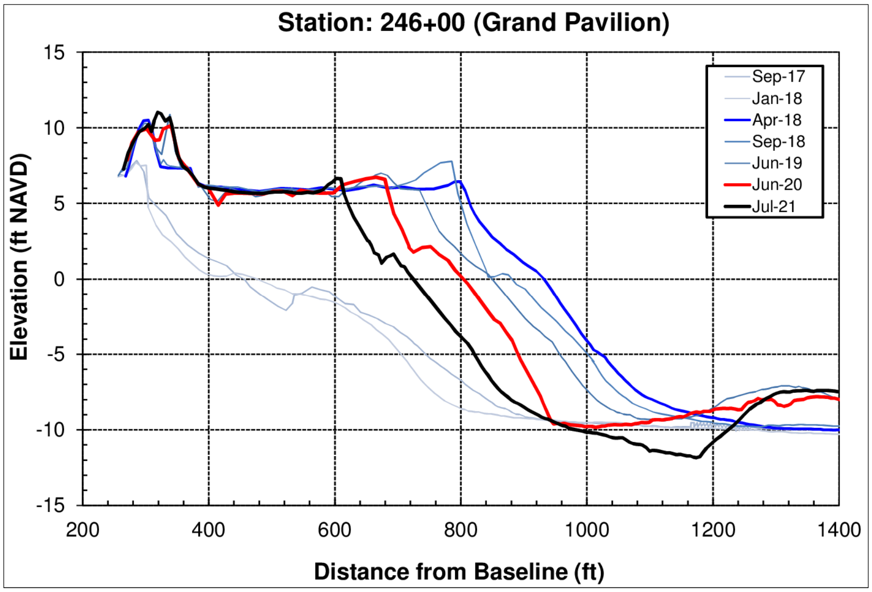
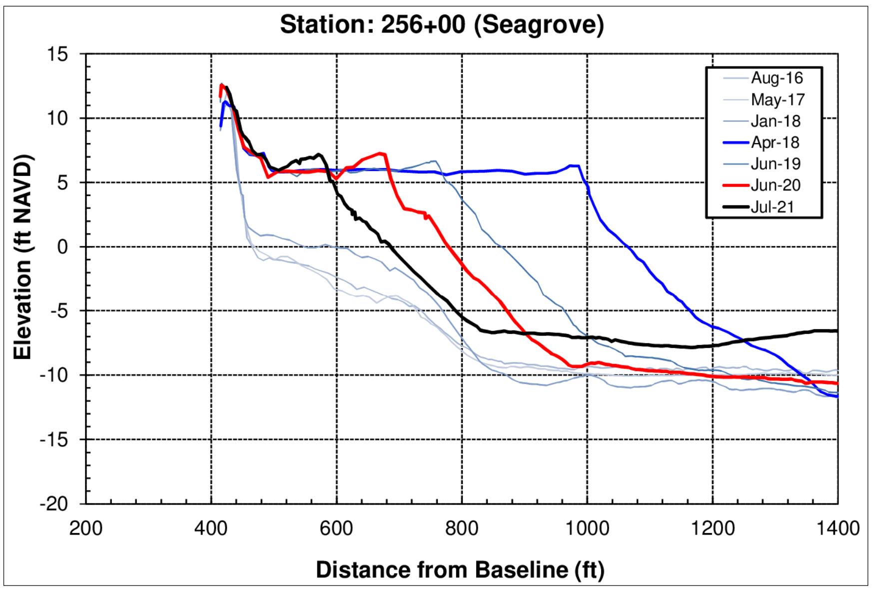


FIGURE 4.13. Reach 5 profiles. The data shown indicate that the berm fronting Grand Pavilion and Beachwood East remains ~400 ft wider than pre-project conditions.



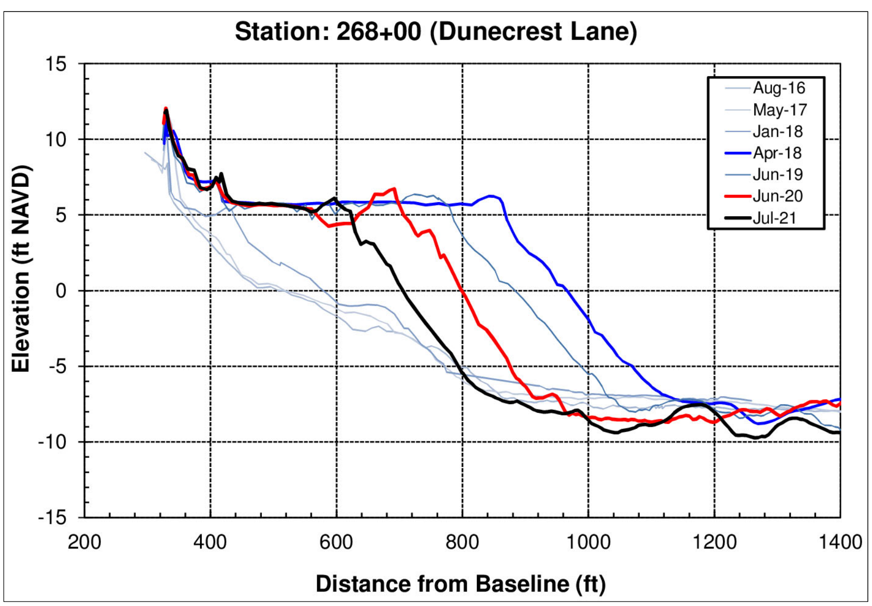


FIGURE 4.14. Ground photos of Reach 6 in July 2021 showing Station 240 **[UPPER]**, Station 256 **[MIDDLE]**, and Station 276 **[LOWER]**.

FIGURE 4.15. Although volumetric losses along Reaches 5 and 6 averaged -36.5 and -21.5 cy/ft, respectively, between June 2020 and July 2021, the wide dry beach in place since completion of the 2018 renourishment remains hundreds of feet wide in most locations. This suggests that most of the volumetric change detected in the surveys has occurred along the submerged portion of the beach profile.

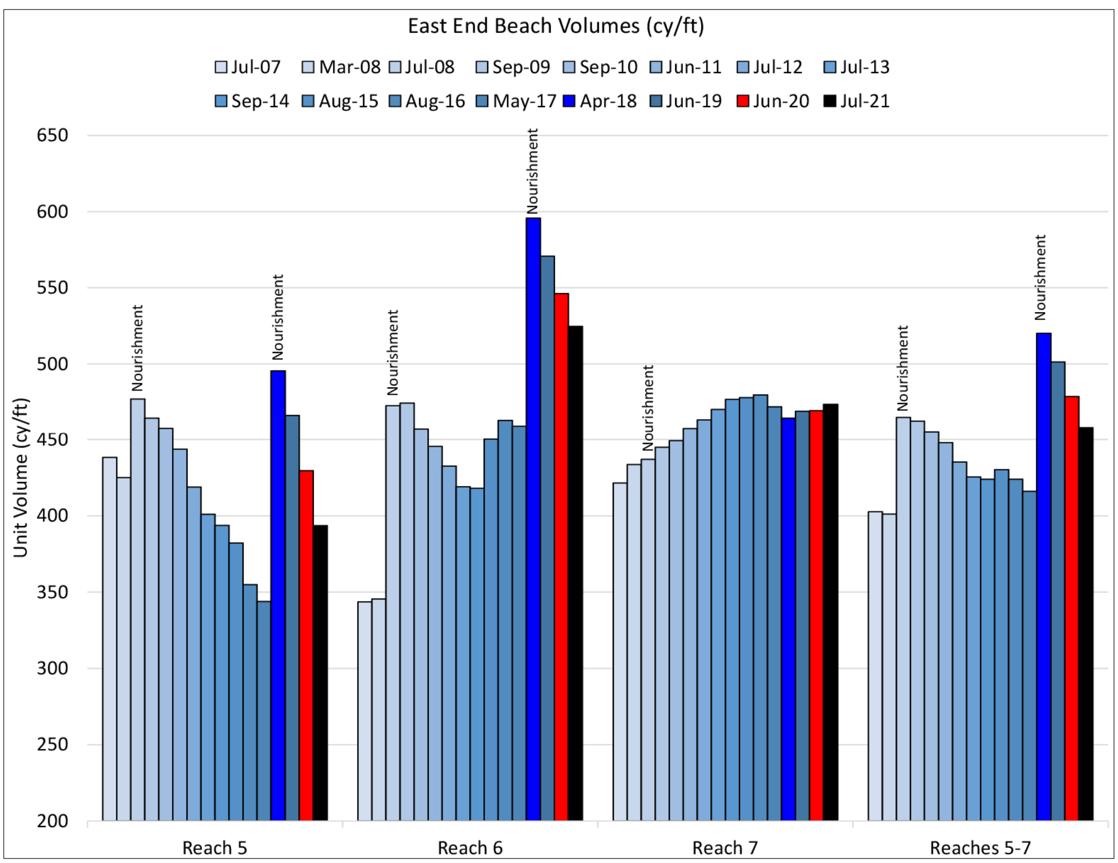


FIGURE 4.16. The beach volume history of the eastern end of the island since 2007, with dates following nourishment indicated.

4.2.5 Reach 4

Reach 4 includes the length of beach between 31st and 53rd Avenues (stations OCRM 3140 to CSE 222+00 – Fig 4.17 and Fig 4.18). This reach is ~7,910 ft long and immediately downdrift of the 2008 and 2018 project area. It is also outside of the direct influence of Dewees Inlet and maintains a more typical and consistent beach profile shape. By being positioned downdrift of the nourishment area, it receives nourishment sand spreading from the placement area as well as spreading shoal sand. The reach has gained sand every year since 2009 except for 2016, the year after Hurricane *Matthew* impacted Isle of Palms.

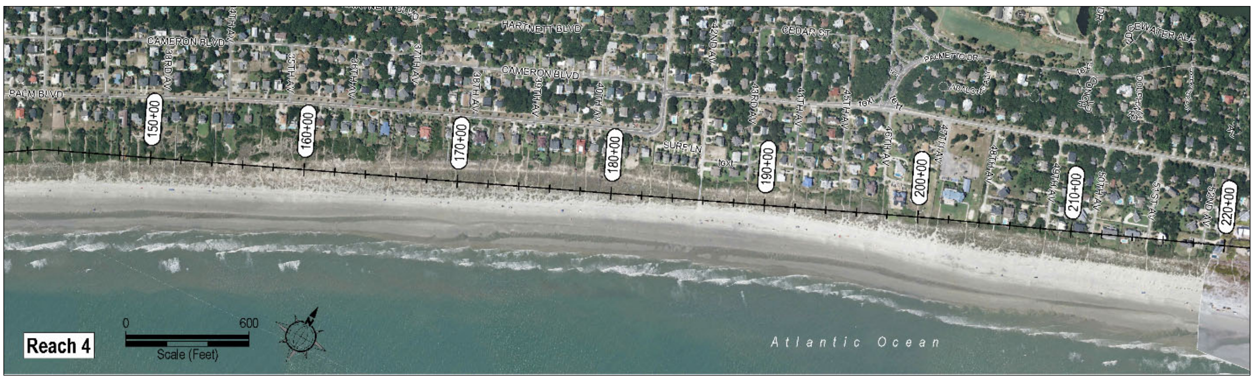


FIGURE 4.17. Baseline stationing along Reach 4 spanning the length of beach between 31st Ave and 53rd Ave.

The reach receives sand eroded from the east end of the island, particularly reaches 5 and 6, with that sand originating from shoal bypass events or nourishment. A significant influx of sand along the northern half of the reach has been observed since the 2018 project; profiles along the northern 2,000 lf of Reach 4 gained up to 66 cy/ft (Station 214) of sand from 2018–2019. The peak in accretion moved ~600 ft west to Station 208 from 2019 to 2020 (80.4 cy/ft). As of July 2021, the peak in accretion was located at Station 200 (~800 ft further west; 43.8 cy/ft). This accretion resulted in a large ridge and runnel system along the wet sand beach and a shift of the dry sand berm over 200 ft seaward (Figure 4.19).

The progressive westward (downshore) migration of the peak in accretion between survey periods indicates nourishment sand is moving westward along the beach like a wave. This contributes to greater beach volumes and larger dunes along Reach 4. Under this scenario, even the areas measuring net erosion (volume loss) typically exhibit a wider dry beach and dune growth. In these locations (eg – stations 3140 and 170), volume losses are occurring underwater. They are likely a result of the ridge and runnel topography migrating through the area rather than a net decrease in beach volume. The east end of the reach holds ~200 cy/ft more sand than in 2008, while the west end has ~50 to 100 cy/ft more sand than in 2008.

FIGURE 4.18. By being positioned downdrift of the nourishment area, Reach 4 receives nourishment sand spreading from the placement area as well as spreading shoal sand. This reach has gained sand every year since 2009 except 2016. As the vegetated dunes expand, sheltered locations (such as low-lying areas behind protective dune ridges) will gradually transform into a shrub habitat with larger areas of wax myrtle replacing dune grasses.

