

**2022 Avon and Buxton
Beach Renourishment Projects**

2024
MONITORING REPORT



Prepared for
Dare County Board of Commissioners
Dare County, North Carolina

COASTAL SCIENCE & ENGINEERING



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**2022 BEACH RENOURISHMENT PROJECTS
AVON and BUXTON
DARE COUNTY (NC)**

Year 2 Post-Project Monitoring Report

Prepared for:



Dare County Board of Commissioners

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EXECUTIVE SUMMARY

A pair of nourishment projects at Avon and Buxton in the summer of 2022 placed a total of 2,200,000 cubic yards (cy) along 28,700 feet (ft) of beach. Along Avon, 1.0 million cy were placed along 13,200 ft, while along Buxton, 1.2 million cy were placed along 15,500 ft. Due to the proximity of the placement sites, both were completed in a single deployment by the same contractor working under the same agreement with Dare County.

This report documents changes at both sites over the course of the second year following project completion. The changes reported herein are determined by a series of quarterly and annual surveys described in the post-project monitoring and mitigation plan, which was submitted as part of the permit applications for each location. This plan was determined through coordination between Dare County and CSE based on guidance from NPS, USFWS, and CAMA personnel.

Results presented in this report and its appendices include:

- Beach and inshore profile surveys (see Sections 4.1 and 4.2)
 - The project area at Avon retains ~32% of the nourishment volume above -6 ft NAVD and 20% of the nourishment volume above -30 ft NAVD.
 - The project area at Buxton retains ~28% of the nourishment volume above -6 ft NAVD and 4% above -30 ft NAVD. Buxton Village (Reach 1) retains 7.9% of the nourishment volume above -30 ft NAVD.
 - Most surveyed profiles along both project areas retain more than 20% of the placed volumes above -30 ft NAVD. This indicates the templates continue to reduce storm damage by attenuating wave energy in the surf zone. However, erosion attributable to the nearshore trough and bar has been higher than the long-term average over the past year.
- Sand compaction in April (see Section 4.4)
 - Compaction survey results collected quarterly over the course of Year 2 indicate both project sites are comparable to the 'Control' area south of Salvo. These results indicate that neither fill template caused an unnatural increase in compaction following project completion.
- Geotechnical characteristics of the fill material (see Section 4.5)
 - Sand samples collected quarterly over the course of Year 2 indicate both project sites exhibit comparable mean grain sizes and distributions to the 'Control' area south of Salvo. Variations observed at both sites over the course of Year 2 were also observed along the 'Control' area. Results indicate that both templates were constructed using appropriate beach-quality sand, with no remarkable differences between the pre-project and two years post-project conditions.
- Borrow area surveys
 - Borrow area surveys collected over the course of Year 2.

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1.0 INTRODUCTION

Between June and August 2022, 2.2 million cubic yards (cy) of beach-quality sand was placed along two project sites, totaling 5.4 miles of ocean-facing shoreline on Hatteras Island, North Carolina. A project at Avon placed 1.0 million cy of sand along 13,200 linear feet (lf) of beach, while Buxton received 1.2 million cy placed along 15,500 lf (Fig 1.1).

Dare County ('the County') was the project owner and administrator, and Coastal Science & Engineering (CSE, Columbia, South Carolina) served as the Engineer. The renourishment project was completed in one phase under two contracts between Great Lakes Dredge & Dock Company, Inc (GLDD, Houston, Texas) and the County.

The North Carolina Division of Coastal Management (NCDCM) Coastal Area Management Act (CAMA) program, the National Park Service (NPS), and the United States Army Corps of Engineers (USACE) issued permits for the Avon and Buxton projects. Specific monitoring schedules and data collection requirements are included in the special conditions of permits. These special conditions dictate that the County monitor beach conditions along the two sites for at least two years following project completion. CSE and the County agreed to conduct five years of post-project monitoring to maintain eligibility for FEMA reimbursements following storm damages under the Category G program.

Several types of information are included in annual monitoring reports. Beach profile and borrow area surveys are scheduled annually for five years, while benthic monitoring surveys are scheduled quarterly for two years. Additional data include aerial photography, compaction and escarpment surveys, sediment sampling, and benthic monitoring. Survey requirements for both Avon and Buxton are identical, as shown in Table 1.1.

This report details the findings of Coastal Science & Engineering's (CSE) October 2024 (Year 2) survey compared to conditions observed during the August 2022 post-project survey and September 2023 survey (Year 1). Additional comparisons are made between the current (October 2024) data and earlier (eg – pre-June 2022) surveys. Where applicable, quarterly data collected over the course of Year 2 are included as well.

The main text of this report presents selected profiles and imagery, along with compaction and geotechnical results; complete records and data are provided in Appendices A, B, and C, respectively.

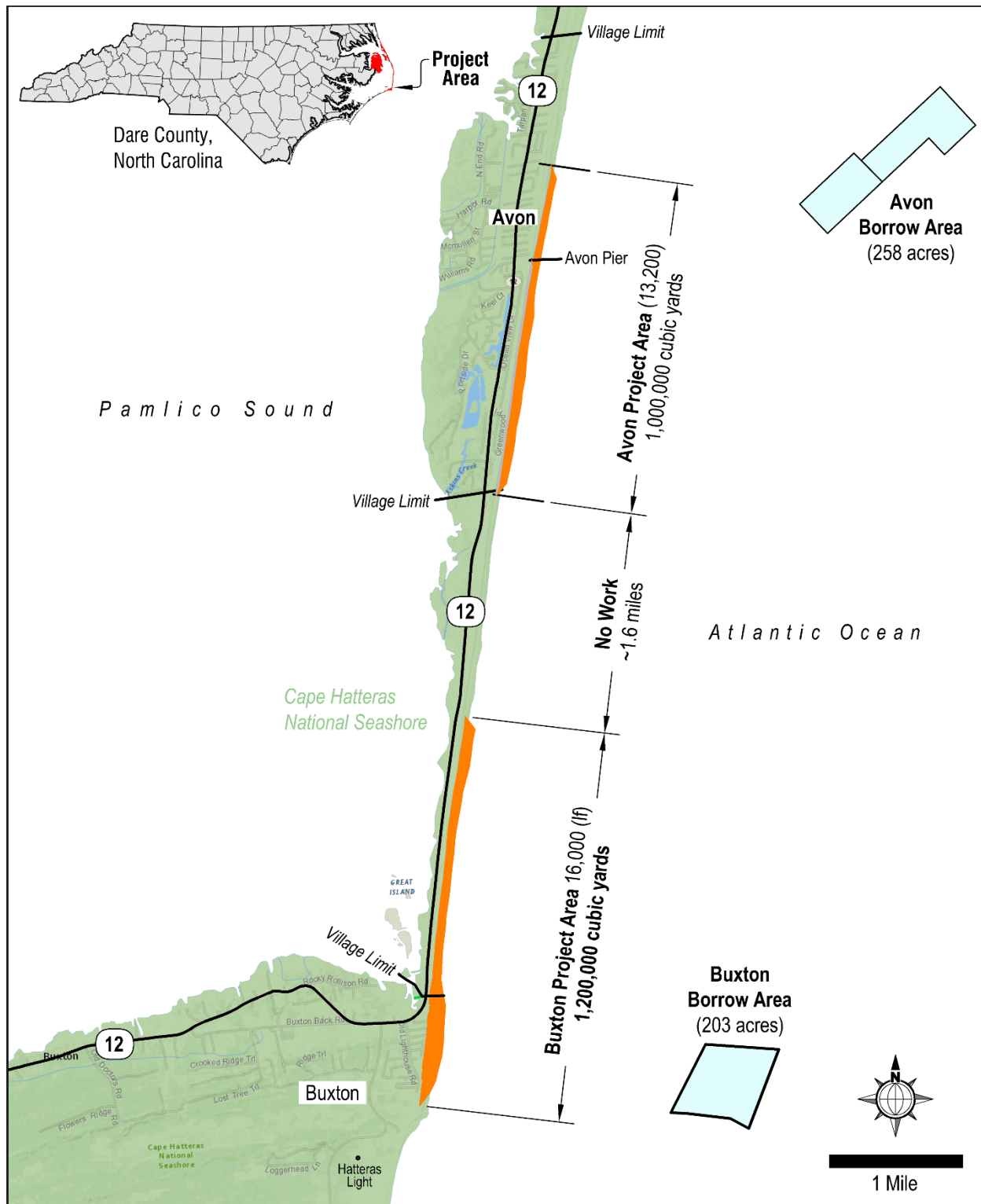


FIGURE 1.1. Project vicinity map for the Avon and Buxton renourishment projects occurring in 2022. The design fill template and indicated volumes at Avon extended from just north of Avon Pier to the southern village limits. The template at Buxton extended from ~10,000 feet north of the village limit to the former Cape Hatteras Lighthouse site on Old Lighthouse Road in Buxton Village. Borrow areas permitted for the two projects were located 2 to 3 miles off each site within state waters. Due to the close proximity of the projects and GLDD's decision to use hopper dredges, both the Avon and Buxton borrow areas were utilized for constructing the Buxton project. Only the Avon borrow area was used for the Avon portion of the fill.

TABLE 1.1. USACE, CAMA, and NPS permits require a range of post-project monitoring data to track performance of a beach nourishment project in North Carolina. This visual is CSE's internal method for tracking monitoring requirements following project completion. The data requirements and survey frequencies shown are for Buxton. The same permit special conditions are required for Avon.

Post Project Required Monitoring Information, Comparisons, and Analysis											
Project Number:	2403-M	Project Name:	Village of Buxton Beach Renourishment Project					Permit Number:	SAW-2021-01266		
Timeline			Beach Profiles	Borrow Area Surveys	Beach Sediment Samples	Lighting Survey	Aerial Oblique Photos	Compaction	Escarpments	Aerial Ortho Photos	MHW & Veg Lines
Report	Year										
Pre Project	2022	Required	●	●	●		●	●		●	●
		Date Complete	6/16/2022	6/16/2022	6/17/2022		6/17/2022	6/17/2022		6/17/2022	6/15/2022
Post Project	2022	Required	●	●	●		●	●		●	
		Date Complete	8/21/2022	8/21/2022	8/18/2022		8/18/2022	8/18/2022		8/18/2022	
Year 1 Annual	2023	Required	●	●	Quarterly	Twice	●	Quarterly		●	
		Date Complete	9/8/2023	11/30/2023			8/22/2023				
Year 2 Annual	2024	Required	●		Quarterly		●	Quarterly		●	
		Date Complete	10/31/2024								
Year 3 Annual	2025	Required	●				●			●	
		Date Complete									
Year 4 Annual	2026	Required	●				●			●	
		Date Complete									
Year 5 Annual	2027	Required	●				●			●	
		Date Complete									
Description of Monitoring Requirements											
	Beach Profiles: BD survey performed within 3 months of construction for entire project area and submitted to DCM and USACE. AD final survey must be submitted within 60 days of project completion.			Borrow Area Surveys: AD survey provided to DCM within 60 days after project completion.			Beach Sed Samples: 16 transects in Buxton, 10 control transects south of Salvo, 3 samples at each transect: toe of dune, berm, LTT. 10 sampling events, pre, post, quarterly for 2 years.				
	Lighting Survey: Two surveys must be conducted from the beach fill area using standard techniques in year following construction. First between May 1 and May 15, brief summary provided to Service. 2nd between July 15 and Aug 1. (USACE #49)			Aerial Obliques: Not required but CSE will collect.			Compaction: Will be conducted along with beach sediment sampling and ecological study.				
	Escarpments: Visual surveys for escarpments along the project area shall be made immediately after completion of the sand placement, and within 30 days prio to May 1. Exceed 18 inches in height for a distance of 100 ft shall be leveled.			Aerial Orthos: Not required but CSE will collect.			MHW and Static Veg Survey: Existing MHW line shall be surveyed prior to nourishment activity. Static veg line, line that existed within one year prior to construction shall be established using aerial imagery.				

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2.0 SETTING AND HISTORY

2.1 Project Setting

Dare County encompasses ~90 miles of ocean shoreline on North Carolina's Outer Banks. The Outer Banks is a chain of barrier islands and spits bordering the Atlantic Ocean from just south of Virginia Beach (VA) to Cape Lookout (NC). Figure 1.1 shows the project location within Dare County and North Carolina.

Approximately half of Dare County's oceanfront shoreline is developed, while the remainder is undeveloped and managed by the National Park Service as Cape Hatteras National Seashore (CAHA). The northern 30 miles of oceanfront beaches in Dare County include (from north to south) the towns of Duck, Southern Shores, Kitty Hawk, Kill Devil Hills, and Nags Head. There is a 5-mile undeveloped portion of CAHA between the southern boundary of Nags Head and Oregon Inlet. The rest of Dare County's oceanfront beaches are on Hatteras Island. These include the National Seashore and the communities of Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, and Hatteras. Approximately 16 miles are developed, and 38 miles are undeveloped along the oceanfront.

Hatteras Island is a classic micro-tidal, wave-dominated barrier island (Hayes 1994) in which littoral sands (ie – sand in the active beach zone) of the inner continental shelf have been shaped into a thin, elongated form miles from the mainland. A characteristic of wave-dominated barrier islands is their tendency to be long and narrow, with widely separated inlets. Over a 400-year period, up to 30 inlets of varying longevity have been documented along CAHA. However, only three—Oregon Inlet, Hatteras Inlet, and Ocracoke Inlet—have persisted for many decades. The others either closed naturally after a brief life or were closed artificially (Everts et al 1983, Mallinson et al 2008).

Breach inlets, although infrequent, typically occur where the barrier island is narrowest and lacks high dunes. Hurricane *Irene* (August 2011) produced several breach inlets—one adjacent to Oregon Inlet and another along Pea Island, which closed naturally within several weeks. A breach at Rodanthe (Mirlo Beach) was closed artificially soon after the hurricane. Prior to Hurricane *Irene*, breaches occurred approximately one mile north of Buxton in 1962 (USACE 1963) and near Hatteras Village (west of Buxton) during Hurricane *Isabel* in 2003 (Wutkowski 2004, Walmsley et al 2010). Both breaches were closed artificially within a year to restore vehicle access to the area and to rebuild NC Highway 12, the only road through CAHA.



FIGURE 2.1. Aerial photo taken on 10 September 2014 showing sand movement from north to south and a sand deposit at Cape Point. Sand also accumulates from the west at Cape Point under prevailing winds and waves from the southwest. [Source: CSE]

Avon and Buxton are east-facing beaches near the downcoast terminus of a primary littoral cell extending from the Virginia Capes at the entrance of the Chesapeake Bay to Cape Hatteras, a foreland that marks a prominent turn in the shoreline. A secondary littoral cell that affects Avon and Buxton's beaches extends from south of Oregon Inlet to Cape Point (see Fig 2.1). Beaches within the primary and secondary littoral cells are exposed to similar waves from the northeast and experience some of the highest waves along the US East Coast (Leffler et al 1996). During Hurricanes *Irene* (2011) and *Sandy* (2012), peak wave heights about one mile off Duck and Nags Head, North Carolina (~40 to 55 miles north of Avon), exceeded 27 ft (McNinch et al 2012, CSE 2013). During hurricanes *Florence* (September 2018) and *Dorian* (September 2019), the maximum wave heights at the wave buoy located at Diamond Shoals (NOAA WDBC Station 41025 (~20 miles southeast of Avon)) reached ~30 ft (CSE 2020).

While hurricane waves often propagate and drive sand to the north, more frequent northeast waves produce net southerly transport along Hatteras Island (Inman & Dolan 1989). Sand moving north to south accounts for the extension of Cape Point (see Fig 2.1). West of Cape Hatteras, the ocean shoreline is sheltered from northeast waves, allowing southerly waves to dominate and drive sand east toward Cape Point. Thus, Cape Hatteras and Diamond Shoals are a convergence zone for sand moving along Hatteras Island. Because the northerly waves east of Cape Point are generally more powerful than the southerly waves to the west, the balance of wave energy results in a net westward movement of Cape Hatteras over the long term (see Section 2.2 for more discussion).

Hatteras Island beaches exhibit the full spectrum of conditions from accreting segments (eg – Waves, Salvo, and Frisco to Cape Point) to retreating erosional segments (eg – Pea Island, Rodanthe, and East Buxton) (Morton & Miller 2005, NCDENR 2024). At decadal to century time scales, littoral sand along Hatteras Island is generally conserved, but shifts from segment to segment with alongshore movement of sand waves and across-shore movement of nearshore bars. Along some high-erosion segments, shoreline recession rates exceed 11 ft per year (NCDENR 2024). Accreting segments such as Waves and Salvo exhibit seaward growth rates of >4 ft per year.

