

**2018 Isle of Palms Restoration Project
Year 5 Monitoring Report**

**2023
MONITORING REPORT**



Prepared for
**City of Isle of Palms
Isle of Palms, South Carolina**

COASTAL SCIENCE & ENGINEERING

CSE

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**2018 Isle of Palms Restoration Project
Year 5 (2023) Monitoring Report
Annual Beach and Inshore Surveys**

Prepared for:



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[2492YR5 — Monitoring Year 5]

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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, Inc (CSE) as part of an ongoing beach monitoring effort that 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 August 2023 and compares this condition with selected earlier dates, including the pre-2018 project condition. This is the fifth 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 2023 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
- August 2022 –Year 4 Survey
- August 2023 –Year 5 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 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. These shoals were likely, 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” barrier island.

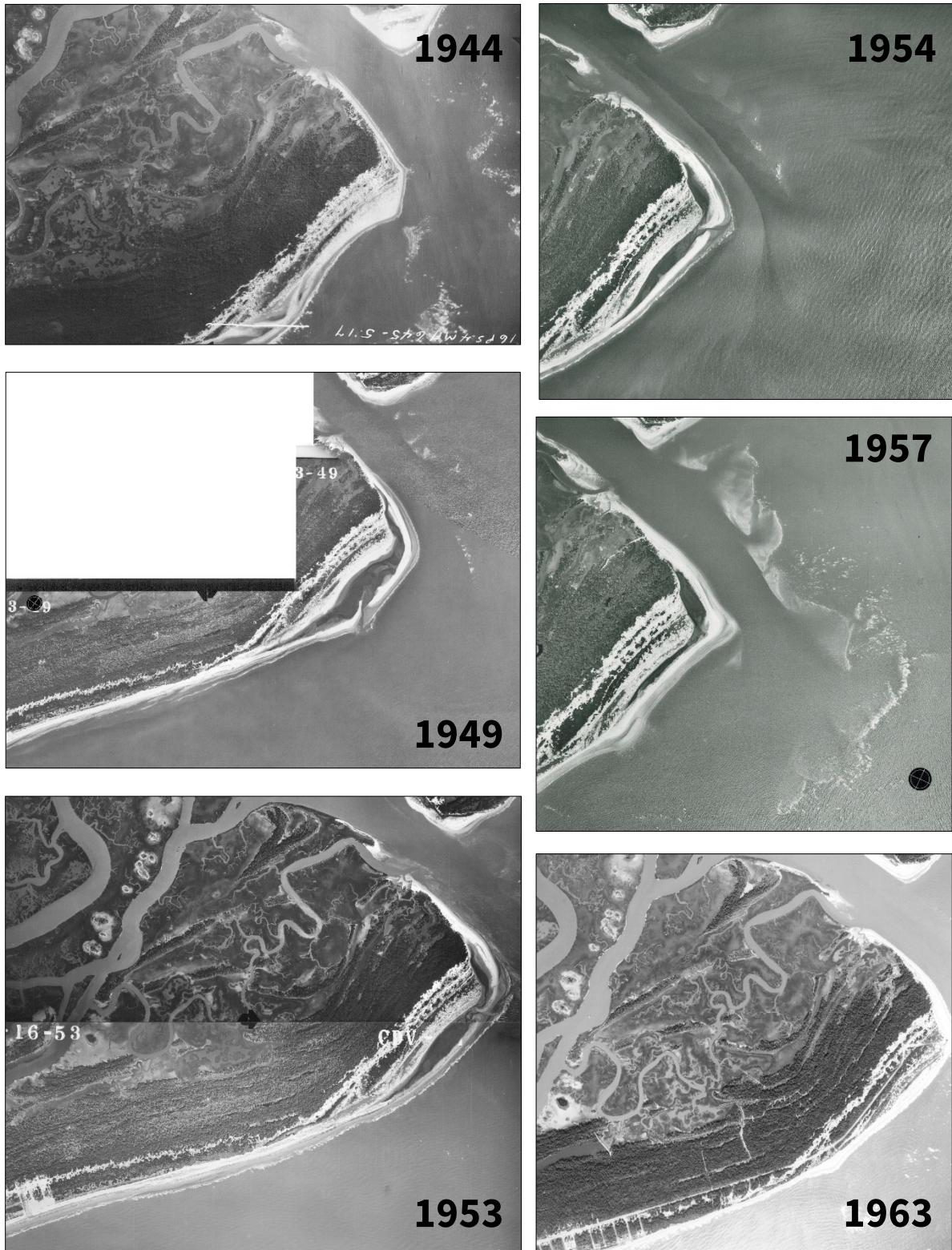


FIGURE 2.2. Historical aerials from CSE 2010 report page 56 (Figure 3.35).

Photo sequence begins (left column from top) in 1944, 1949, and 1953, then continues (right column from top) through 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 in 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, and 1998 (Figure 2.3) that 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 Ocean 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 permit applicant. Permits were obtained (P/N 2007-02631-2IG), and the City contracted with Weeks Marine for a project involving the 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) that compares to the project area before renourishment (2007).



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

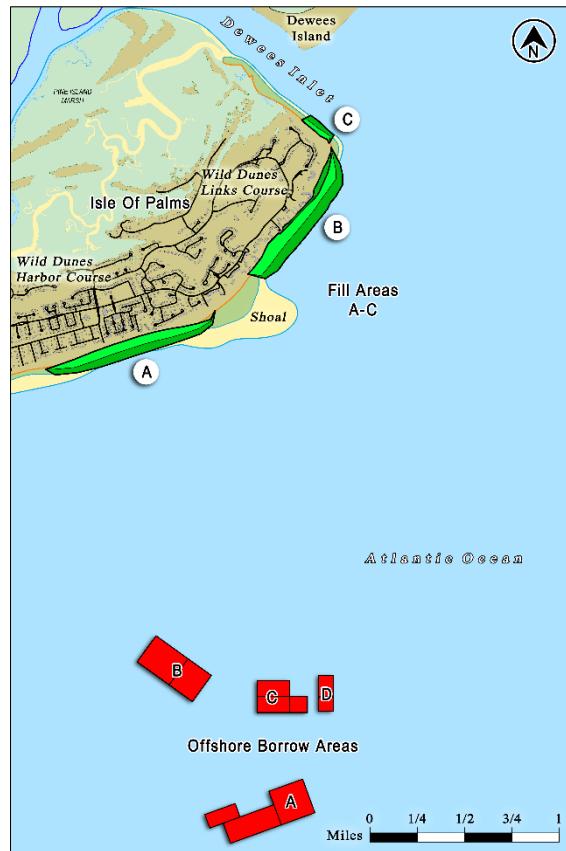


FIGURE 2.8. [RIGHT] 2008 nourishment project map.



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 began 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).

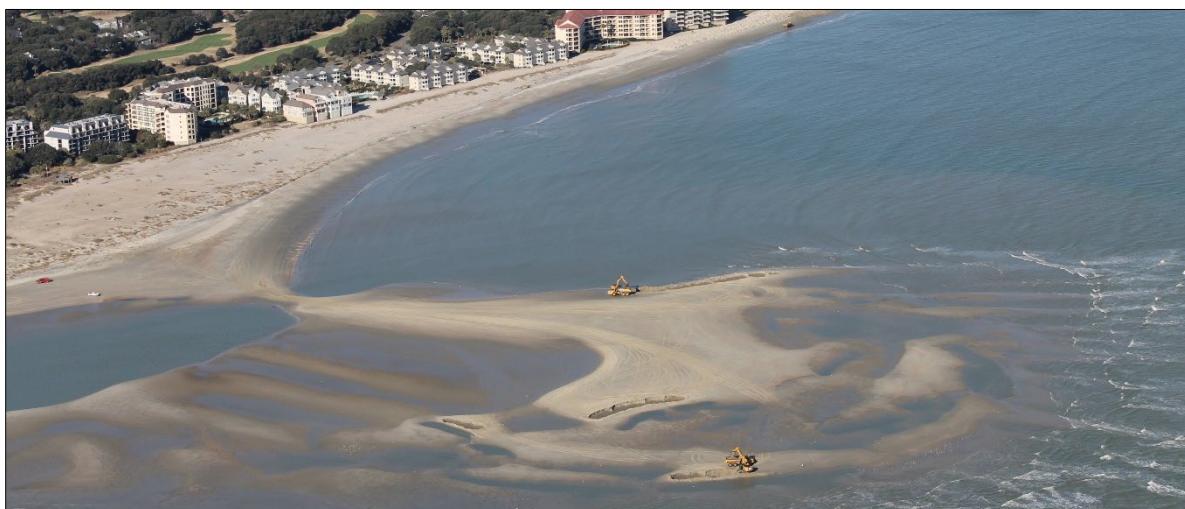


FIGURE 2.10. January 2015 aerial image of the 2014–2015 shoal management project showing equipment transferring sand from an attaching shoal to the eroded beach.

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 hotspots 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 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 a 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 project 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

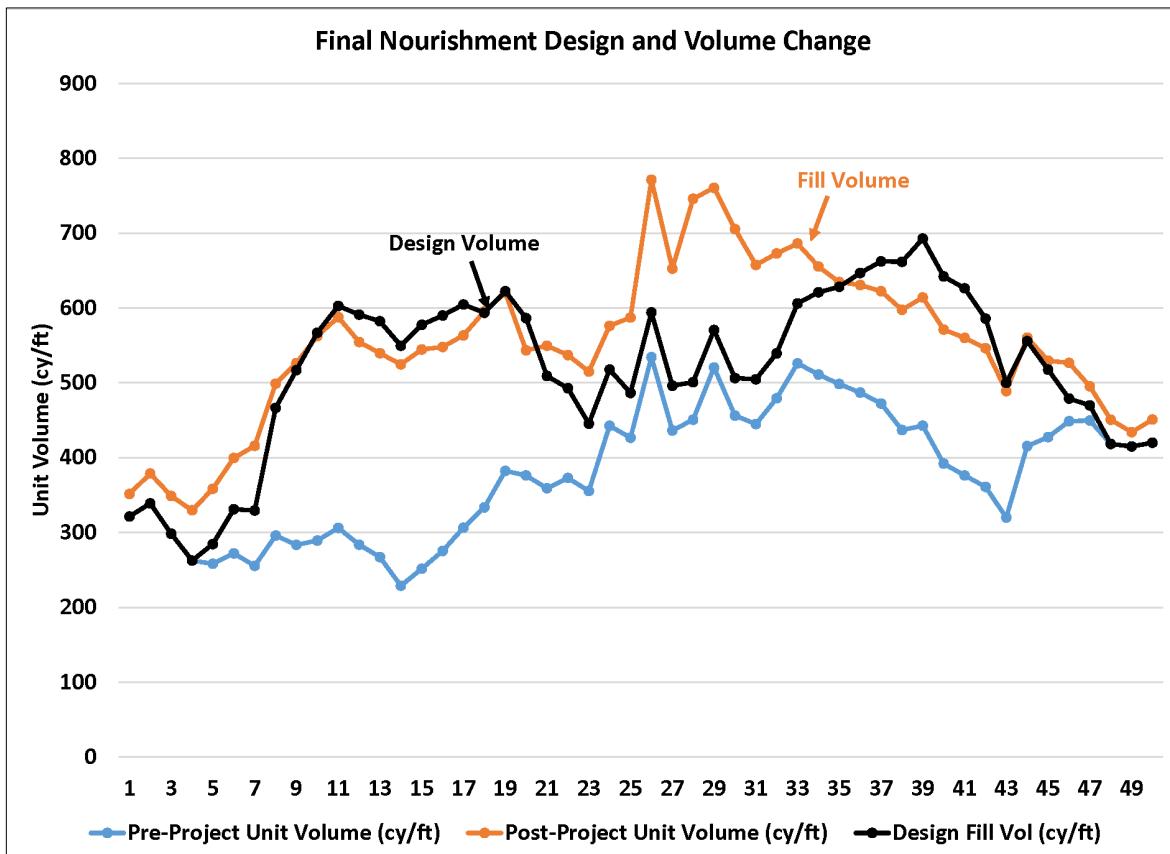


FIGURE 2.11. A graphic representation of the 2018 final fill template (shown in TABLE 2.2).

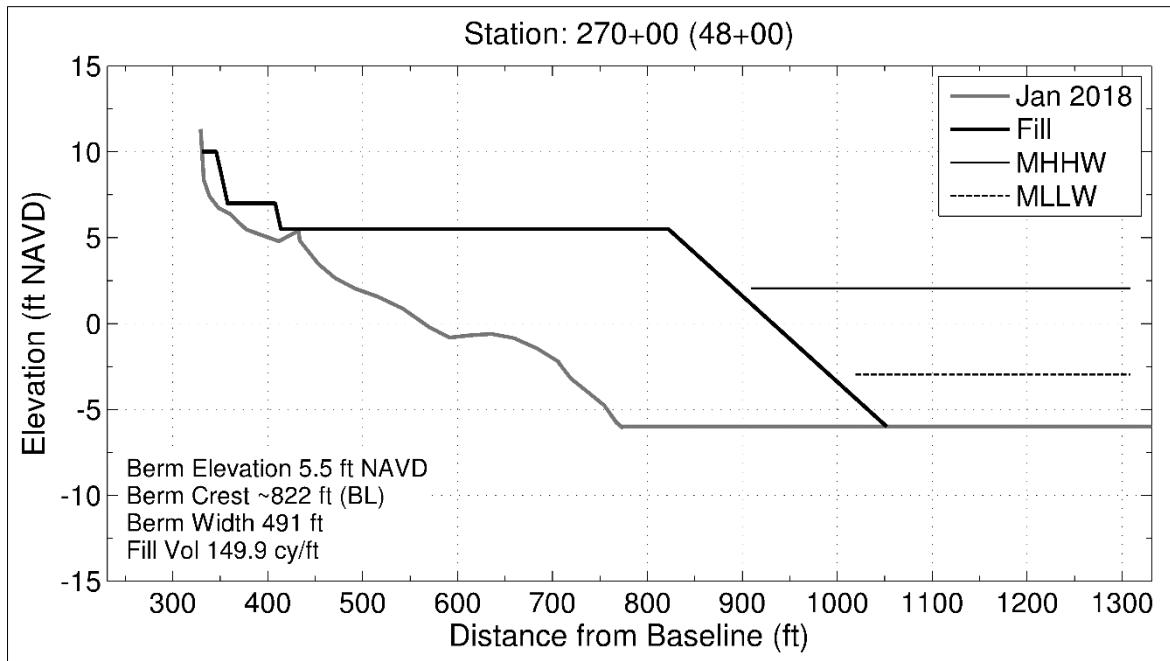


FIGURE 2.12. The 2018 design fill profile incorporated a dune, storm berm, wide fill berm, and sloping section.

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 August 2023. 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 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 a 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.

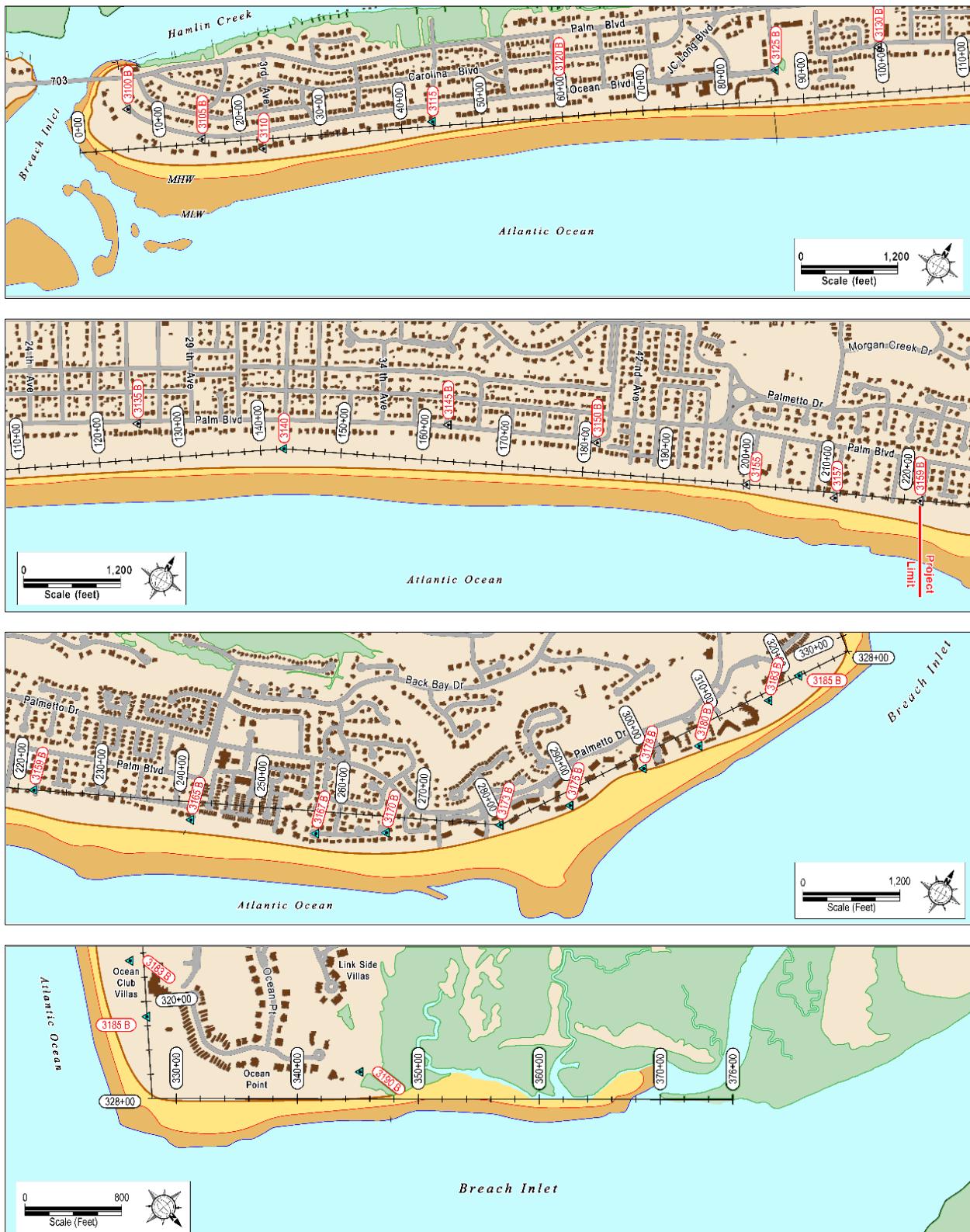


FIGURE 3.1. Baseline map of Isle of Palms showing the reference line used to establish monitoring profiles. Stationing increases to the north from Breach Inlet.



FIGURE 3.2.

Surveying beach profiles involves collection of land-based data at low-tide and hydrographic data collection 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 6 th Avenue
Reach 2	OCRM 3115 to OCRM 3125	6 th Avenue to Sea Cabins Pier
Reach 3	OCRM 3125 to OCRM 3140	Sea Cabins Pier to 31 st Avenue
Reach 4	OCRM 3140 to 222+00	31 st Avenue to 53 rd Avenue
Reach 5	222+00 to 280+00	53 rd 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

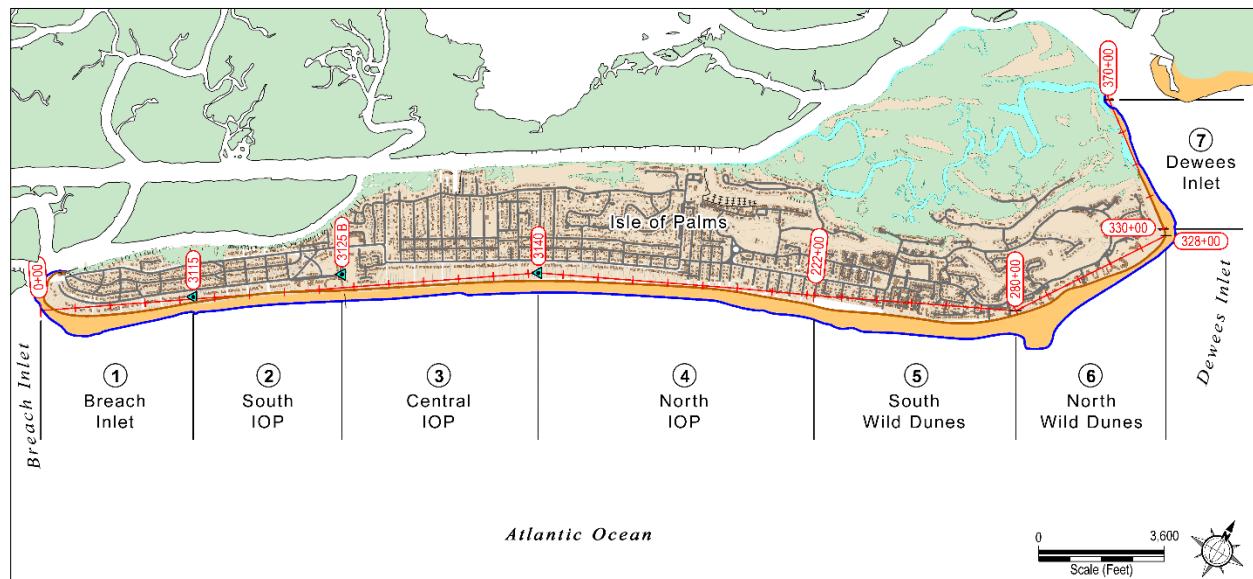


FIGURE 3.3. Reach limits used in the present monitoring report.