Volume trends measured along Reach 4 reflect the spreading of a sand wave downcoast from the 2018 renourishment project area. The reach gained ~132,400 cy (16.7 cy/ft) of sand from June 2020 to July 2021, which is slightly less volume than it gained from June 2019 to June 2020 (~150,700 cy, or ~19.1 cy/ft). These increases are two to three times greater than the volume increases observed from May 2017 to April 2018 (~45,000 cy, or ~5.7 cy/ft) or April 2018 to June 2019 (~73,800 cy, or ~9.3 cy/ft).

The beach volume in Reach 4 has increased by ~792,700 cy since September 2009, which is an average annual accretion rate of 9.2 cy/ft per year. The dune width has increased by at least 50 ft along the reach, not including the wider dry sand berm seaward of the dune. This level of accretion is of similar magnitude to many beach nourishment projects conducted along coastal communities in South Carolina and is equivalent to a $10–15-million-dollar nourishment investment. The dune has grown ~3 ft in elevation and offers substantially more storm protection than the 2009 condition. CSE anticipates continued accretion over the next few years as more sand spreads from the 2018 project area, with the rate of accretion slowly decreasing as sand is lost to the dune system and offshore.

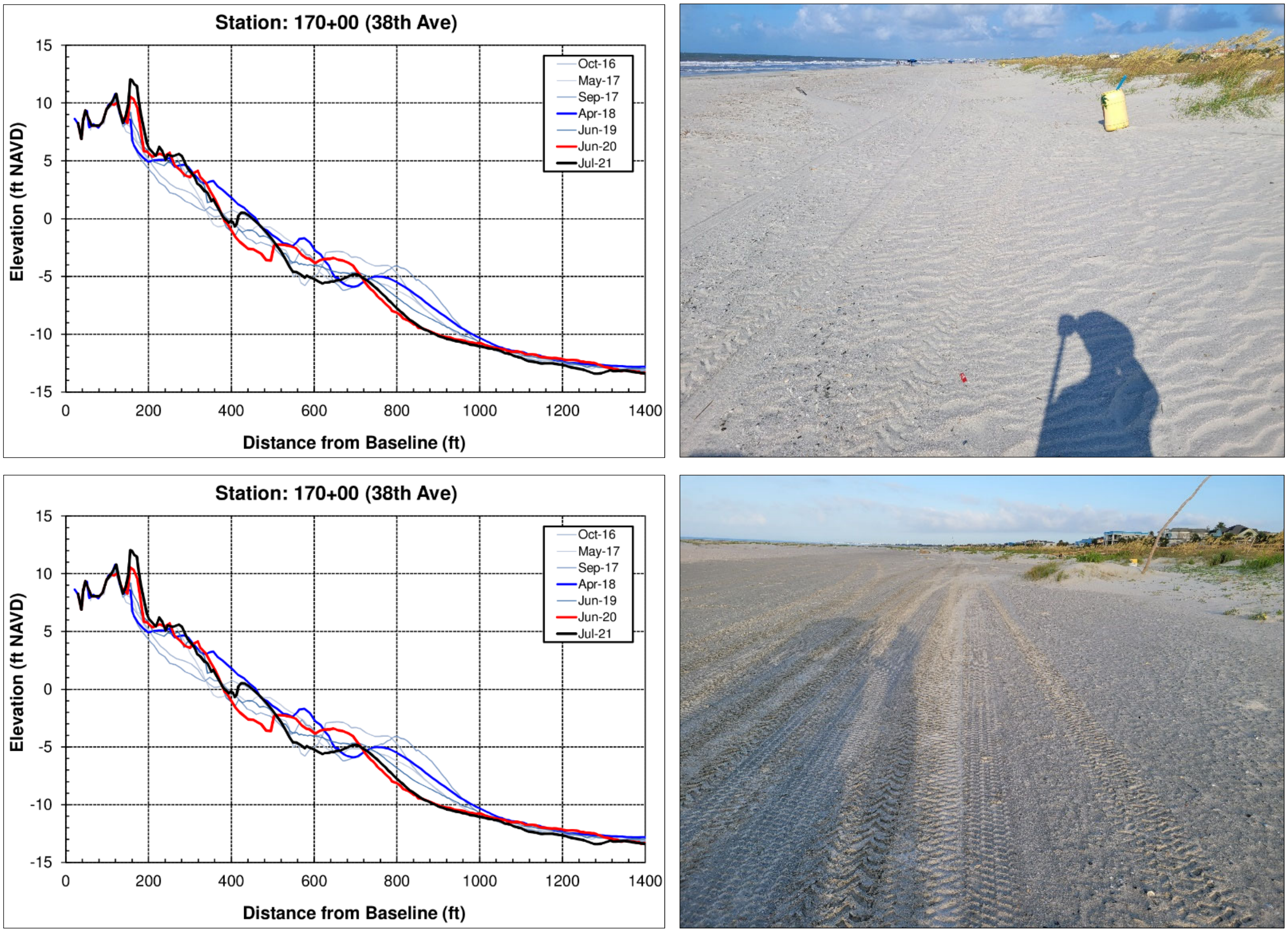


FIGURE 4.19. **[LEFT]** Profiles along the northern 2,000 lf of beach gained up to 150 cy/ft of sand since 2018. This accretion resulted in a large ridge and runnel system along the wet sand beach and a shift of the dry sand berm over 200 ft seaward. **[RIGHT]** Ground photos from Station 170 **[UPPER]** and Station 216 **[LOWER]** in July 2021.

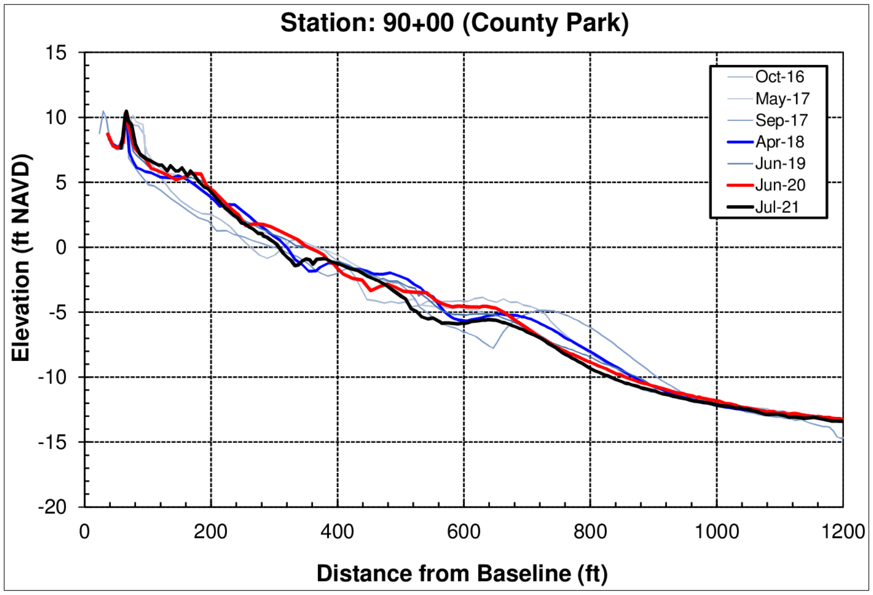
4.2.6 Reach 3

Reach 3 extends from the Sea Cabins Pier to 31st Avenue (OCRM monuments 3125 to 3140 – Fig 4.20 and Fig 4.21). Like Reach 4, the long-term trend in this area is stable to accretional. Dwellings in the reach are well set back from the beach, generally between 400 ft and 500 ft, except at the western end where Sand Dune Lane and the county park are set back ~150 ft. The reach has shown periods of erosion and accretion since CSE began island-wide monitoring in 2009. This is typical for stable to moderately accretional beaches as variations in wave conditions from year to year and temporary changes in sediment supply lead to minor fluctuations in yearly volume change. Over the long term, the trend is accretion.

FIGURE 4.20. Baseline stationing along Reach 3 spanning the length of beach from the Sea Cabins Pier to 31st Ave.

FIGURE 4.21. The long-term trend for Reach 3 is stable to accretional. Dwellings in the reach are generally set back from the beach between 400 ft and 500 ft.

Reach 3 gained beach volume every year from 2018 to 2020, but lost a minor amount of sand from June 2020 to July 2021. Over the past year, only Station 90 near the Sea Cabin Pier recorded a loss greater than 5.0 cy/ft. A closer look at that profile reveals these changes primarily occurred below the low tide level and did not have an apparent effect on the dry beach width or dune health. The remainder of the reach was relatively stable regarding beach volume. Overall, the reach lost ~1,700 cy (0.3 cy/ft) of sand over the past year. This is the first decrease in reach-wide volume observed since 2016–2017. Profile plots from the reach (Figure 4.22) show that the dune continues to increase in width as it recovers from the series of hurricanes impacting the area from 2015 to 2019.



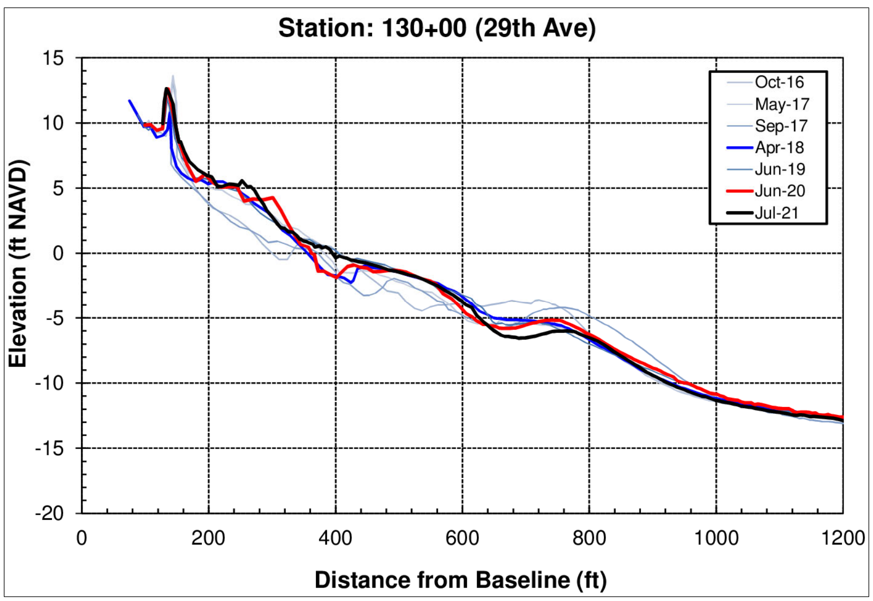


FIGURE 4.22. According to these profile plots the base of the dune has increased in width over the past year along most of the reach; however, it is still eroded compared to the pre-*Matthew* condition along the western end of the reach.

Overall, the reach holds ~258,900 cy more sand than the 2009 condition, equivalent to an average annual accretion of 4.3 cy/ft per year. Figure 4.22 shows the accretional trend over the past decade. Photos of the reach in July 2021 show a recovering dune system with a significant dry sand beach seaward of the growing dune (Fig 4.21).

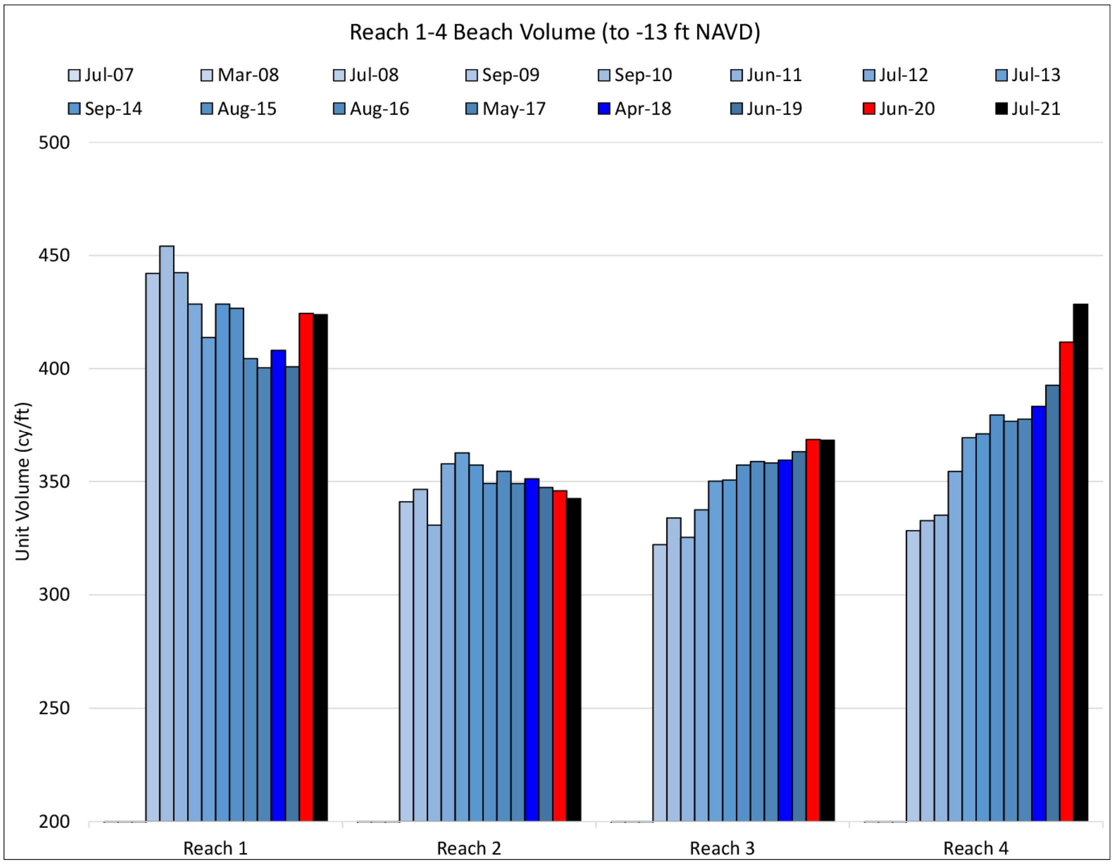


FIGURE 4.23. This graphic illustrates the accretional trend of reaches 3 and 4 over the past ~15 years.