Everts et al (1983) prepared a detailed analysis of shoreline change for the Outer Banks, which researched measurements of ocean and sound shoreline positions between the 1850s and 1980s and reviewed earlier maps and charts. This analysis was a cooperative study conducted by the Coastal Engineering Research Center (CERC) and National Ocean Service (NOS) within the US Army Corps of Engineers (USACE) and the National Oceanic & Atmospheric Administration (NOAA) (respectively). Everts et al found that the Outer Banks, on average, was narrowing by ~0.9 meter, or ~3 ft per year, with most of the recession occurring along the oceanfront (~0.8 meter per year

average). The study found that the sound shoreline was stable with an average net recession of 0.1 meter per year (~0.3 foot per year). The Everts et al study theorized that the principal losses of sand along the Outer Banks are associated with inlets, particularly the deposits of sand into the sound (Everts et al 1983). This finding has been corroborated by more recent empirical models (Nienhuis & Lorenzo-Trueba, 2019)

2.2 Background, Purpose, and Need

Compared to other tourism-dependent coastlines, such as New Jersey, South Carolina, and Florida, the Outer Banks have seen relatively few large-scale nourishment projects (ASBPA 2025). However, there is a long tradition of human intervention designed to mitigate coastal erosion and land loss on Hatteras Island. Cape Hatteras National Seashore was established in 1937 when there was already a permanent population of 'Outer Bankers' living on the island chain. As a result, the NPS has committed to mitigating erosion on the islands at various times (Wirth 1952, Binkley 2007).

Past interventions along Cape Hatteras National Seashore include planting vegetation to promote dune stabilization, closing storm-cut breaches following erosional events, and installing dunes or sandbags to prevent surge-driven flooding (Dallas et al. 2013). In more recent decades, NPS has moved away from such active restoration measures as the population of seasonal tourists has grown on the Outer Banks. NCDOT sponsors scraping along NC Highway 12 following overwash events, with excess material placed back on the dry beach.

NPS policy of the 1930s through the 1960s called for active dune building and revegetation efforts along CAHA (Stratton 1957). However, by the 1970s, the policy was reversed, allowing the beach and dunes to evolve without stabilization measures. Because erosion along Hatteras Island has not been uniform during the past century (NCDENR 2024), a spectrum of conditions exists today. In some places, segments of the beach are relatively stable, and natural processes maintain high dunes. In other areas, erosion has encroached on the dunes, and washovers have extended landward into developed uplands or infrastructure, such as NC Highway 12.

Dare County, over the past decade, has coordinated local and county-level funds to initiate and execute beach nourishment projects. In 2017, Buxton became the first community to use this community assistance to subsidize a beach restoration project (CSE 2017). Positive local feedback from that effort and multiple projects along the communities north of Oregon Inlet, listed above, led to the County initiating planning for an additional two projects at Avon and Buxton.

Avon and Buxton are relatively small communities compared to the larger towns along the northern portions of Dare County, but they play a significant role in driving recreational tourism and fishing

in the region. Historically, shoreline erosion rates along portions of Avon and Buxton have been modest compared to more vulnerable locations on the Outer Banks (NCDENR 2024). This is particularly true for most of the Avon Village shorefront and much of the undeveloped beach on either side of Buxton.

Although long considered a stable beach with multiple dune ridges offering protection from rough surf and high water, Avon experienced erosion that has dramatically reduced storm protection since ~1998 (Fig 2.2). Portions of Avon have been particularly affected, along a ~2-mile reach of shoreline south of Avon Pier, where the protective foredune was largely eroded before the 2022 project was initiated (Fig 2.3). CSE was retained by Dare County in 2020 to prepare a feasibility study for sand placement via dredge at Avon and determine whether large-scale renourishment was a practicable solution for the ongoing beach erosion problem. More specific details on the formulation of the Avon project are provided below.

Erosional hot spots near Buxton Village are related to the long-term migration of Cape Hatteras in a southwestward direction, which is driven by large-scale atmospheric and oceanic processes (Fig 2.4, cf – Inman and Dolan 1989). Three groins were built at the old Cape Hatteras Lighthouse in 1969 to help reduce the shoreline recession and provide some degree of protection for the lighthouse itself. Unsuccessful efforts to mitigate erosion on the beachfront at the lighthouse site resulted in NPS moving the structure landward in 1999 (Dallas et al 2013). Although the groins have deteriorated over time, they retain some sand-trapping capacity, and there is an offset in the shoreline between Cape Point and the groins, and between the groins and Buxton Village (Fig 2.1 and Fig 2.5).

Such an offset will necessarily cause a gradient in longshore sediment transport. In the case of Buxton, this has resulted in considerable sand losses along the developed shorefront of Buxton Village. CSE was retained by Dare County to perform a feasibility study for beach restoration at Buxton and recommended large-scale renourishment (CSE 2013). More specific details on the formulation of the Buxton project are provided below.

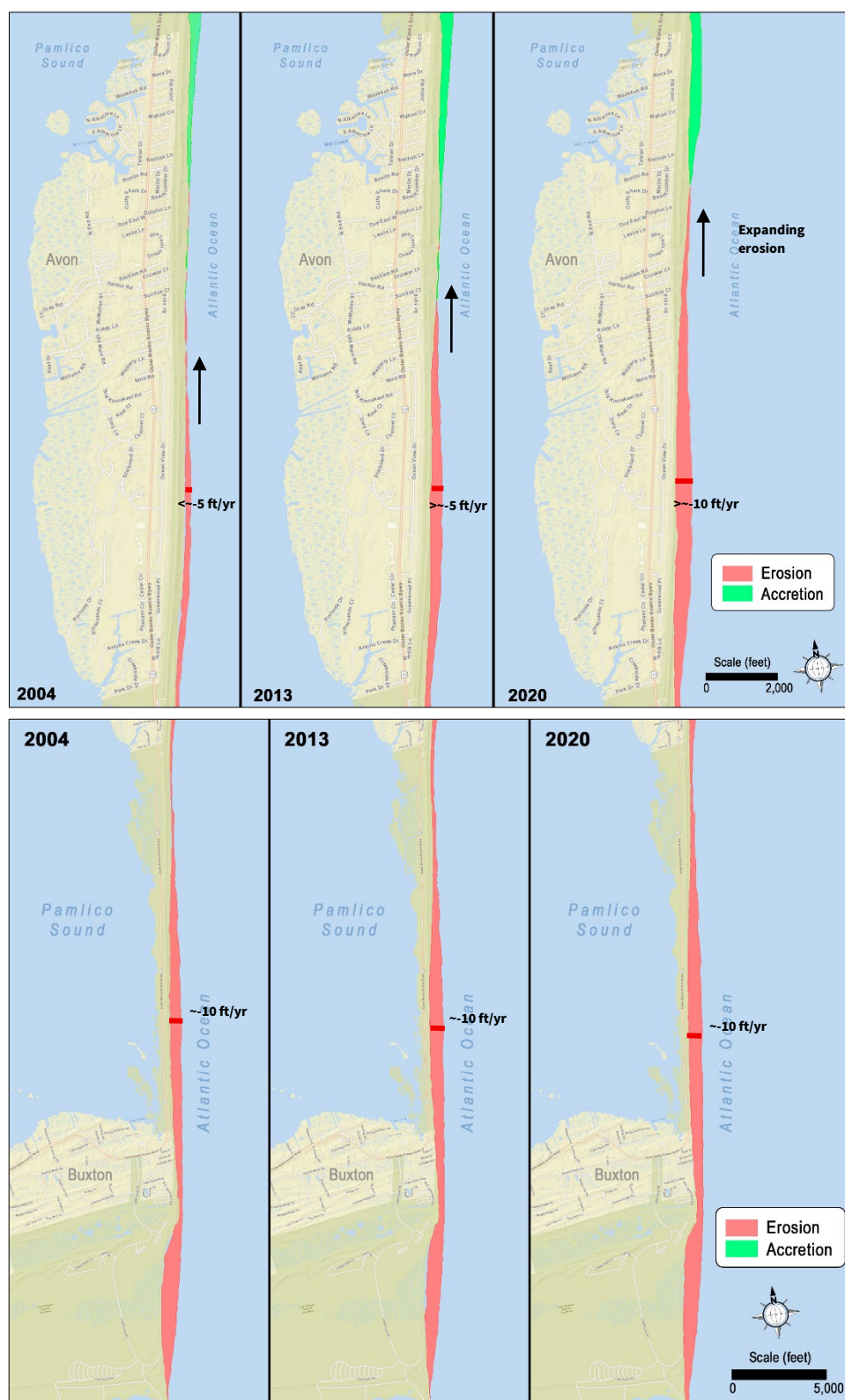


FIGURE 2.2. The state of North Carolina adopts erosion rates to help communities identify hot spots and plan for future changes in shoreline position. **[UPPER]** As recently as 2013, annualized erosion rates along much of Avon ranged from 3 to 5 ft/yr, with only a few locations experiencing more dramatic beach recession. However, by 2020, erosion rates along south Avon in particular were at or above 10 ft/yr. **[LOWER]** At Buxton, the state has observed more than 10 ft/yr of erosion along much of the shoreline for at least 20 years.



FIGURE 2.3. Until the past ~10 to 15 years, erosion rates along south Avon were not dramatically higher than many locations along Hatteras Island. The state-adopted erosion rates along south Avon measured ~4 to 6 ft/yr as recently as 2000, but by 2020 were higher than 15 ft/yr in many locations.

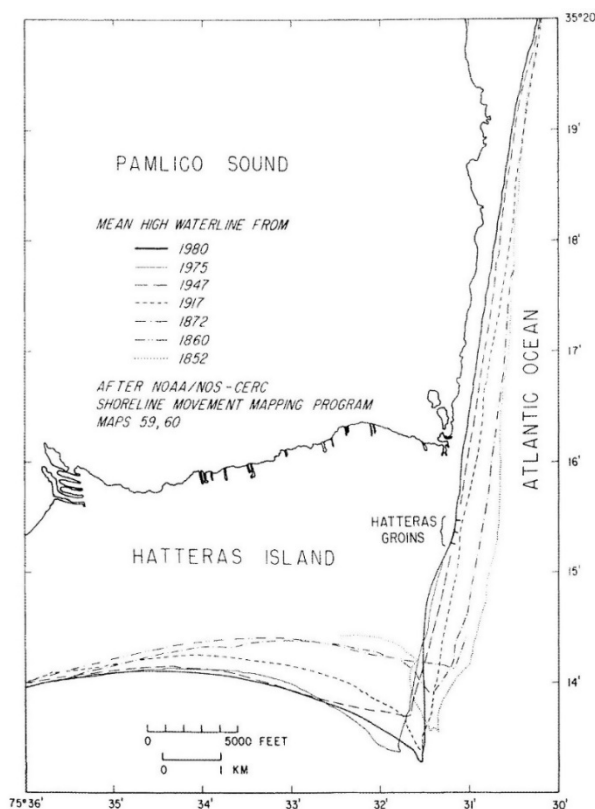


FIGURE 2.4. Historic positions of the shoreline in the Cape Hatteras area. The Village of Buxton is located just north of the Hatteras groins labeled here. Between 1852 and 2022, the shoreline at Buxton Village moved more than one thousand feet westward and resulted in a strong alongshore sediment transport gradient between the village proper and adjacent undeveloped beaches (Everts et al 1983).



FIGURE 2.5. Oblique aerial image of Buxton Village taken from the former lighthouse site on 17 June 2022, just weeks before pumping began.

2.1.1 Avon

Large-scale beach nourishment had not occurred at Avon Village before the 2022 effort. The NC Division of Coastal Management (NCDQM) reported official erosion rates (setback factors) for Avon in 2020, ranging from 2.0 feet per year (ft/yr) north of Avon Pier to 6.0 ft/yr along a ~4,000 ft section of beach south of the pier. Erosion reduces to 3.0 ft/yr at the south limit of the village.

CSE analyzed historical shorelines for fourteen different dates between 1852 and 2020 and determined that the critically eroded section south of Avon Pier has experienced higher erosion over the past 20 years. For example, between 1946 and 1998, shoreline recession averaged ~1.8 ft/yr, whereas it has averaged ~16 ft/yr since ~1998. Because state erosion rates average over 60+ years, the official rate is lower but increasing with each update along south Avon. The cause of accelerated erosion is unclear, but one factor is rhythmic alongshore sand waves spaced ~3000 ft apart that slowly migrate downcoast, producing systematic variations in beach width. The trough (narrow dry beach area) of one such rhythmic sand wave has persisted south of Avon Pier in recent years. These erosion features are likely linked to offshore shoals and the longshore bar system that persists along Outer Banks.

2.1.2 Buxton

Several nourishment projects were conducted in the Buxton area in the 1960s and 1970s, with more recent projects in 2017–2018 and 2022. The two recent projects were constructed along the same stretch of oceanfront and placed approximately 2.6 million cubic yards (cy) of sand along 2.9 miles of beach within and just north of Buxton Village. The annualized erosion rate from February 2018 to August 2020 was over 50 cy/ft/yr along the project area, which is several times higher than the historical average adopted for the design of the 2017–2018 project (9.5 to 10.2 cy/ft/yr). Due to the loss of nearly 75% of the 2017–2018 nourishment volume in the two years following project completion, in 2019, CSE recommended initiating permitting and design for a follow-up renourishment project at Buxton.

The cause of elevated erosion from 2018 to 2020 at Buxton is due to several interacting dynamics related to nearshore bathymetry, the Salient (a bulge in the shoreline) created around the Hatteras groins, and the position of Cape Point. A deep trough with minimum elevations below –25 ft NAVD persists along much of Buxton Village and runs the length of the project area. Once nourishment material is deposited in this trough, wave and current conditions generally do not allow the material to migrate back onshore. Instead, sand spreads away from the salient at the groins with much of it shifting to the segment of beach on the east side of Cape Point (see Fig 2.1).

Another cause of the elevated erosion rates observed at Buxton from 2018 to 2020 is a series of tropical and non-tropical cyclones that impacted the region. Six named storms (*Irma*, *Jose*, *Katia*, *Maria*, *Florence*, and *Dorian*) impacted Cape Hatteras over that period, along with a string of rough nor'easter-type storms in the intervening winter seasons. The relatively short time between storm impacts prevented the beach system from effectively recovering volumes lost from the upper shoreface. This led to rapid reductions in beach volume during relatively minor storms.

The quick succession of multiple named and unnamed storms along the Buxton project site likely exacerbated the rapid erosion observed from 2018 to 2020. Because these storms often approach from the south and west, they also draw sand from north to south along the deep trough mentioned above. This accelerates the loss of volume from the project area.

2.3 Project Sponsor

The 2022 beach renourishment project was sponsored by Dare County, North Carolina. The County served as project owner and administrator. Project funding included contributions from the Dare County Beach Nourishment Fund, a North Carolina Department of Environmental Quality (NCDEQ) grant, and reimbursement from FEMA (Federal Emergency Management Agency), as well as the state

of North Carolina for sand volume loss due to hurricanes *Florence* and *Dorian* under Public Assistance Program Category G – Beaches.

The construction portion of the project, consisting of mobilization/demobilization, dredge-and-fill, and pre- and post-project third-party surveys, cost a total of \$25,870,000. Of this total, Dare County's beach nourishment fund sponsored \$17,996,958. An NCDEQ grant sponsored an additional \$1,557,607, while FEMA and State reimbursements totaled \$6,315,435. The sand fencing and dune grass installation portion of the work was completed for an additional \$79,369.

CSE performs all pre- and post-project engineering, consulting, and monitoring under a separate contract with Dare County.

2.4 Project Planning

2.4.1 Template Design

The project was implemented by two hopper dredges by the Contractor, Great Lakes Dredge & Dock Company (GLDD). The work included dredging, placement, grading, and environmental protection measures (as specified under federal and state permits) of 2,200,000 cubic yards along 28,700 linear feet of Hatteras Island. Both templates were divided into two reaches, as shown below:

Avon

- 1) Reach 3 (Stations 1550+00 to 1590+00) — 172,000 cy over 4,000 linear feet
- 2) Reach 4 (Stations 1590+00 to 1682+00) — 828,000 cy over 9,200 linear feet

Buxton

- 3) Reach 2 (Stations 1770+50 to 1880+50) — 525,000 cy over 11,500 linear feet
- 4) Reach 1 (Stations 1880+50 to 1925+50) — 675,000 cy over 4,500 linear feet

The average fill density (volume of nourishment per linear foot of beach) was 76 cubic yards per foot (cy/ft) of shoreline at Avon and 77 cy/ft at Buxton, which is equivalent to an average beach width increase after natural profile adjustment of ~60 ft. The berm was constructed at +7 ft NAVD with a 1 on 15 seaward slope with initial width varying from ~100 ft (in Reaches 3 and 2) to ~250 ft (in Reaches 4 and 1). Dunes were constructed along Reaches 1 and 4 with an elevation of +13 ft NAVD, a typical crest width of 40 ft, and a seaward slope of 1 on 3.

3.0 METHODOLOGY

3.1 Elevation Survey

In accordance with the monitoring requirements for each project, CSE uses a project baseline and survey profiles at 500 ft spacing for comparison with pre-project data. Profiles extend from the foredune to at least ~2,000 ft offshore and are spaced at 500-ft intervals along both project areas. Stationing for these profiles is based on the same survey network established by CSE for the County in 2013 (CSE 2013), with the origin based at Oregon Inlet and the baseline running along the central axis of Hatteras Island. Individual station numbers are measured in feet south of Oregon Inlet and are recorded using standard engineering notation.