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.

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 by 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 sediment volumes. Position data were entered into the 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.

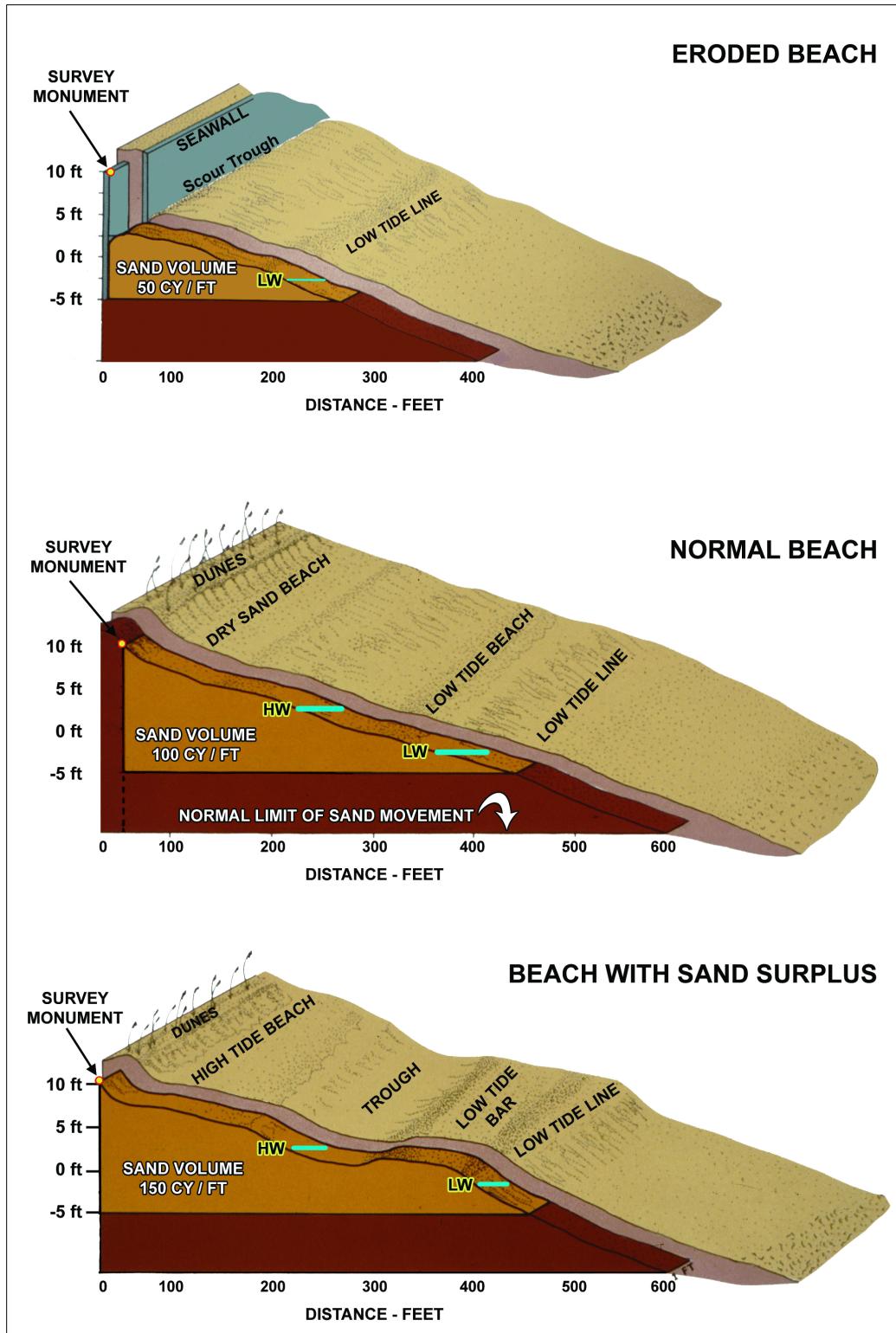


FIGURE 3.4. Illustration of the profile volume concept.

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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 2022 and 2023. 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 ~506,000 cy of sand between August 2022 and August 2023. It is nearly double the loss from the highest annual losses previously measured (2011) since monitoring began in 2009. 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 was again most severe along the Wild Dunes area and Breach Inlet (Reaches 1 and 6). Within Wild Dunes, there were distinct variations in volume change, with some areas gaining sand and others eroding. Accretion downcoast of the project area (south of 53rd Ave) continued as in prior years. Across the entire island, the beach holds ~485,000 cy more sand than the 2017 pre-nourishment condition and ~239,000 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 ~44 cy/ft along Breach Inlet to an increase of ~3 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.

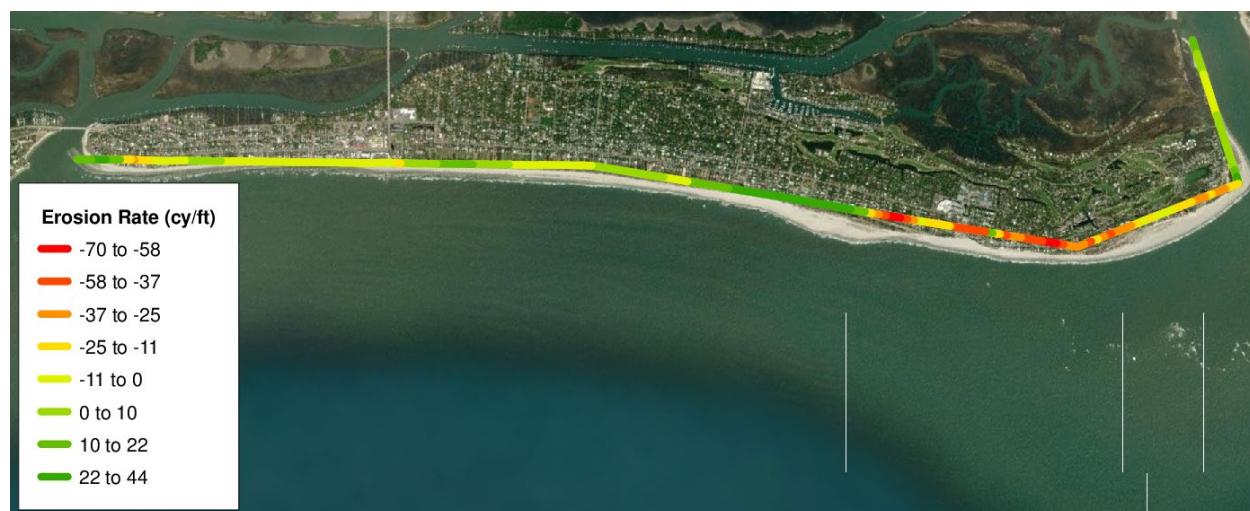


FIGURE 4.1. Line map showing erosion and accretion patterns over Isle of Palms from August 2022 – Aug 2023.

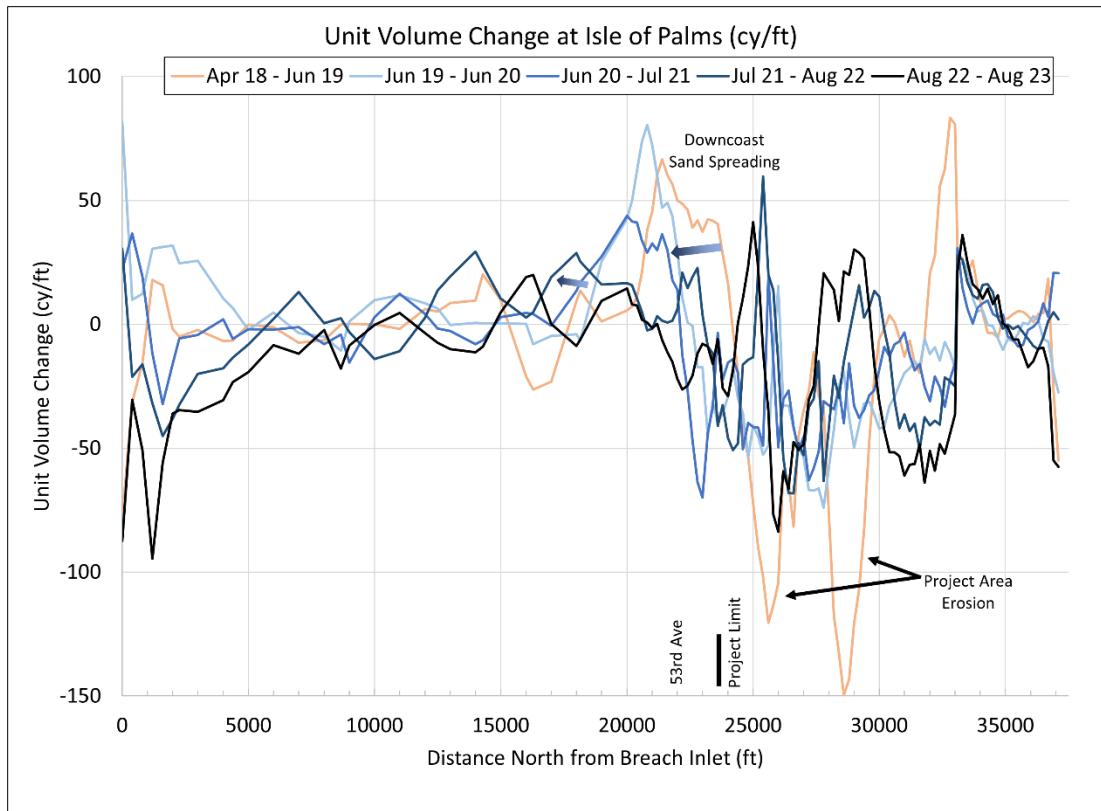


FIGURE 4.2. Beach unit volume change between each monitoring event at Isle of Palms. The X axis represents the distance from Breach Inlet. This graph highlights the erosion occurring in the project area and accumulation of spreading sand adjacent to the project area.

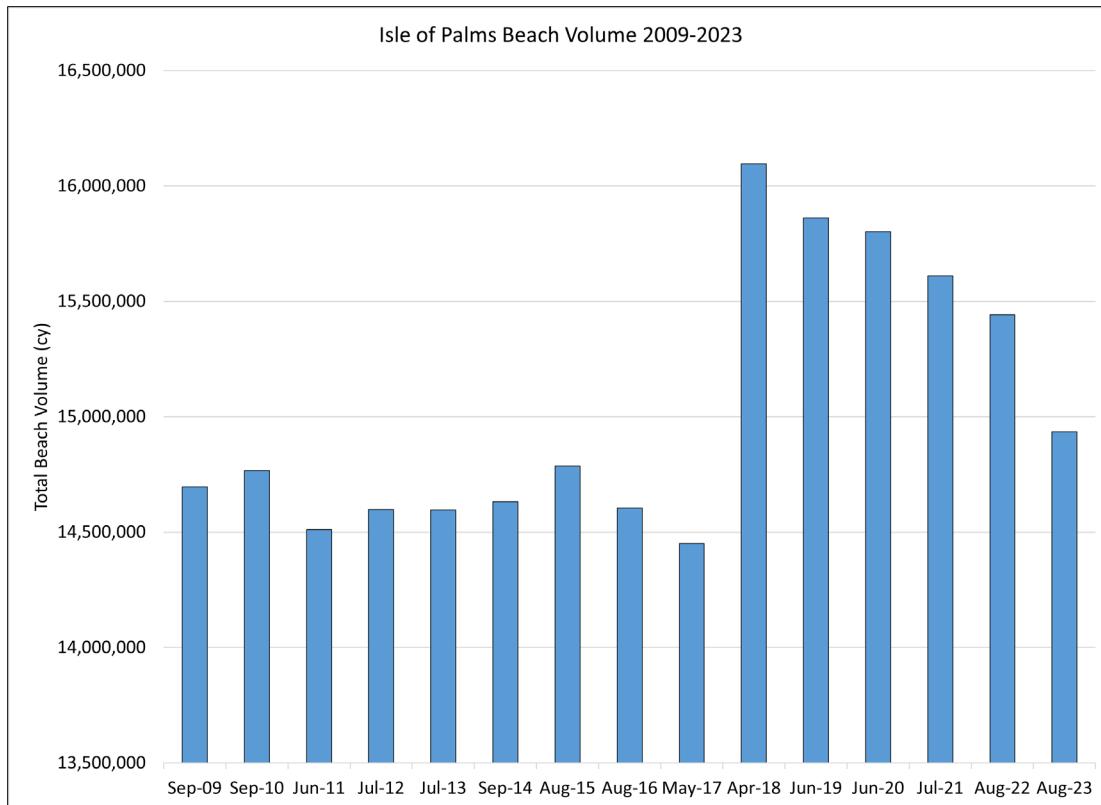


FIGURE 4.3. Total beach volume at Isle of Palms from 2009 to 2023. Effects of the 2018 project are seen in the rapid increase in the April 2018 island-wide beach volume.

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 ~20 cy/ft per year and 27 cy/ft per year respectively in reaches 5 and 6 to gains of 2 cy/ft per year in reach 4.

Total Volume (cy)													
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							1,940,568	1,993,036	1,942,143	1,881,344	1,816,322	1,787,947
Reach 2	4,280							1,459,694	1,482,097	1,415,263	1,531,344	1,552,061	1,528,779
Reach 3	5,620							1,810,569	1,876,140	1,828,257	1,896,808	1,967,693	1,970,583
Reach 4	7,910							2,631,739	2,631,737	2,611,113	2,801,254	2,344,325	2,007,460
Reach 5	6,000							2,766,193	2,766,193	2,766,313	2,406,324	2,362,229	2,233,119
Reach 6	4,900							2,323,458	2,239,921	2,315,187	2,119,653	2,053,612	2,206,134
Reach 7	4,000							1,794,665	1,794,665	1,747,99	1,908,371	1,911,566	1,818,396
Reaches 5-6	10,900							4,985,887	5,108,772	4,844,691	4,632,311	4,459,253	4,498,536
Reaches 1-7	37,100							14,986,761	14,767,463	14,511,169	14,598,121	14,592,222	14,613,967
Total Island Volume								14,767,463	14,511,169	14,598,121	14,613,967	14,604,770	14,611,096
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							442,0	454,1	424,4	428,5	413,7	426,6
Reach 2	4,280							341,0	346,5	330,7	357,8	362,6	357,2
Reach 3	5,620							322,2	333,9	325,3	337,5	350,1	350,6
Reach 4	7,910							323,2	337,2	345,5	369,3	371,0	371,5
Reach 5	6,000							476,9	425,0	457,6	418,8	393,7	382,2
Reach 6	4,900							472,5	472,5	457,1	419,1	418,0	450,2
Reach 7	4,000							436,9	421,5	444,9	449,2	457,4	470,0
Reaches 1-7	37,100							396,1	398,0	391,1	393,5	394,5	393,7
Profile Volume Change Since Last Survey (cy)													
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							53,048	-51,492	65,140	-64,898	-20,713	-23,292
Reach 2	4,280							23,303	-67,734	116,035	112,888	22,889	-34,539
Reach 3	5,620							65,871	-48,183	68,550	70,886	8,738	-3,446
Reach 4	7,910							35,002	19,374	152,624	117,518	13,081	67,739
Reach 5	6,000							-79,389,26	31,175,542	-75,379,44	-106,333	-43,986	-66,03
Reach 6	4,900							9,432,24	62,211,95	8,271,342	-40,548	-56,058	-63,310
Reach 7	4,000							48,342,72	13,344,27	31,601,55	17,556	32,336	22,972
Reaches 1-7	37,100							70,703	-256,294	388,951	-398	34,744	-182,770
Unit Volume Change Since Last Survey (cy/m)													
Length (ft)		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11		Jul-12	
Reach 1	4,390							12,1	-11,7	-13,9	-14,8	-14,8	-13,9
Reach 2	4,280							5,4	-15,8	4,8	-5,4	-8,1	5,3
Reach 3	5,620							11,7	-8,6	12,2	0,5	6,6	1,2
Reach 4	7,910							4,4	2,4	19,3	14,9	8,6	3,7
Reach 5	6,000							-13,2	-12,6	-14,0	-24,8	-17,7	-11,1
Reach 6	4,900							1,9	127,0	1,7	-12,9	8,2	1,3
Reach 7	4,000							12,1	3,3	1,9	-6,9	2,3	0,0
Reaches 1-7	37,100							14,767,463	14,511,169	14,598,121	14,613,967	14,604,770	14,611,096
Total Volume (cy)													
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							1,940,568	1,993,036	1,942,143	1,881,344	1,816,322	1,787,947
Reach 2	4,280							1,459,694	1,482,097	1,415,263	1,531,344	1,552,061	1,528,779
Reach 3	5,620							1,810,569	1,876,140	1,828,257	1,896,808	1,967,693	1,970,583
Reach 4	7,910							2,631,739	2,631,737	2,611,113	2,801,254	2,344,325	2,007,460
Reach 5	6,000							2,766,193	2,766,193	2,766,313	2,406,324	2,362,229	2,233,119
Reach 6	4,900							2,323,458	2,239,921	2,315,187	2,119,653	2,053,612	2,206,134
Reach 7	4,000							1,794,665	1,794,665	1,747,99	1,908,371	1,911,566	1,818,396
Reaches 1-6	10,900							4,985,887	5,108,772	4,844,691	4,632,311	4,459,253	4,498,536
Reaches 1-7	37,100							14,986,761	14,767,463	14,511,169	14,598,121	14,613,967	14,611,096
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							442,0	454,1	424,4	428,5	413,7	426,6
Reach 2	4,280							341,0	346,5	330,7	357,8	362,6	357,2
Reach 3	5,620							322,2	333,9	325,3	337,5	350,1	350,6
Reach 4	7,910							323,2	337,2	345,5	369,3	371,0	371,5
Reach 5	6,000							476,9	425,0	457,6	418,8	393,7	382,2
Reach 6	4,900							472,5	472,5	457,1	419,1	418,0	450,2
Reach 7	4,000							436,9	421,5	444,9	449,2	457,4	470,0
Reaches 1-7	37,100							396,1	398,0	391,1	393,5	394,5	393,7
Profile Volume Change Since Last Survey (cy)													
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							53,048	-51,492	65,140	-64,898	-20,713	-23,292
Reach 2	4,280							23,303	-67,734	116,035	112,888	22,889	-34,539
Reach 3	5,620							65,871	-48,183	68,550	70,886	8,738	-3,446
Reach 4	7,910							35,002	19,374	152,624	117,518	13,081	67,739
Reach 5	6,000							-79,389,26	31,175,542	-75,379,44	-106,333	-43,986	-66,03
Reach 6	4,900							9,432,24	62,211,95	8,271,342	-40,548	-56,058	-63,310
Reach 7	4,000							48,342,72	13,344,27	31,601,55	17,556	32,336	22,972
Reaches 1-7	37,100							70,703	-256,294	388,951	-398	34,744	-182,770
Unit Volume Change Since Last Survey (cy/m)													
Length (ft)		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11		Jul-12	
Reach 1	4,390							12,1	-11,7	-13,9	-14,8	-14,8	-13,9
Reach 2	4,280							5,4	-15,8	4,8	-5,4	-8,1	5,3
Reach 3	5,620							11,7	-8,6	12,2	0,5	6,6	1,2
Reach 4	7,910							4,4	2,4	19,3	12,6	7,6	3,7
Reach 5	6,000							-13,2	-12,6	-14,0	-24,8	-17,7	-11,1
Reach 6	4,900							1,9	127,0	1,7	-12,9	8,2	1,3
Reach 7	4,000							12,1	3,3	1,9	-6,9	2,3	0,0
Reaches 1-7	37,100							14,767,463	14,511,169	14,598,121	14,613,967	14,604,770	14,611,096
Total Volume (cy)													
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							1,940,568	1,993,036	1,942,143	1,881,344	1,816,322	1,787,947
Reach 2	4,280							1,459,694	1,482,097	1,415,263	1,531,344	1,552,061	1,528,779
Reach 3	5,620							1,810,569	1,876,140	1,828,257	1,896,808	1,967,693	1,970,583
Reach 4	7,910							2,631,739	2,631,737	2,611,113	2,801,254	2,344,325	2,007,460
Reach 5	6,000							2,766,193	2,766,193	2,766,313	2,406,324	2,362,229	2,233,119
Reach 6	4,900							2,323,458	2,239,921	2,315,187	2,119,653	2,053,612	2,206,134
Reach 7	4,000							1,794,665	1,794,665	1,747,99	1,908,371	1,911,566	1,818,396
Reaches 1-6	10,900							4,985,887	5,108,772	4,844,691	4,632,311	4,459,253	4,498,536
Reaches 1-7	37,100							14,986,761	14,767,463	14,511,169	14,598,121	14,613,967	14,604,770
Length (ft)		Jul-07		Mar-08		Jul-08		Sep-09		Sep-10		Jul-11	
Reach 1	4,390							442,0	454,1	424,4	428,5	413,7	426,6
Reach 2	4,280							341,0	346,5	330,7	357,8	362,6	357,2
Reach 3	5,620							322,2	333,9	325,3	337,5	350,1	350,6
Reach 4</td													

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.