4.2.7 Reach 2

Reach 2 spans 4,280 ft between 6th Avenue and the Sea Cabins Pier (OCRM monuments 3115–2125 – Fig 4.24 and Fig 4.25). It includes the oceanfront commercial area at the eastern end of the reach. Reach 2 shows an erosion/accretion pattern similar to Reach 3 with intermittent periods of accretion and erosion and a long-term accretion trend. Since monitoring began in 2009, Reach 2 has been the most stable reach, typically showing lower magnitudes of volume change compared to the other reaches.

FIGURE 4.24. Baseline stationing along Reach 2 spanning between 6th Avenue and the Sea Cabins Pier.

Volume data for Reach 2 shown in Figure 4.23 highlight the varying trends of accretion and erosion over the past decade. The magnitude of volume change has ranged from +27.1 cy/ft (June 2011 to July 2012) to –15.8 cy/ft (September 2010 to June 2011). The reach alternated periods of accretion and erosion each year between 2014 and 2019 but has eroded each of the past three years (2019 to 2021). This trend implies Reach 2 is sensitive to yearly changes in weather patterns impacting short-term sediment supply, rather than large-scale inlet dynamics that tend to overwhelm volume changes closer to Breach and Dewees Inlets. The trend also suggests the sand wave moving west from the project area remains upcoast from Reach 2, with no discernable volume contribution.

Over the past year, the reach was fairly stable, losing ~14,800 cy (3.5 cy/ft) of sand. All stations lost volume within the reach, but none exceeded 10 cy/ft. Compared to the 2009 condition, the eastern half of the reach has accreted up to ~10 cy/ft while the western half has eroded up to ~15 cy/ft. Much of the erosion occurring along the west end of the reach was due to a combination of storm impacts after 2015 and an erosional arc formation that impacted the area from 2012–2015. This erosional arc may have developed from changes occurring in Breach Inlet or from a temporary interruption in sediment supply from upcoast. It appears that the erosional phase along the western half has ended, and the dune is recovering, though it is still set further landward than the pre-2012 condition.

Photos and profiles show the healthier condition of the eastern end of the reach (south of the pier) compared to the western end (Fig 4.25). The dune constructed in 2017 following Hurricane *Irma* remains mostly in place three years after construction. This dune was scraped from the intertidal beach following the storm to accelerate the natural beach recovery cycle.

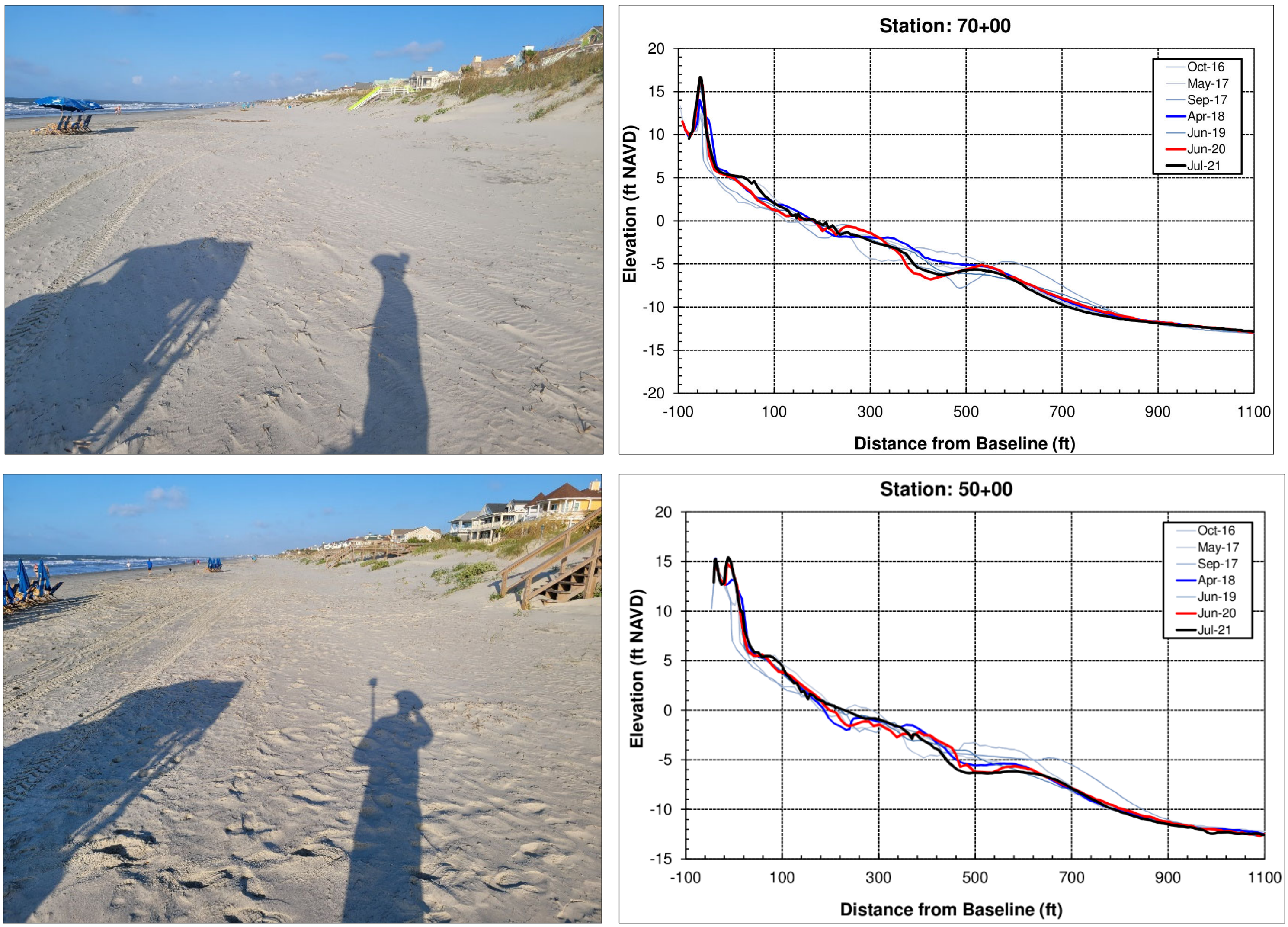


FIGURE 4.25. July 2021 photos of Reach 2. **[UPPER LEFT]** View west from Station 70. **[LOWER LEFT]** View west from Station 50. The photos show a healthy beach with dry sand seaward of the dune. Profiles show that the dune remains more landward than the 2012 condition; however, it has been fairly stable since 2017.

Aerial photos (Fig 4.26) of the reach show a crescent-shaped beach extending south of the pier, with a pronounced landward offset of the shoreline south of the pier. It is unclear whether the crescent shoreline is a result of sediment trapping from the pier or if it is a result of natural morphologic features associated with Breach Inlet. The shoreline morphology coupled with the lower accretion rate observed in this area should be closely monitored, as building setbacks are generally less than reaches 3–4.

FIGURE 4.26. Aerial views of Reach 2 in July 2021. Since monitoring began in 2009, Reach 2 has been the most stable reach, typically showing lower magnitudes of volume change compared to the other reaches along Isle of Palms. The arc in the shoreline west of the pier indicates that the pier may act to trap sand, which may impact Reach 2 in certain wave conditions.

4.2.8 Reach 1 – Breach Inlet

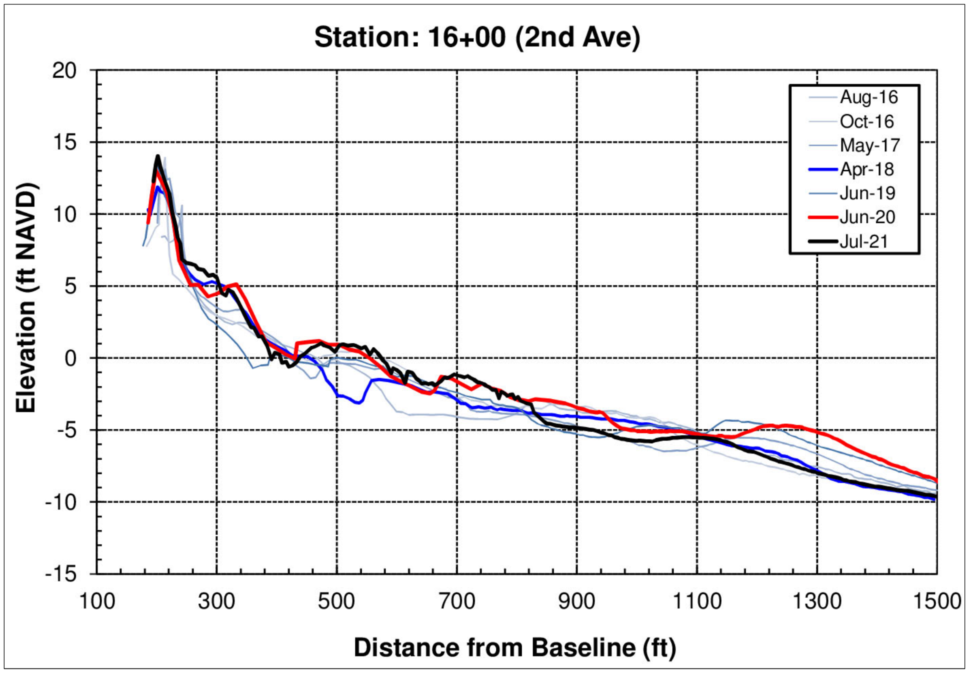
Reach 1 encompasses the beach between Breach Inlet and 6th Avenue (Fig 4.27) and is classified as an unstabilized inlet erosion zone due to the dynamic nature of the shoals associated with the inlet delta. The long-term trend in the reach is accretion, evidenced by a new row of houses being built seaward of the original "beachfront" row in the 1980s. Sand supply originates from shoal-bypass events at Dewees Inlet and longshore sand transport from north to south over the length of the Isle of Palms. Excess sand is deposited along the southern spit of the island 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 Isle of Palms reaches.

FIGURE 4.27. Baseline stationing along Reach 1 which encompasses the beach between Breach Inlet and 6th Avenue.

Similar to Reach 2, Reach 1 has experienced variable periods of erosion and accretion, with the long-term trend showing erosion since 2009. From April 2018 to June 2019, the reach lost ~31,900 cy (7.3 cy/ft), while from June 2019 to June 2020, the reach was highly accretional, gaining 103,000 cy (23.6 cy/ft) of sand. Between June 2020 and July 2021, Reach 1 lost ~2,500 cy of sand (0.6 cy/ft). The volume increase from 2019 to 2020 was the most accretion observed during any annual monitoring effort since the area was first measured in 2009. However, secondary peaks in accretion were observed in 2014 and 2018.

Profiles from this area show growth or stability of the dune and the formation of a dry sand berm seaward of the dune (Fig 4.28). A large sandbar was also present near the low tide elevation. The dune line along the reach is still ~80 ft landward of the 2012 position, which was the healthiest observed condition (prior to Hurricane *Sandy*). With the formation of the dry sand berm, additional dune growth is likely over the next year, as the berm acts as a source for wind-blown sand to accumulate along the toe of the dune. The dune placed after Hurricane *Irma* in 2017 has performed well north of 2nd Ave. West of there, the dune eroded through 2020 but has since rebuilt naturally.

The Breach Inlet reach has been dynamic since 2009 and needs to be closely monitored moving forward. CSE recommends the City pursue discussions with the US Army Corps of Engineers (USACE) to place material along this area as a beneficial use of dredged material when the Intracoastal Waterway is dredged in the future.