Surveys were performed using a Trimble™ Model R10 GNSS with VRS RTK-GPS for backshore, intertidal, and surf-zone work (Fig 3.1). Bathymetry seaward of the surf zone was obtained using an Applanix POS MV Surfmaster positioning system linked to a precision fathometer (Odom Echotrac CV 100 and SMSW200–4a transducer) mounted on CSE’s research vessel, the *R/V Southern Echo*. Raw data were collected at 50 hertz (Hz) (or 50 points per second). Data were collected in x–y–z format and converted to x–z format (distance–elevation pairs), referencing survey monuments for direct comparison with historical data. Raw data were filtered and averaged using HYPACK® software and were reduced to a manageable size for each profile. CSE’s precision for bathymetric profiles is ± 3 centimeters in the horizontal and ~ 5 centimeters (~ 2 inches) in the vertical, with vessel track lines ± 20 ft from the planned route.

3.2 Volume Calculations

The basic approach to beach monitoring is to track the volume of sand in the beach zone within a specified ‘sand box’ filled nearly to the top along the landward edge and tapering to a thin layer along the seaward edge. The total volume in this sandbox is measured before nourishment and compared to post-project surveys. The differences between these volume measures represent the approximate amount of sand losses (erosion) or gains (accretion) over the survey period. This section describes CSE’s methodology for calculating these volumes using survey data.

CSE computes the ‘unit volume’ of sand in each profile within prescribed contour intervals or cross-shore positions. Unit volumes are the amount of sand (in cy) contained in a one-foot length of beach (ie – cy/ft) between the foredune or some reference backshore limit and a particular depth offshore (Fig 3.2). In most cases, the crest of the foredune is the standard geomorphic indicator for starting distances. Around oceanfront buildings, the seaward edge of man-made structures is used as a baseline.

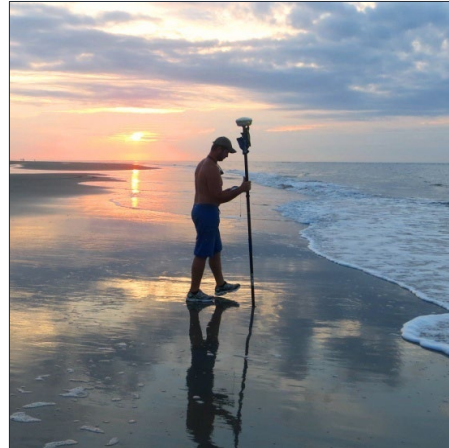


FIGURE 3.1.

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

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

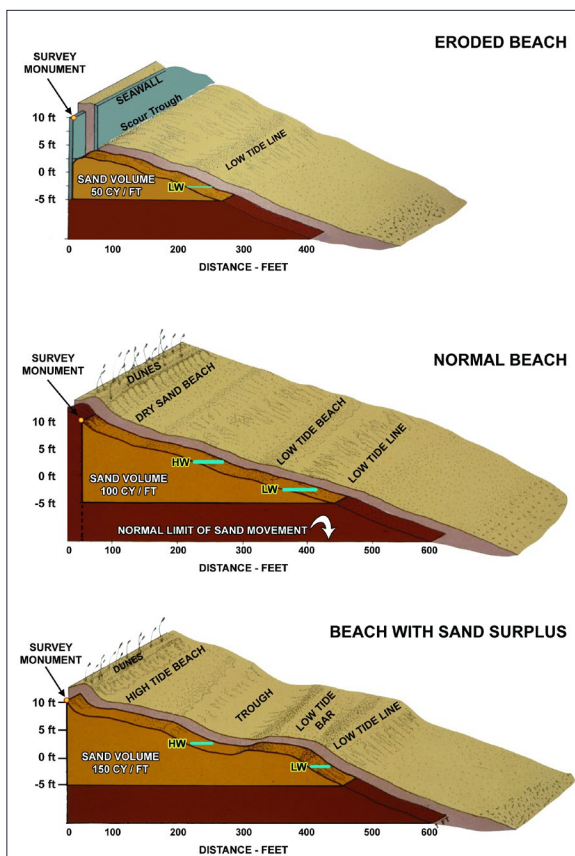


FIGURE 3.2. 'Unit volume' is the quantity of sand contained in one unit length of beach from the foredune/seawall to some designated depth offshore.
[From Kana 1990]

These measurements account for variability among profiles and yield an objective quantity for comparison. Changes in unit volume can be interpolated between adjacent profiles to yield net volume change. The net volume change is compared year-to-year and profile-to-profile.

Most changes in bottom elevation that could affect dry beach widths on Hatteras Island occur above –30 ft NAVD (Barrineau et al 2021). CSE adopted this contour for ‘closure depth’ (aka ‘DOC’ – depth of closure), representing the seaward limit of measurable elevation change at both sites. This depth represents the outer limit of the active littoral zone within which beach sands move from year to year. CSE also computed changes above other depths (+7 ft NAVD, –6 ft NAVD, –19 ft NAVD, and –24 ft NAVD) to assess volume changes along different portions of the active beach profile:

Storm waves generally shift sand from the dunes and beach (above +7 and –6 ft NAVD, respectively) to the trough or even deeper beyond the bar (above –19, –24, or –30 ft NAVD). Calculating volume changes above the upper lens depths often reflects more recent wave and wind conditions, whereas measurements to closure depth represent a more holistic accounting of beach volumes.

Beach profiles are commonly grouped into continuous portions of shoreline known as ‘reaches.’ This enables engineers and resource managers to effectively track the volume of sand contained within a particular section of beach. In some cases, prominent features like a rocky headland or tidal inlet serve as natural boundaries between reaches. For the purposes of post-project monitoring, this report distinguishes five reaches along Avon and four along Buxton; these are listed in Table 3.1. Along both sites, the central two reaches represent the extent of the fill areas for the 2022 project. The end reaches represent adjacent portions of the NPS-administered shoreline with little to no shorefront development.

3.1 Aerial Photography

CSE maintains and operates a DJI Phantom 4 Pro (P4P) unmanned aerial system (UAS, or ‘drone’) to collect aerial imagery. A Federal Aviation Administration (FAA)-licensed UAS pilot oversees the safe operation of the UAS at all times as required by federal regulations. The P4P is equipped with a 20-megapixel, 1-inch CMOS image sensor and a mechanical shutter. This payload yields a powerful camera that can be utilized for both oblique and vertical aerial photography. The drone can map ~150 acres with a flight time of ~30 minutes on a single battery. The use of multiple batteries allows coverage of larger areas on numerous flights.

TABLE 3.1. Project area (shaded) and monitoring reach boundaries for the Avon and Buxton renourishment projects. The 2022 project placed sand along Reaches 3 and 4 (the 'Pier' and 'Central' reaches) of Avon, and the 'NPS' and 'Buxton' reaches of Buxton.

Project Area	Reach	Station	Project Area	Reach	Station
Avon	1 - "NPS"	1470+00	Buxton	Upcoast	1720+00
		1475+00			1725+00
		1480+00			1730+00
		1485+00			1735+00
		1490+00			1740+00
		1495+00			1745+00
	2 - "North Avon"	1500+00		NPS	1750+00
		1505+00			1755+00
		1510+00			1760+00
		1515+00			1765+00
		1520+00			1770+00
		1525+00			1775+00
		1530+00			1780+00
		1535+00			1785+00
		1540+00			1790+00
		1545+00			1795+00
	3 - "Pier"	1550+00			1800+00
		1555+00			1805+00
		1560+00			1810+00
		1565+00			1815+00
		1570+00			1820+00
		1575+00			1825+00
		1580+00			1830+00
		1585+00			1835+00
	4 - "Central"	1590+00			1840+00
		1595+00			1845+00
		1600+00			1850+00
		1605+00			1855+00
		1610+00			1860+00
		1615+00			1865+00
		1620+00			1870+00
		1625+00			1875+00
		1630+00			1880+00
		1635+00		Buxton	1885+00
		1640+00			1890+00
		1645+00			1895+00
		1650+00			1900+00
		1655+00			1905+00
		1660+00			1910+00
	5 - "South"	1665+00		Downcoast	1915+00
		1670+00			1920+00
		1675+00			1925+00
		1680+00			1930+00
		1685+00			1935+00
		1690+00			1940+00
		1695+00			1945+00
		1700+00			1950+00
					1955+00
					1960+00
					1965+00
					1970+00
					1975+00
					1980+00

4.0 BEACH AND INSHORE SURVEYS

The monitoring results presented herein focus on the beach condition as surveyed at Avon and Buxton in October 2024. These results are compared to pre- and post-project conditions measured in May-June 2022 and August 2022, respectively, as well as to Year 1 conditions in August 2023 and September 2023. Results are presented first as large-scale changes across both project areas above the local DOC (~30 ft NAVD), followed by a more focused analysis of changes above different depths and within individual reaches. Tables containing station- and reach-specific survey results are provided in Appendices A-2 and A-4.

4.1 Avon Summary Results to -30 ft NAVD (local DOC)

CSE measured an increase of 868,298 cy above -30 ft NAVD along the Avon project area between May and August 2022. This quantity includes background changes and differs from the contract and dredge survey volumes, which followed a tighter survey grid (100 ft versus 500 ft spacing between profiles) and measured in situ volumes immediately following placement.

Between August 2023 and October 2024, the project area at Avon lost ~731,000 cy (-56.2 cy/ft) of sand above -30 ft NAVD (local DOC). Only 20% of the project volume remains in the active beach profile above the local DOC. Including adjacent upcoast and downcoast reaches, the Avon survey area lost ~922,500 cy (-40.1 cy/ft) between August 2023 and October 2024.

Figure 4.1 shows unit volume changes by station from August 2023 to October 2024 and unit volume changes by reach from July 2020 (CSE's initial survey) through October 2024. The greatest losses along any depth at Avon occurred within ~2,000 feet of Avon Pier and correspond to the locations receiving the highest fill densities during the 2022 project. This is a common observation following beach nourishment projects, indicating that the fill template is equilibrating to natural background wave and current conditions. These areas of volume loss within the fill template tend to spread laterally and decrease in magnitude over the first year or two following project completion.

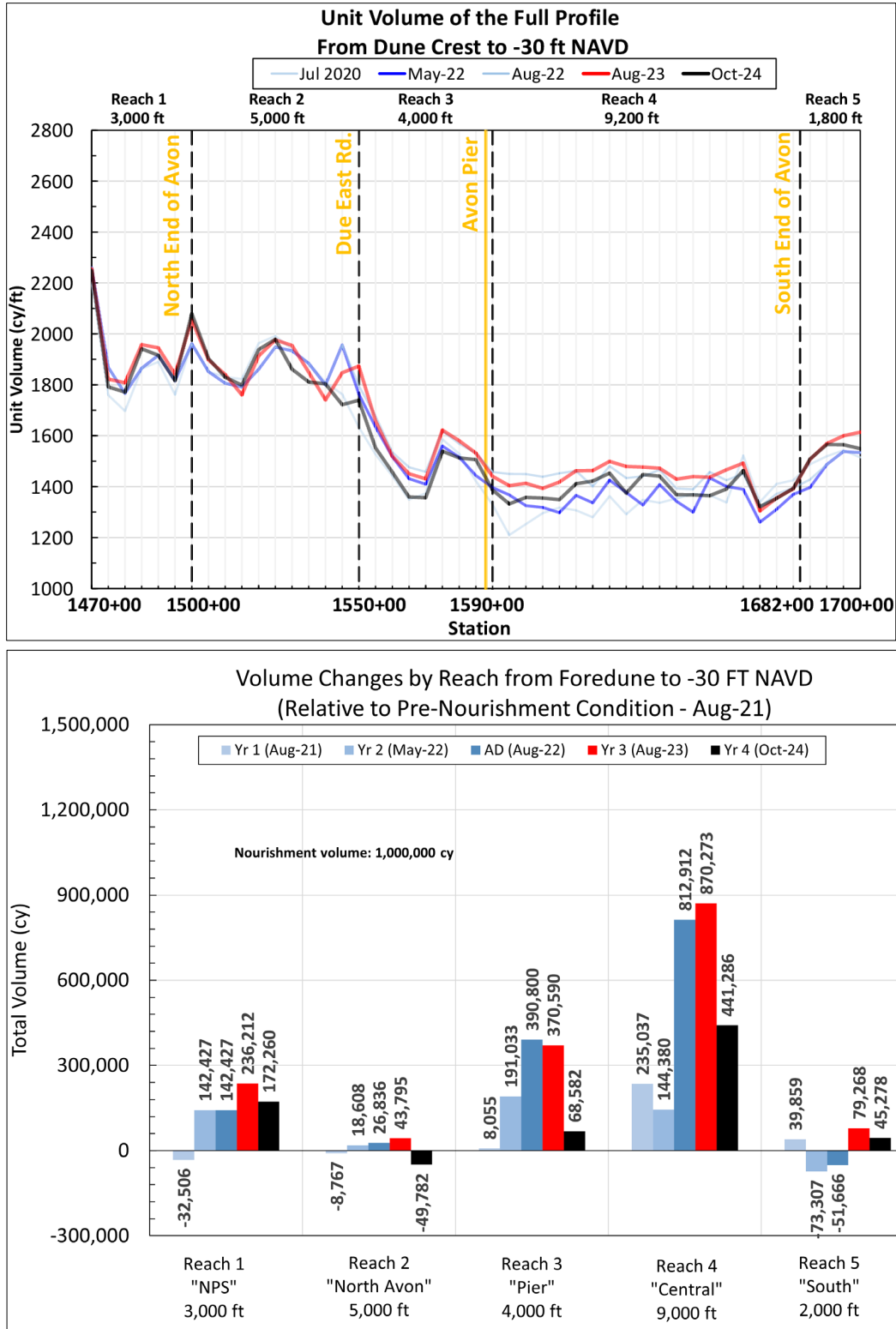


FIGURE 4.1. Unit volume change by station (upper) and reach (lower) along Avon from July 2020 to October 2024. Computations are to -30 ft NAVD the local DOC. The greatest changes above DOC occurred along Reaches 3 and 4, which constitute the entire length of the 2022 nourishment template. The substantial volume decrease between September 2023 and October 2024, measured in Reaches 1 and 5, indicates that nourishment sand is spreading away from the project area and feeding adjacent reaches.

4.1.1 Changes by Depth and Reach

-24 ft NAVD

Along Avon, changes observed out to the -24 ft contour include all changes to the wet and dry beach, trough, and alongshore bar. Although more than 99% of the observed volume changes along the Avon project area are measured above the -24 ft NAVD depth contour, much of the Pier Reach profiles exhibit changes between the -24 ft and -30 ft contours.

From August 2023 to October 2024, the project area lost ~378,240 cy (-29.1 cy/ft) above -24 ft NAVD. Losses observed above higher contours (discussed below) were probably transported into deeper water and helped keep losses above -24 ft NAVD relatively low. Within the project area, Reach 3 lost ~258,060 cy (-64.5 cy/ft), and Reach 4 lost ~120,170 cy (-13.4 cy/ft). Including adjacent upcoast and downcoast reaches, the Avon survey area lost ~368,760 cy (-16.0 cy/ft) above -24 ft NAVD.

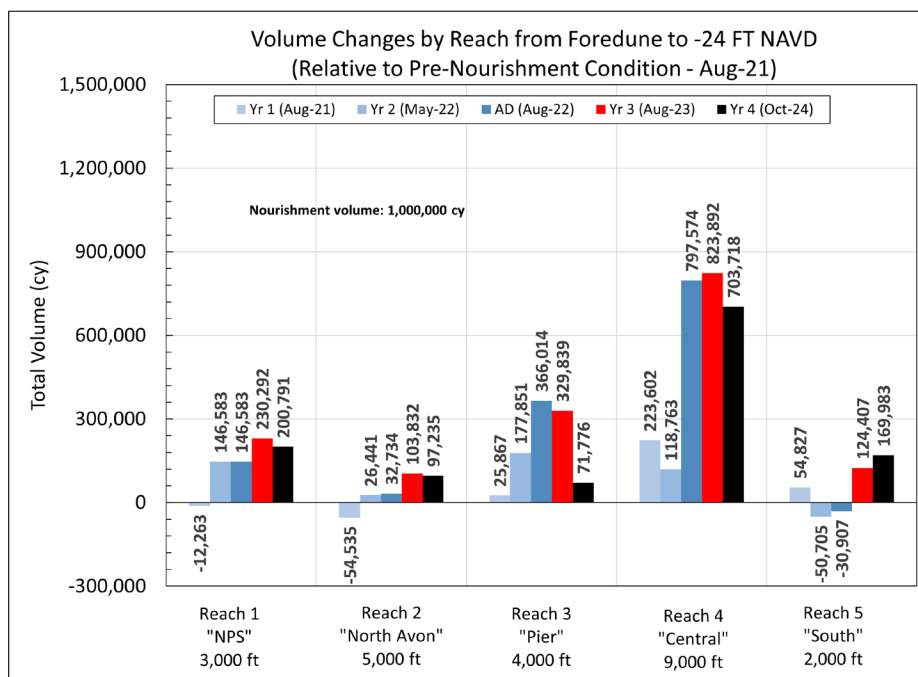


FIGURE 4.2a. Total volume changes of the project area above -24 ft NAVD since the pre-project condition (August 2021).

-19 ft NAVD

The -19 ft contour includes the landward side of the nearshore trough and the most active portions of the beach profile along Avon. Volumes above this contour absorb the primary impact of wave energy during minor to moderate-strength storm events.