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 the reach has generally gained sand since 2018.



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, and 2023, Reach 7 has remained stable or accretional since 2009 (Fig 4.5). From August 2022 to August 2023 the reach lost ~6,100 cy (1.5 cy/ft) of sand. Within the reach, the recent erosion pattern documented in prior years has continued, with the seaward end of the reach gaining sand rapidly, while the landward area inland of the groin erodes. Stations 368 and 370 were significantly more erosional than prior years as the channel of Cedar Creek has eroded the tip of the spit.

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 2023. Accretion at the seaward end of the reach has led to an increase of over 260 ft of berm width since 2008, including over 150 ft of growth since 2018. All stations seaward of the 17th tee (groin) show at least 10 cy/ft more sand than the most eroded condition since 2008, and Stations 330 through 340 all have over

100 cy/ft more sand now than in 2008. Ground photos from the reach show an established dune field along the east end; however, minor scarping was present along the reach at the time of the survey. 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 ~127,200 cy of sand since 2007, which is an average annual increase of 2.5 cy/ft per year.

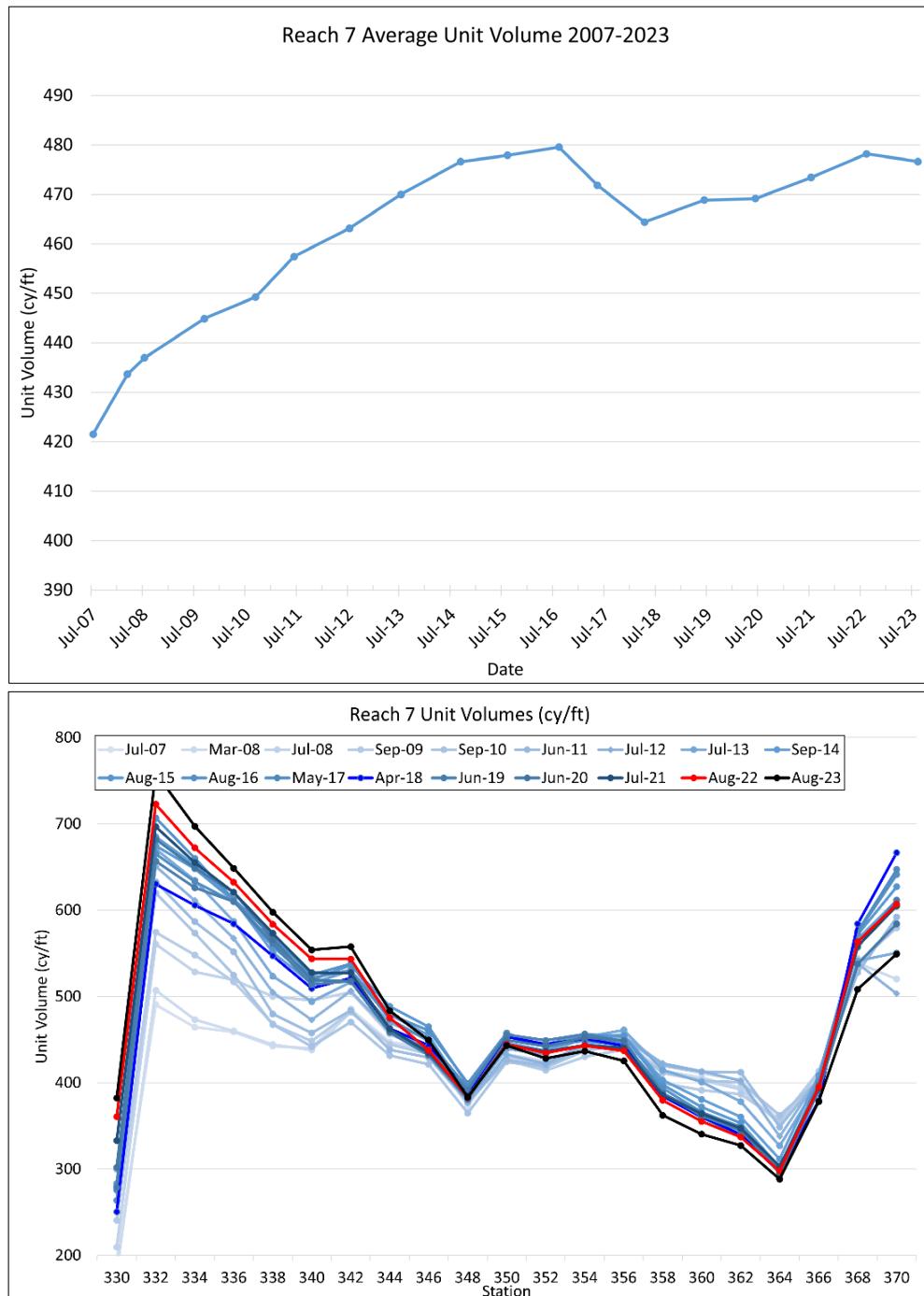


FIGURE 4.5.

[UPPER] Average beach volume in Reach 7 since 2007.

[LOWER] Profile unit volumes for each monitoring line in Reach 7.

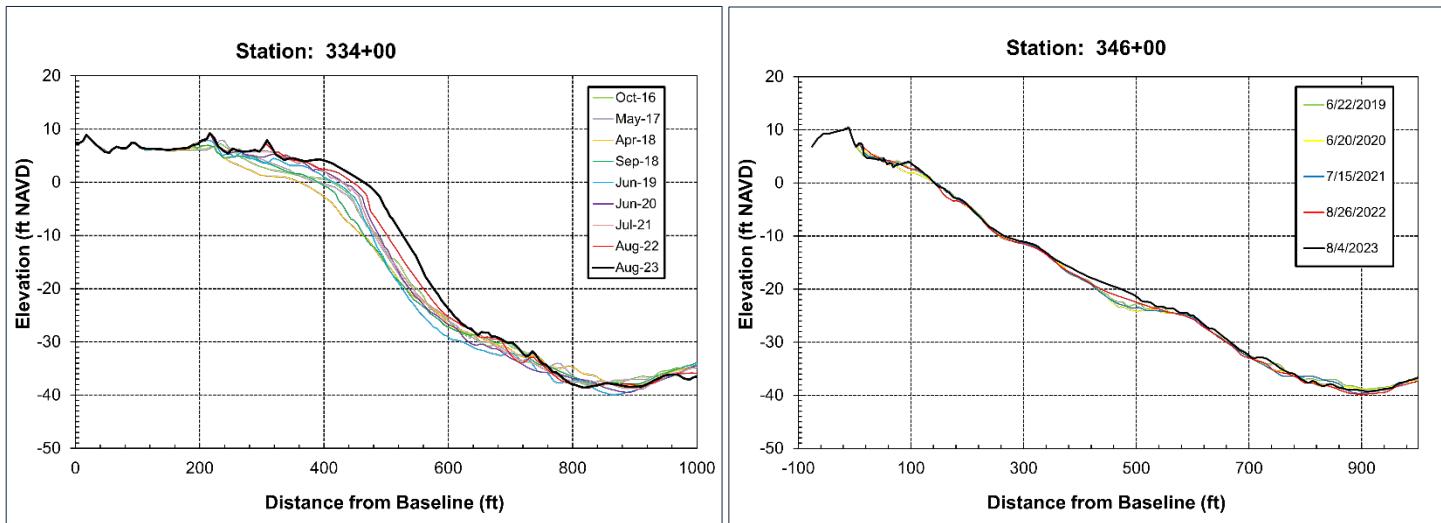


FIGURE 4.6.

[UPPER] Beach profiles from Reach 7.

[MIDDLE] Aerial photo of Reach 7 collected August 2023.

[LOWER] Ground photos from Station 332 **[LEFT]** looking seaward and Station 346 looking inland **[RIGHT]** in Aug 2023.

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.

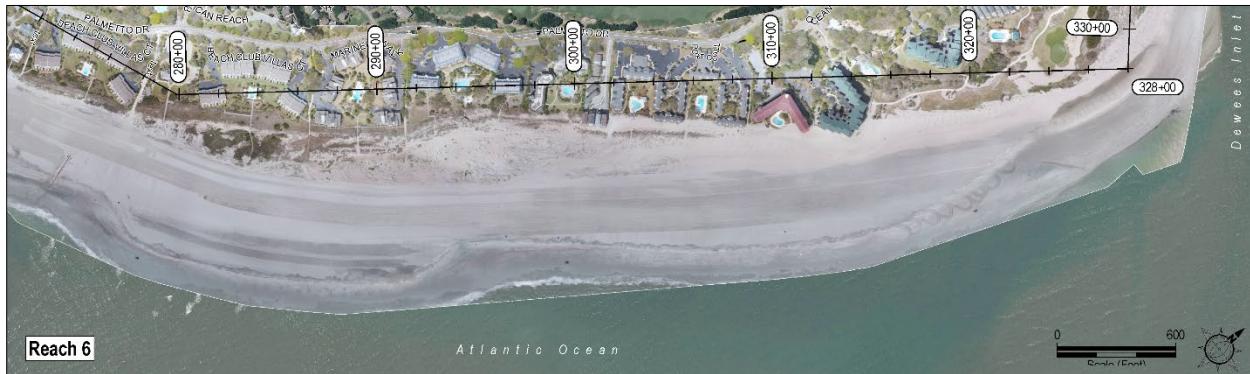


FIGURE 4.7. Baseline stationing along Reach 6 encompassing ~4,900 lf of beach between Wild Dunes Property Owners Beach House and the 18th Hole of the Links Course.

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 east 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, which called for less sand at the east of the reach and additional sand at the west end. The reach gained ~670,000 cy of sand via nourishment in 2018.

Reach 6 has exhibited similar gross erosion rates in each survey period following project completion in 2018; however, the pattern of erosion occurring within the reach has varied. The western end was initially highly erosional, but has accreted since 2021. The opposite trend has been observed along the eastern end of the reach, which initially gained sand after nourishment, but is now rapidly eroding. The erosion pattern is characteristic of the mid-phases of a shoal attachment process, where sand builds in the lee of the shoal and erosion increases along adjacent areas. Beach width decreased by ~100 ft at the Ocean Club building (Station 314+00) over the past year. This compares to gains of ~80 ft near Marines Walk.

Volume change within the reach ranged from -64 cy/ft to +30 cy/ft. Overall, the reach lost 133,800 cy (27.3 cy/ft) of sand from August 2022 to August 2023. This is the highest loss recorded since 2018, as each previous year lost between 94,500 and 123,000 cy. In total, the reach has lost 576,800 cy since 2018. This represents ~74% of the nourishment volume added in 2018; however, the condition highly varies within the reach compared to pre-project conditions. Stations 280–292 show an average loss of 33.2 cy/ft compared to the pre-project condition, whereas stations 294–328 show an average of 36 cy/ft more sand than pre-nourishment. The beach east of Shipwatch still holds more than 25% of the nourishment volume placed in the area. Stations near Beach Club Villas presently hold less sand than the pre-nourishment condition (Figure 4.8), but are in better overall condition due to a more favorable pre-project condition.

Figures 4.9 and 4.10 show aerial and ground photos of the reach in August 2023. The images show the relative stability of the western end of the reach, and narrowing beach widths towards the east. The beach is beginning to respond to an approaching shoal and CSE expects the volume trends identified here to magnify over the next 1–2 years.

Overall, the reach holds ~659,000 cy more sand than the 2007 condition. Nourishment projects in 2008 and 2018 have resulted in an average annual volume increase of 12.5 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.

Details of changes occurring within the Dewees Inlet delta will be discussed in more detail in Section 6.0.

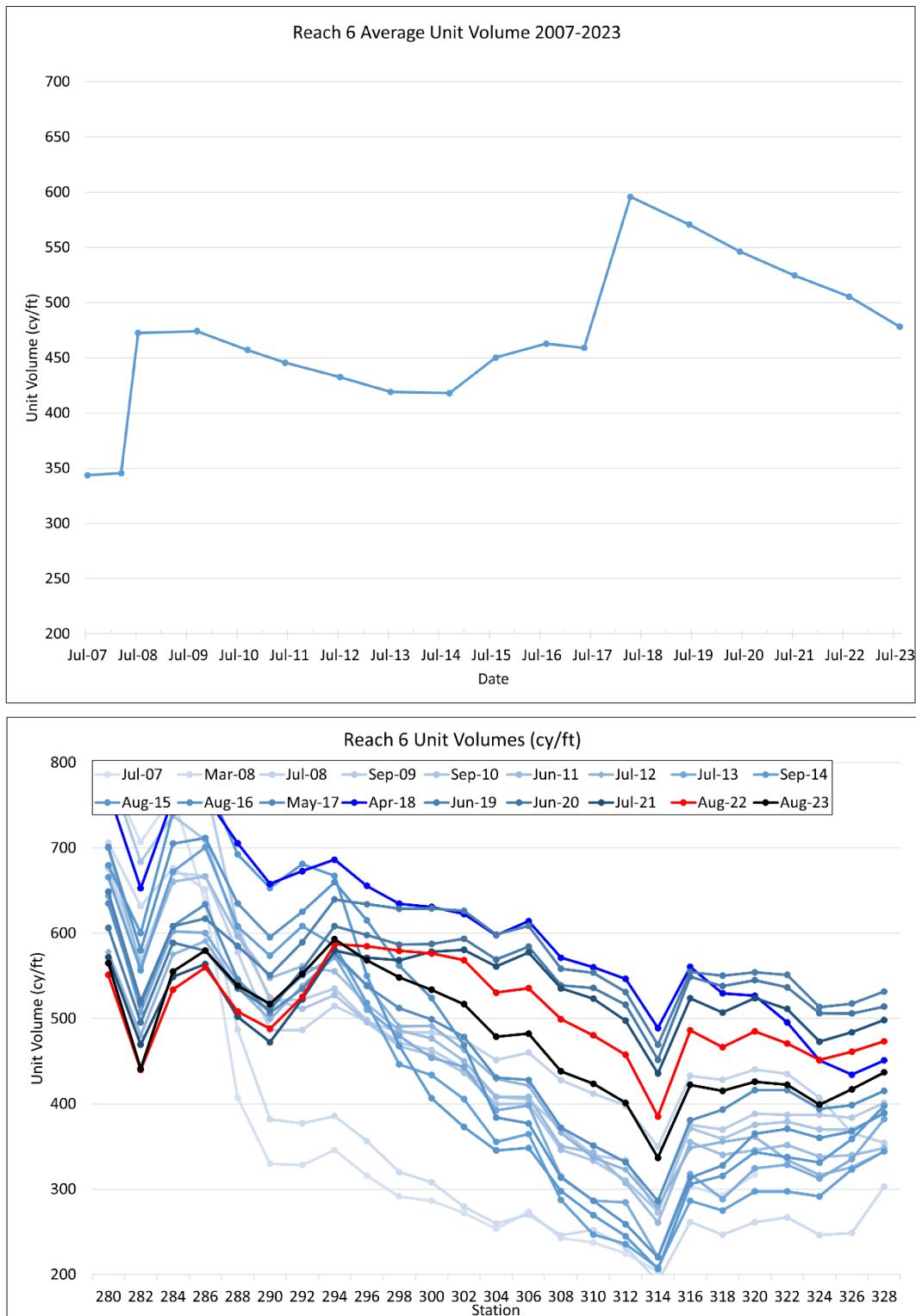


FIGURE 4.8. [UPPER] Average beach volume in Reach 6 since 2007. [LOWER] Profile unit volumes for each monitoring line in Reach 6.

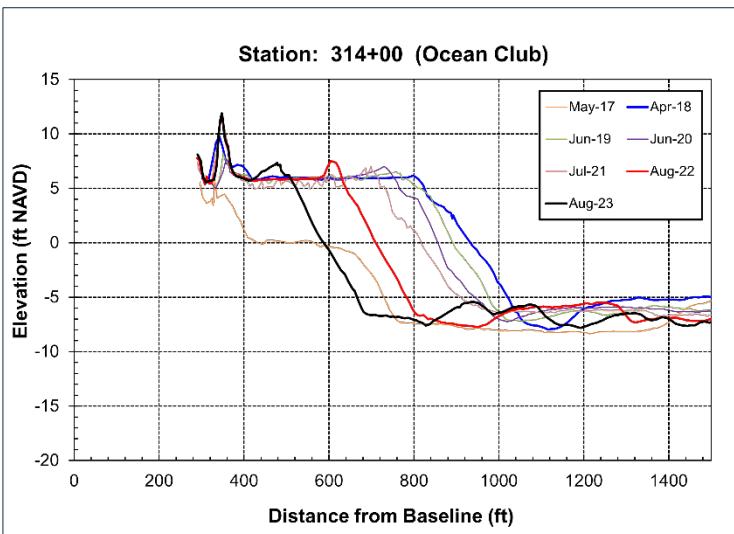
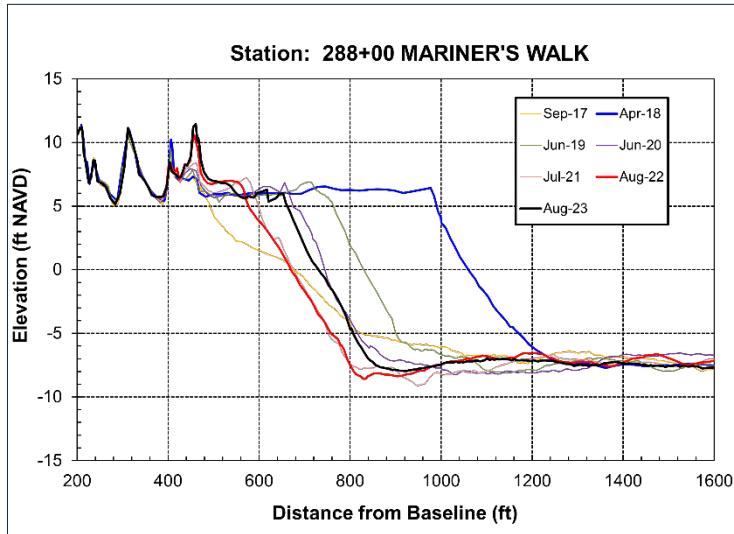


FIGURE 4.9. [LEFT] Reach 6 profiles. The rapid erosion in this area is suspected to be a continuation of the higher erosion trend observed prior to the 2018 project. **[RIGHT]** Aerial photos collected in August 2023.



FIGURE 4.10. Ground photos from Station 284 [UPPER] and Station 316 [LOWER] in August 2023.

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 portions 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.

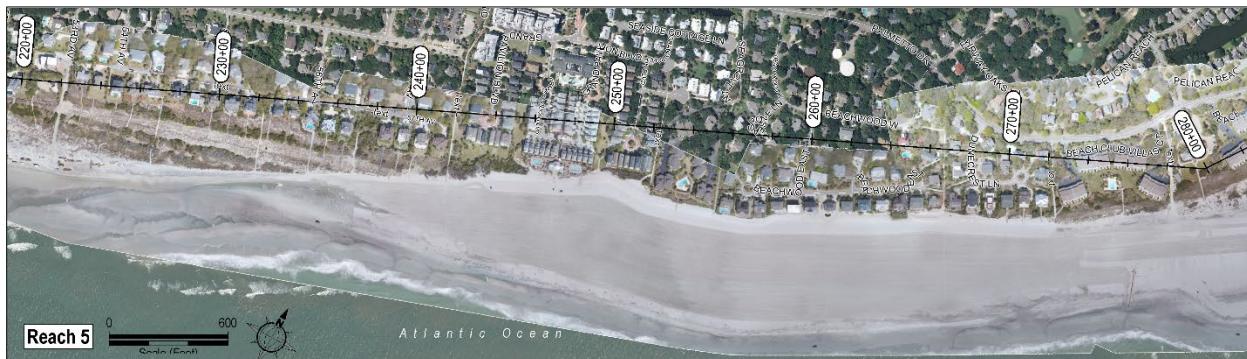


FIGURE 4.11. Baseline stationing along Reach 5 which spans ~5,800 lf of beach between 53rd Avenue and Wild Dunes Property Owners Beach House.