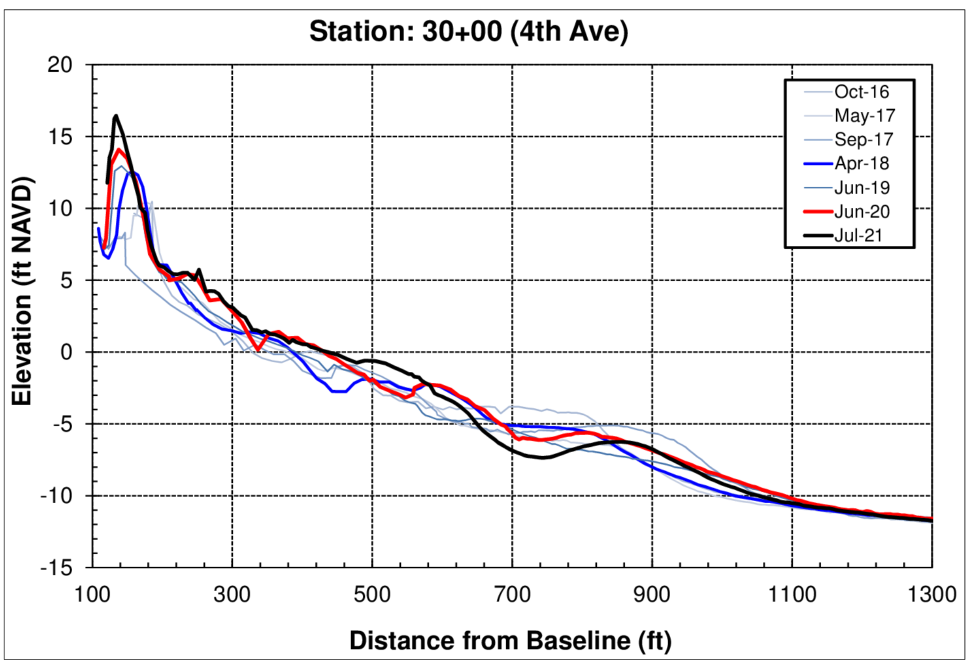


FIGURE 4.28. Profile plots for Reach 1 indicate that while recent erosion rates are higher than historical trends, the majority of volume loss has been restricted to the portion of the profile below the high tide line. This means that the dunes have been more stable than the erosion rate would suggest.

CSE obtained bathymetric data spanning most of the Breach Inlet channel and created a digital terrain model of the data (Figure 4.29). The model shows a well-defined primary channel bordering Sullivan's Island (red arrow). In 2019, there were no secondary channels present in the data coverage area; however, by June 2020, there was a distinct secondary channel oriented to the south. That channel migrated ~500 ft southwest (towards Sullivan's Island) between June 2020 and July 2021 (pink arrows). The primary ebb channel has also moved closer to the dry beach on Sullivan's Island and has decreased in width substantially since 2019. These two observations indicate Breach Inlet is undergoing an ebb-tidal delta breach (see FitzGerald et al 2000), which will likely result in the shoal between the primary and secondary channels attaching to Sullivan's Island.

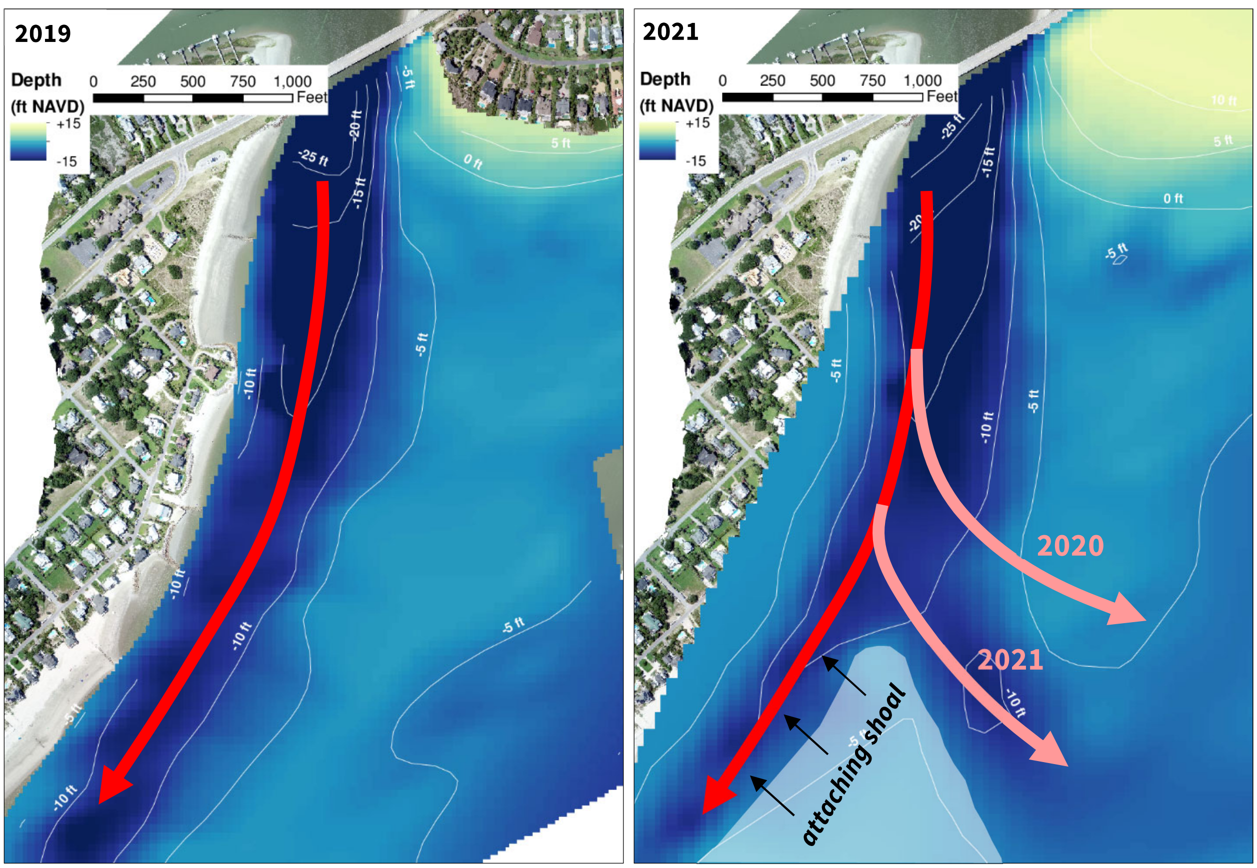


FIGURE 4.29. A pair of digital terrain models spanning the majority of the Breach Inlet channel collected in 2019 (left) and 2021 (right). The model shows a well-defined primary channel abutting Sullivan's Island (red arrow), and the smaller secondary channel draining towards the southeast (pink arrows). That channel migrated several hundred feet south and west between June 2020 and July 2021, and the primary channel width has reduced from ~500 ft in 2019 to ~150 ft in 2021 (black arrows). The shoal located between the two ebb channels (highlight, right panel) will migrate onto Sullivan's Island over the next year.

5.0 BORROW AREAS

**NOTE: BORROW AREA MONITORING IS REQUIRED IN 2019, 2021, AND 2023 PER PERMIT REQUIREMENTS. NO MONITORING WAS COMPLETED IN 2020; HOWEVER, THIS SECTION USES DATA FROM THE 2019 SURVEY FOR REFERENCE. THE 2021 SURVEY INCLUDES AN UPDATED ANALYSIS OF CHANGES OCCURRING WITHIN THE BORROW AREA.*

Per conditions of the permit for the 2018 nourishment project, the City is required to obtain bathymetric surveys of the borrow areas to monitor infilling rates. CSE collected bathymetric data at 100 ft spacing over all dredged areas within permitted borrow areas E and F in June 2019. Data were used to generate digital terrain models of the borrow areas and compared to pre- and post-project surveys.

Figure 5.1 shows the models for both borrow areas. The effects of the 2018 nourishment are clearly visible as the blue shaded colors in the elevation models. The 2018 post-project model shows a rough surface of the seafloor, which was generated by the arcing motion of the cutterhead during dredging. By 2019, the contours revealed a less rugged bathymetry as sediment shifted from high spots and infilled lower areas. As of July 2021, the slope breaks have continued to soften, particularly around the edges of both borrow areas. Generally, the boundaries of the dredged areas showed erosion of the top of the slope and accretion along the foot of the slope.

Figure 5.2 contains cross-sections of the borrow area bathymetry and their locations within each borrow area. At borrow area E, the sections show ~2 to 3 ft of infilling along the north/south section line, except at the area's southern (seaward) end. Some erosion of the upper boundaries of the side slopes is also evident, with up to one foot of loss along the landward slope. The west-to-east section shows ~1 to 2 ft of infilling within the small area dredged along the western half of the borrow area and ~2 to 3 ft of infilling along the eastern half of the area. Of note is a small mound that was not dredged along the eastern end of the area showed continued flattening, as would be expected. Less infilling was observed in Area F, with ~1 to 2 ft of burial between 2019 and 2021. The north/south section view shows the landward and seaward edges of the dredged area exhibit continued shifting of sand from the upper slope to the lower portion of the slope.

Table 5.1 shows the sediment volume within the dredged areas for the pre- (2017), post- (2018), 1-year post- (2019), and 3-year post-dredge (2021) surveys. These areas include the actual dredge footprint and areas immediately adjacent to the dredge areas. This means that some of the volume gains within the dredged areas will be negated by slumping of the adjacent areas. Borrow areas E and F showed a net loss of ~1,917,900 cy of sand between 2017 and 2018, which included the nourishment project. This quantity is similar to the measured in place volume but also includes any nourishment losses occurring during the project. Nourishment losses include fine-grained material that has spread beyond the project limits before settling out of suspension.

Borrow Area E gained ~131,400 cy of sand from 2018 to 2019, which is ~10 percent of the volume removed during nourishment. Area F actually exhibited a loss of sand over that period, losing 23,000 cy from 2018 to 2019. Measured losses are due to erosion of the upper slopes of the borrow area boundary and potentially some landward movement of sediment from the measurement area. Also, for an area the size of the borrow area, a volume of 23,000 cy represents a vertical elevation change of only two inches, which is within the accuracy limitations of survey equipment in this setting.

From 2019 to 2021, both areas gained volume and combined for a total increase of ~351,400 cy. Since project completion, the two borrow areas have gained ~459,600 cy or ~24% of the volume removed during nourishment. Sufficient beach compatible sand infilled the 2008 borrow areas to allow for a portion of one of the dredge areas to be reused for the 2018 project (the central-southern portion of Area E). Over time, the offshore zone may prove to be a renewable borrow source for future projects.

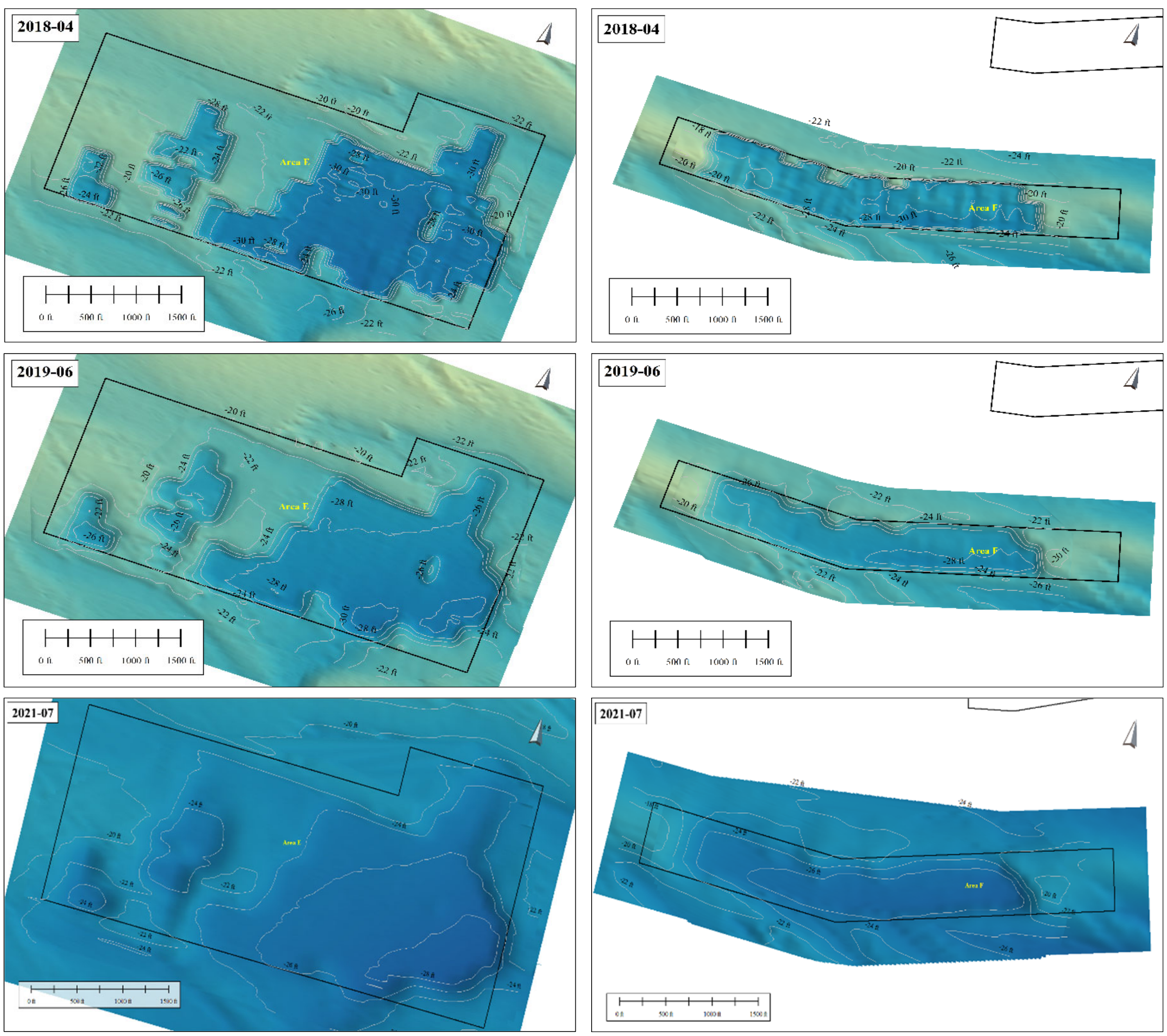


FIGURE 5.1. Terrain models for both borrow areas used in the project for each survey. The color scale is slightly darkened for the 2021 survey, but the same contour values and intervals are used for all of the panels.