From August 2023 to October 2024, the project area at Avon gained ~22,400 cy (1.7 cy/ft) above –19 ft NAVD. Within the project area, Reach 3 lost ~192,300 cy (–48.1 cy/ft), and Reach 4 gained ~214,710 cy (+23.9 cy/ft). Including adjacent upcoast and downcoast reaches, the Avon survey area gained ~197,700 cy (8.6 cy/ft) above –19 ft NAVD.

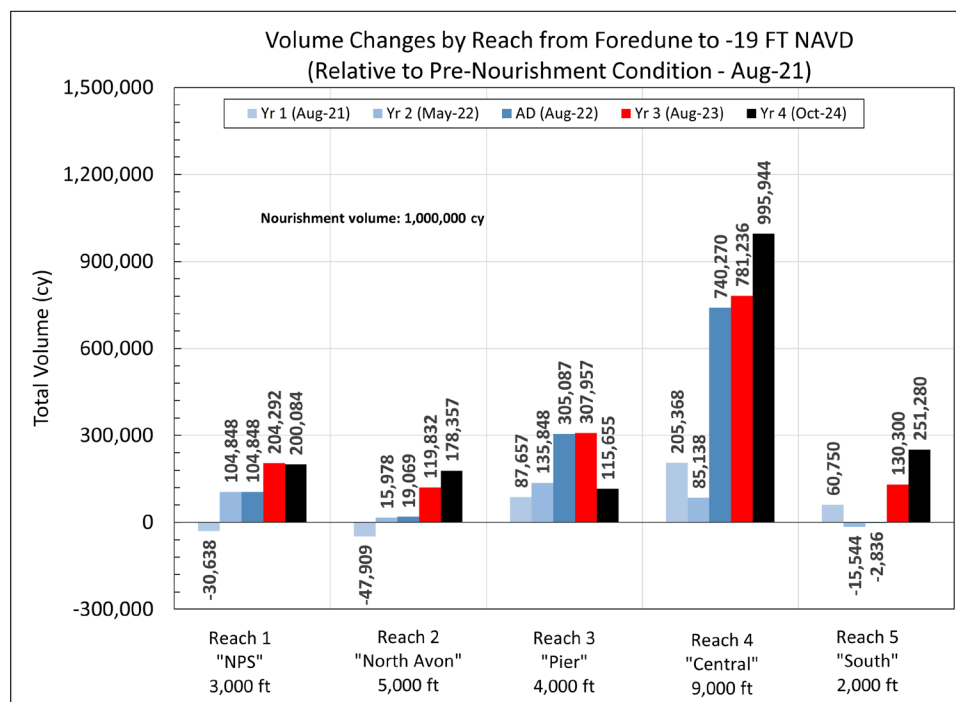


FIGURE 4.2b. Total volume changes of the project area above –19 ft NAVD since the pre-project condition (August 2021).

–6 ft NAVD

The logistics of constructing a beach nourishment project restrict sand placement to elevations above the MLW contour. Factoring in the ‘run out’ of sediment from that elevation toward deeper water that occurs with any shorefront sand placement effort, the post-construction template typically extends beyond the –6 ft NAVD contour.

Above the –6 ft contour, CSE surveys detected a total volume increase of 973,037 cy between May and August 2022; this volume is close to the contract volume of 1,000,000 cy because most of the fill template had not yet been transported into deeper water before the post-project survey. From August 2023 to October 2024, the Avon project area lost ~222,520 cy (–17.1 cy/ft) above –6 ft NAVD. Including adjacent upcoast and downcoast reaches, the Avon survey area lost ~282,550 cy (–12.3 cy/ft) above –6 ft NAVD.

These losses were entirely offset by volume increases in deeper water. This means these losses represent the equilibration of the fill template to background wave and wind conditions, and the loss

rates observed from August 2023 to October 2024 above –6 ft NAVD should decrease in future surveys. However, erosion attributed to nearshore trough and bar movement has been excessive over the past year. While it is not possible to know when this temporary increase in erosion rates will subside, the bar along project areas is closer to the shoreline than in any previous survey.

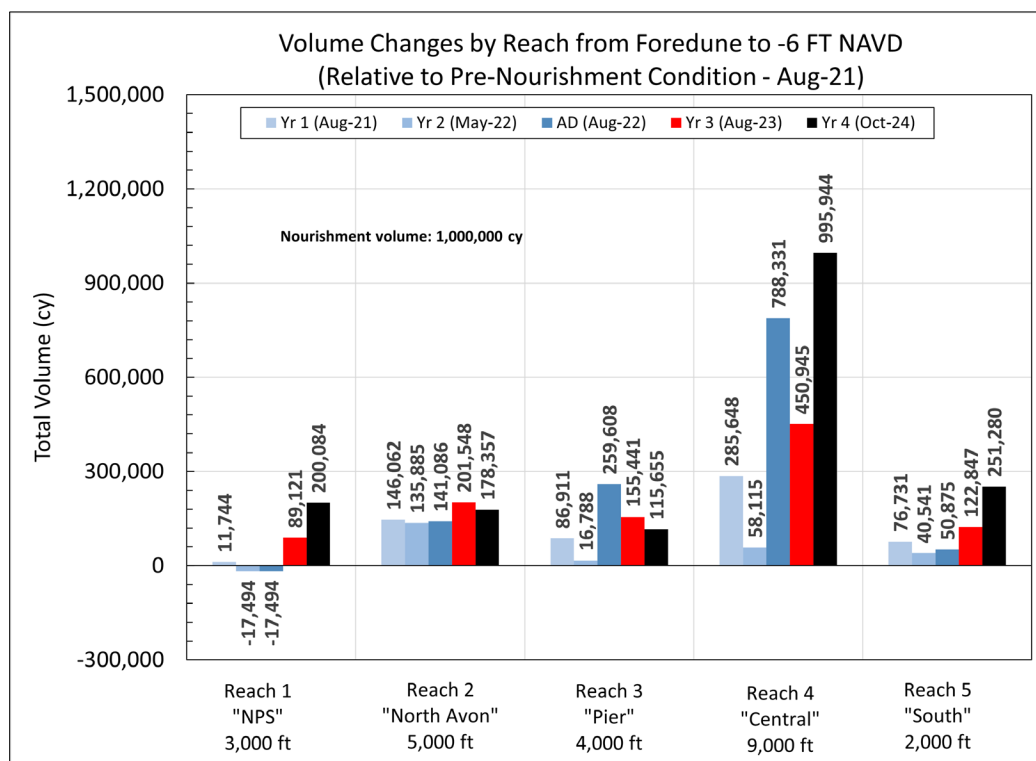


FIGURE 4.2c. Total volume changes of the project area above –6 ft NAVD since the pre-project condition (August 2021).

+7 ft NAVD

Changes above the +7 ft NAVD contour indicate volume gains above the design elevation of the nourishment berm. From August 2023 to October 2024, the Avon project area gained ~61,890 cy (4.8 cy/ft) above +7 ft NAVD. Including adjacent upcoast and downcoast reaches, the Avon survey area gained ~183,910 cy (8.0 cy/ft) above +7 ft NAVD.

This volume increase is reflected in the qualitative improvement of foredune conditions between the pre- and post-project surveys, as well as the October 2024 survey at Avon. A continuous foredune with crest elevations above the storm wave run-up height (>15 ft NAVD along much of the Outer Banks) is the best means of protecting developed uplands, minimizing overwash, and lessening loss of beach sands to the back barrier. While the foredune along Avon has become healthier after being nourished by natural additions of sand, we expect this trend to reverse in the near future due to sand losses offshore.

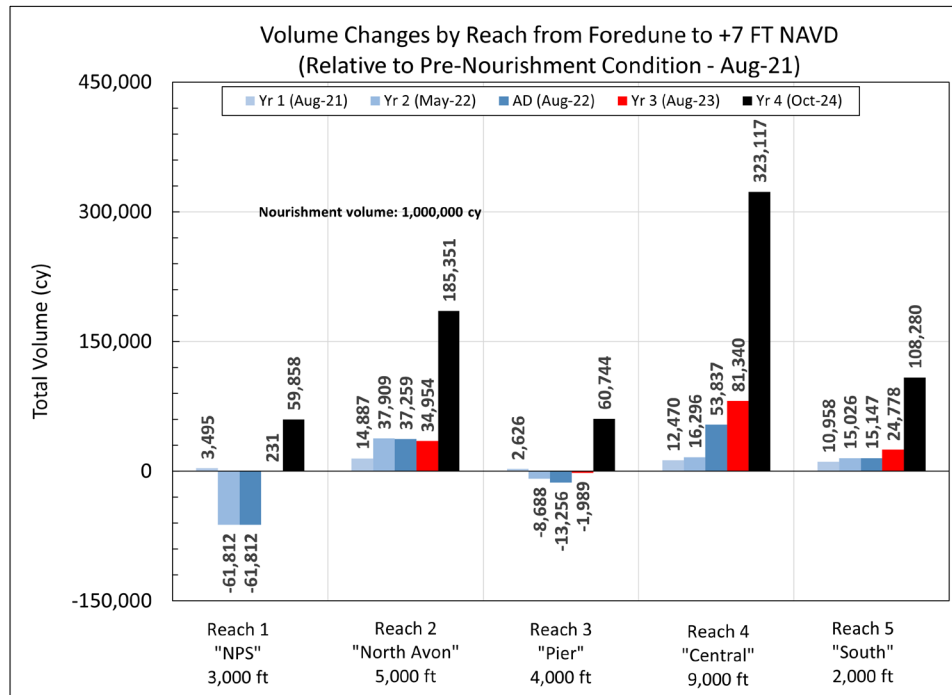


FIGURE 4.2d. Total volume changes of the project area above +7 ft NAVD since the pre-project condition (August 2021).

4.2 Buxton Summary Results to -30 ft NAVD (local DOC)

CSE measured an increase of ~1,604,000 cy above -30 ft NAVD along the Buxton project area between May and August 2022. This quantity includes background changes and is thus different from the contract and dredge survey volumes, which followed a tighter survey grid (100 ft versus 500 ft spacing between profiles) and measured in situ volumes immediately following placement.

The Project Area at Buxton lost ~1,593,510 cy (-99.6 cy/ft) of sand above -30 ft NAVD between September 2023 and October 2024. Along the 'National Seashore' Reach north of the Village of Buxton, the beach lost ~1,011,000 cy (-87.9 cy/ft) and retains 1.4% of the project volume. Along the village, the beach lost ~582,500 cy (-129.4 cy/ft) and retains less than 0% of the project volume. Including adjacent upcoast and downcoast reaches, the Buxton survey area lost ~2,175,020 cy (-83.7 cy/ft) between September 2023 and October 2024.

Figure 4.2 shows unit volume changes by station from September 2023 to October 2024 and comparative aerial photos of the September 2023 and October 2024 conditions along the central project area. The most significant losses along any depth at Buxton occurred along the developed village shoreline, particularly just north of the Hatteras Motel and in the vicinity of the three groins at the former Hatteras Lighthouse site.

The other hot spot near the old lighthouse site is located along two features that can alter year-to-year volume changes. The first is a bulge in the shoreline that creates an offset between MHW along Buxton Village and the undeveloped National Seashore to the south. The shoreline offset tends to draw sand away from the area around the groins via the same mechanism that tends to erode headlands on higher-relief coasts (wave refraction). Stronger-than-usual wave energy out of the south between September 2023 and October 2024 may have led to increased erosion just north of this offset, due to the reduction in longshore sediment transport caused by the groins. This phenomenon is described in more detail in Section 5.1.

The second is a ~30-ft-deep shore-parallel trough that runs along much of the project area. Bar-trough behavior in wave-dominated environments is often cyclical; the offshore distance between MHW and the bar crest will change with wave and current conditions (Castelle and Masselink 2022). Reviewing CSE's annual surveys from 2016, it appears that the bar was last at its current configuration in 2019. From 2016 through 2019, the bar moved ~500 ft onshore with a crest elevation decrease of ~2 to 3 ft (left side of Fig 4.3). Over the same period, the deepest portion of the trough also shoaled from ~-30 ft to ~-20 ft.

Then, from 2019 to 2020, the bar moved ~500 ft offshore and shoaled upward by ~2 to 3 ft. Over the same period, the trough elevation dropped from ~-20 ft NAVD to ~-25 ft NAVD. From 2020 through the October 2024 survey, the crest elevation of the bar has remained relatively constant, but the crest has also gradually migrated landward relative to its 2019 position off Buxton Village (right side of Fig 4.3). Over the same period, the deepest portion of the trough has also moved ~500 ft landward and increased from ~-25 ft NAVD in 2023 to ~-30 ft NAVD in 2024.

Over the period from 2020 to 2024, following the 'reset' in which the bar moved offshore from 2019 to 2020, the bar has also attached to the active beach face (eg – a less pronounced trough present) along the northern end of the survey area in the National Seashore. The location of this attachment zone has gradually moved south from Station ~1730+00 in 2020 to Station ~1780+00 in 2021, Station ~1810+00 in 2022, Station ~1830+00 in 2023, and Station ~1875+00 in 2024 (Fig 4.4). It is unclear whether this feature will continue migrating toward Buxton Village or begin shifting north at some point in the near future.

A deep shore-parallel trough can serve as a conduit for longshore sediment transport away from the upper beach, with the direction of transport (north or south) depending on predominant conditions. Shifts in the bar crest position and depth alter the hydrodynamic balance of forces in the trough between the bar and Buxton Village. South of the village, the groins keep the position of MHW constant relative to the offshore position and depth of the trough and bar.

During periods in which the bar and trough move landward, erosion and loss of dry beach area along Buxton Village are likely to be relatively high. This was certainly the case between 2016, 2019, and 2024, when the project area (including NPS Reach 2) along Buxton lost nearly one million cy. By comparison, during periods in which the bar and trough move seaward or remain relatively constant, losses along Buxton Village are likely to be relatively low.

It is likely that the current arrangement of the bar, relatively close to MHW and relatively deep at the crest, triggered higher-than-average erosion rates along Buxton Village. If the current cycle of bar-trough behavior mimics the one observed from 2016 through 2020, a seaward reset in the bar position should lead to reduced erosion rates along the village. The exact timing of such an event is difficult to predict without a more detailed analysis.

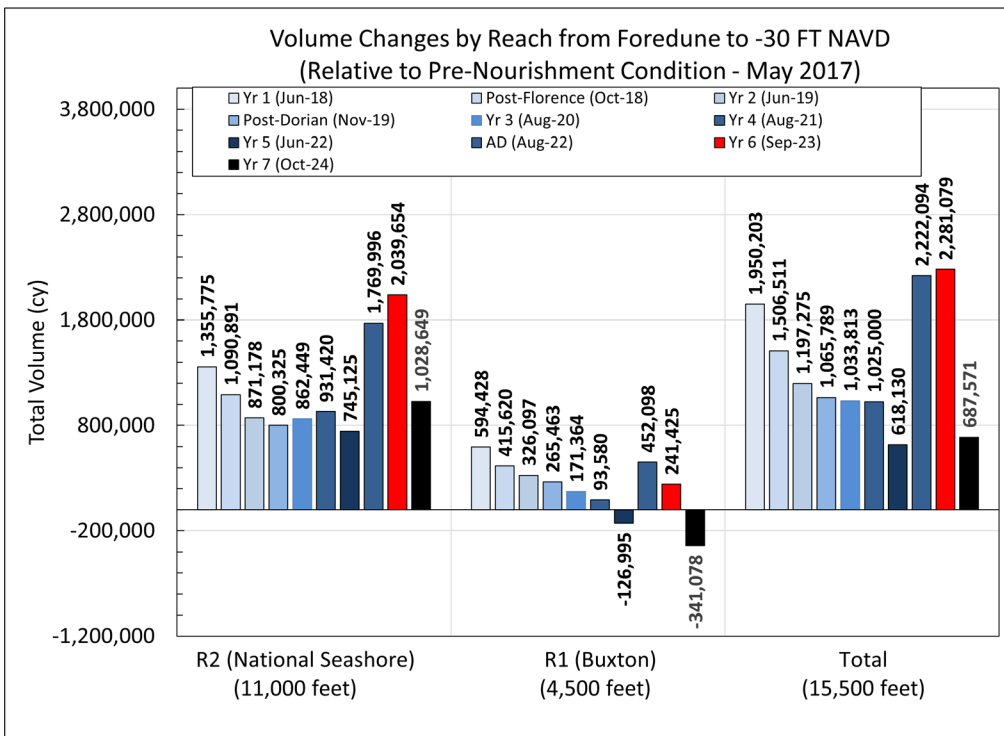
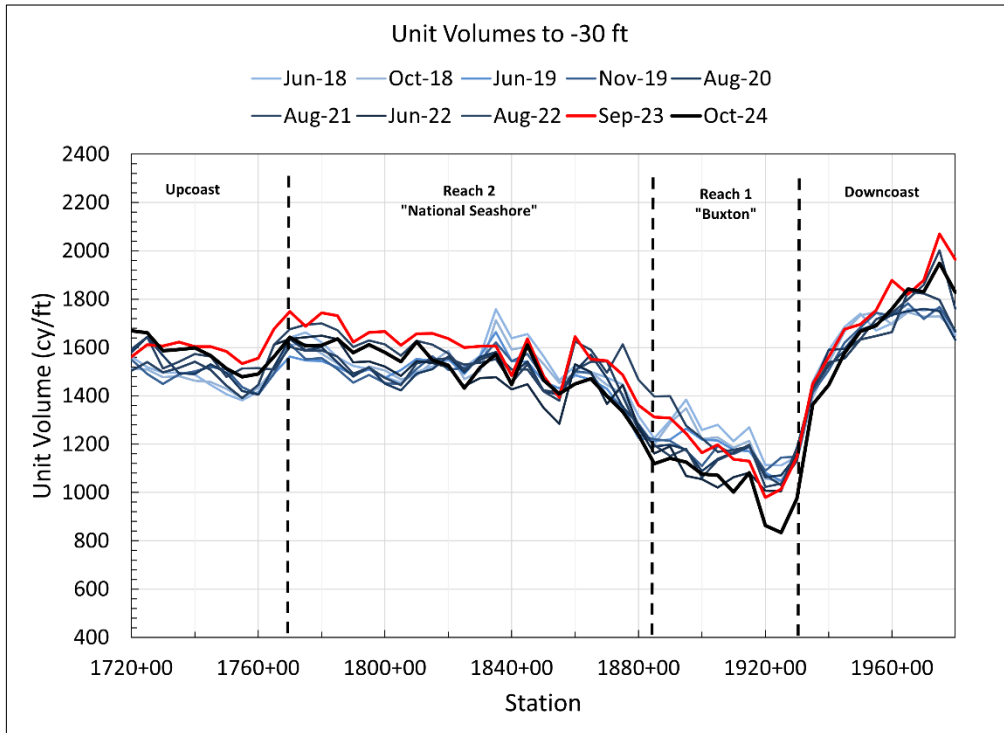


FIGURE 4.3. Unit volume change by station (upper) and reach (lower) along Buxton from October 2014 to October 2024. Computations are to -30 ft NAVD the local DOC. The greatest changes above DOC occurred along Reaches 1 and 2, which constitute the entire length of the 2022 nourishment template. Substantial volume increases between September 2023 and October 2024, measured in the Upcoast and Downcoast reaches, indicate nourishment sand is spreading away from the project area and feeding adjacent areas.