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.

Reach 5 lost ~20 to 40 cy/ft between each survey from 2018 to 2022 (119,600–176,000 cy). Net erosion was less severe over the past year but was still highly erosional, losing 114,800 cy (19.1 cy/ft). Erosion trends within the reach were due to separate shoal events. A small shoal attachment is occurring near the Grand Pavilion (Stations 244–252), which has led to a stable dry-sand beach and gains in the underwater portion of the profile. The eastern end of the reach is beginning to show accretional trends from an attaching shoal (continued from Reach 6). Erosion accelerated near Beachwood East, between the two shoals. Finally, erosion dominated the western end of the reach as sand previously accreted from the 2018 nourishment shifted further south.

Figure 4.12 (lower) shows the profile volume record for Reach 5 since 2007. The orange and red lines represent the pre- and post-project condition (respectively), while the difference between the blue and black lines represents changes from 2022 to 2023. At the very eastern end of the reach, the beach volumes continue to be near the lowest measured volume since 2007, but CSE expects the area near Beach Club Villas to grow over the next year due to continued shoal attachment.

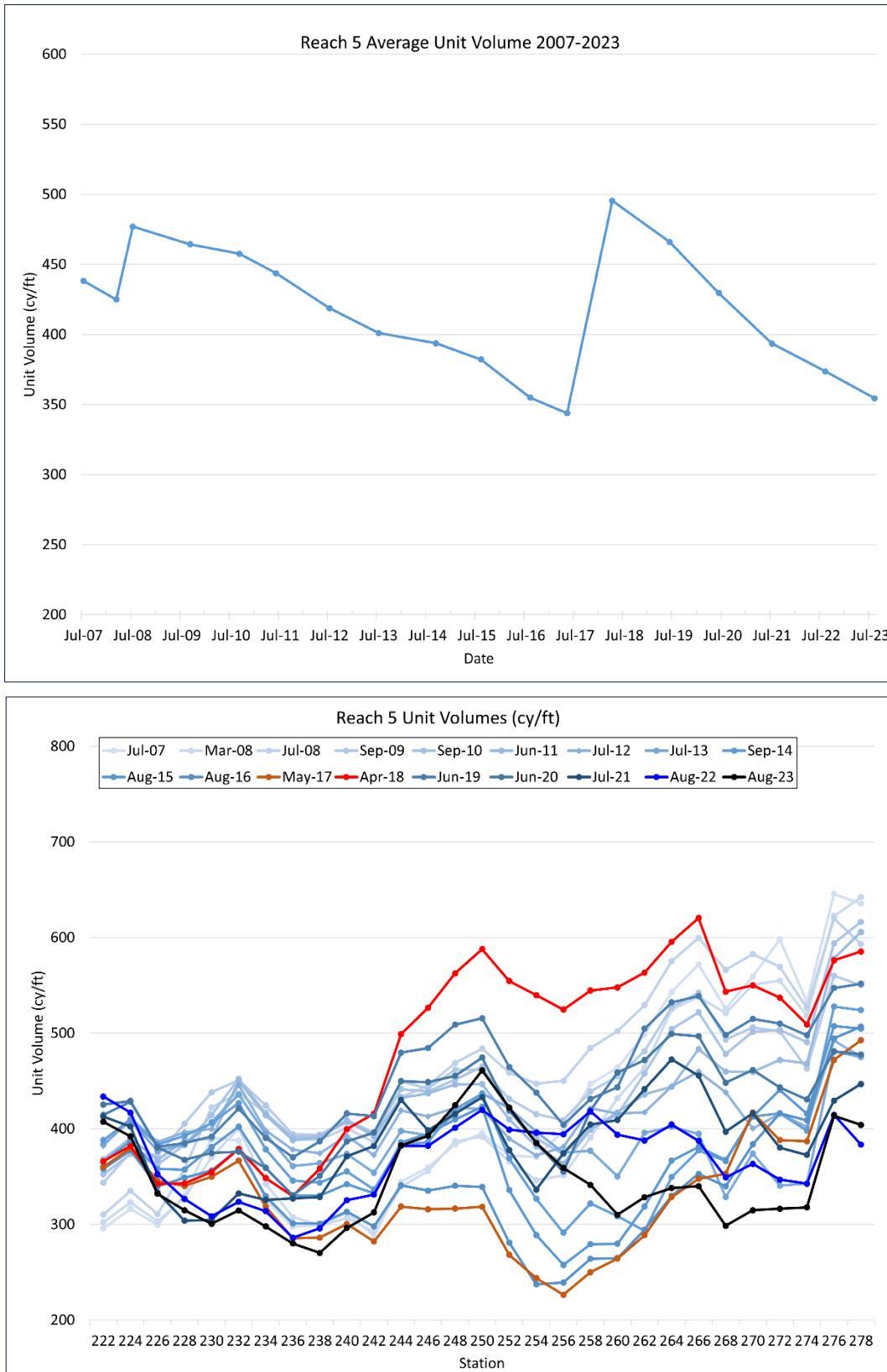


FIGURE 4.12. [UPPER] Average beach volume in Reach 5 since 2007. [LOWER] Profile unit volumes for each monitoring line in Reach 5.

Within the reach, beach volume change ranged from -83.7 to +41.3 cy/ft, with an average of -21.1 cy/ft. Accretion was measured between stations 244–252 and in Station 278. The accretion along these areas occurred mostly along the underwater zone (Figs 4.13 and 4.14). The accretion near Grand Pavilion has created a bulge in the shoreline and maintained a healthy beach width. CSE anticipates additional erosion of the Beachwood/Dunecrest area as the main shoal continues to migrate landward over the next year.

4.2.4 *Summary of East End Changes*

Overall, the 2018 project area reaches (5 and 6) have lost ~1,423,000 cy (130.5 cy/ft) of sand from April 2018 to August 2023. This value equates to an annual loss of 24 cy/ft per year and represents ~85% of the nourishment pay quantity. This is a much higher value than historical erosion rates along the eastern end of the island, which are variable but are generally thought to be between 5–10 cy/ft per year (CSE 2007). The higher erosion rates likely result from a combination of shoal configuration and storm events but could also be impacted by rising sea levels (discussed in Section 7). Hurricanes have heavily impacted South Carolina since 2015, and CSE has observed higher-than-typical erosion rates along several communities over that time.

While the magnitude of the erosion is high, the beach condition along the majority of the Wild Dunes area remains in much better condition than in 2017. Most of the shoreline along Reaches 5 and 6 retains at least 100 ft more beach width than the 2017 condition (Fig 4.15). Erosion trends have shifted from adjustment of the nourishment fill whereby sand spreads from placement areas to downcoast areas, to a pattern associated with shoal bypass events. This transition means that overall beach changes will be determined by proximity to the shoal attachments, and volume change will be rapid in affected areas, despite exiting total volumes. The shoal impacts will magnify over the next year as it gets closer to the beach. Once attached (Stage 3), sand will spread in both directions from the attachment site. Recent erosion rates have accelerated, and certainly outpace the volume additions from shoals over the past 20 years. This is counter to the historical trend that built the eastern end of the island, and will require regular additions of sand via nourishment to maintain the shoreline position.

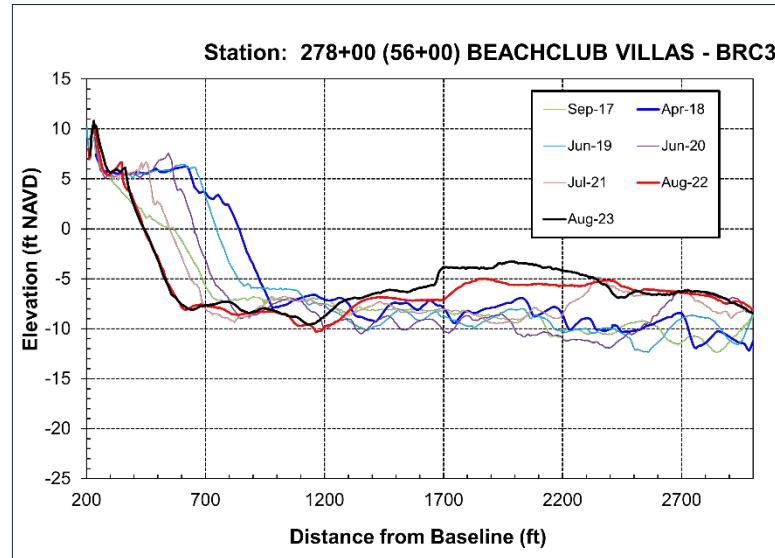
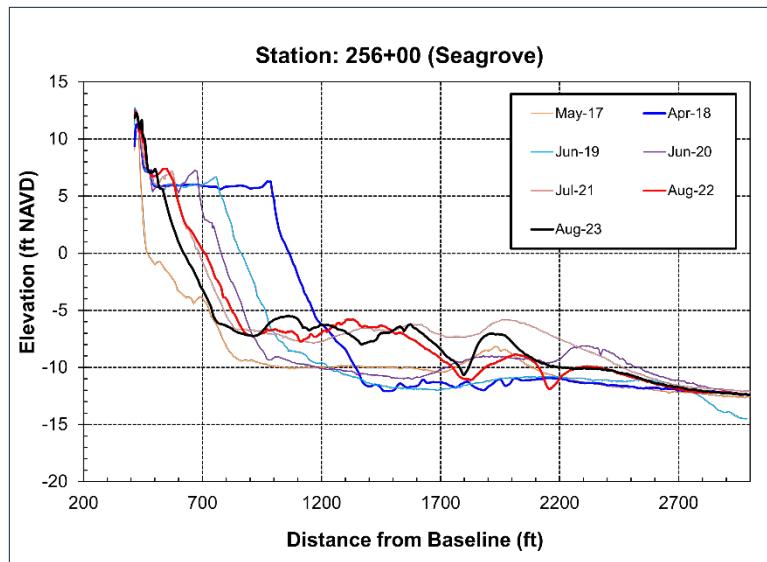
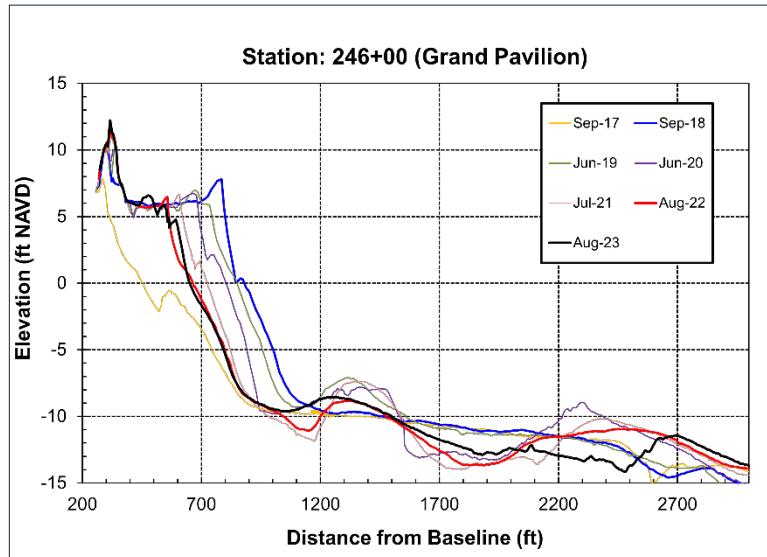


FIGURE 4.13. Reach 5 profiles.

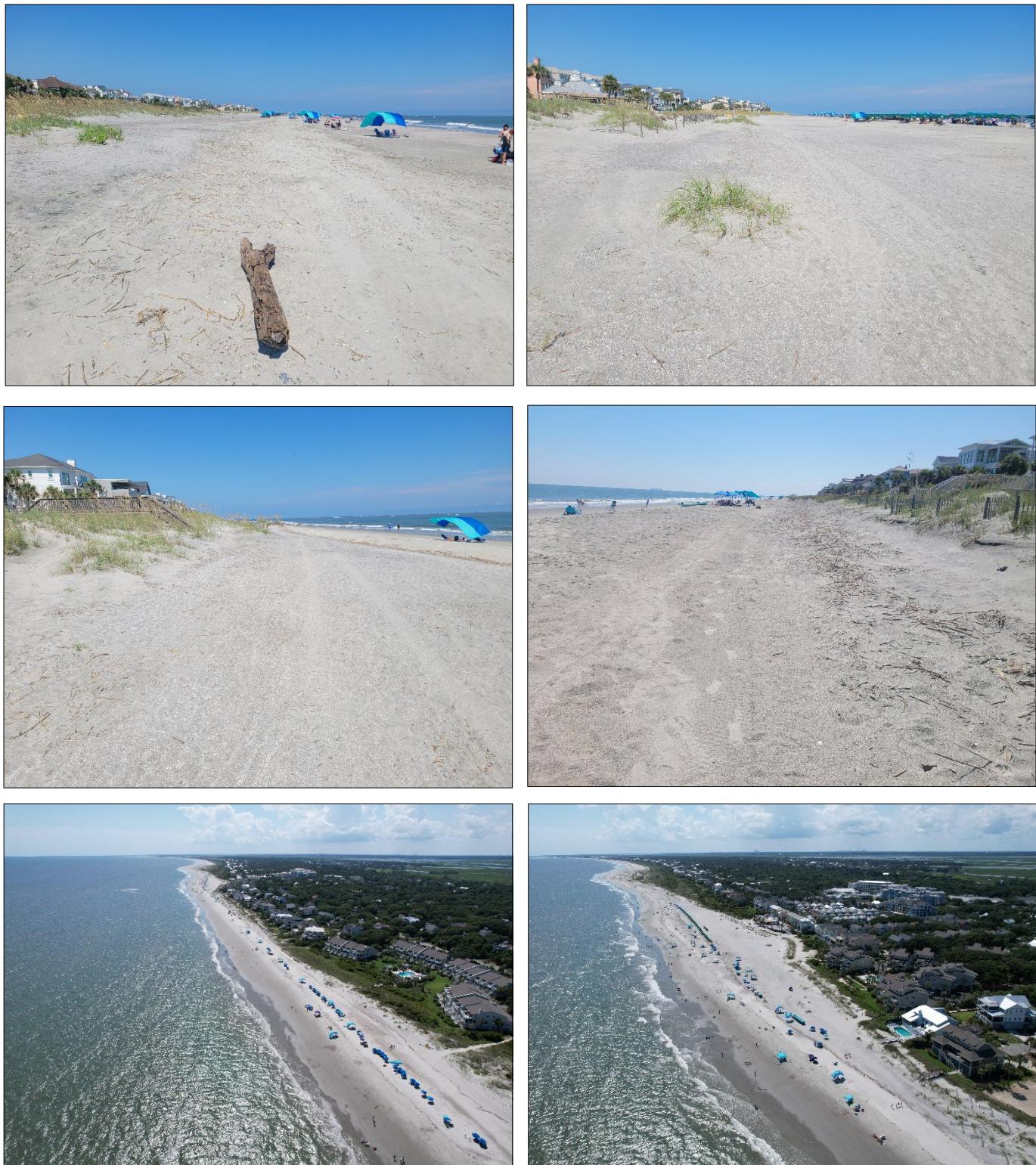


FIGURE 4.14. Ground photos of Reach 6 in August 2023 showing Station 236 [UPPER LEFT], Station 244 [UPPER RIGHT], Station 256 [MIDDLE LEFT], and Station 272 [MIDDLE RIGHT]. Aerial photos from August 2023 are shown in the bottom two photos.

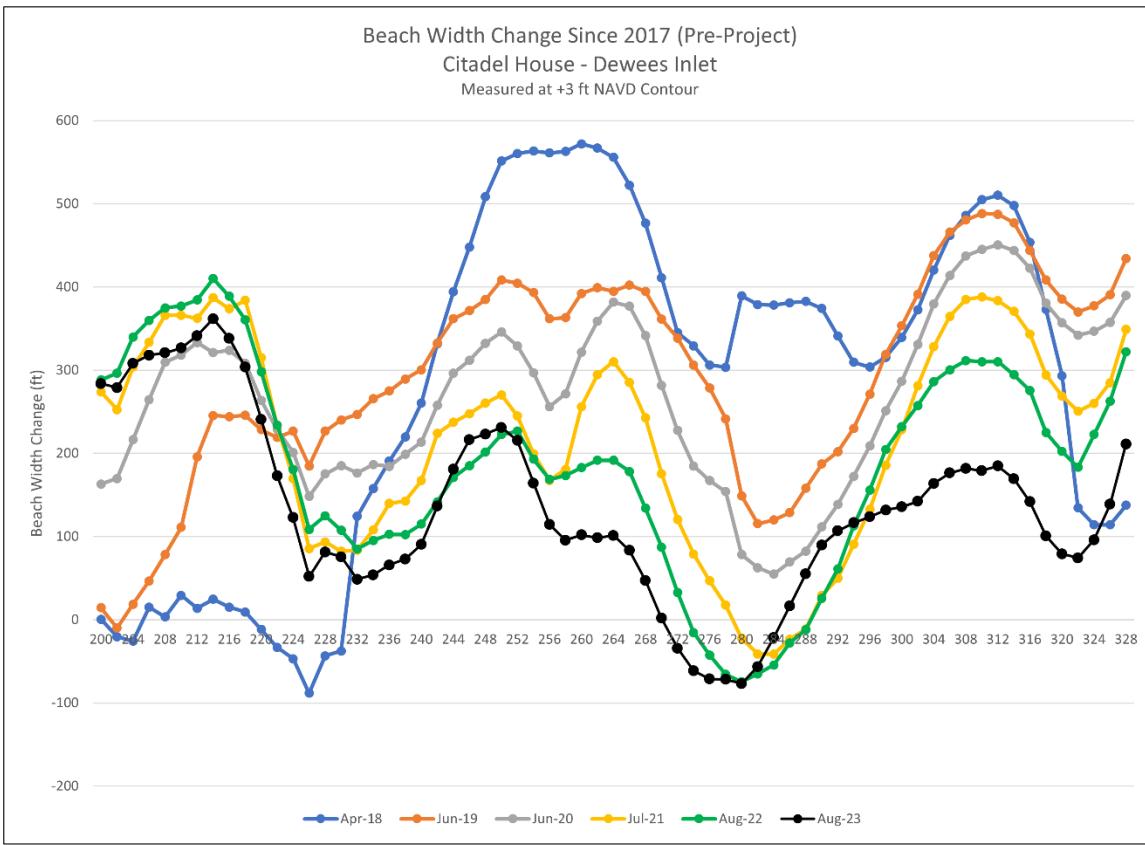


FIGURE 4.15a. Beach width changes along the area spanning the Citadel House to the 18th Hole of the Links Course. Note that the majority of the beach holds at least 100 ft more sand than in 2017; however, the area around Beach Club Villas (~Station 280) has lost sand relative to 2017. Also note the extensive accretion present south of the 2018 project area (left side of image from stations 200–230).

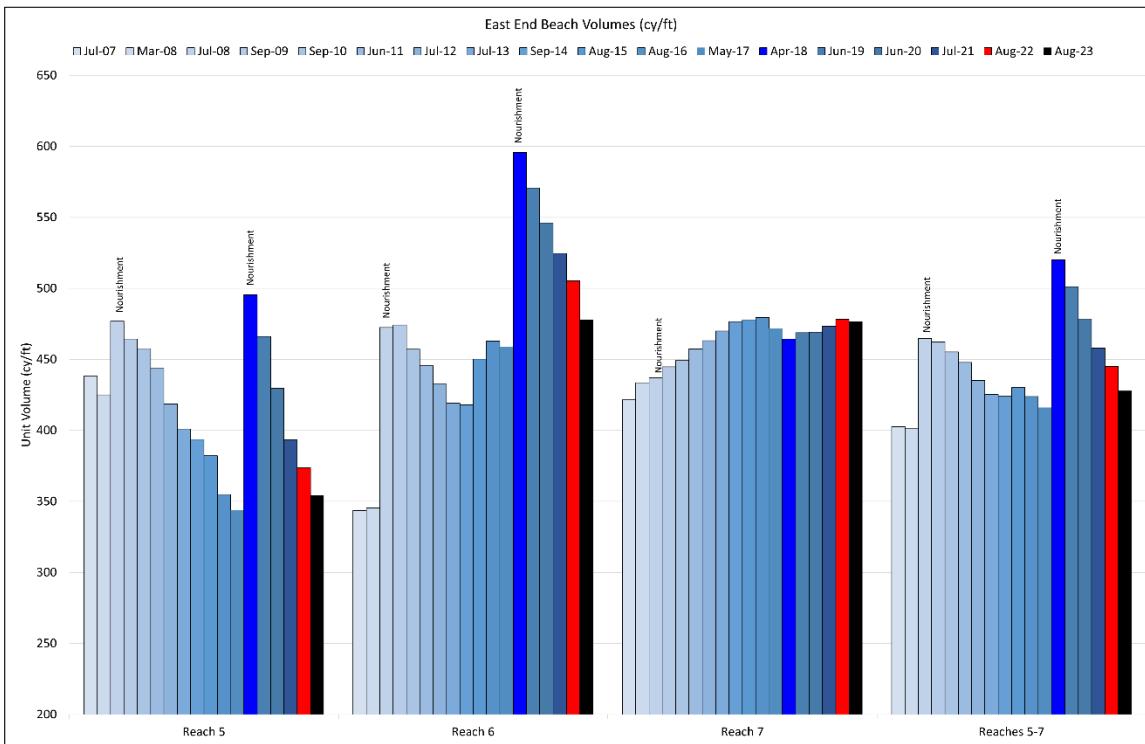


FIGURE 4.15b. The beach volume history of the eastern end of the island since 2007, with dates following nourishment indicated.