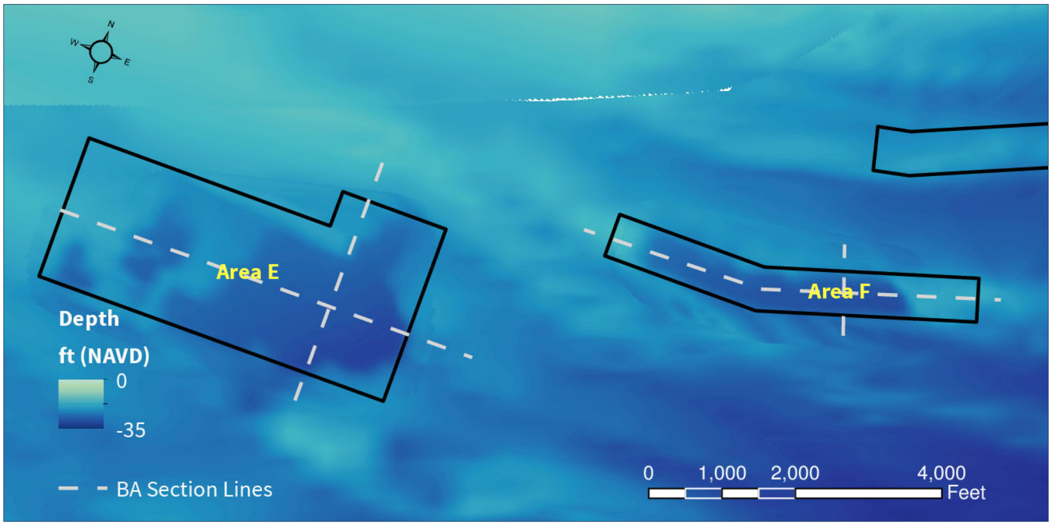


FIGURE 5.2.
[UPPER] Locations of cross sections within Borrow Areas E and F.

[LOWER] Cross-sections of the borrow area bathymetry for Borrow Area E and Borrow Area F.

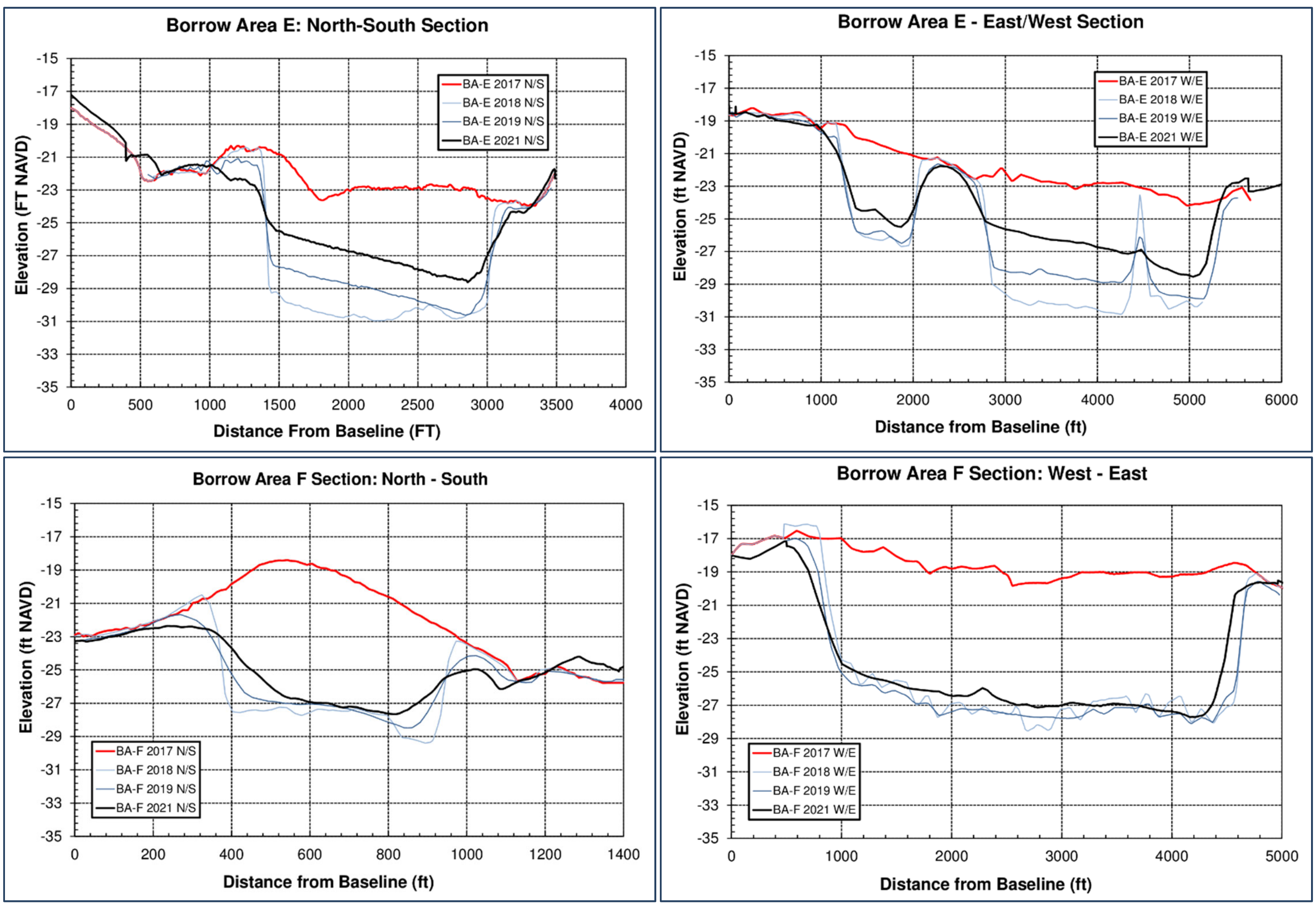


TABLE 5.1. Sediment volume within the dredged areas for the pre-, post-, and 1-year-post dredge surveys. These areas include the actual dredge footprint and areas immediately adjacent to the dredge areas.

Borrow Area Volume (cy)				
Total Volume to -40 ft NAVD				
	May-17	Apr-18	Jun-19	Jul-21
Area E	5,850,914	4,521,774	4,653,192	4,936,883
Area F	2,481,726	1,892,951	1,869,660	1,937,396
Total	8,332,640	6,414,725	6,522,852	6,874,279
Volume Relative to BD condition (cy)				
	May-17	Apr-18	Jun-19	Jul-21
Area E	0	-1,329,140	-1,197,722	-914,031
Area F	0	-588,775	-612,066	-544,330
Total	0	-1,917,915	-1,809,788	-1,458,361
Volume Relative to AD condition (%)				
	May-17	Apr-18	Jun-19	Jul-21
Area E	0	0.00	9.89	31.23
Area F	0	0.00	-3.96	7.55
Total	0	0.00	5.64	23.96
Volume Change Year to Year				
	May-17	Apr-18	Jun-19	Jul-21
Area E	0	-1,329,140	131,418	283,691
Area F	0	-588,775	-23,291	67,736
Total	0	-1,917,915	108,127	351,427

6.0 DEWEES INLET CHANGES

The City of Isle of Palms has sponsored comprehensive surveys of the Dewees Inlet delta since 2007. Previous monitoring reports have detailed morphological changes occurring each year; however, the general observation is that a large-scale channel avulsion (relocation) event occurred between 2007 and 2010. During this period, the main channel of the inlet was closed by a migrating shoal on the seaward lobe of the delta, and a new channel opened through the delta further to the northeast. Once the new channel was fully formed in 2010, it began migrating to the southwest near the 2007 position by 2017. By 2020, a new opening formed, and the cycle is repeating. The new channel has increased in area and depth between 2020 and 2021, indicating that the cycle of shoal bypassing continues off Wild Dunes. The series of models reveal the delta's cyclic evolution, where shoals migrate from the seaward lobe of the delta towards the beach. A portion of the sand stays on the beach to feed downcoast areas, and the remainder is recycled back into the inlet. **CSE computed the total sand volume in the delta in 2008 and 2021, finding a net increase of ~1,009,000 cy of sand during that time.** This value does not include the nourishment sand added during nourishment projects.

Figure 6.1 shows selected models of the Dewees Inlet delta since 2007. The 2019 monitoring report discussed the importance of the trailing ebb spit and how it acts to trap sand along the northeast end of the island. CSE has been monitoring the spit and predicting that it would merge with the beach in the near future. Over the past year, the spit has begun to merge with the low tide beach, as was discussed in Section 4. The attachment is closer to the beach at the northeast end of the island and tapers further offshore to a point where it merges with the terminus of the Dewees Inlet delta lobe near Beach Club Villas.

The main channel present in 2017 has now completely closed (at the –10 ft contour), and a new main channel is developing to the north in line with the main throat of Dewees Inlet. This is a similar configuration to the delta in 2010 after closure of the 2007 main channel. The main difference in the two configurations is the presence of the trailing ebb spit, which is responsible for much of the overall increase in volume measured in the delta. In July 2021, a low shoal located ~1,500 ft from the beach was evident. This series of events (eg – onshore migration of a trailing ebb spit, followed by a new shoal causing migration in the main ebb channel) occurred in 2009-2010 before the most recent shoal bypass event. Based on previous observations, CSE expects significant growth of the shoal over the next year though it will remain offshore for a few more years before attaching to the beach.

While the net volume increase will be a positive result, shoal-induced erosion of localized areas may be significant and needs to be monitored closely. As mentioned previously, the two large-scale nourishment projects have increased the total volume of sand within the beach and delta system at the northeast end of the island by over 2,000,000 cubic yards. The volume will help buffer development from impacts of the shoal events and hopefully allow the processes to occur without the need for mitigation via sand transfers.