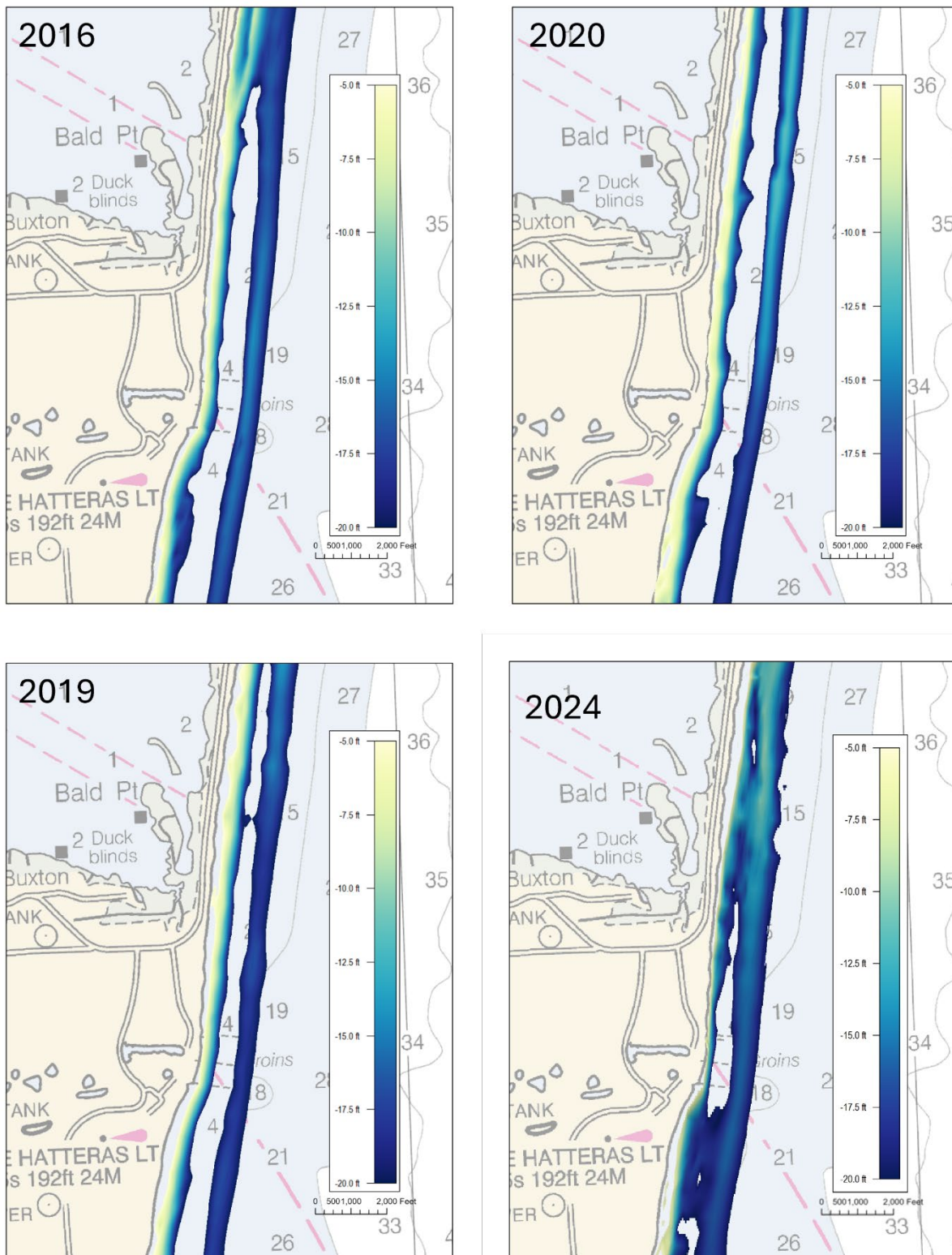


FIGURE 4.4. Position of the offshore bar from 2016 to 2024, with elevations clipped to the range between -5 ft and -20 ft NAVD. From 2016 to 2019, the bar shifted onshore by ~500 ft. This led to a steeper shoreface along the village, and increased erosion rates during that time period. From 2019 to 2020, the bar jumped back to near its ~2016–2017 position, and erosion began to slow. From 2019 to just before the 2022 project, erosion slowed to about 20% of the rate observed from 2016 to 2019. From 2023 to 2024, the bar moved landward, and erosion rates accelerated.

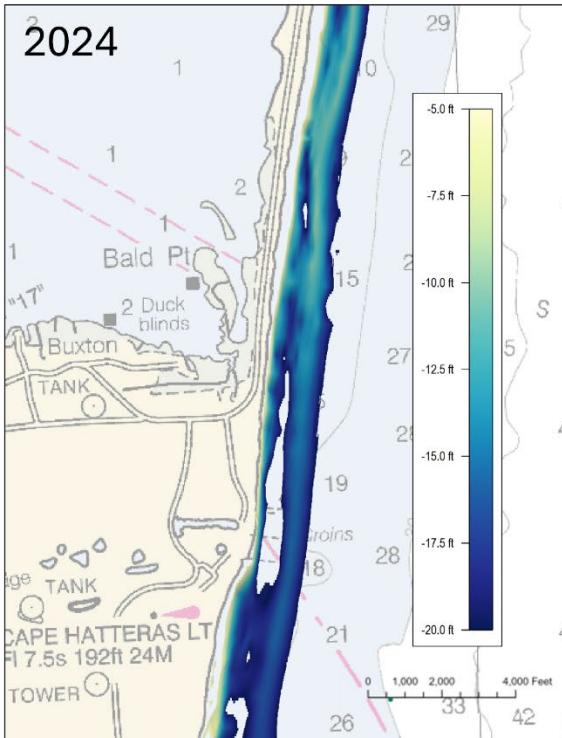
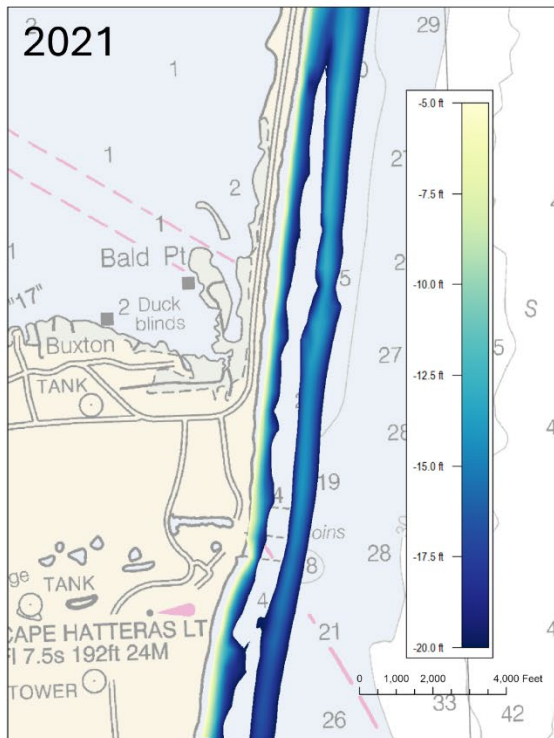
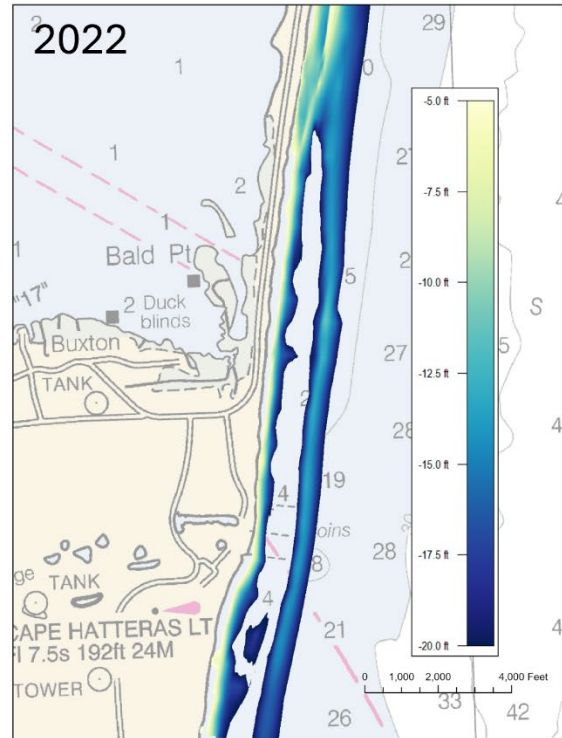
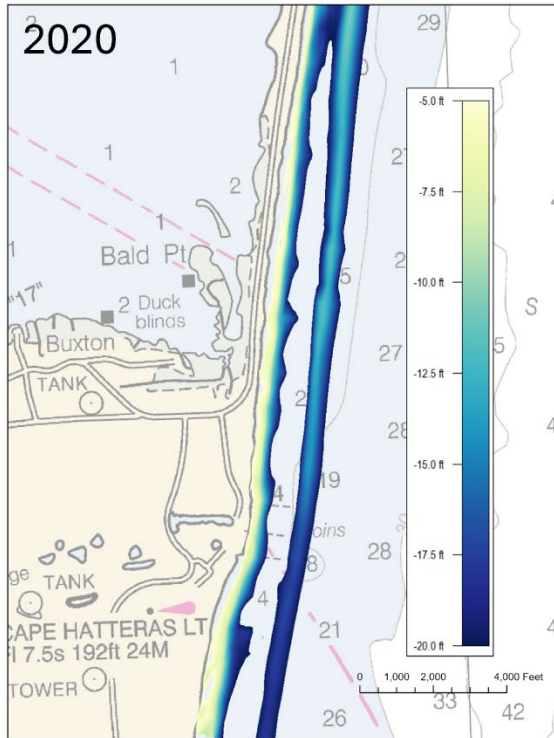


FIGURE 4.5. The offshore bar remains ‘attached’ to the active beach face ~1 to 2 miles north of Buxton village along the Seashore. From 2020 to 2024, this attachment zone has migrated towards the village by 5,000 ft from 2020 to 2021, by 3,000 ft from 2021 to 2022, from 2022 to 2023 by ~2,000 ft and by 4,500 ft from 2023 to 2024.

Note: The blank areas within the digital bathymetry represent depths greater than 20 ft NAVD.

4.2.1 Changes to Upcoast and Downcoast Reaches

Upcoast (1720+00 to 1765+00) mostly saw accretion compared to the pre-project condition (May 2017), although this portion was not nourished. Overall, upcoast gained ~115,150 cy (+25.59 cy/ft) on dry beach above +7 ft NAVD and ~588,000 cy (+130.67 cy/ft) above -24 ft NAVD between May 2017 and October 2024 (Fig 4.5). From September 2023 to October 2024, the upcoast gained about ~19,740 cy (+4.39 cy/ft) above -24 ft NAVD, ~67,470 (13.5 cy/ft) above -19 ft NAVD, ~228,050 cy (45.6 cy/ft) above -6ft NAVD, and 53,800 cy (+11.96 cy/ft) above +7 ft NAVD.

Between May 2017 and October 2024, Downcoast (1930+00 to 1980+00) experienced a gain above +7 ft NAVD, as well as alternative accretion and erosion above -6ft NAVD and -24 ft NAVD, due to the bar trough movement. Overall, Downcoast gained 87,920 cy (+17.59 cy/ft) on dry beach and 599,630 cy (+119.93 cy/ft) above -24 ft NAVD. Between September 2023 and October 2024, Downcoast lost ~117,020 cy (-23.40 cy/ft) above -24 ft NAVD due to the landward movement of the trough at 1930+00. Above -19 ft NAVD Downcoast lost ~115,690 cy (-23.1 cy/ft) and lost ~117,540 cy (-23.5 cy/ft) above -6 ft. However, Downcoast gained ~20,030 cy (+5.61 cy/ft) above +7 ft NAVD.

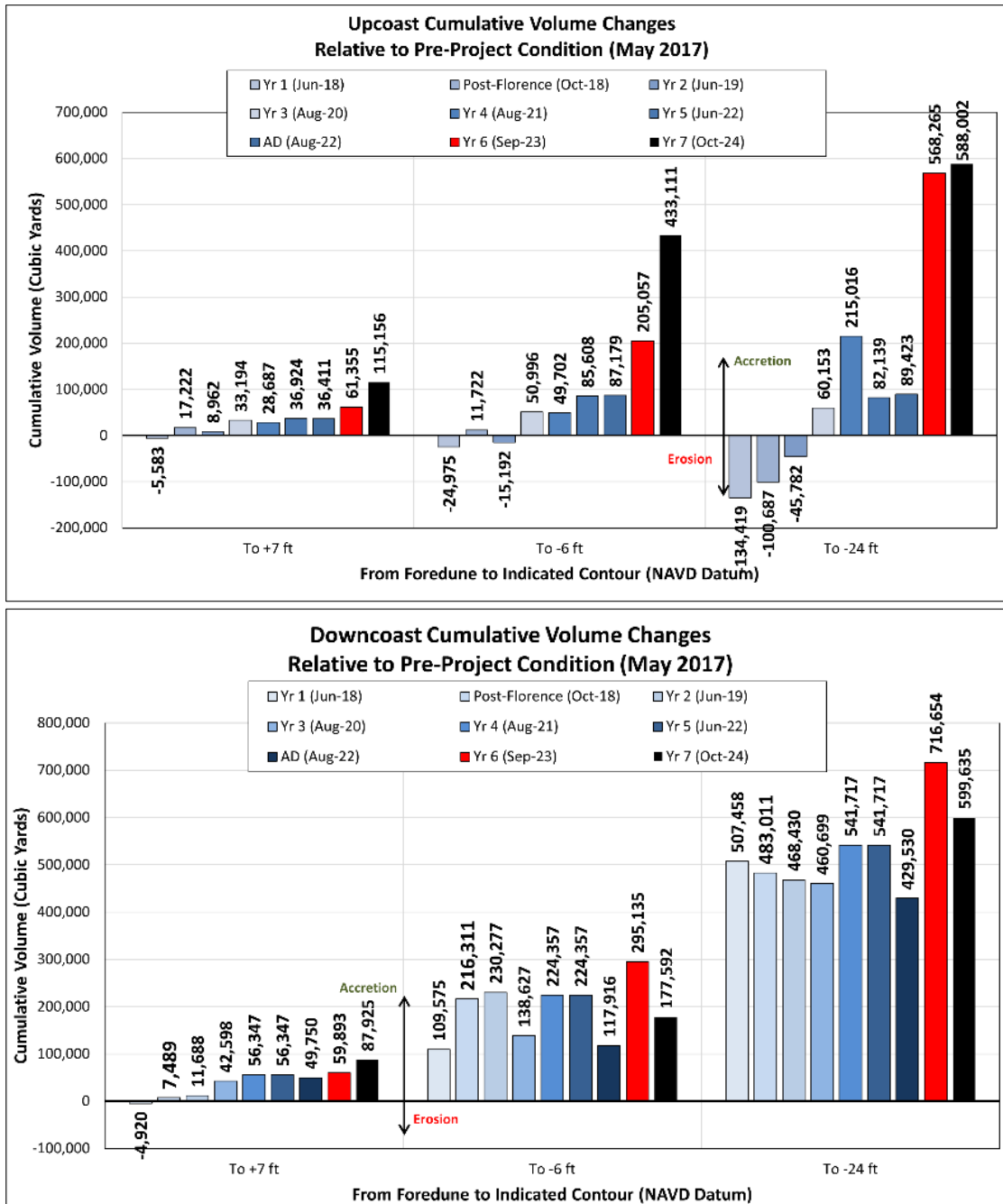


FIGURE 4.6. Total volume changes of Upcoast (top) and Downcoast (bottom) since the pre-project condition (May 2017). Volume increases between September 2023 and October 2024, measured in the Upcoast at all the lens depths and Downcoast reaches at +7 ft NAVD.