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, which will eventually form a shoal and recycle back to the beach. The volume increases observed along Reach 7 in recent years and 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). Of note is that the erosional trend following the 2018 project is over twice as high as the trend following the 2008 project. This trend will improve with attachment of the incoming shoal; however, the attachment will likely not provide enough sand to offset the rapid losses observed over the past 5 years. Future project planning will need to account for a higher long-term erosion rate to maintain a sufficient beach condition along the east end.

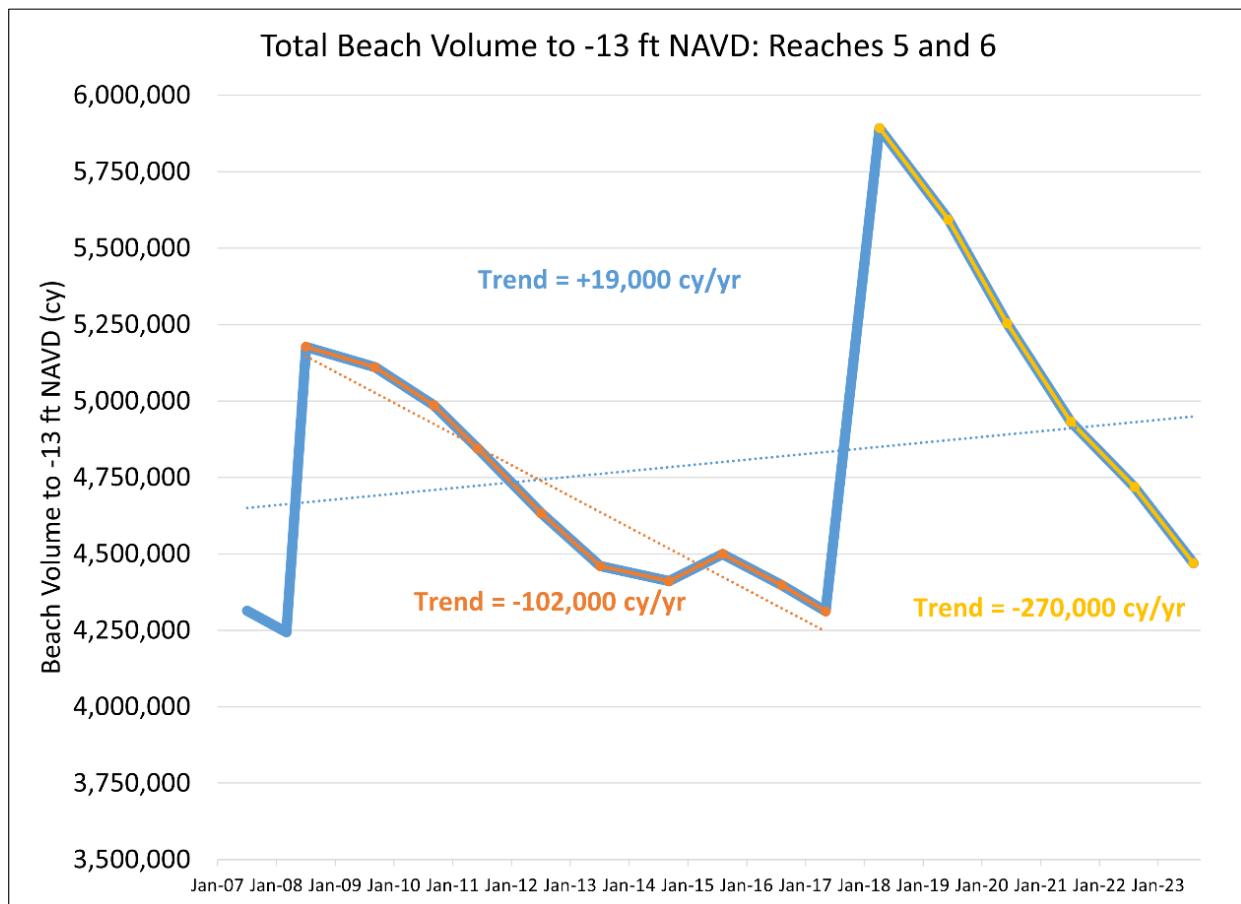


FIGURE 4.16. Total beach volume history of the eastern end of the island since 2007. The graph illustrates the overall erosional trend along reaches 5 and 6 between nourishment projects.

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 Dewees Inlet's direct influence 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 the 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 island's east end, particularly reaches 5 and 6, with that sand originating from shoal bypass events or nourishment. A significant influx of sand has been observed along the reach since the 2018 project, with an accretional wave propagating south. The leading edge of the spreading sand is visible as a span of high accretion relative to adjacent areas. Over time, the magnitude of the accretion wave decreases as sand spreads at uneven rates. Initially, the peak accretion reached up to 66–80 cy/ft, but by 2023, the highest accretion rates were 20 cy/ft. Accretion has led to the creation of a new dune ridge and wide dry-sand beach along the reach. (Figure 4.19).

Reach 4 gained ~22,300 cy (2.8 cy/ft) of sand from August 2022 to August 2023. This is lower than the previous two years. The eastern end of the reach has started to erode following several years of gains from downcoast spreading of nourishment sand. Stations just south of 53rd Ave lost up to 22 cy/ft. The central and southern portions of the reach generally gained sand, and the accretional wave from downcoast spreading has reached Station 150+00 (33rd Ave). Assuming that Station 150 is the leading edge of the accretional wave, then the wave is moving at a rate of ~1,600 ft/yr. The reach presently holds nearly 917,000 cy more sand than the 2009 condition, including a net gain of 480,000 cy since 2018. The beach between the Citadel House and 53rd Ave holds 275,000 cy more sand than in 2018.



FIGURE 4.18. August 2023 aerial photo of Reach 4 (53rd Avenue is at the right of the image). 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. The 2008 dune line is shown by the red arrow.

The beach volume in Reach 4 has increased at an average annual accretion rate of 9 cy/ft per year since 2009. Profiles show the dune width has increased by at least 50 ft along the reach, and the dry-sand beach by at least another 50 ft. Along the northern end of the reach, the beach is over 400 ft wider than the 2009 condition, with unit volume gains of over 160 cy/ft. This level of accretion is of similar magnitude to many large 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 ~3–5 ft in elevation and offers substantially more storm protection than the 2009 condition. CSE anticipates that accretion along Reach 4 will slow over the next few years due to lower inputs of sand from the upcoast area. **Combined with Reach 3, there is a net gain of 1,168,146 cy of sand along the downcoast areas of Isle of Palms (Sea Cabins Pier to 53rd Ave), which is a direct benefit of the 2008 and 2018 nourishment projects.**

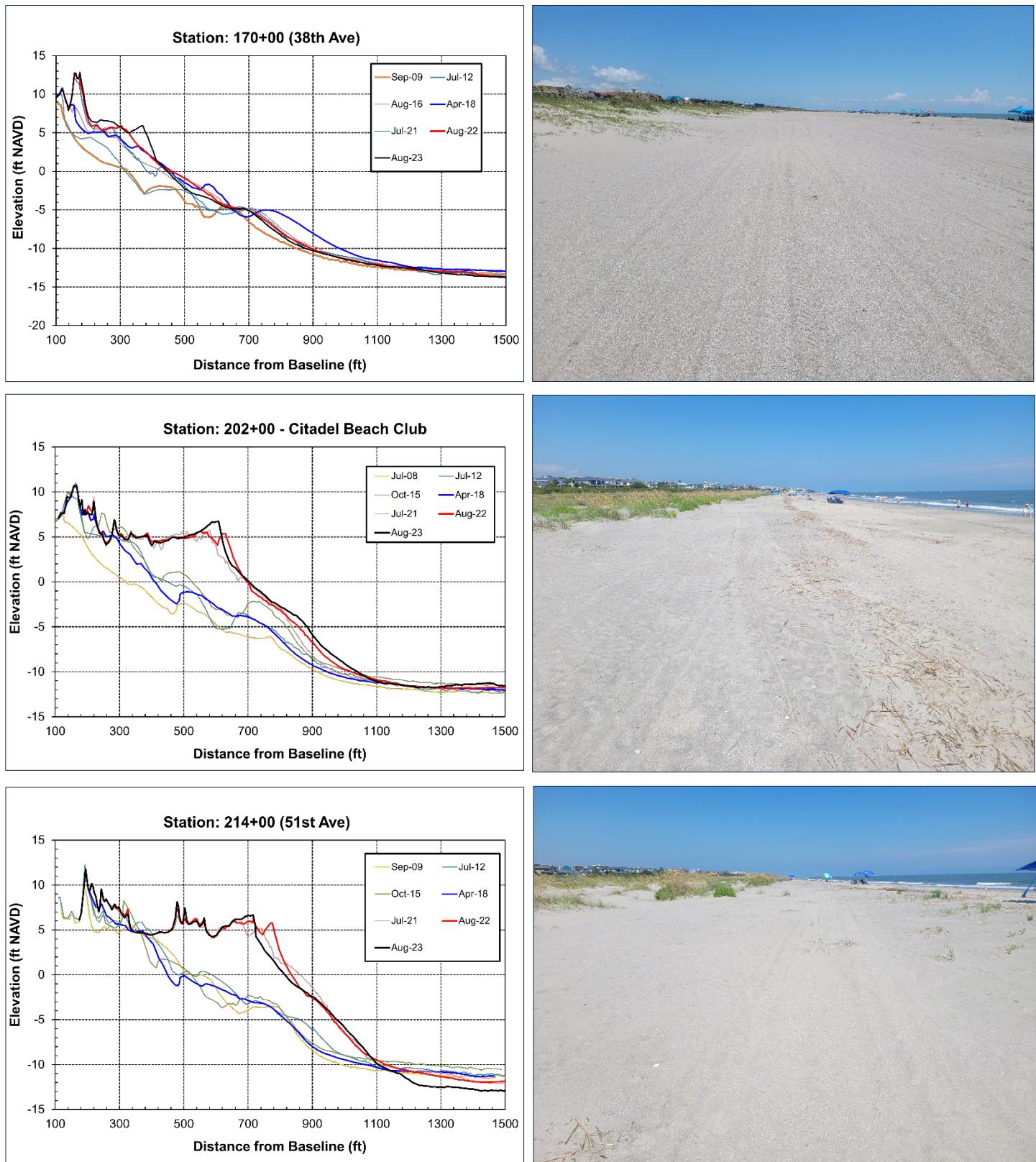


FIGURE 4.19. [LEFT] Profiles along Reach 4 show accretion has led to gains of over 300 ft of dry-sand width and formation of new dune ridges. [RIGHT] Ground photos from Station 170 [UPPER], Station 220 [MIDDLE], and Station 214 [LOWER] in August 2023.

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. Since 2009, the long term trend has been accretional.



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



FIGURE 4.21. Aerial photo of Reach 3 in August 2023 (29th Ave in the foreground). 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 has been fairly stable in recent years, with minor gains the general trend. Over the past year, the reach lost 26,800 cy (4.8cy/ft), which is the most erosion observed since 2011. The northern and southern end of the reach eroded, losing an average of 8.1 cy/ft between stations 120 and 140 and an average of 13.3 cy/ft between stations 3125 and 90+00; however, losses were restricted to the underwater portion of the profile, and there was evidence of dune growth observed in the profiles. Erosion along the southern portion of the reach is a continuance of higher erosion occurring in Reach 2 in 2023. Overall, the reach has gained nearly 42,000 cy since 2018, and 251,000 cy since 2009. This is an average annual accretion rate of 3.5 cy/ft per year since 2009. Profile plots from the reach (Figure 4.22) show that the dune continues to increase in width despite minor losses offshore.

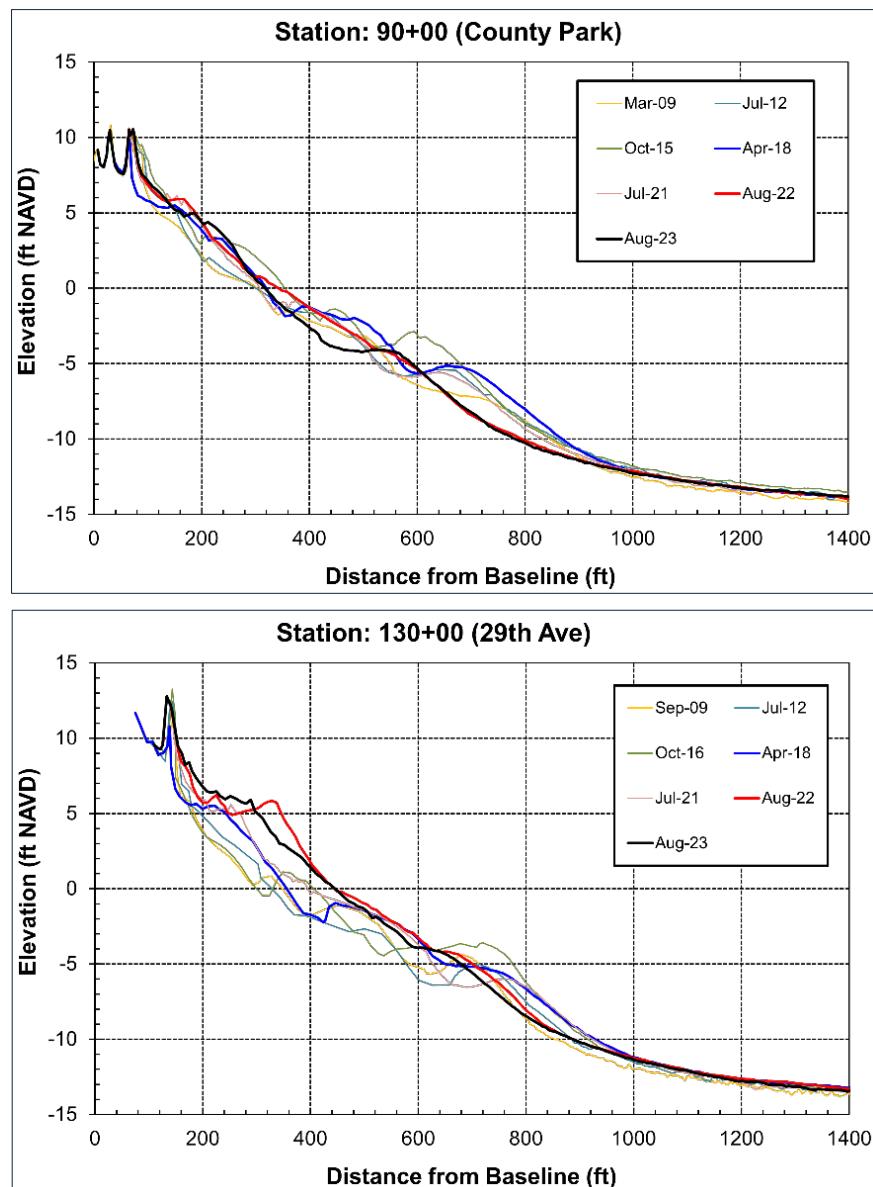


FIGURE 4.22. Example profiles from Reach 3. At Station 90+00, there was a net loss of volume due to movement of the underwater sandbar. The dry beach remained stable over the past year.

Figure 4.23 shows the accretional trend over the past decade. Photos of the reach in August 2023 show a recovering dune system with a significant dry-sand beach seaward of the growing dune (Fig 4.21).

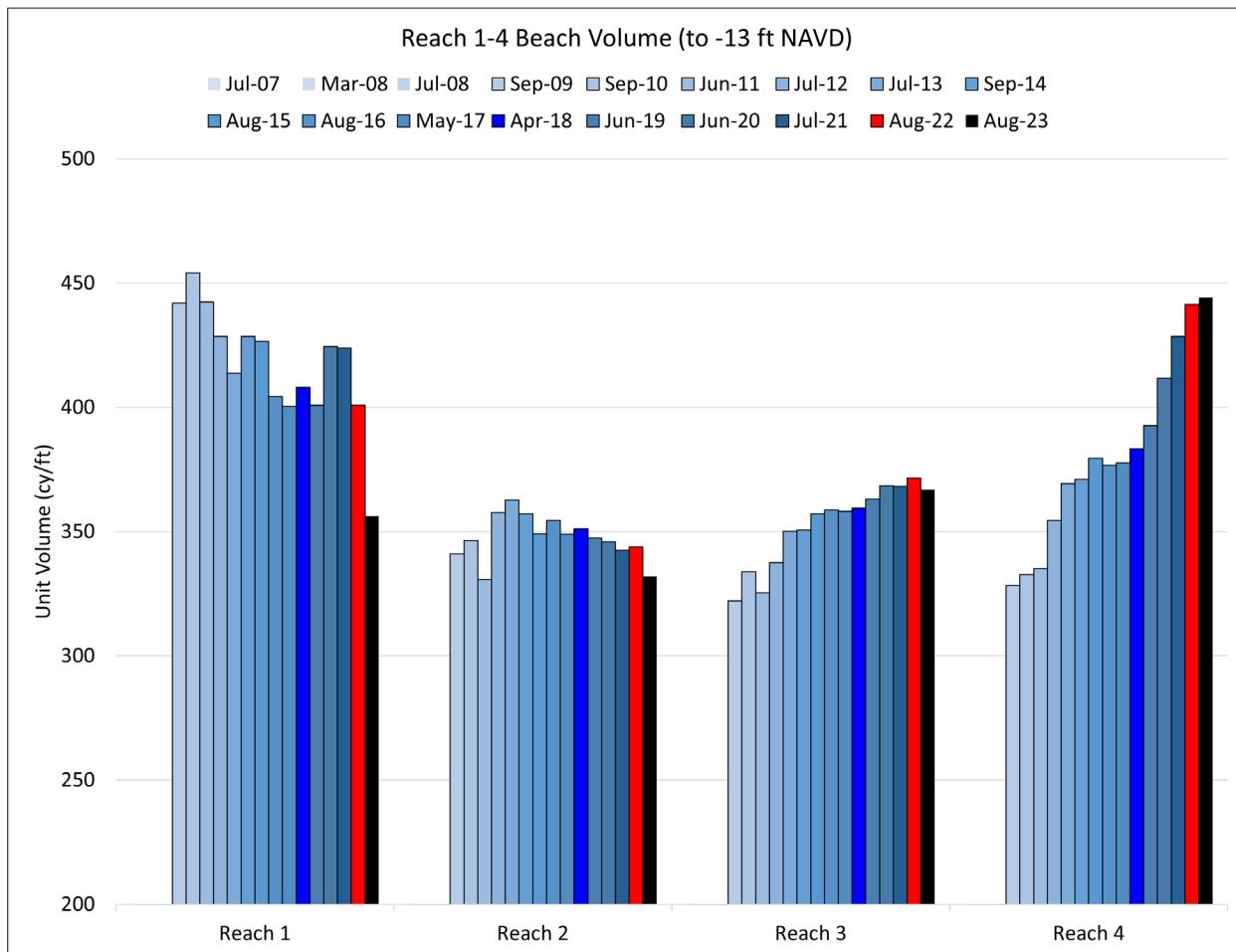


FIGURE 4.23. This graphic illustrates the stable and accretional trend of reaches 3 and 4 over the past ~15 years.

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 a lower magnitude of volume change than 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 eroded each year from 2019 to 2021 and accreted in 2022. Over the past year, the reach lost 11.9 cy/ft of sand (51,000 cy). Similar to Reach 3, this was the most erosion observed since 2011. This trend implies Reach 2 is generally more 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. However, recent changes in the Breach Inlet delta may be impacting the southern end of Reach 2. The trend also suggests the sand wave moving west from the project area remains upcoast from Reach 2, with no discernable excess volume contribution.