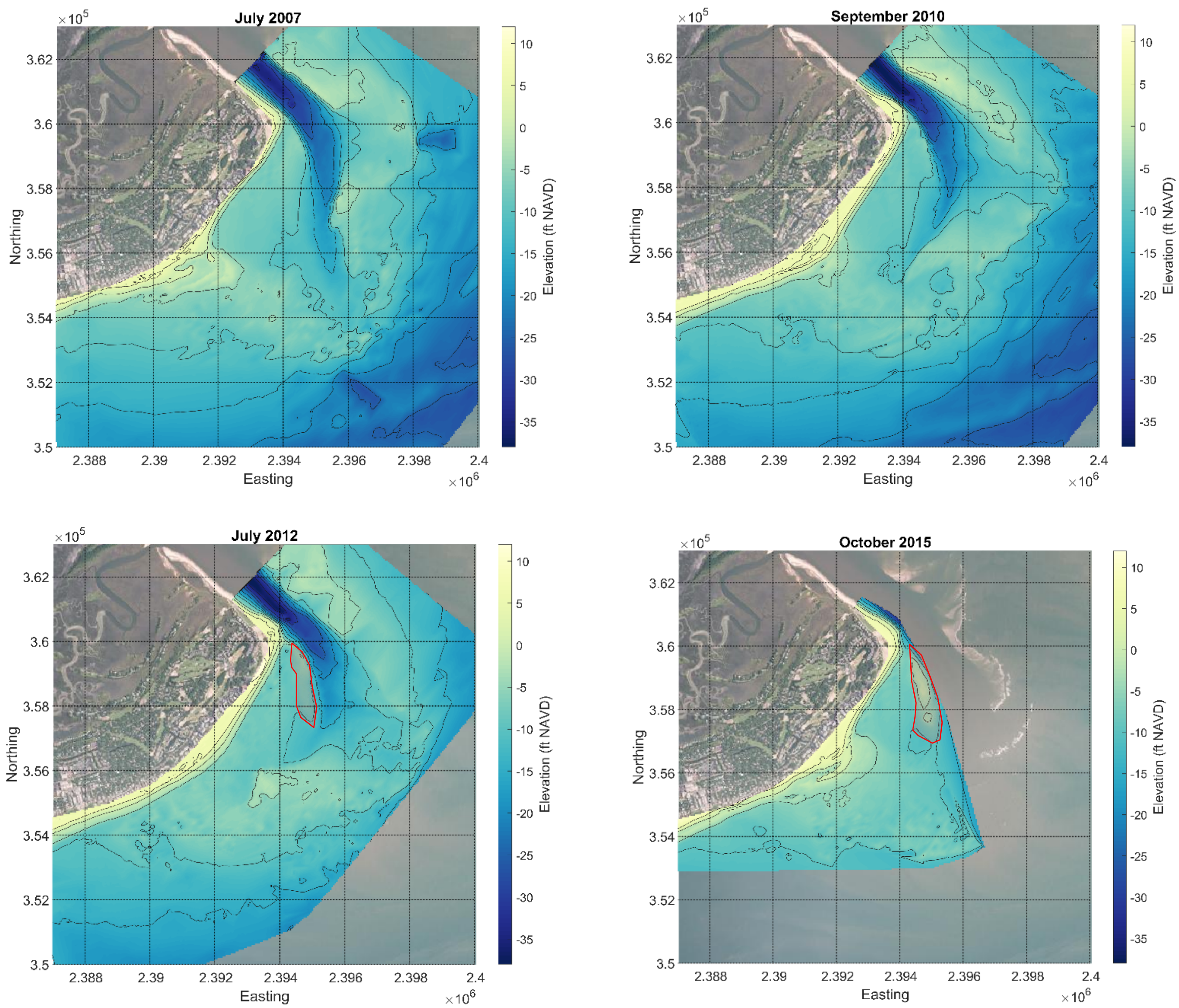
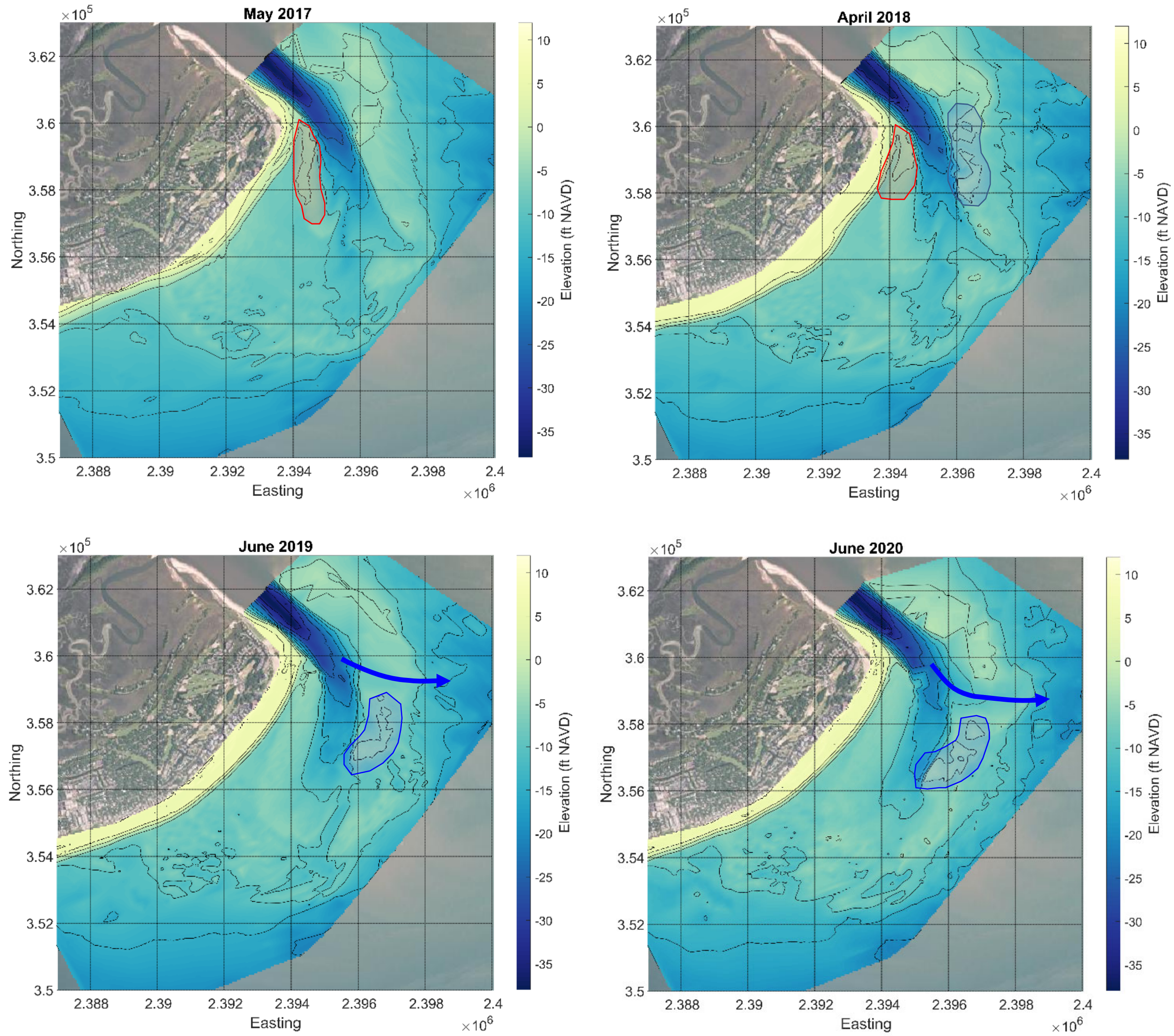


FIGURE 6.1. (page 1 of 2) Selected models of the Dewees Inlet delta since 2007. As the main channel shifts between more and less straightened orientations, there are substantial differences in the delta — most notably is the existence of a significant sand body connected to the northeast end of the island called a "trailing ebb spit" (highlighted with red polygon). As the main channel migrates into a more deflected position (eg pointing south instead of southeast), this spit will attach to the beach.



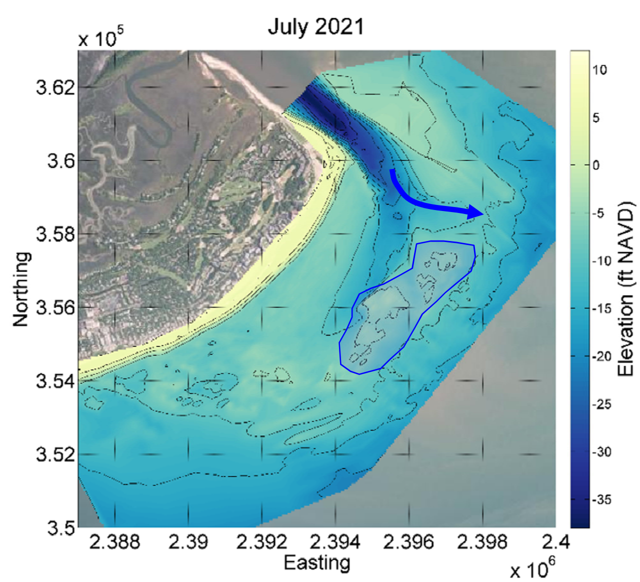


FIGURE 6.1. (page 2 of 2) Selected models of the Dewees Inlet delta since 2007. As the main channel shifts between more and less straightened orientations, there are substantial differences in the delta — most notably is the existence of a significant sand body connected to the northeast end of the island called a "trailing ebb spit" (highlighted with red polygon). As the main channel migrates into a more deflected position (eg pointing south instead of southeast), this spit will attach to the beach. After attachment, the main channel will re-orient towards the southeast and a larger shoal bypass event will occur (blue arrow indicates the new channel position, blue polygon indicates the shoal bypassing towards the beach). By 2018, the trailing ebb spit was fully attaching to the beach and an offshore shoal (blue polygon) became more notable in the elevation data. From 2019 to 2021, that shoal has moved south and west along the seaward edge of the Dewees Inlet ebb tidal delta. As of July 2021, the shoal is ~2000 ft from Shipwatch Villas.

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7.0 COASTAL RESILIENCY UPDATE

7.1 Weather and Climate Conditions, June 2020 to July 2021

CSE gathered weather and climate data from outside sources (all NOAA-supported) to evaluate observed changes to the beach with respect to environmental conditions. Wind and wave data reported here cover the time period from 20 June 2020 to 15 July 2021 (the same as the survey data presented herein). Wind data are compared to historical data covering the period from 1945 to 2021. Real-time and historical hourly wind data from across the United States are aggregated by the Midwestern Regional Climate Center (MRCC), a cooperative program between offices of the National Oceanic and Atmospheric Administration (NOAA) and Illinois State Water Survey (MRCC 2020, http://mrcc.isws.illinois.edu/). The closest operational station is located at Charleston International Airport (FAA Identifier – CHS) in North Charleston, ~20 miles northwest of Pawleys Island.

The average wind speed and direction* was 12.9 miles per hour (mph) from ~165° (approximately south-southeast, Fig 6.2). The peak observed wind speed was a gust to 47.4 mph from ~168° (approximately south-southeast) on 8 July 2021 during the passage of Hurricane *Elsa*. According to data from MRCC-NOAA, wind data over the study period were similar to the long-term trends. The proportion of winds from the southeast (90°–180°) and southwest (180°–270°) quadrants represent ~50.0 percent of the total from 1945 to 2020; between June 2020 and July 2021, these have represented ~46.9 percent of the total incoming winds. Northerly winds were consistent with long-term trends, as well.

Wave data are recorded by the National Data Buoy Center (NDBC) Station 41004 ('Edisto'), 41 nautical miles (nm) southeast of Charleston (SC). However, no wave data were recorded at Station 41004 from February to May 2021, so we have elected to use data from Station 41008 ('Grays Reef'), ~100 nm south of the Isle of Palms. Station 41008 has a similar exposure to north and northeasterly winds as the Isle of Palms (NOAA 2021, http://www.ndbc.noaa.gov/station_page.php?station=41008). The average wave height at Station 41008 was ~3.1 ft with an average wave period of ~7.3 seconds. The maximum observed wave height was ~10.3 ft on 21 March 2021 during the passage of a low-pressure system that triggered some of the highest-speed wind gusts measured over the current survey period. The average wave direction** was ~125° (approximately southeast).

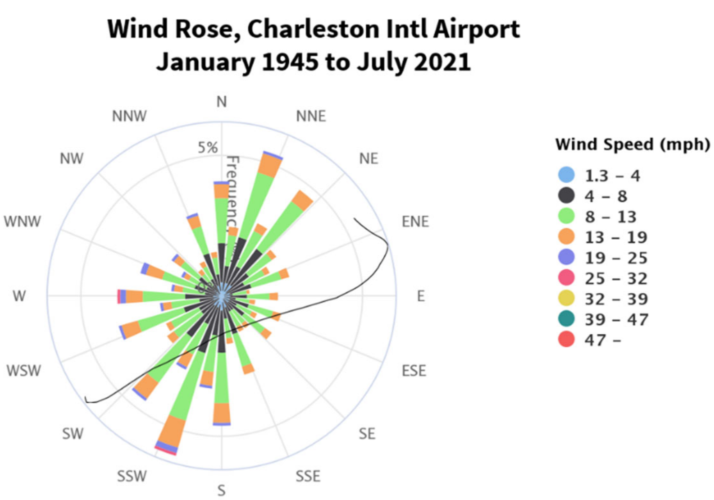
* *Herein, wind and wave direction is either given in degrees north or in terms of the direction from which it propagates.*

** *The direction from which waves propagate toward NDBC Station 41004.*

*** *The beach cycle refers to the natural buildup of a beach during fair weather (eg summer season) and erosion of the dry beach during storms (or winter season). When the onshore-offshore transport of sand balances, the beach is in dynamic equilibrium. More storms or higher water levels than normal interrupt this balance and lead to more erosion.*

From June 2020 to July 2021, Station 41008 experienced relatively calm wave conditions compared to recent years. Data from Station 41008 have been collected nearly continuously since December 2009, and in the period from then until June 2021, wave height exceeded 10 ft 269 times and 15 ft 32 times. Wave height exceeded 10 ft just once from June 2020 to July 2021 and did not exceed 15 ft over the same period.

Similarly, atmospheric pressure dropped below 1000 millibars (mb) 211 times from 2009 to 2021 but did not drop below 1000 mb once from 2020 to 2021 (Fig 7.3). This metric is used because most Category 1 hurricanes have a central pressure of ~980–990 mb, and many nor'easter-type storms will feature central pressures below 1000 mb. Similarly, wave height is an easy parameter for the relative intensity of storm events. However, atmospheric pressure and wave height are imperfect measures because these are simply proxies for the physical processes that result in beach erosion (eg – a more energetic surf zone with alongshore transport in a particular direction occurring in phase with high tide).



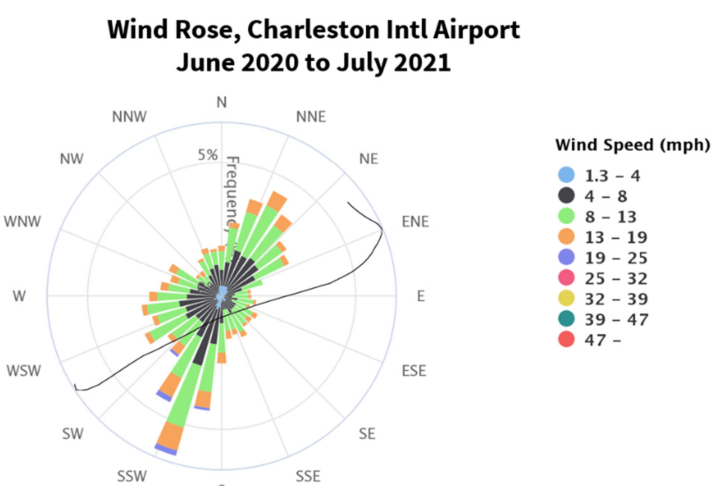


FIGURE 7.1. Wind roses showing direction and magnitude of winds measured at Grand Strand Regional Airport from January 1949 to July 2021 **[UPPER]** and from June 2020 to July 2021 **[LOWER]**. The line across the wind rose indicates the oceanfront shoreline orientation along the entire Isle of Palms.