4.2.2 Changes by Depth and Reach within the Project Area

-24 ft NAVD

The -24 ft contour includes the seaward side of the nearshore bar running along much of the Buxton survey area. Volumes above this contour absorb the primary impact of wave energy during minor to moderate-strength storm events. From September 2023 to October 2024, the project area lost ~1,077,430 cy (-67.3 cy/ft) above -24 ft NAVD. This total includes a ~-634,340 cy (-55.2 cy/ft) loss in the National Seashore Reach north of the village and a ~443,090 (-98.5 cy/ft) loss in the village.

Losses along the village between August 2022 and September 2023 occur primarily above the -6 ft NAVD contour (-279,770 cy, or -62.2 cy/ft). However, between September 2023 and October 2024, losses extended below the -6 ft NAVD contour. Between -6 ft NAVD and -24 ft NAVD, the Village Reach lost ~315,320 cy (-70.1 cy/ft).

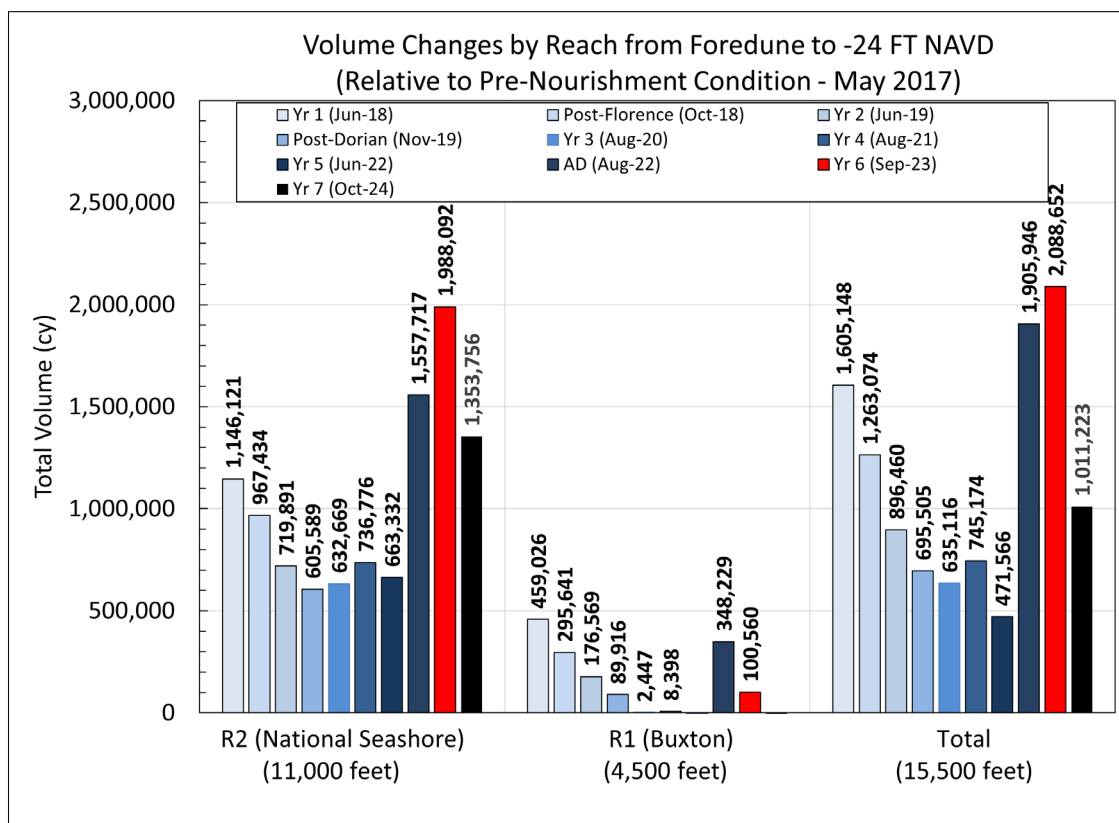


FIGURE 4.7a. Total volume changes of the project area above -24 ft NAVD since the pre-project condition (May 2017).

-19 ft NAVD

The -19 ft contour includes the landward side of the nearshore trough and the most active portions of the beach profile along Buxton. Volumes above this contour help reduce wave heights even during minor to moderate-strength storm events. From September 2023 to October 2024, the project area lost ~914,650 cy (8.3 cy/ft) above -19 ft NAVD. This total includes a ~480,780 cy (-41.8 cy/ft) loss in the National Seashore Reach north of the village and a ~433,870 (-96.4 cy/ft) loss in the village.

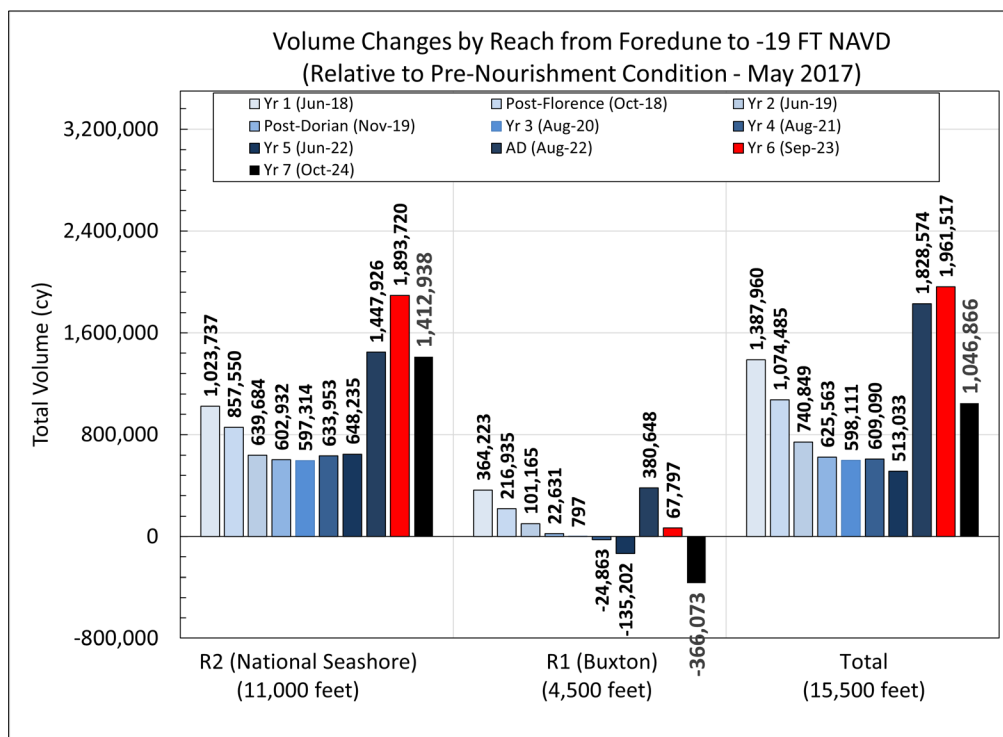


FIGURE 4.7b. Total volume changes of the project area above -19 ft NAVD since the pre-project condition (May 2017).

-6 ft NAVD

The logistics of constructing a beach nourishment project restrict sand placement to elevations above the MLW contour. Factoring in the ‘run out’ of sediment from that elevation toward deeper water that occurs with any shorefront sand placement effort, the post-construction template typically extends beyond the -6 ft NAVD contour. This depth represents the base of the most active portion of the beach profile, including swash bars and the constructed template.

Above the -6 ft contour, CSE surveys detected a change of 980,033 cy between June and August 2022; this volume is 85% of the contract volume of 1,200,000 cy because some of the fill had already

been transported into deeper water before the post-project survey. From September 2023 to October 2024, the Buxton project area lost ~219,890 cy (~13.7 cy/ft) above –6 ft NAVD. Losses were recorded along both the National Seashore and Village Reaches, which lost ~92,130 cy (–8.0 cy/ft) and ~127,770 cy (–28.4 cy/ft), respectively.

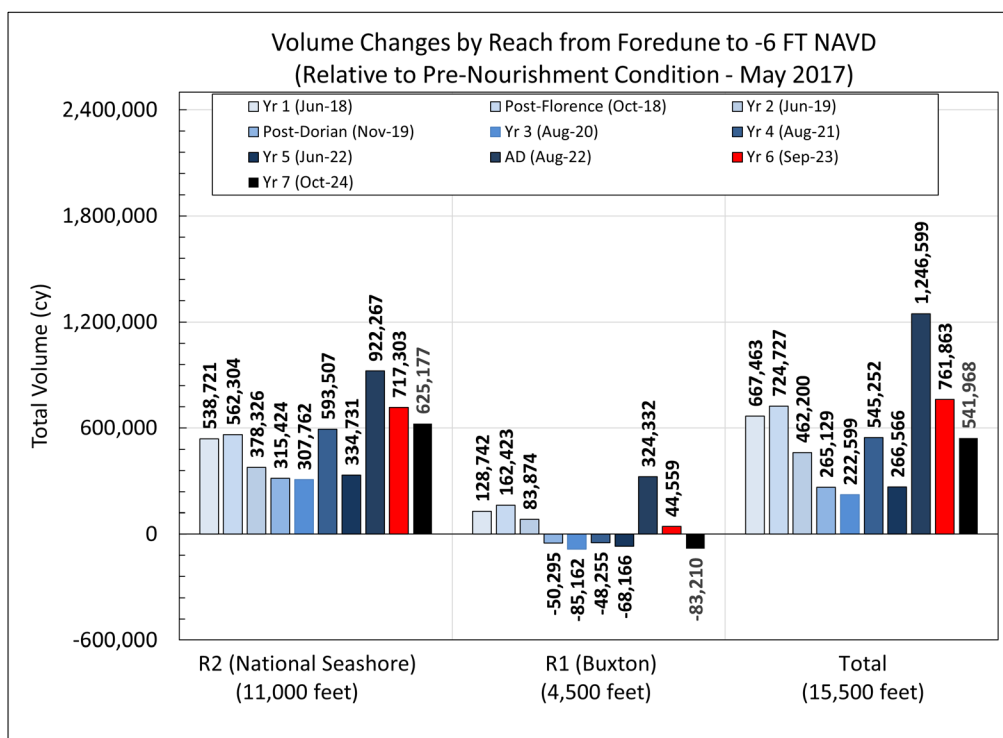


FIGURE 4.7c. Total volume changes of the project area above –6 ft NAVD since the pre-project condition (May 2017).

+7 ft NAVD

Changes above the +7 ft NAVD contour indicate volume gains above the design elevation of the nourishment berm. These volume changes reflect localized changes in the template as it equilibrates to background conditions, as well as the volume increases in the foredune following project completion. From September 2023 to October 2024, the Buxton project area gained ~18,940 cy (1.2 cy/ft) above +7 ft NAVD. This total includes a ~33,980 cy (3.0 cy/ft) gain in the National Seashore Reach north of the village and a ~15,040 (–3.3 cy/ft) loss in the village.

Including adjacent upcoast and downcoast reaches, the Buxton survey area between September 2023 and October 2024, gained ~100,770 cy (4.2 cy/ft) above +7 ft NAVD. The Upcoast Reach north of Buxton gained ~53,800 (10.8 cy/ft), while the Downcoast Reach south of Buxton gained ~28,030 cy (5.6 cy/ft).

The volume increases above +7 ft NAVD along portions of the project area are reflected in the qualitative improvement of foredune conditions between the pre- and post-project surveys and the October 2024 survey at Buxton. A continuous foredune with crest elevations above the storm wave run-up height (>15 ft NAVD along much of the Outer Banks) is the best means of protecting developed uplands, minimizing overwash, and lessening loss of beach sands to the back barrier.

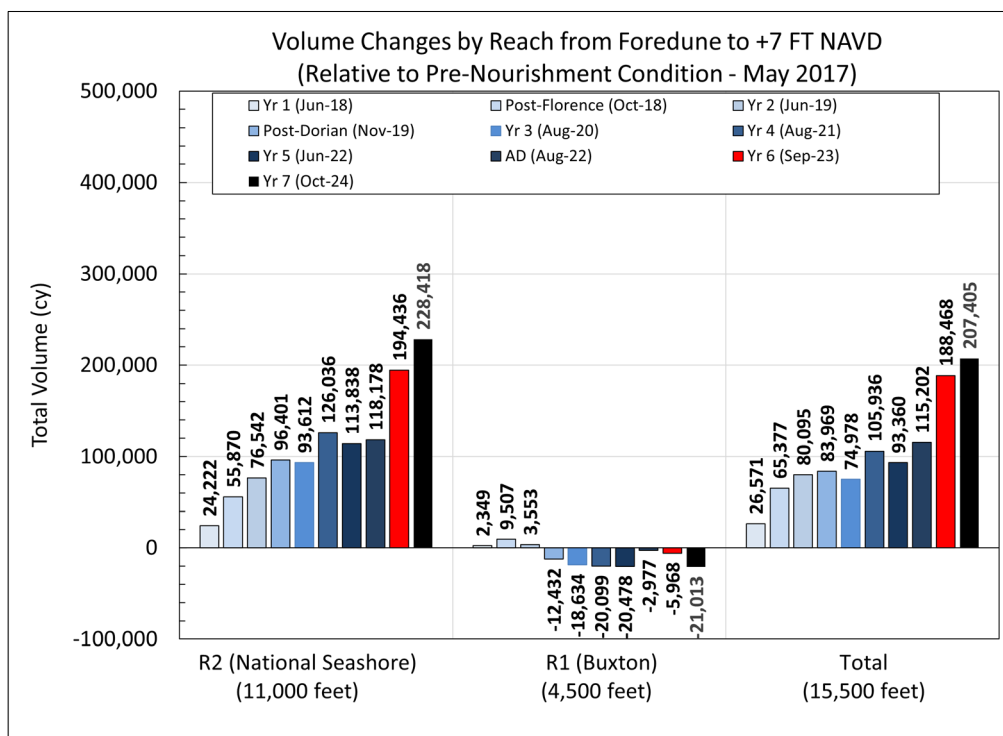


FIGURE 4.7d. Total volume changes of the project area above +7 ft NAVD since the pre-project condition (May 2017).