Erosion was prevalent within the entire reach, though rates of loss were highest along the south end (Station 50 – 6th Ave). Erosion along the south end is likely affected by losses in Reach 1, which are discussed in the next section. Compared to the 2009 condition, the northern half of the reach has accreted up to ~8.2 cy/ft while the southern half has eroded up to ~52 cy/ft. The recent erosion trend is atypical for the area, as the historical trend has been consistent accretion. Over the past ~10 years, the reach has lost a total of ~30 cy/ft and seen recession of the dune line. Should this trend continue, mitigation measures such as nourishment may be required to offset long-term losses of sand.

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).

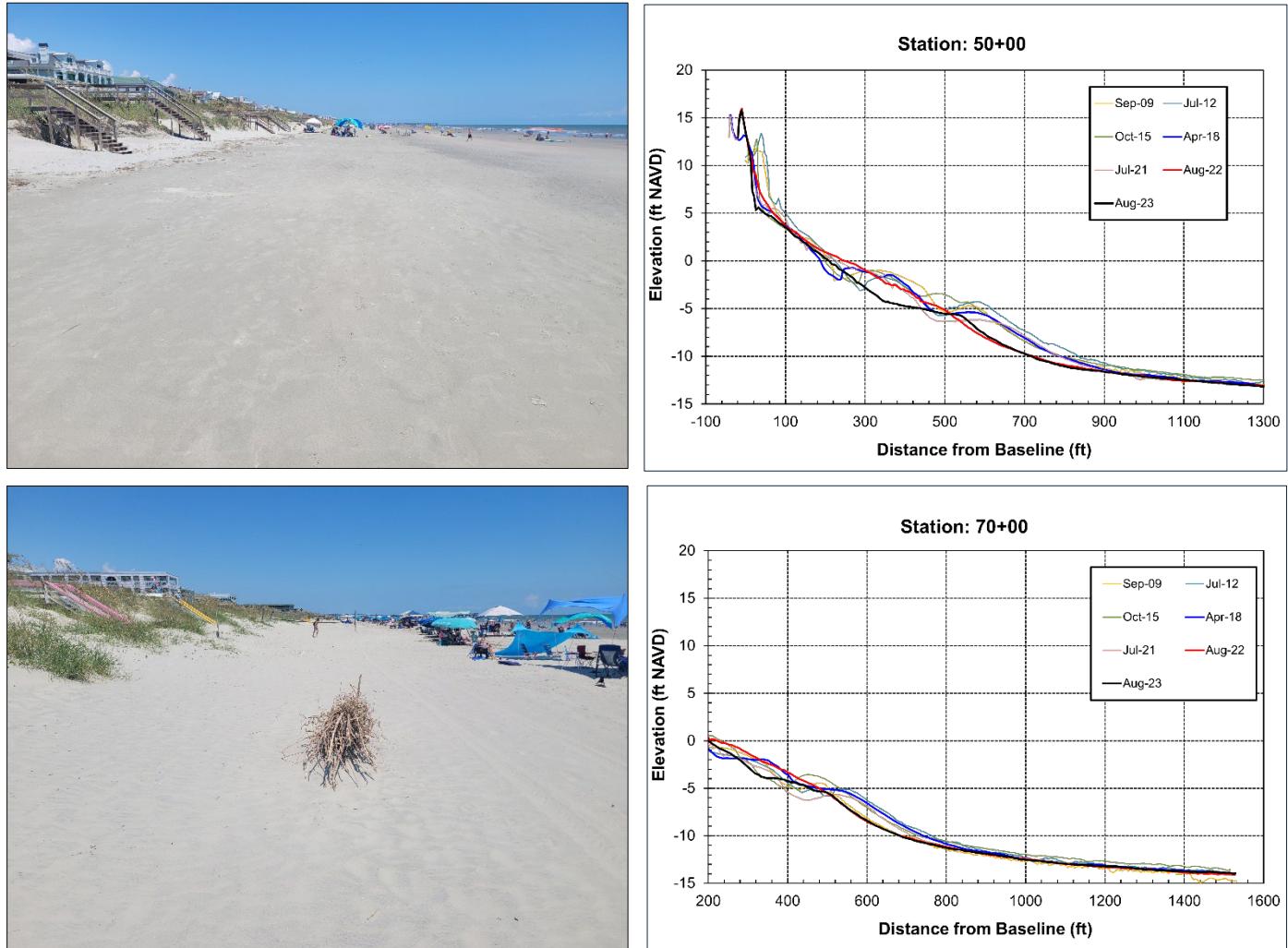


FIGURE 4.25. Aug 2023 photos of Reach 2. [UPPER LEFT] View north from Station 50. [LOWER LEFT] View north from Station 70. The photos show a recently eroded beach at Station 50, but a healthy beach with dry-sand seaward of the dune at Station 70.

Aerial photos (Fig 4.26) of the reach show a crescent-shaped beach extending south of the pier. The shoreline morphology and the variable erosion patterns observed in this area should be closely monitored, as building setbacks are generally less than reaches 3–4. Should an erosional period persist, or a major storm impacts the area, structures along Front Beach or the southern end of the Isle of Palms could become threatened. At a minimum, additional erosion along the south end of the reach will reduce the dry beach width, limiting recreational area. CSE recommends that this area continue to be included in future permit applications for nourishment.



FIGURE 4.26. Aerial views of Reach 2 in Aug 2023. 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. Erosion over the past year has reduced the beach width, especially south of 7th Ave.

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 built seaward from 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. The 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.

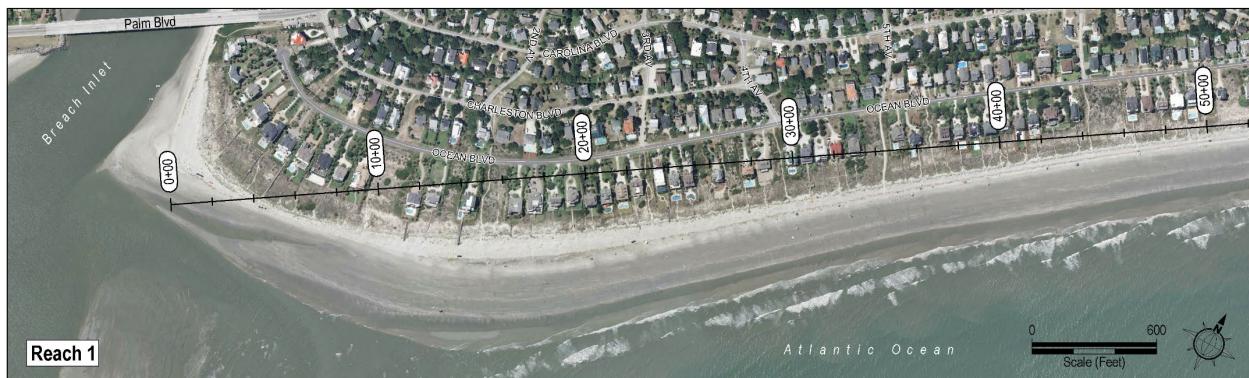


FIGURE 4.27. Baseline stationing along Reach 1 which encompasses the beach between Breach Inlet and 6th Avenue.

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). Erosion accelerated in 2022, with the area losing 101,000 cy (23.0 cy/ft). Erosion has continued to increase, with the reach losing 196,033 cy (44.7 cy/ft) between August 2022 and August 2023. This is an extreme increase in erosion and unprecedented for the area based on historical beach volume changes. Volume loss was most pronounced near south of 2nd Ave but was high along all of the reach.

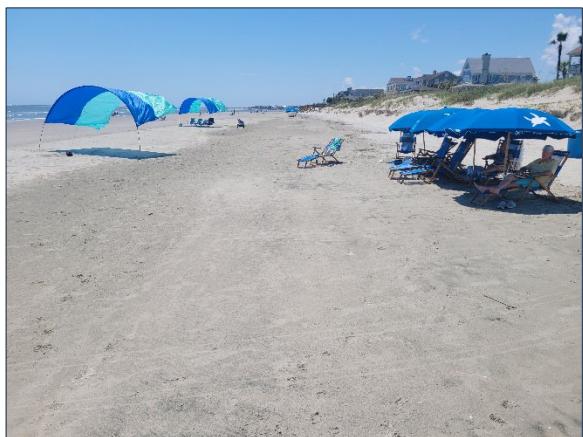
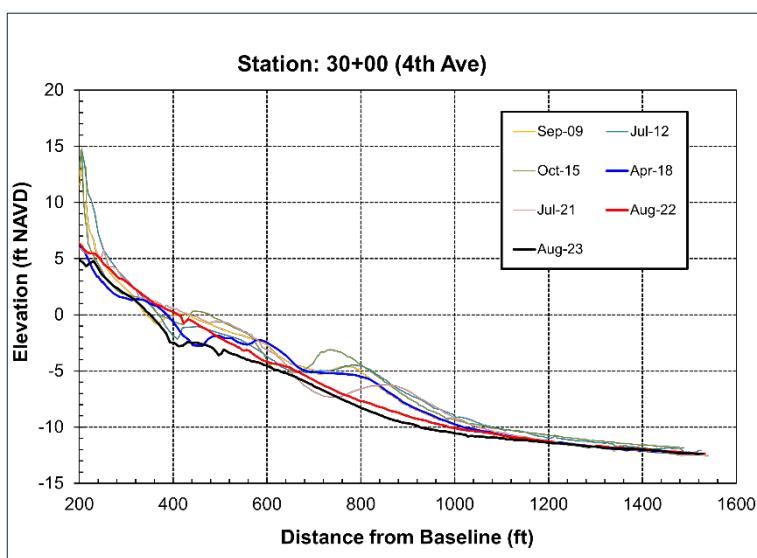
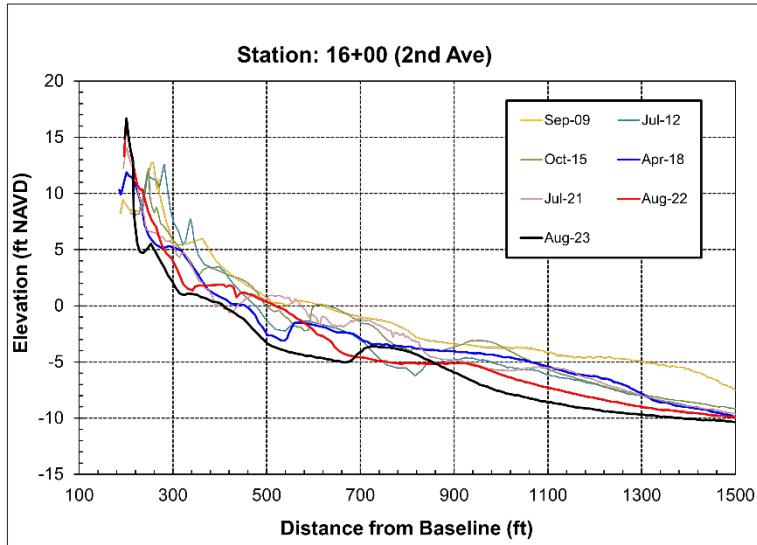


FIGURE 4.28. [LEFT] Profile plots for Reach 1 indicate that while recent erosion rates are higher than historical trends, the majority of volume loss has been restricted to the portion of the profile below the high tide line. This means that the dunes have been more stable than the erosion rate would suggest. **[RIGHT]** August 2023 photos from Reach 1 **[TOP]** Station 12 looking south **[MIDDLE]** Station 30 looking south **[BOTTOM]**.

The pace and magnitude of erosion along Reach 1 suggest that most of the erosion is being caused by large-scale changes in the Breach Inlet system. The erosion rate over the past year is more than double the losses measured at any other annual monitoring since 2009. As sandbars migrate and new channels open, they can alter wave and current patterns and draw sand off of the beach. The impacts of changes in the inlet are likely magnified by an overall high erosion period observed across the island. It is difficult to quantify the proportion of losses attributable to the inlet versus interruptions in upcoast sand supply; however, the losses observed in Reach 1 in 2022 despite gains in upcoast areas suggest that the inlet is the major factor.

CSE obtained bathymetric data spanning most of the Breach Inlet channel and created a digital terrain model of the data (Figure 4.29). The most notable development is that the delta breach and bypass of sand onto Sullivan's Island predicted in CSE's 2022 report began between 2022 and 2023.

The data show extension of the spit running south from the Isle of Palms shoreline, with the tip of that submerged spit extending ~1,000 ft from 2022 to 2023 (red arrow Fig 4.29). The shoal separating the primary ebb channel from Sullivan's Island has also moved towards the Sullivan's dry-sand beach over the same period (blue circle Fig 4.29). These processes are common during sand bypass events at mixed-energy inlets like Breach inlet.

Mixed-energy inlets are inherently dynamic systems. Breach and bypass cycles in settings like Breach Inlet occur periodically, but not always with regularity. The Breach Inlet reach has been dynamic since 2009 and needs to be closely monitored moving forward.

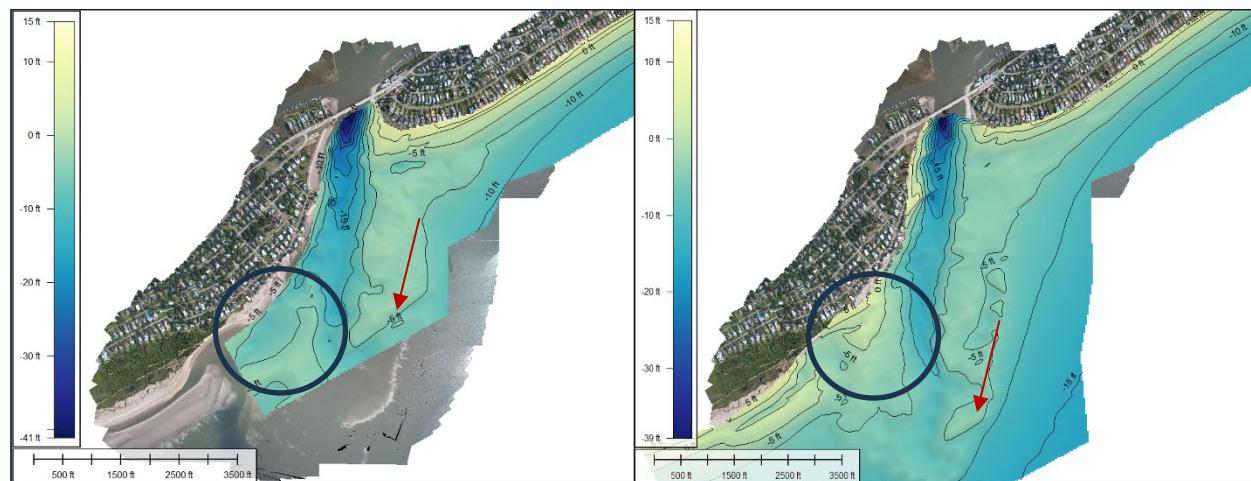


FIGURE 4.29. A pair of digital terrain models spanning the majority of the Breach Inlet channel collected in 2022 (left) and 2023 (right). The model shows the old main channel present in 2021 has infilled and the secondary channel has become the new main channel. No significant changes were observed along the northern shoal; however, it is elongating, which may draw sand off of Isle of Palms.

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5.0 BORROW AREAS

**NOTE: BORROW AREA MONITORING IS REQUIRED IN 2019, 2021, AND 2023 PER PERMIT REQUIREMENTS.*

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 2019. Data were used to generate digital terrain models (DTMs) of the borrow areas and compared to pre- and post-project surveys.

Figure 5.1 shows the DTMs for both borrow areas. The effects of the 2018 nourishment are clearly visible in the blue-shaded colors in the upper two panels. These 2018 post-project models show 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 (CSE 2019). As of July 2021, the slope breaks had softened considerably, particularly around the edges of both borrow areas (Fig 5.1). The 2023 survey reflects continued smoothing of the edges and infilling of the depressions left by the 2018 project.

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 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 infilling within the small area dredged along the western half of the borrow area and 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, which showed continued flattening, as would be expected. Less infilling was observed in Area F. 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), 3-year post-dredge (2021), and 5-year post-dredge (2023) 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 ~1.9 million 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.

From the post-project survey collected in April 2018 through the Year 5 survey collected in 2023, Borrow Area E regained ~44% of the dredged volume while Area F regained ~21% of the dredged volume. The net average recovery across both borrow areas measures ~37% from 2018 through 2023.

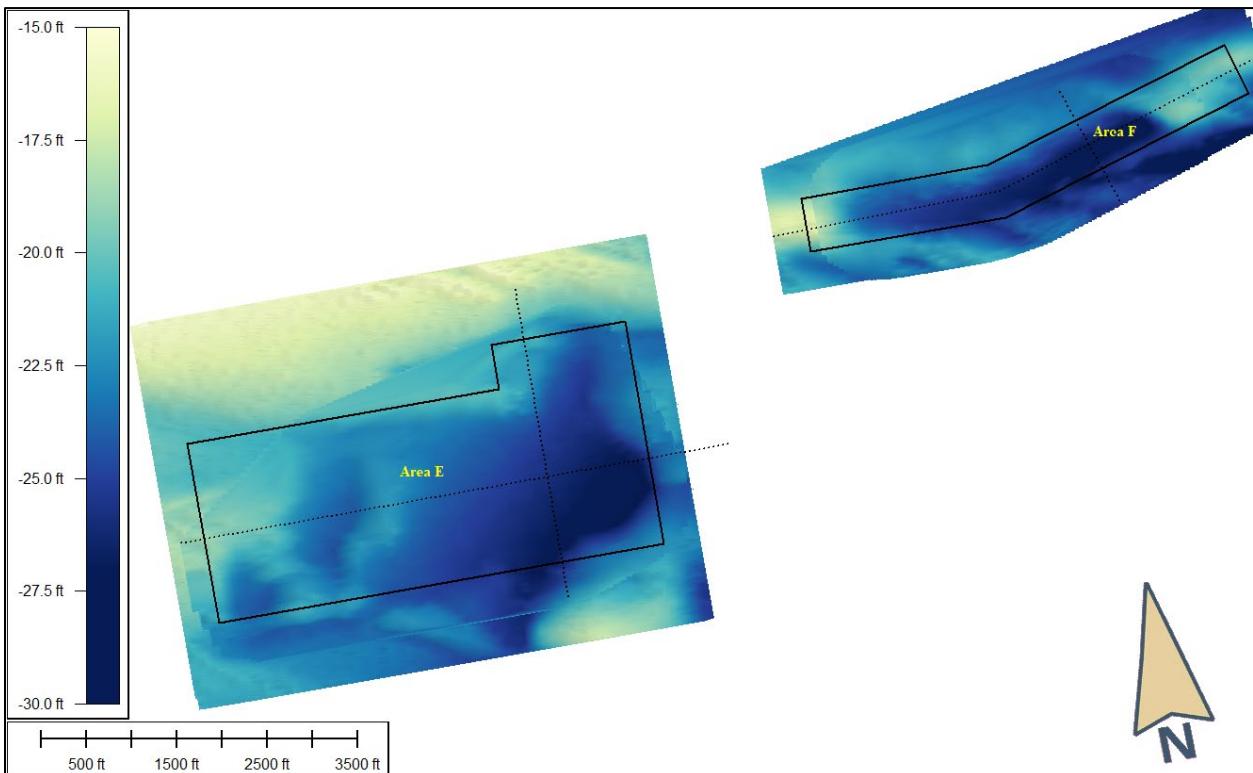
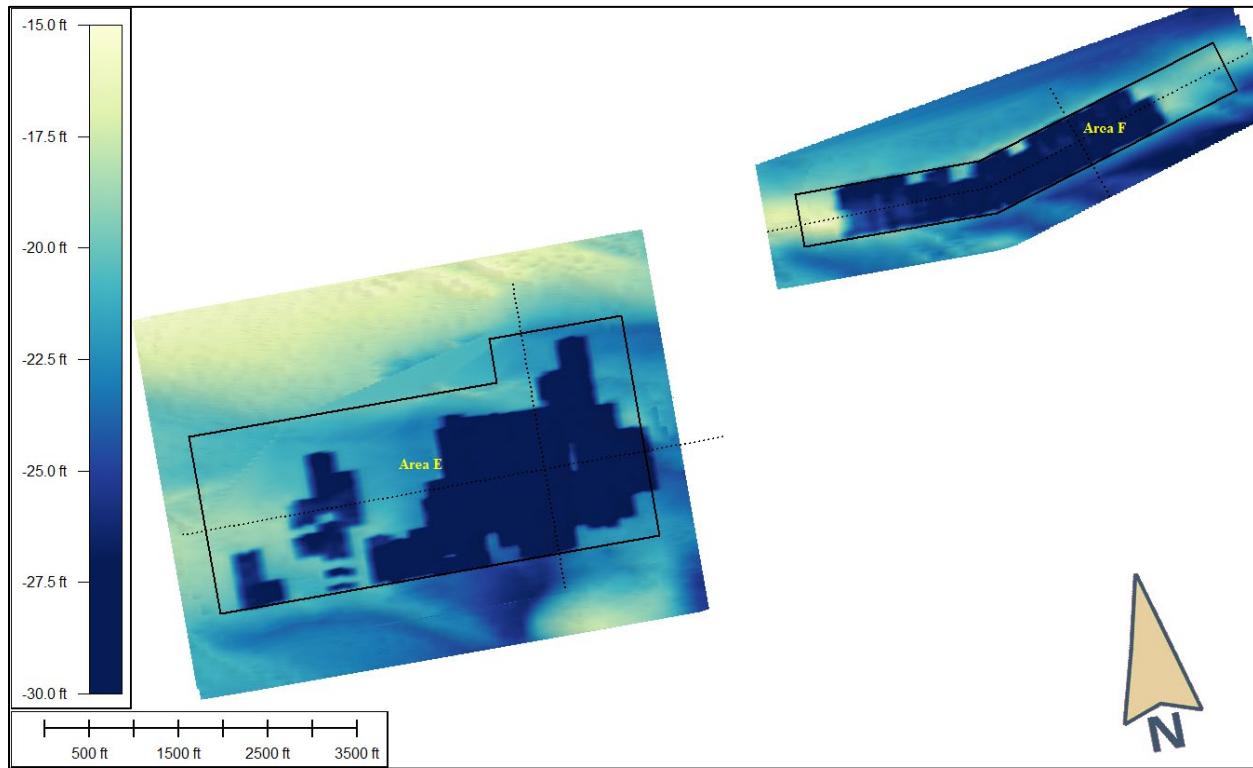


FIGURE 5.1. Terrain models for both borrow areas used in the project for the post-project survey (upper) and the Year 5 survey (lower).