The work of erosion is fundamentally a sand transport problem. An increase in erosion indicates more sand is being transported away from a location than being transported to replace lost volume. Sand transport increases exponentially with current velocity, and wave energy increases by the square of the wave height. So in tidal channels, a doubling of velocity will result in an eight-fold increase in net transport, while a doubling of wave heights produces a four-fold increase in erosive force. This helps explain why even minor storms can do significant damage along the coast. A four-foot wave impacting a structure or the foredune will be much more impactful than a normal two-foot wave.

Engineers and scientists use measurements of wave properties like height, wavelength, and speed to estimate the magnitude of energy exerted by a wave striking the beach. The estimate is expressed as 'wave power' in kilowatts per meter of crest length (kW/m). Because sand can migrate either way along a beach, wave power must be adjusted so that waves resulting in southerly transport (ie – north to south) and northerly transport (ie – south to north) can be differentiated. To accomplish this, wave power can be calculated so that northerly transport is measured above zero (positive) while southerly transport is measured below zero (negative). Wave power at Station 41008 is presented in Figure 6.3 with wave height. The larger-magnitude wave power values from August to November 2020 represent the passage of cyclonic storms during the fall and winter. In the spring and summer, lower-magnitude positive values tend to dominate.

The most powerful waves from June 2020 to July 2021 exhibited ~8 kW/m of wave power in a southerly direction, while the most powerful northerly-directed wave was ~7 kW/m (Fig 7.3). The average power of a northerly-directed wave from June 2020 to July 2021 was 0.6 kW/m, while the average southerly-directed wave power was –0.9 kW/m. From 2010 to 2021, the average energy was larger in the southerly direction (eg –12.2 kW/m versus 9.1 kW/m). This suggests sediment transport rates were lower during the survey period from June 2020 to July 2021 compared to the previous decade – a conclusion corroborated by the volume results presented herein.

Calculating the sum of all wave power indicates more individual waves moved in a southerly direction (~–4,700 kW/m) than in a northerly direction (~3,200 kW/m) over the same period. Using this metric suggests a *predominant* southerly-directed transport occurred from June 2020 to July 2021. Since 2010, a similar pattern has been observed wherein approximately two to three times more energy is expended moving waves in a southerly direction, compared to a northerly direction. This result corroborates long-term observations along the Isle of Palms documenting southerly-directed drift. It is important to note that Station 41008 is ~100 nm south of the island, with significantly more exposure to northeasterly waves than the Lowcountry. Thus, the net total wave power exhibited at Station 41008 may be somewhat different from the inshore zone off of the Isle of Palms.

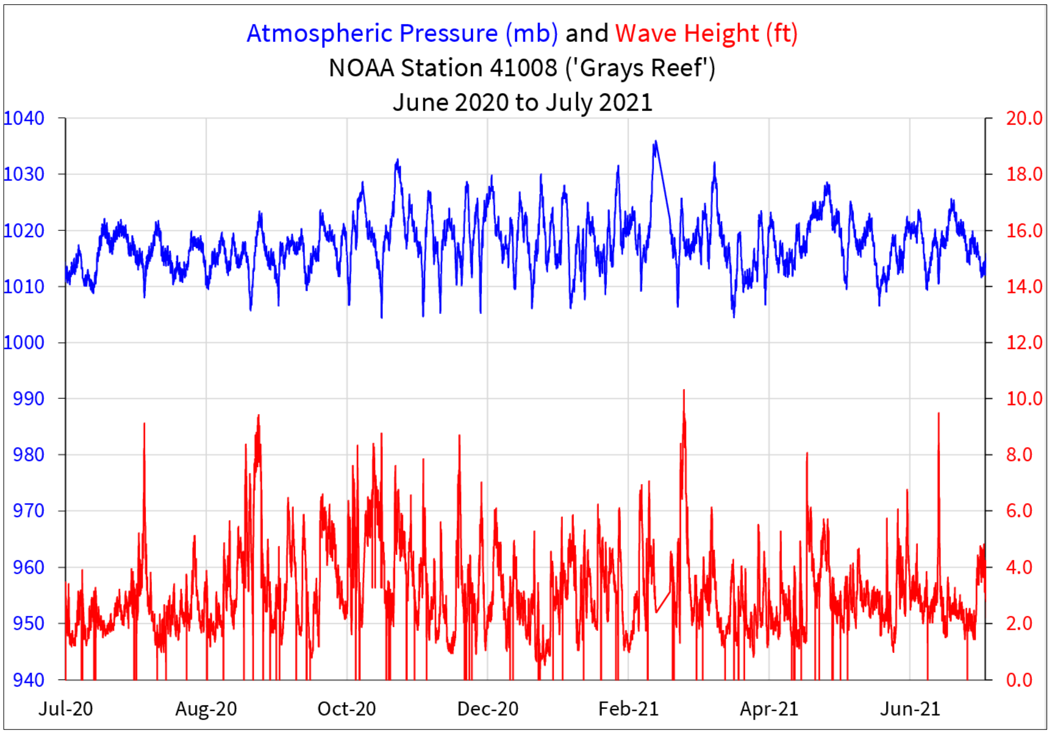


FIGURE 7.2. Atmospheric pressure and wave height at NDBC 41008 from June 2020 to July 2021. Wave heights exceeded 10 ft only once during the study period – far below the annual average since 2010 – and atmospheric pressure did not go below 1000 mb. These two parameters indicate conditions have been relatively calm over the past year.

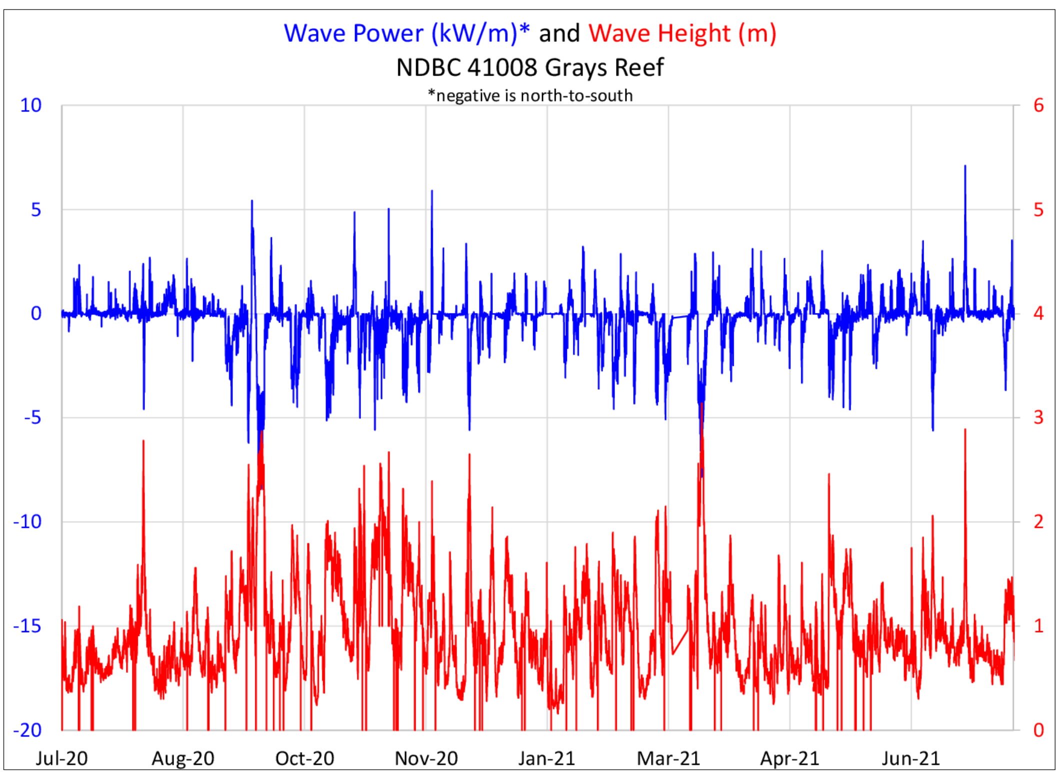


FIGURE 7.3. Wave power (in kW/m) and wave height (in m) for NDBC 41008 from June 2020 to July 2021. Wave power is a useful parameter for determining the relative magnitude and direction of wave energy in an alongshore direction along a beach. Positive values indicate waves move from south to north (ie – northerly transport), while negative values indicate predominance of north-to-south (ie – southerly) transport.

7.2 Flood Vulnerability

While analyzing past sea level trends is useful for predicting changes in the short-term (eg – years to decades), longer-term future sea level trends are more useful for strategic planning within coastal communities. To that end, NOAA and several national and international organizations regularly update future sea levels through the end of this century. Regional projections of average sea level rise (SLR) within the Southeast US range from ~1 ft to ~10 ft (Sweet et al 2017). These projections are based on six modeled values of future emissions, shifts in ocean circulation, vertical movements in the Earth's crust, and changes to Earth's gravitational field and rotation. They range from 'Low' – ~1 ft by 2100 to 'Extreme' – ~10 ft by 2100, with a 'High' scenario at 8 ft and three 'Intermediate' values averaging ~4 ft (Fig 7.6; NOAA 2021). For reference, the highest astronomical tide (aka 'King Tide') expected at Isle of Palms would bring water levels ~3 ft above mean sea level (MSL). So, the water levels observed during those King Tide events represent the higher range of projected MSL by ~2060 and the lower-intermediate projected MSL by ~2100 (Fig 7.6).

Relative to 1995–2014 conditions, the likely global mean sea level rise by 2100 is ~1 to 2 ft under the *lowest* scenario. This scenario calls for warming to be held at or below 1.5 °C by 2100 compared to 1900 and for 'net-zero' CO_2 emissions by 2100. 'Net-zero' emissions represent the condition in which removals of atmospheric carbon exceed emissions. The 'intermediate' scenarios are approximately in line with the upper (eg – higher-emitting) end of international emissions agreements, while the 'very high' scenario assumes no additional climate policy beyond what is currently in place. Intermediate and very high emissions scenarios are expected to trigger likewise increases in SLR.

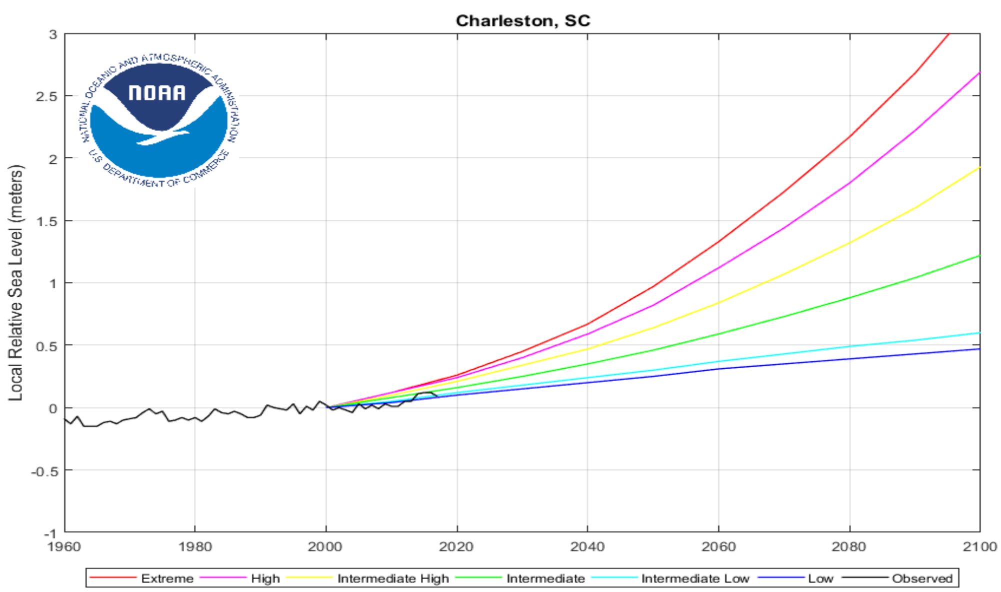


FIGURE 7.4. Projected MSL values under an 'Intermediate' emissions scenario average ~2 ft by 2060, and ~4 ft by 2100 at Charleston Harbor. These projections are global-scale predictions of future water levels (based largely on emissions) adapted to the Lowcountry by accounting for regional and localized changes in ocean circulation, vertical movement in the ground surface, and other factors.

Keep in mind that any rise in *mean* sea level in the future is accompanied by a corresponding rise in mean high tide. So in simple terms, today's high tide level would become a future mean tide level, and a future normal high tide level could be the equivalent of the storm tides the Isle of Palms experienced during hurricanes *Matthew* or *Dorian*.