4.3 Oblique Aerial Photography

CSE collected a set of oblique aerial images via drone on 29 October 2024 (Figs 4.5–4.6). The following images are selected for quality and comparability with earlier aerals of the project area:

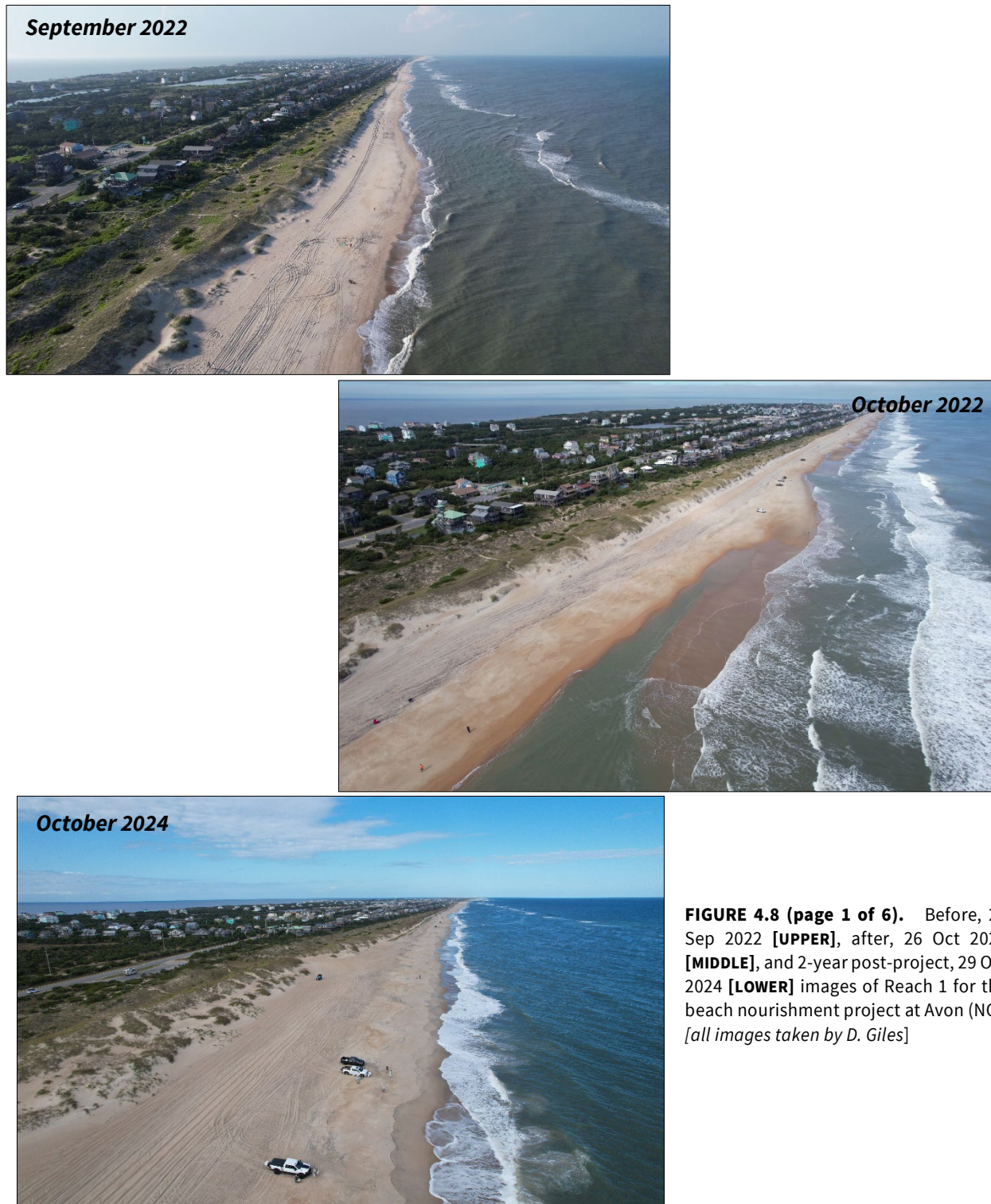
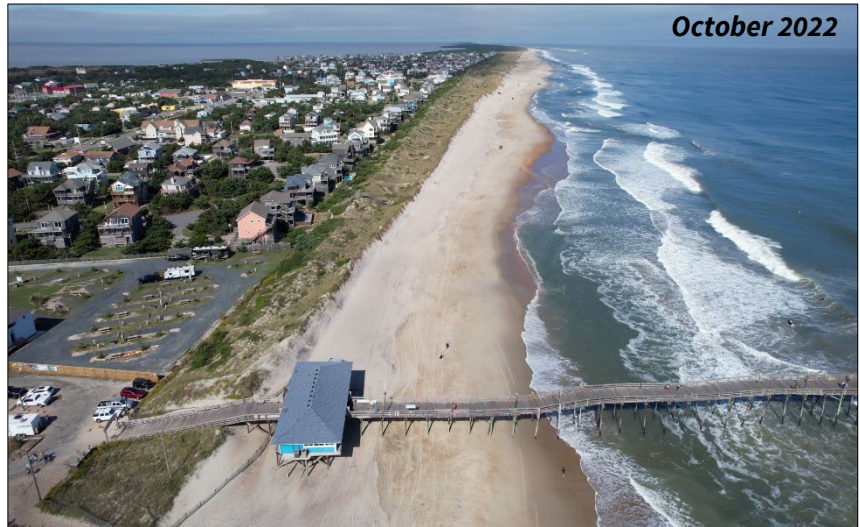


FIGURE 4.8 (page 1 of 6). Before, 27 Sep 2022 [**UPPER**], after, 26 Oct 2022 [**MIDDLE**], and 2-year post-project, 29 Oct 2024 [**LOWER**] images of Reach 1 for the beach nourishment project at Avon (NC). [all images taken by D. Giles]

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FIGURE 4.8 (page 2 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 2 for the beach nourishment project at Avon (NC).

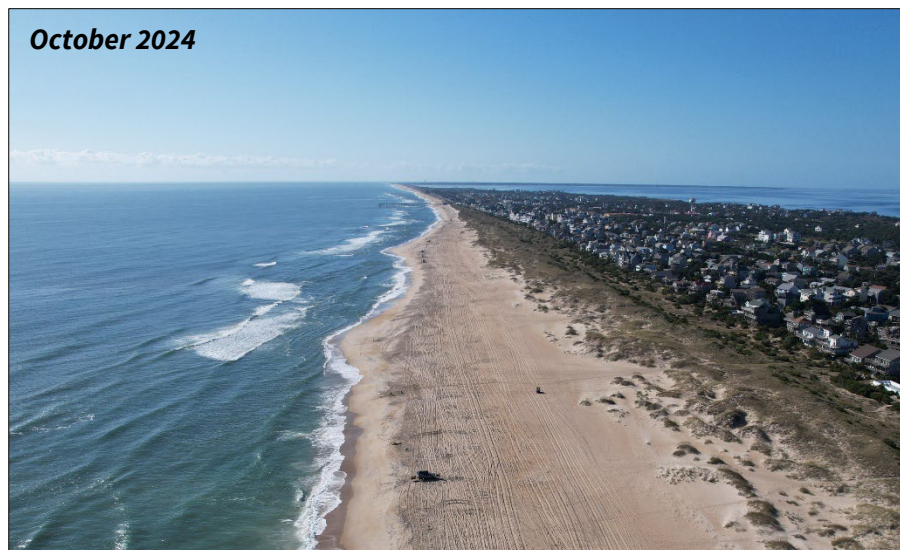
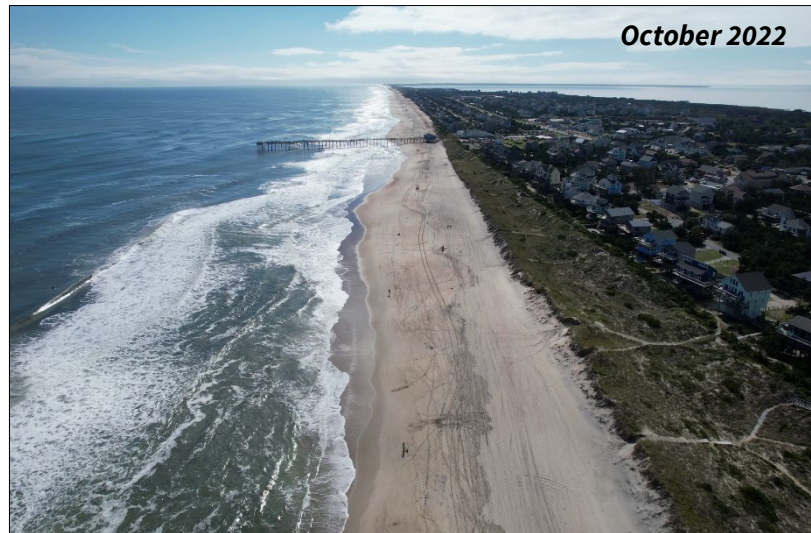


FIGURE 4.8 (page 3 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 2 for the beach nourishment project at Avon (NC).

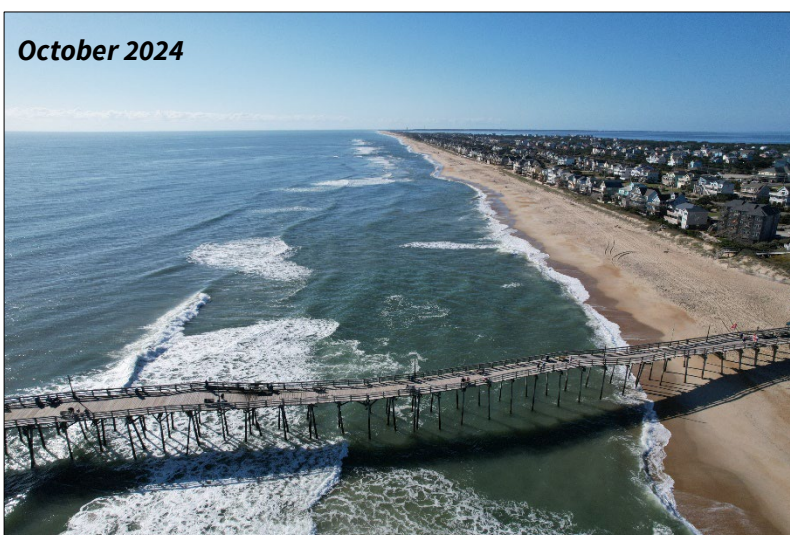
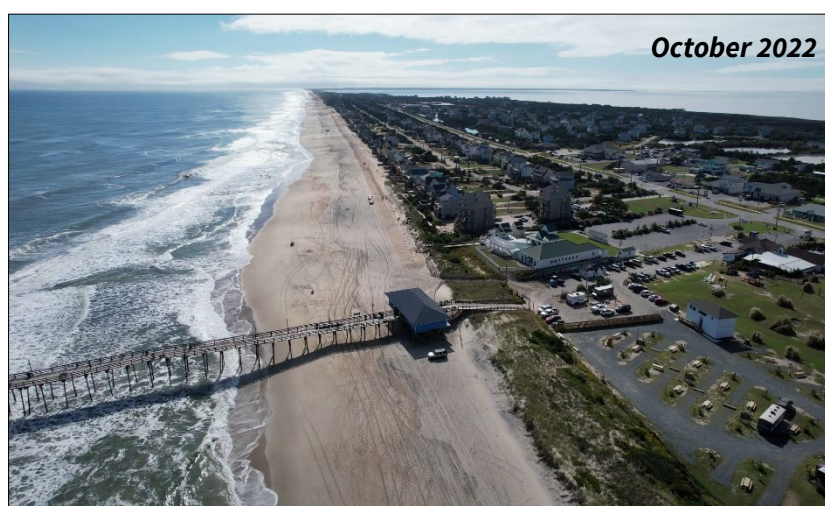
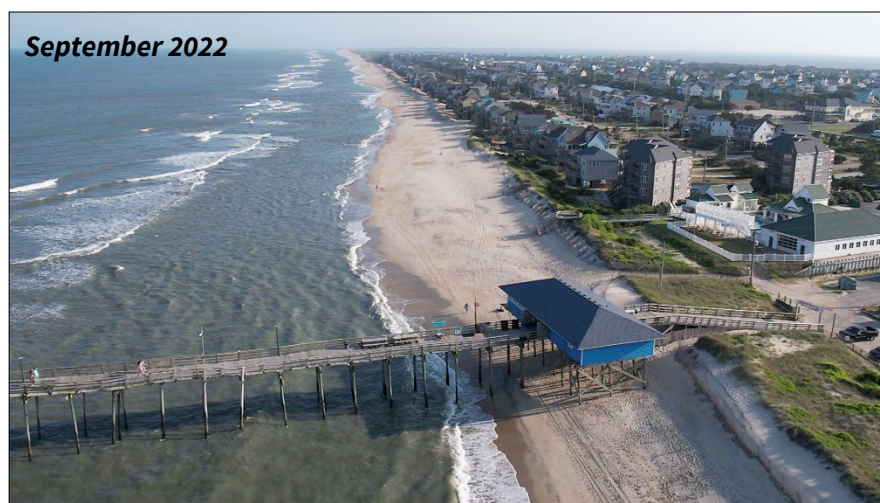


FIGURE 4.8 (page 4 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 3 for the beach nourishment project at Avon (NC).

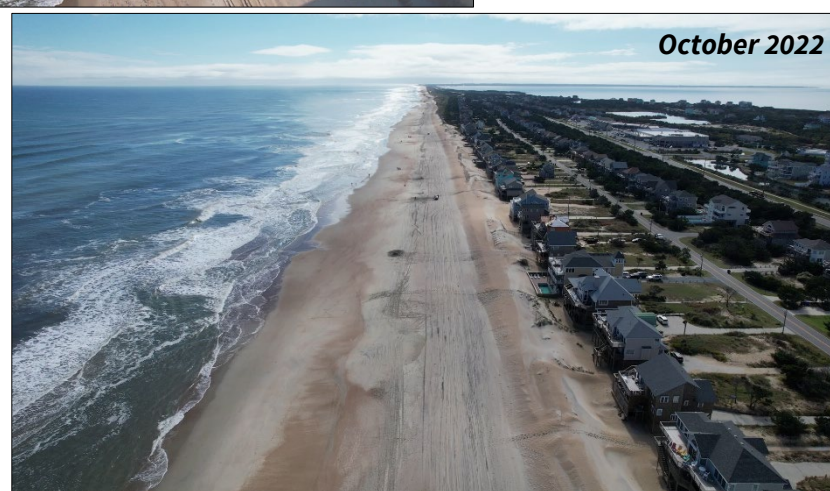


FIGURE 4.8 (page 5 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 4 for the beach nourishment project at Avon (NC).

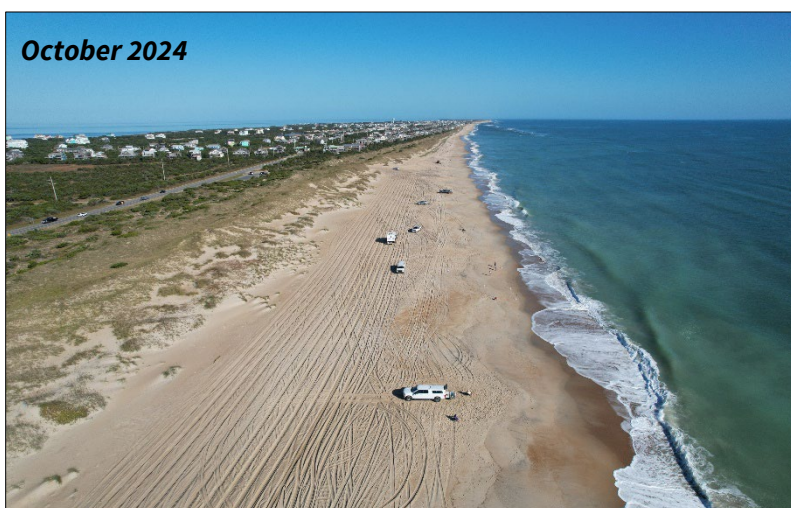
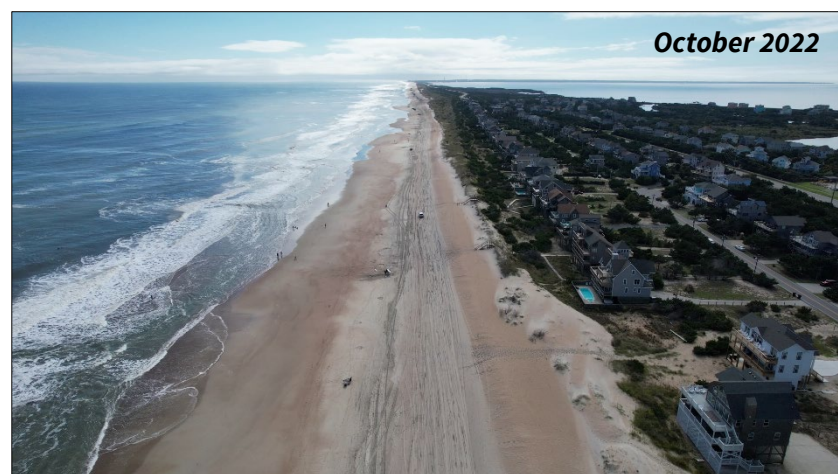


FIGURE 4.8 (page 6 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 5 for the beach nourishment project at Avon (NC).

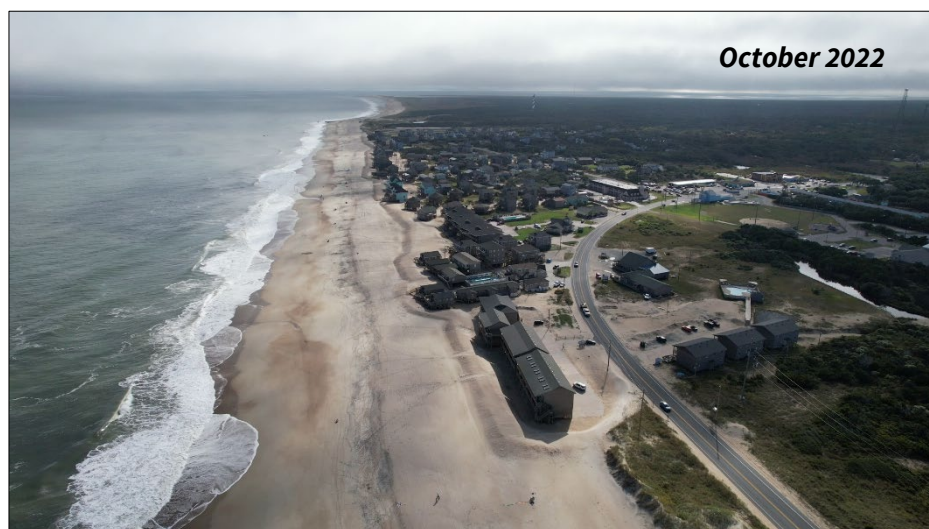


FIGURE 4.9 (page 1 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 1 for the beach nourishment project at Buxton (NC).