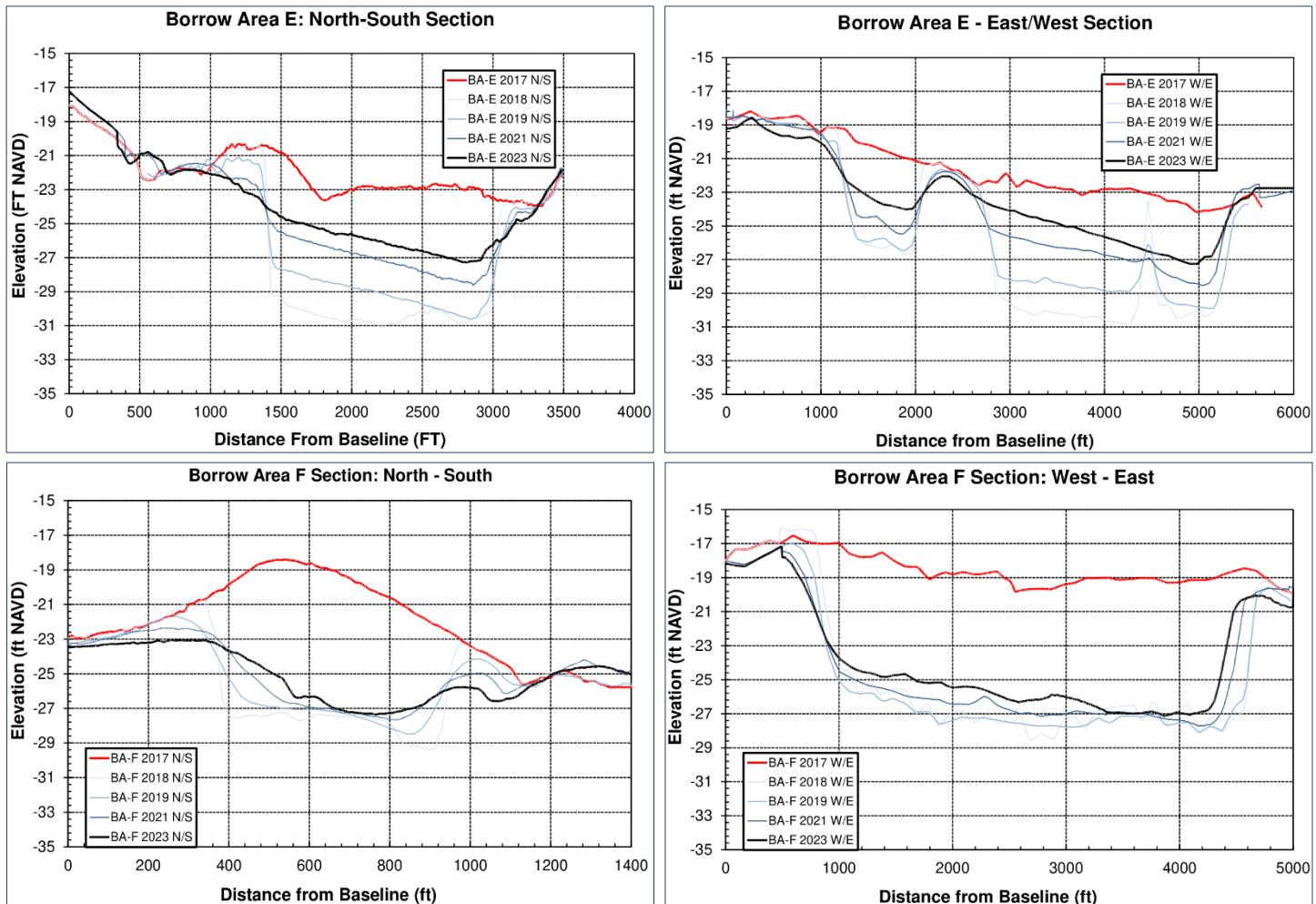
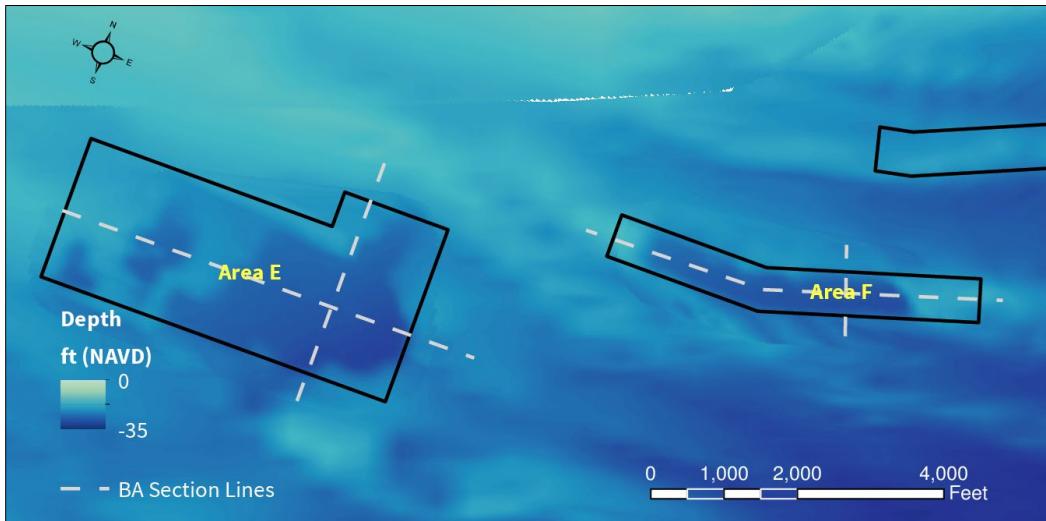


FIGURE 5.2.

[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-, 1-year-post, 3-year-post, and 5-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	Aug-23
Area E	7,319,020	6,007,901	6,127,751	6,411,722	6,580,458
Area F	2,322,692	1,740,855	1,744,469	1,819,810	1,860,177
Total	9,641,712	7,748,756	7,872,220	8,231,532	8,440,635
Volume Relative to BD condition (cy)					
	May-17	Apr-18	Jun-19	Jul-21	Aug-23
Area E	0	-1,311,119	-1,191,269	-907,298	-738,562
Area F	0	-581,837	-578,223	-502,882	-462,515
Total	0	-1,892,956	-1,769,492	-1,410,180	-1,201,077
Volume Relative to AD condition (%)					
	May-17	Apr-18	Jun-19	Jul-21	Aug-23
Area E	0	0.00	9.14	30.80	43.67
Area F	0	0.00	0.62	13.57	20.51
Total	0	0.00	6.52	25.50	36.55
Volume Change Year to Year					
	May-17	Apr-18	Jun-19	Jul-21	Aug-23
Area E	0	-1,311,119	119,850	283,971	168,736
Area F	0	-581,837	3,614	75,341	40,367
Total	0	-1,892,956	123,464	359,312	209,103

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 had formed, and the cycle began to repeat. From 2020 to 2023, the new channel has grown and developed a terminal lobe at the seaward end. It has also already started shifting south. The delta of the previous channel has coalesced into a low shoal that has migrated landward and is starting to impact the beach between the Wild Dunes Grand Pavilion and Dunecrest Lane. The shoal appears to be larger than recent events, with a leading edge that runs over 3,000 ft parallel to the beach. The series of models reveals 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 2023, finding a net increase of ~700,000 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 trailing ebb spit's importance and how it traps sand along the island's northeast end. The spit began to merge with the shore in 2021, and has essentially completely merged by 2022. A new spit is developing as of August 2023, and will likely continue to grow over the next few years. The sediment building of this spit originates from the northern end of Wild Dunes, and is recycled through the Dewees Inlet Delta via this spit growth and onshore migration.

The shoal is maturing into a fully developed migratory shoal in Stage 2 of the shoal-bypass cycle. It has a pronounced leading edge that extends further south than other recent events. The main body of the shoal extends from Station 268+00 to Station 298+00, with the northern end containing more sand and moving faster landward. As the shoal is approaching the beach, it is moving landward at a rate of ~900 ft per year and shifting slightly southwest as it approaches (Figure 6.2). The peak elevation is (~) -3 ft NAVD, which is still below the normal low-tide elevation. CSE expects the elevation to increase over the next year, and portions of the shoal will likely be exposed at low tide.

The beach in the lee of the shoal near Beach Club Villas is beginning to build seaward as expected (Figure 6.3). Sand from adjacent areas, including Beachwood East and Dunecrest Lane is moving to

the north as waves refract around the shoal. This process will likely worsen over the next year as the shoal gets closer to the beach, leading to significant erosion along Beachwood similar to the 2014–2015 time period.

A small sand body offshore of the Wild Dunes Grand Pavilion is currently attaching to the beach, which is maintaining a healthy sand beach in that area. Continued influx of sand over the next year is expected, as there are still significant amounts of sand underwater and moving onshore.

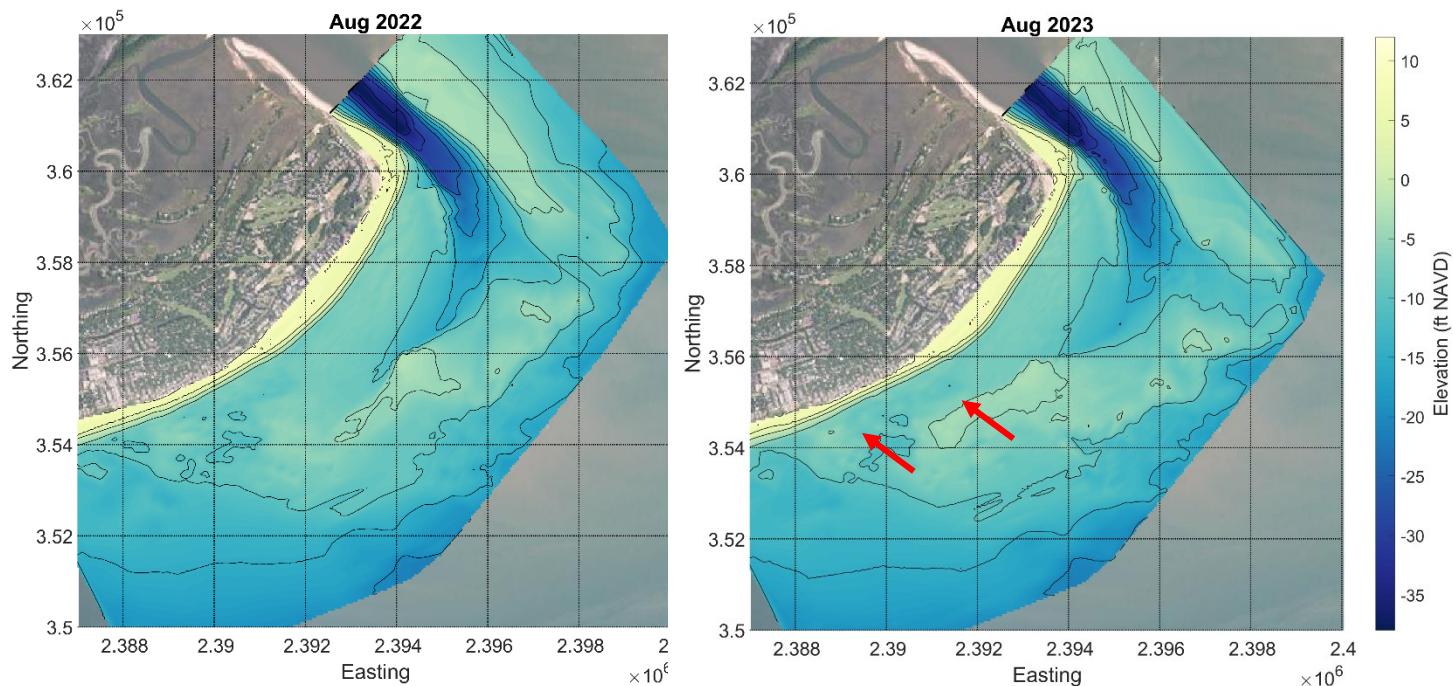


FIGURE 6.1. 2022 and 2023 models of the Dewees Inlet Delta. The most significant change over the past year was growth and onshore migration of a shoal offshore of Beach Club Villas II – Mariners Walk. This shoal will continue to migrate towards the beach, likely attaching in 1–2 years.

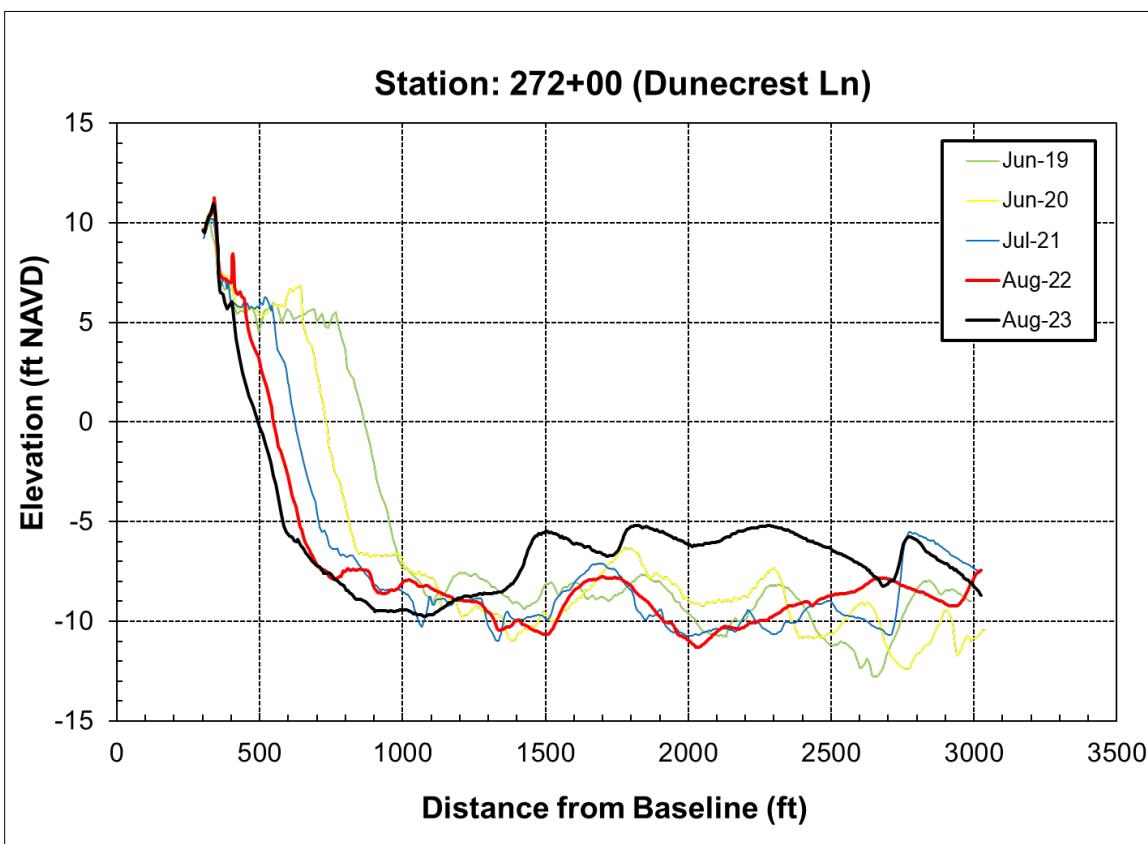
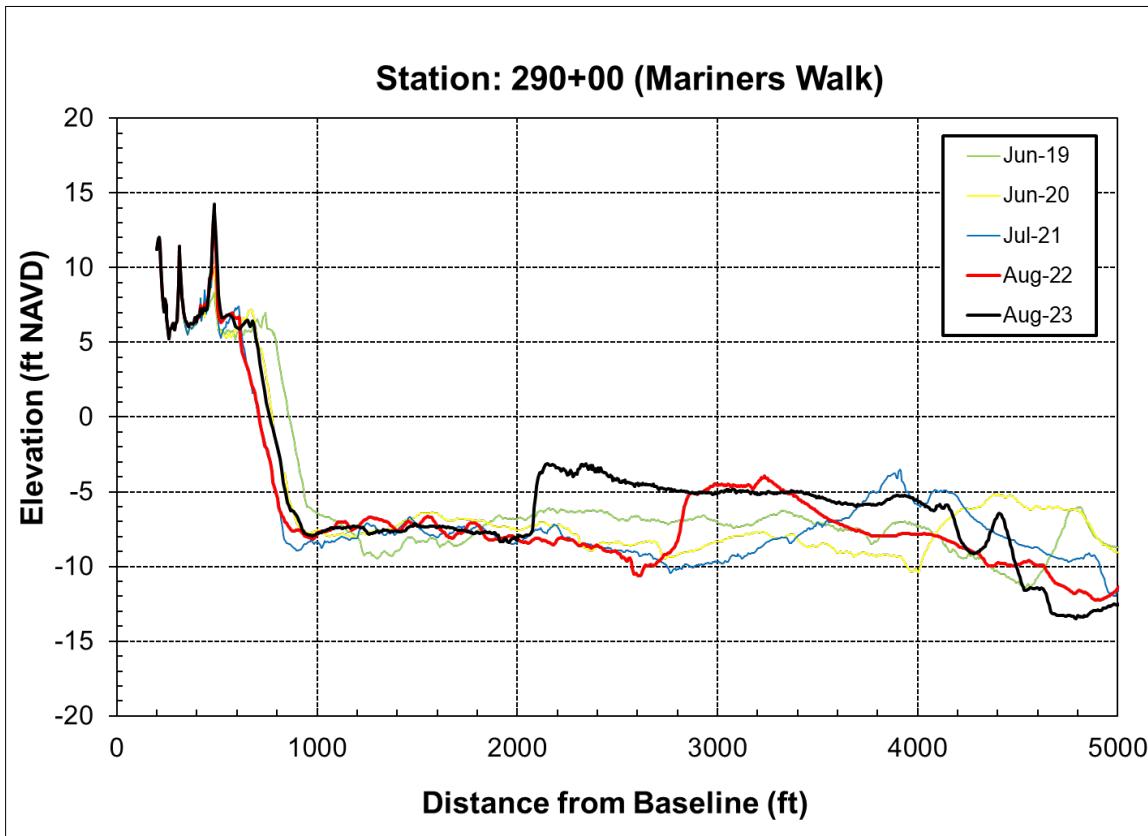


FIGURE 6.2. Profiles from stations 290 [UPPER] and 272 [LOWER] showing growth and onshore migration of a large shoal in Dewees Inlet.



FIGURE 6.3. August 2023 aerial image of the shoal offshore of Wild Dunes. Erosion began to accelerate along the beach later in 2023.

7.0 COASTAL RESILIENCY UPDATE

7.1 Weather and Climate Conditions, September 2022 to August 2023

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 August 2022 to August 2023 (the same as the survey data presented herein). Wind data are compared to historical data covering the period from 1945 to 2023 (Fig 7.1). 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 Purdue University (MRCC 2022, <http://mrcc.purdue.edu/>). The closest operational station is located at Charleston International Airport (FAA Identifier – CHS) in North Charleston, ~20 miles northwest of Isle of Palms.