Coastal communities are becoming more aware of the subtle differences in these impacts as they begin to feel pressure from sunny-day 'nuisance' floods (see Sweet et al 2018, Sweet et al 2020). Such floods will tend to impact low-lying sheltered shorelines, including causeways over the marsh or backyards fronting sheltered estuaries. Just a small super-elevation of the tide can quickly overtop a road that is barely above normal spring tide levels. On the other hand, locations on the open ocean generally don't experience nuisance floods the same way. This is because dunes grow vertically just inland from the beach, leading to relatively higher elevations than the 'back side' of barrier islands, where the shoreline transitions more gradually into marsh and creek habitats.

Figure 7.5a,b shows a range of SLR scenarios between 1 ft and 4 ft above mean higher high water (MHHW). MHHW is presently 2.62 ft above 0 ft NAVD at the Charleston Harbor entrance. So, ~2 feet of SLR would bring MSL up to present-day MHHW and likewise move MHHW upwards. These visualizations do not distinguish between MSL and MHWW; however, they indicate the water level at 1, 2, 3, and 4 ft above MHHW. This means the maps show where the highest astronomical tide would flood under these scenarios. It is apparent that with increasing SLR, flooding will be more impactful along the backside of the island.

NOAA provides a 'Sea Level Rise Viewer' (SLRV; see https://coast.noaa.gov/digitalcoast/tools/slr.html) to help people identify local variations in flood impacts under different SLR scenarios. This tool allows users to specify water levels and then generate inundation maps showing MSL as well as depth in previously dry areas. Figure 6.5 shows example results for scenarios of MHHW plus 1 ft, 2 ft, 3 ft, and 4 ft SLR for the Isle of Palms. The NOAA viewer is a handy tool to see which SLR scenarios begin to impact a particular property.

At present, all properties on the island remain above MHHW. Under a SLR scenario of 1 ft (Fig 7.5), some of the marsh edge along the Intracoastal Waterway, Waterway Island, and the landward side of Wild Dunes would be inundated. The road could be threatened by nuisance flooding on a more frequent basis than at present. This is particularly true for the portions of Waterway Boulevard near Holes 6 through 8 of the Harbor Course. This scenario is equivalent to projected MHHW in ~2040 under an 'Intermediate' scenario (see Fig 7.4).

A 2-ft increase in MHHW would lead to further marsh creep and periodic inundation of Holes 6 through 10 of the Harbor Course (Fig 7.5). Marsh edges behind the Harris Teeter and around Marsh Island Lane and Merritt Boulevard would continue to move inland and upward, and these areas would likely see increased nuisance flooding. According to NOAA projections under an 'Intermediate' scenario, this increase would occur by ~2070 (see Fig 7.4). Kiawah Island has begun strategic planning to address impacts from this rate and magnitude of SLR (see Town of Kiawah Island 2018).

The SLRV indicates that the most significant changes could occur when MHHW increases from 2 ft to >3 ft above present (Fig 7.5). Many properties would be permanently inundated, particularly along Waterway Boulevard, between 2nd and 6th Ave, behind the Harris Teeter, and along Back Bay Drive in Wild Dunes. With 3 ft of SLR, Palm Boulevard near the Hunley Bridge will become permanently inundated. At 4 ft of SLR, a large portion of the neighborhood bound by 32nd Ave, Hartnett Boulevard, and 41st Ave would be inundated.

SLR of 3 ft and 4 ft on the oceanfront could trigger a mixture of impacts. If sufficient sand volumes are maintained along the oceanfront, the first 1 or 2 rows of beachfront homes would likely remain high and dry even with a 4-ft rise in MHHW. This is because most oceanfront properties are elevated higher than back-barrier buildings to accommodate surge and wave runup. Keep in mind that such properties may be safe from normal conditions, but will still be exposed to higher water levels in storms. Houses presently elevated to the 100-yr flood level standard will become more vulnerable to lower return-period storm surges – perhaps as frequently as a 30-yr interval – under the likely SLR scenarios in the next 80 years (see Marsooli et al 2019).

A 3 ft increase in MHHW is possible under the 'Intermediate' scenario by ~2090 (see Fig 7.4), whereas a 4 ft SLR under the same scenario is not expected until after 2100. Folly Beach plans to adapt to SLR of 3 ft by ~2060 (see SC Sea Grant 2017). Extensive research is being conducted worldwide to improve predictions of future sea levels and ramifications for individual locations. A key finding of the August 2021 IPCC* report is that regardless of any level of reduction in atmospheric CO_2, sea levels will rise through 2100 by at least 2 to 3 ft.

** IPCC – the Intergovernmental Panel on Climate Change was formed by the United Nations to provide regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. The panel currently has 195 members from around the world, with dozens of additional scientists making contributions to each report.*

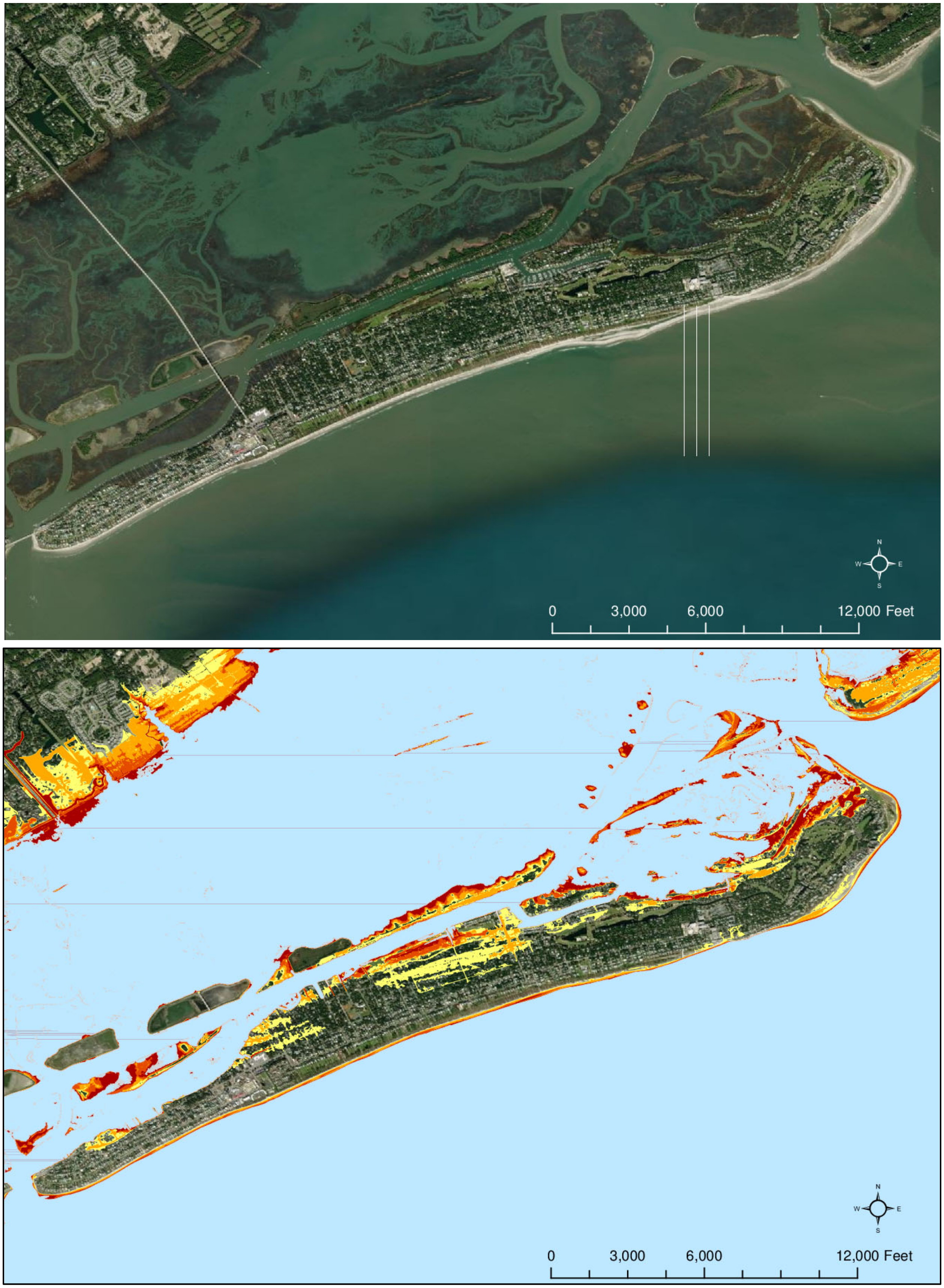


FIGURE 7.5a,b. Sea level inundation models around the Isle of Palms generated using data from NOAA (https://coast.noaa.gov/digitalcoast/tools/slr.html). Shades of yellow, orange, red, and maroon are used to signify SLR of 1, 2, 3, and 4 ft above present-day MHHW.

7.3 Coastal Resiliency in the 21st Century

NOAA's Ocean Service defines coastal resiliency as the "ability of a community to 'bounce back' after hazardous events…rather than simply react to impacts" (NOAA 2021). NOAA recommendations for effectively preparing for hazardous situations, and improving coastal resiliency, include being "informed and prepared" for the impacts of SLR as a community.

As mentioned above, many communities around the nation, the world, and a handful of communities in South Carolina have begun strategic planning initiatives to address the impacts of projected SLR. The impacts of SLR are diverse and extensive, and conditions vary significantly from one community to another. Individualized plans developed at a community level help prepare for these impacts using a variety of tools and adaptation strategies.

Other communities in South Carolina have categorized potential adaptation strategies according to their role and utility in mitigating impacts from future SLR. These include water infrastructure management, uplands management and/or conservation, transportation adaptation, and education/communication. The order of mitigation and adaptation strategies should be timed according to the vulnerability and capabilities of the community in question. Shorter-term goals (eg – 1 to 3 years) are focused on generating plans and recommendations based on a detailed inventory of the vulnerability of upland properties at a parcel scale. Medium- and long-term goals (eg – 3 to 5+ years) include implementing recommendations.

SLRV data indicate flooding along Waterway Boulevard and portions of Wild Dunes will present issues for the entire island by mid-century under 'Intermediate' SLR scenarios. Mitigation and adaptation strategies for that particular vulnerability should target improving drainage following rain events and elevating the road surface above future MHHW. On a longer time scale ('Intermediate' scenarios as projected by the end of the century), developed properties between Hartnett Boulevard and the Harbor Course as well as near the Exchange Club will be vulnerable to persistent flooding even during calm weather conditions.

The City should consider sponsoring a Climate Change and SLR adaptation plan similar to those developed by Folly Beach and Kiawah Island to improve its coastal resiliency. Adaptation plans are not unlike the Beachfront Management Plans prepared by many communities, although due to the broad array of SLR impacts, they can represent a more interdisciplinary effort. These plans contain recommendations and identify time horizons for specific priorities and goals. More importantly, they inform a community of the hazards presented by SLR and how to prepare adequately before those hazards negatively impact the community.

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8.0 SUMMARY & RECOMMENDATIONS

This report describes beach condition changes occurring at Isle of Palms beach from 2020 to 2021. Overall, the island lost ~191,200 cy of sand from June 2020 to July 2021, equivalent to a unit volume loss of –5.1 cy/ft over that time period. This compares to a loss of ~59,600 cy from 2019 to 2020 and 234,000 cy from 2018 to 2019. Since project completion, erosion has been most severe along the center of the project area, with adjacent portions of the beach receiving sand as the fill template spreads alongshore. This trend will continue, although the magnitude of volume changes between surveys should generally decrease with time.

Since the 2018 renourishment, the project area has lost ~960,100 cy. Much of this sand has spread to adjacent areas or into the Dewees Inlet delta. The project area still holds ~620,000 cy more sand than the pre-nourishment condition. The majority of the island west of the nourishment area remained relatively stable from June 2020 to July 2021, except for Reach 2, which spans the oceanfront west of Sea Cabins Pier. The evolution of the beach since completion of the 2018 project follows the expected pattern of erosion that generally occurs after large-scale nourishments, with sand eroding from the ends of the project and shifting to downcoast areas. This is especially evident along Reach 3, which has gained ~401,900 cy since before the 2018 project.

Presently, a shoal is forming in Dewees Inlet that should migrate to shore between Beach Club Villas and Beachwood within 1 to 3 years. Breach Inlet is also bypassing sand to Sullivan's Island, and a reconfiguration of primary and secondary channels within that ebb-tidal delta will affect volumes along the southern tip of Isle of Palms.

While much of the Isle of Palms is protected by a healthy beach and dune system, certain flood hazards along sheltered parts of the island are expected to increase in coming years. Based on a review of coastal resilience in physical systems around Isle of Palms, the City should consider sponsoring a sea level rise adaptation plan that can be used to more easily obtain funding for infrastructure improvements and hazard reduction projects. The next monitoring effort for Isle of Palms is scheduled for the summer of 2022. It will provide an update on the condition of the beach and evolution of the 2018 nourishment project. Copies of this report and associated data will be sent to regulatory agencies to satisfy permit compliance requirements.

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