The average wind speed and direction* was 14.8 miles per hour (mph) from ~170° (approximately south, Fig 7.1). The peak observed wind speed was a gust to 73.4 mph from ~22° (approximately north) on 30 September 2022 during the passage of a low-pressure trough. 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 2023; between August 2022 and August 2023, these have represented ~47.0 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) (NOAA 2022, http://www.ndbc.noaa.gov/station_page.php?station=41004). The average wave height at Station 41004 from August 2022 to August 2023 was ~4.2 ft, with an average dominant wave period of ~7.3 seconds. The maximum observed wave height was ~21.5 ft on 30 September 2022 during the passage of what would become Tropical Storm *Wanda*. The average wave direction** was ~136° (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.*

From January 2010 to August 2023, Station 41004 experienced similar wave conditions compared to recent years. Data from Station 41004 have been collected nearly continuously since January 2010, and in the period from then until August 2023, wave height exceeded 10 ft ~154 times per year and 15 ft ~20 times per year. Between August 2022 and August 2023, wave height exceeded 10 ft an average of ~494 times per year and exceeded 15 ft ~89 times per year.

Atmospheric pressure dropped below 1000 millibars (mb) ~62 times per year from 2010 to 2022 and detected ~168 times below 1000 mb from August 2022 and August 2023 (Fig 7.2). Most of this was observed in September 2022 during Hurricane *Ian* when pressure dropped below 980 millibars, and a weak low-pressure system that brought storms to the southeast on April 30, 2023. 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).

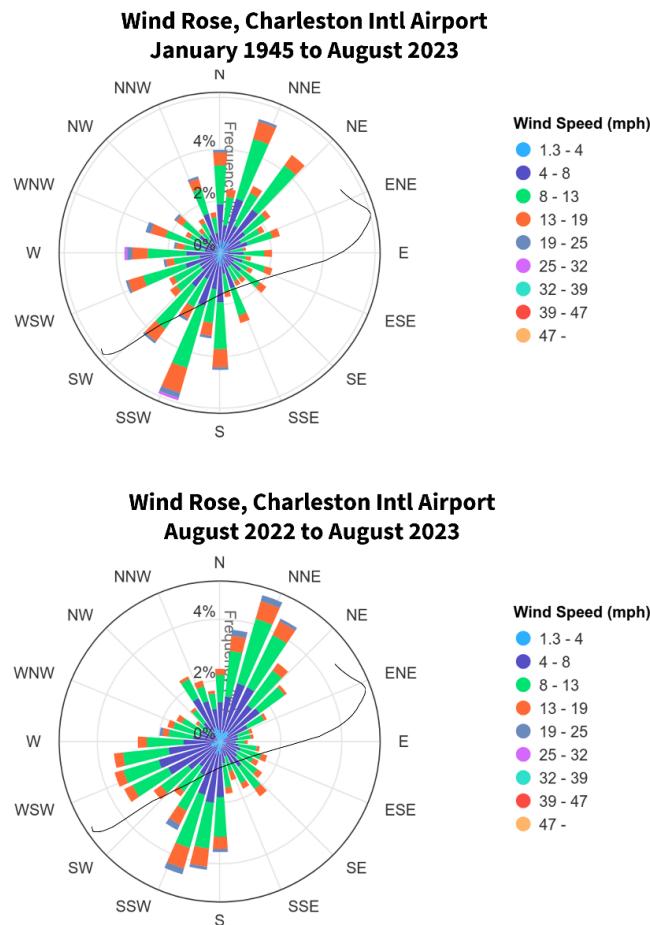


FIGURE 7.1. Wind roses showing direction and magnitude of winds measured at Charleston International Airport from January 1945 to August 2023 [UPPER] and from August 2022 to August 2023 [LOWER]. The line across the wind rose indicates the oceanfront shoreline orientation along the entire Isle of Palms.

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 41004 is presented in Figure 7.3 with wave height. The larger-magnitude wave power values from mid-September 2022 to November 2022 and late March 2023 to mid-May 2023 represent the passage of cyclonic storms. In the spring and summer, lower-magnitude positive values tend to dominate.

The most powerful waves from mid-September 2022 to November 2022 and between April 2023 to mid-May 2023 exhibited more than ~6 kW/m of wave power dominant in southerly direction (Fig 7.3). However, the average power of a northerly-directed wave from August 2022 to August 2023 was 0.81 kW/m, and the average southerly-directed wave power was -0.85 kW/m. Calculating the average of all wave power indicates more individual waves moved in a southerly direction than in a northerly direction over the same period.

These results indicate that most waves at Isle of Palms approach from the south, but the strongest waves approach from the north. Since 2010, a similar pattern has been observed wherein approximately three to four times more total energy is expended moving waves in a northerly direction compared to a southerly direction. However, individual southerly-directed waves are roughly twice as powerful. This result corroborates long-term observations along the Isle of Palms documenting southerly-directed drift. It is important to note that Station 41004 is several dozen miles off the coast with slightly different exposure to northerly winds. Thus, the net total wave power exhibited at Station 41004 may be somewhat different from the inshore zone off the Isle of Palms, but the general trends in long-term wave climate should be similar.

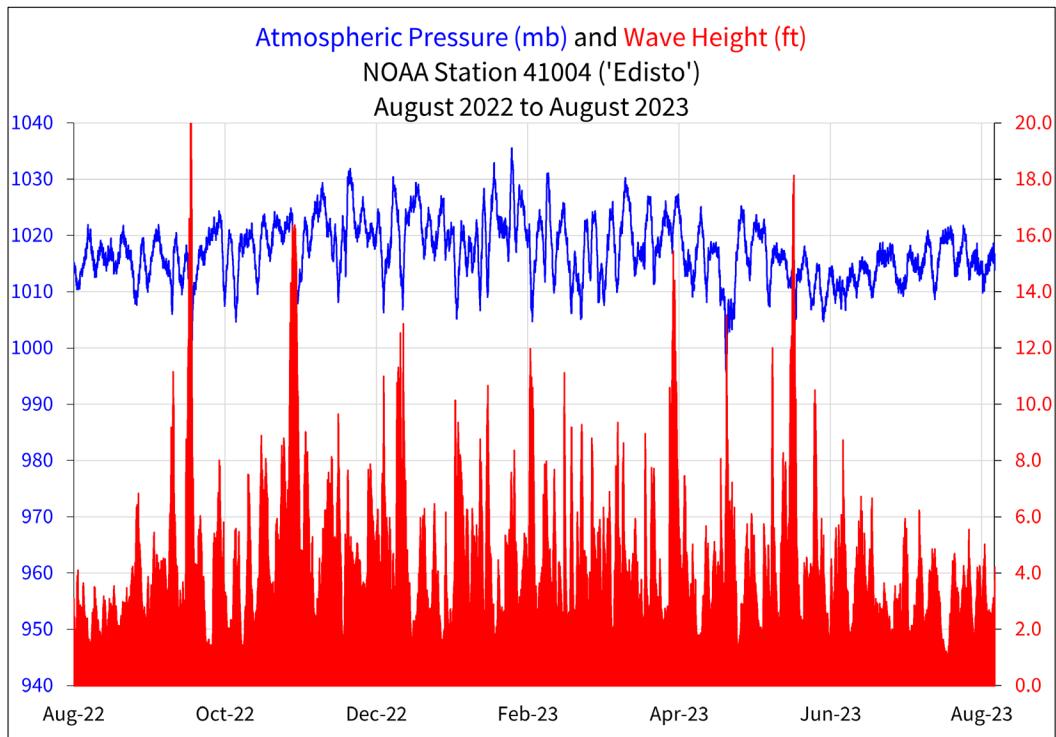


FIGURE 7.2. Atmospheric pressure and wave height at NDBC 41004 from August 2022 to August 2023. Wave heights exceeded 10 ft only once during the study period – far below the annual average since 2010 – and atmospheric pressure did not go below 1000 mb. These two parameters indicate conditions have been relatively calm over the past year.

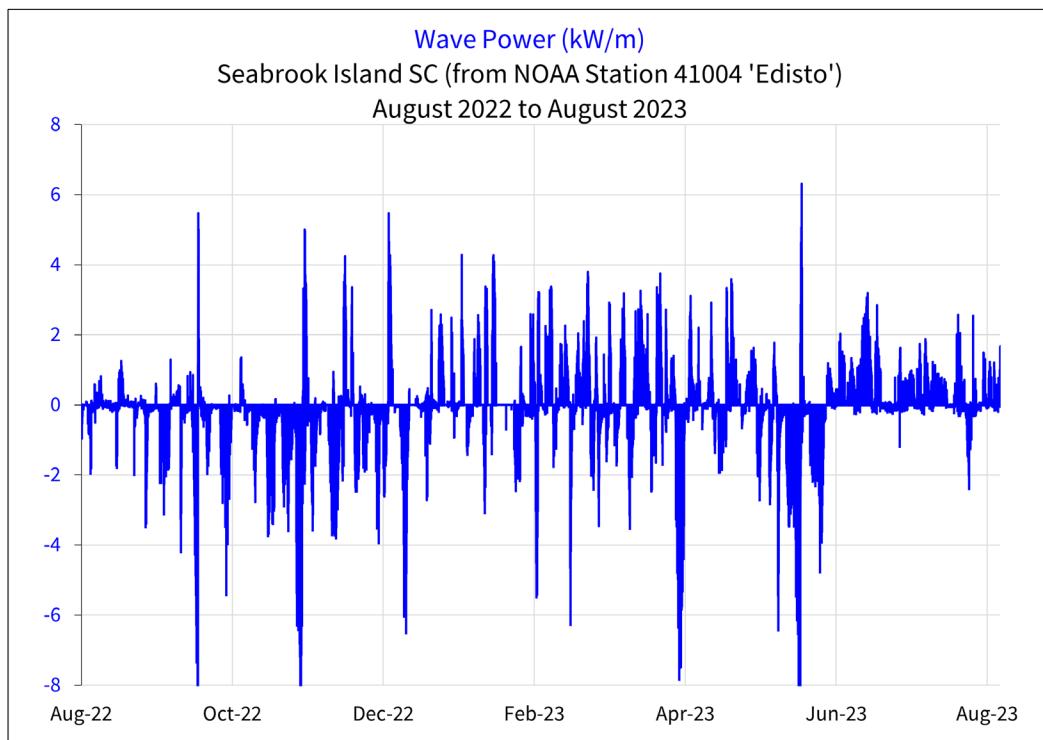


FIGURE 7.3. Wave power (in kW/m) and wave height (in m) for NDBC 41004 from August 2022 to August 2023. Wave power is a useful parameter for determining the relative magnitude and direction of wave energy in an alongshore direction along a beach. Positive values indicate waves move from south to north (ie – northerly transport), while negative values indicate predominance of north-to-south (ie – southerly) transport.

7.2 Flood Vulnerability

Regional projections of average sea level rise (SLR) within the Southeast US range from ~1 ft to ~10 ft (Sweet et al 2022). These projections are based on 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 7.4; 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 7.4).

Relative to 1995–2014 conditions, the likely global mean sea level rise by 2100 is ~1 to 2 ft under the *lowest* emissions scenario. This scenario calls for warming to be held at or below 1.5 °C by 2100 compared to 1900 and for 'net-zero' CO₂ 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 reduced emissions and project ~3 ft of SLR by 2100, while the 'very high' scenario assumes no policy changes and project ~5 to 6 ft of SLR by 2100.

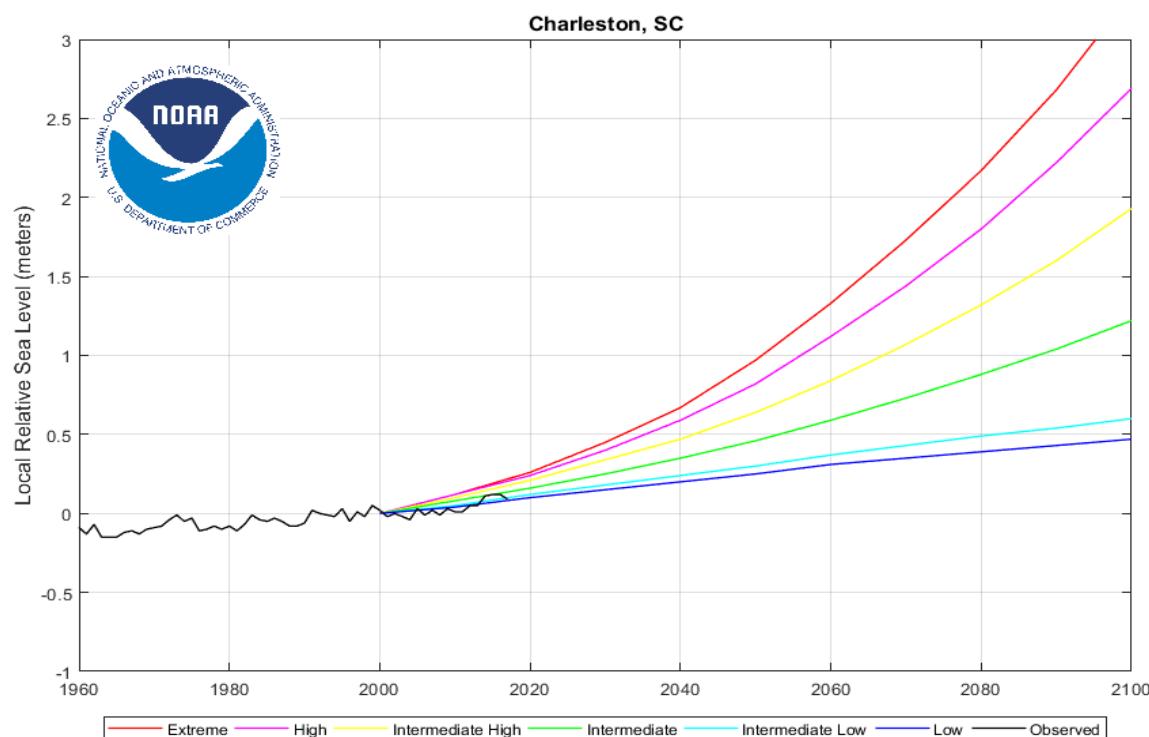


FIGURE 7.4. Projected MSL values under an 'Intermediate' emissions scenario average ~2 ft by 2060, and ~4 ft by 2100 at Charleston Harbor. These projections are global-scale predictions of future water levels (based largely on emissions) adapted to the Lowcountry by accounting for regional and localized 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, Sweet et al 2022). Such floods will tend to impact low-lying sheltered shorelines, such as causeways over the marsh or creek-front backyards. Just a small increase in sea level 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 just inland from the beach lie at higher elevations than the mainland-facing 'back side' of barrier islands, where the shoreline transitions more gradually into marsh and creek habitats.

NOAA provides a 'Sea Level Rise Viewer' (SLRV; see <https://coast.noaa.gov/digitalcoast/tools/slrv.html>) to help people identify local variations in flood impacts under different SLR scenarios. This tool allows users to specify water levels and generate inundation maps showing MSL and depth in previously dry areas. The NOAA viewer is a handy tool to see which SLR scenarios begin to impact a particular property.

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 MHW; 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.

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 more frequently 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 the impacts of this SLR rate and magnitude (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 future sea-level predictions and ramifications for individual locations. A key finding of the August 2021 IPCC* report is that regardless of any level of reduction in atmospheric CO₂, 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 worldwide, with dozens of additional scientists contributing to each report.

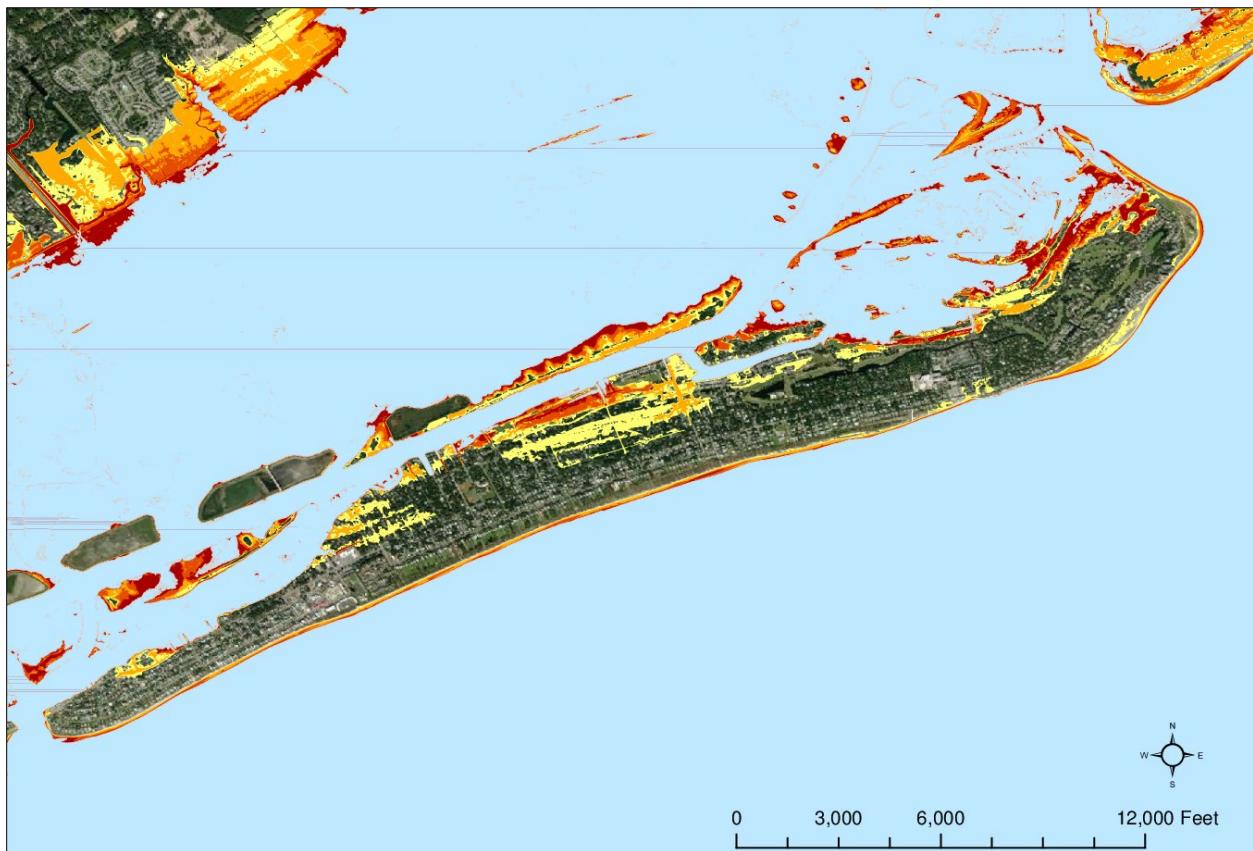


FIGURE 7.5a,b. Sea level inundation models around the Isle of Palms generated using data from NOAA (<https://coast.noaa.gov/digitalcoast/tools/slri.html>). Shades of yellow, orange, red, and maroon are used to signify SLR of 1, 2, 3, and 4 ft above present-day MHHW.

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 timescale ('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 2022 to 2023. Overall, the island lost ~506,000 cy of sand from August 2022 to August 2023, equivalent to a unit volume loss of -13.6 cy/ft over that time period. This is double the amount of erosion observed during any other monitoring period since island-wide monitoring began in 2009. Erosion has typically been most severe along the east end project area; however, all of the island except Reach 4 was abnormally erosional this past year. Reach 1 (Breach Inlet) to Reach 2 were especially atypical this year. CSE expects the general trend to continue at the east end until an oncoming shoal attaches and begins to spread sand. A surplus of sand along the central portion of the beach is likely to move south over the next year and will hopefully return the southern end of the island to a more stable condition.

Since the 2018 renourishment, the project area has lost ~1,422,700 cy, which is ~85% of the nourishment volume. While the magnitude of loss is high, erosion is concentrated in a few areas, and much of the project area remains in fair condition. Losses have primarily occurred in the underwater portion of the project along the center of the project area, though some areas are beginning to show worrisome beach widths, especially around Beachwood East and adjacent areas.

Much of the lost sand has spread to adjacent areas or into the Dewees Inlet delta. The project area holds ~157,300 cy more sand than the pre-nourishment condition. Most of the island west of the nourishment area slightly eroded from August 2022 to August 2023, except for Reach 1, which spans the area near Breach Inlet had more erosion. 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 4, which has gained ~526,000 cy since 2017.

Presently, a shoal is in state 2 of the shoal bypass cycle and approaching the beach. Wave refraction around the shoal is starting to impact the beach condition around Beach Club Villas and Beachwood East, with the typical pattern of erosion adjacent to the attachment site (Beachwood) and stability or accretion in the lee of the shoal (Beach Club Villas and Mariners Walk). CSE expects this pattern to magnify over the next year as the shoal gets closer to the beach and the breakwater effect increases. 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.

The next monitoring effort for Isle of Palms is scheduled for the summer of 2024. 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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