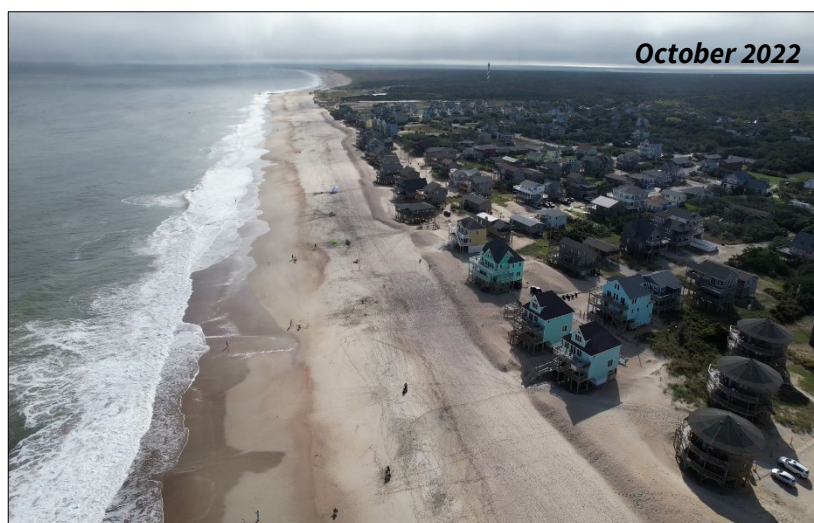


FIGURE 4.9 (page 2 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 1 for the beach nourishment project at Buxton (NC).



FIGURE 4.9 (page 3 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 1 for the beach nourishment project at Buxton (NC).



FIGURE 4.9 (page 4 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 1 for the beach nourishment project at Buxton (NC).



FIGURE 4.9 (page 5 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images of Reach 1 for the beach nourishment project at Buxton (NC).

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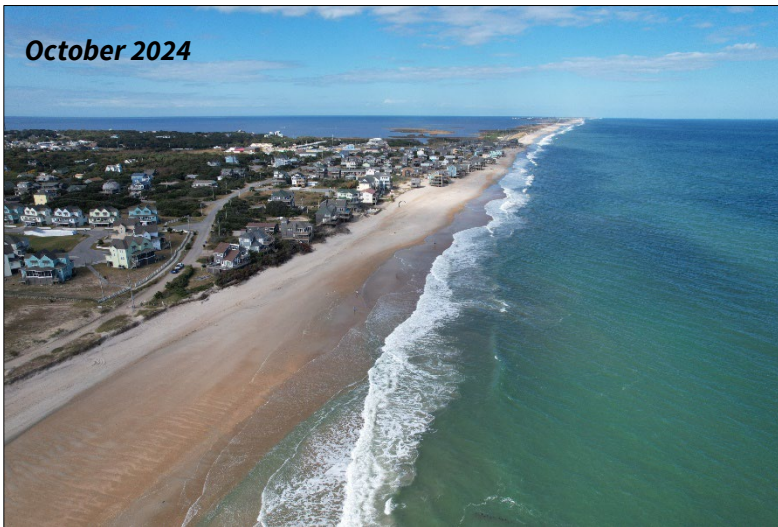


FIGURE 4.9 (page 6 of 6). Before [UPPER], after [MIDDLE], and 2-year post-project [LOWER] images for the beach nourishment project at Buxton (NC).

4.4 Compaction and Escarpment Surveys

CSE took post-project sediment compaction readings using a cone penetrometer along both project areas and a control area located south of Salvo. This control area was determined via consultation with NPS and NFWS personnel before the project began. Measurements were made before dredging (May 2022), after dredging (August 2022), and quarterly throughout monitoring Year 1 (Q1 – November 2022, Q2 – February 2023, Q3 – May 2023, Q4 – August 2023, Q5 – November 2023, Q6 – February 2024, Q7 – May 2024). Compaction sampling stations were located at 500-ft intervals at two measurement locations: the dune toe and the berm, and at 3 depths (6, 12, and 18 inches). The data is collected in kilogram-force per square centimeter ($\text{kg}\cdot\text{cm}^2$) and converted to Pound-force per square inch (psi) by dividing by 0.0703. Table 4.1 lists the averaged results for each survey event at all three depths along nourished and unnourished portions of the dune toe and beach berm. A complete listing of all results is provided in Appendix B.

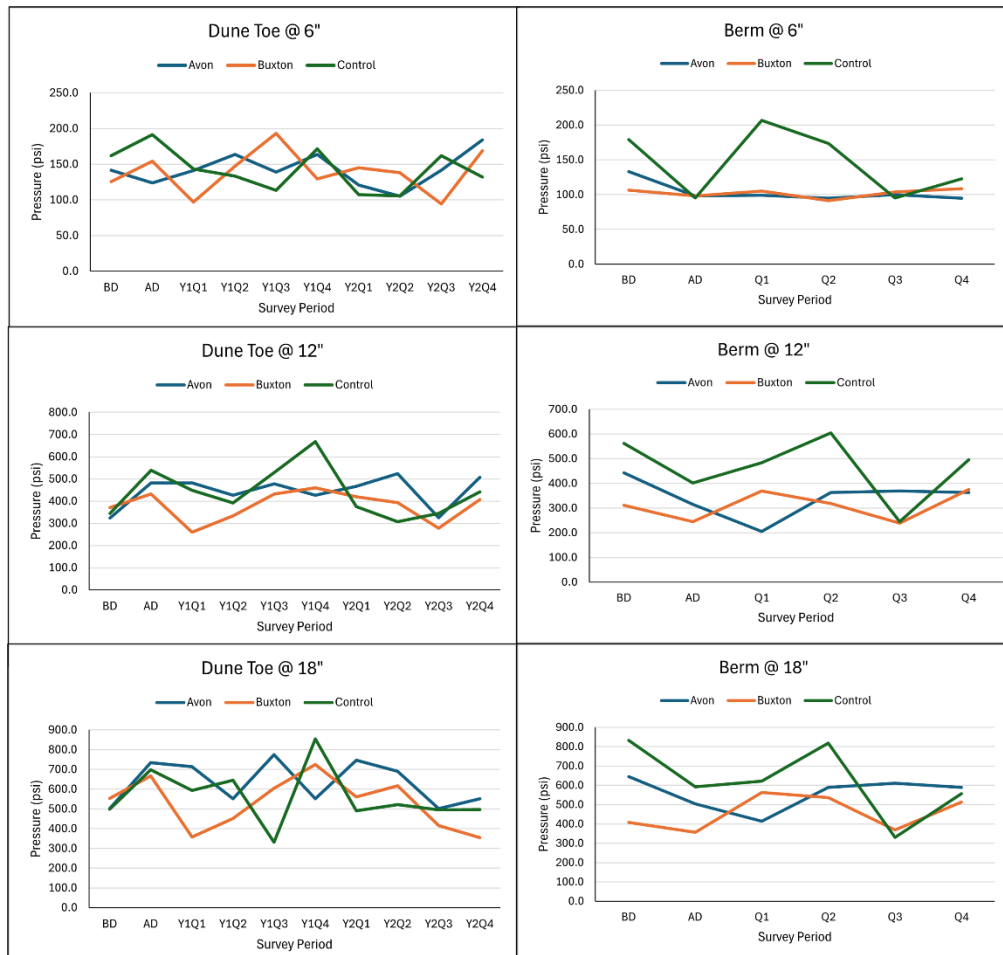
Compaction increases with depth and is lower at the dune toe than along the middle of the dry-sand beach. No specific compaction readings are required in the Biological Opinion. A 500-psi threshold has been recommended for project sites in Florida; however, these differ from Hatteras Island beaches in several respects, making it difficult to translate the results to a North Carolina setting. Comparison between the project and control areas provides the strongest test for whether nourishment sand led to greater compaction.

The results demonstrate that the average compaction through Year 2 in both the Avon and Buxton project areas is comparable to or lower than that measured along the control area. When averaged across the entire survey area(s) and for each survey event, the project areas exhibited less compaction than the control over 80% of the time. Visualizing the average results by depth and cross-shore position (Fig 4.7) suggests natural shifts in sediment transport and wave conditions drive the greatest changes in compaction observed across all three sites through Year 2.

Based on these results, CSE does not recommend tilling along either Avon or Buxton. Compaction results at both sites indicate that both levels and changes over time fall within acceptable natural variation. Moreover, narrow berm widths along portions of Buxton may not allow for the passage of heavy equipment to perform the work.

TABLE 4.1 and FIGURE 4.10. Summary Compaction results collected in Year 2. Observations suggest the nourished beach is less compact than adjacent unnourished beaches along the mid-berm, while dune toe observations suggest the two are similar.

Dune											
Date	6"			Date	12"			Date	18"		
	Avon	Buxton	Control		Avon	Buxton	Control		Avon	Buxton	Control
BD	141.6	125.7	161.8	BD	324.5	370.6	345.0	BD	501.6	553.2	497.9
AD	123.6	154.1	191.4	AD	482.1	432.7	538.8	AD	733.9	666.3	698.2
Y1Q1	140.9	96.9	143.4	Y1Q1	481.9	259.6	449.3	Y1Q1	714.3	358.3	593.5
Y1Q2	163.6	147.0	133.4	Y1Q2	426.1	334.0	391.8	Y1Q2	551.4	451.1	644.8
Y1Q3	138.9	192.9	113.2	Y1Q3	477.9	432.2	528.7	Y1Q3	774.9	604.3	330.7
Y1Q4	163.6	129.5	171.3	Y1Q4	426.1	460.2	668.6	Y1Q4	551.4	725.2	854.7
Y2Q1	120.6	145.2	107.3	Y2Q1	467.4	419.9	375.8	Y2Q1	746.1	560.4	490.2
Y2Q2	105.0	138.1	105.5	Y2Q2	523.9	393.6	307.0	Y2Q2	690.6	616.1	521.0
Y2Q3	141.6	94.2	161.8	Y2Q3	324.8	278.0	345.0	Y2Q3	501.6	414.9	494.3
Y2Q4	183.9	168.9189	132.2	Y2Q4	507.0	407.8	441.6	Y2Q4	551.0	354.4	496.1
AVG	142.3	139.3	142.1	AVG	444.2	378.9	439.1	AVG	631.7	530.4	562.1
Beach											
Date	6"			Date	12"			Date	18"		
	Avon	Buxton	Control		Avon	Buxton	Control		Avon	Buxton	Control
BD	133.1	106.5	179.0	BD	443.0	310.7	561.9	BD	644.3	407.1	832.1
AD	98.2	98.4	95.4	AD	315.3	245.1	401.8	AD	504.3	357.3	591.5
Y1Q1	98.9	104.9	206.9	Y1Q1	205.6	369.3	483.0	Y1Q1	414.5	563.2	621.1
Y1Q2	94.8	91.3	173.7	Y1Q2	363.0	318.9	604.6	Y1Q2	588.9	535.9	818.4
Y1Q3	99.9	104.0	95.4	Y1Q3	369.2	239.3	244.8	Y1Q3	611.3	369.1	330.7
Y1Q4	94.8	108.8	122.7	Y1Q4	363.0	375.5	496.1	Y1Q4	588.9	513.9	557.1
Y2Q1	99.2	134.5	117.9	Y2Q1	352.2	265.8	410.7	Y2Q1	504.6	394.4	692.3
Y2Q2	97.2	133.1	125.7	Y2Q2	339.4	309.4	419.0	Y2Q2	516.2	544.7	613.4
Y2Q3	133.1	85.3	179.0	Y2Q3	443.0	291.3	561.9	Y2Q3	639.6	381.7	815.0
Y2Q4	108.7	118.2	132.2	Y2Q4	244.9	354.4	391.8	Y2Q4	413.2	460.9	625.3
AVG	105.8	108.5	142.8	AVG	343.9	308.0	457.6	AVG	542.6	452.8	649.7



4.5 Geotechnical Sampling

Per the monitoring and maintenance plan submitted with the permit application, CSE collected representative sediment samples from both project and control areas (eg – Avon, Buxton, and Salvo ‘Control’). Samples were collected before dredging in May and June 2022, after dredging in August 2022, and quarterly throughout the Year 1 monitoring period (Q1 – November 2022, Q2 – February 2023, Q3 – May 2023, Q4 – August 2023) and quarterly throughout the Year-2 monitoring period (Q1 – November 2023, Q2 – February 2024, Q3 – May 2024, Q4 October 2024).

Samples were collected along survey transects described in Section 3.1 at 1,000-ft spacing along all three sites, with three cross-shore samples collected per transect. There are fourteen transects along Avon, sixteen along Buxton, and ten along the Salvo control site. Each sampling event consisted of 120 samples, resulting in a net total of 720 samples across all six events.

Samples were dried, sieved, and weighed at quarter-phi intervals according to standard ASTM procedures. Fine- and coarse-size grain contents were determined using dry weights from sieve results. Shell content was measured using two rounds of acid treatment, drying, and weighing to isolate the non-carbonate fraction of all samples.

CSE resampled the before- and after-dredge sites to exclude large clasts and chunks of shell that skewed the grain sizes for those events towards a larger mean. This post-processing was applied to both project sites as well as the control. As a result, the specific mean grain sizes of pre- and post-project sediment characteristics differ slightly from those reported in the Final Report (CSE 2023). No alterations were made to the fine, granule, gravel, or shelly material statistics.

Results of mean grain size (in mm), granule content, and shell content for all six sampling events at all three sites are shown in Table 4.2a-c and Figure 4.8a-f. More complete data with full statistical summaries are provided in Appendix C.

Results indicate the nourished sand was a good match for both project sites. Longshore variations in mean grain sizes at both sites vary, and most individual stations exhibit a mean grain size between 0.250- and 0.850-mm. Mean grain sizes also varied according to cross-shore position, such that the swash zone tended to exhibit the largest mean grain size. This is typical for Outer Banks beaches, which include mixtures of shells and pea gravel, concentrated in the high-energy swash zone. Occurrences of granule-size and shelly material were comparable across all three sites, with site-wide averages of <5% granule-size grains and <15% shelly material. Seasonal changes in the mean grain sizes at both project sites across the Year 2 period are mirrored by similar changes in sediment character at the control site near Salvo. In general, all three sites exhibited the smallest mean grain size in November 2023 and February 2024, with a gradual increase in the mean grain sizes exhibited in May 2024 and October 2024 at all sites over the course of Year 2. The seasonal variation in grain

size at the surface substrate occurs because finer sands on the berm tend to shift over the coarse sediments near the low-tide line in winter. During summer months, the beach face becomes steeper as the berm builds up, re-exposing the underlying coarse sediments.

TABLE 4.2a. Geotechnical data summary for Avon, including before- and after-project data along with quarters 1 through 4 of Year 2.

Survey Period > Survey Date>		BD 22-May-22			AD 31-Aug-22			Y2Q1 29-Nov-23			Y2Q2 13-Feb-24			Y2Q3 30-May-24			Y2Q4 14-Oct-24		
Station	Interval	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %
1550+00	Toe of Dune	0.368	0.1	2.8	0.398	0.1	3.0	0.422	0.8	0.1	0.480	0.3	0.0	0.457	0.3	3.4	0.414	0.6	2.6
1550+00	Beach Face	0.434	1.2	1.8	0.284	0.0	3.1	0.372	0.5	0.1	0.404	0.1	0.0	0.411	0.4	1.6	0.196	0.0	0.7
1550+00	Swash	0.614	5.2	4.8	0.368	0.5	10.6	0.373	0.2	0.1	0.453	0.6	0.0	0.812	15.2	7.8	0.301	0.1	2.3
1560+00	Toe of Dune	0.319	0.0	1.1	0.315	1.6	1.2	0.305	0.0	0.1	0.305	0.0	0.0	0.432	0.2	2.7	0.387	0.0	1.5
1560+00	Beach Face	0.415	0.5	1.9	0.306	0.1	4.8	0.411	0.0	0.1	0.399	0.7	0.0	0.622	0.0	3.0	0.316	0.2	3.1
1560+00	Swash	0.617	3.4	21.9	0.314	0.1	6.7	0.362	0.3	0.1	0.462	1.3	0.0	0.727	3.3	5.2	0.342	0.4	3.7
1570+00	Toe of Dune	0.278	0.0	0.4	0.341	0.6	1.9	0.364	0.3	0.1	0.376	0.0	0.0	0.358	0.0	1.7	0.307	0.2	2.2
1570+00	Beach Face	0.261	0.0	0.9	0.225	0.0	2.1	0.317	0.5	0.1	0.360	0.0	0.0	0.404	0.4	1.9	0.281	0.1	2.9
1570+00	Swash	0.633	3.2	9.2	0.289	0.4	7.0	0.402	1.1	0.0	0.484	2.7	0.0	0.589	1.6	4.7	0.338	0.4	3.9
1580+00	Toe of Dune	0.319	0.3	1.7	0.375	1.0	2.2	0.266	0.0	0.1	0.401	0.4	0.0	0.382	0.4	4.4	0.338	0.0	2.8
1580+00	Beach Face	0.363	0.3	1.9	0.259	0.0	4.3	0.449	0.2	0.1	0.440	0.0	0.0	0.462	0.1	2.4	0.369	2.3	9.8
1580+00	Swash	0.842	3.1	10.7	0.464	1.2	21.8	0.315	0.7	0.1	0.388	0.4	0.0	0.849	9.9	4.0	0.670	0.8	20.1
1590+00	Toe of Dune	0.363	0.0	3.1	0.344	0.6	3.6	0.375	1.6	0.1	0.426	4.4	0.0	0.408	0.2	3.4	0.351	0.9	4.9
1590+00	Beach Face	0.413	0.7	3.6	0.284	0.0	4.0	0.330	0.1	0.1	0.492	0.1	0.0	0.372	0.0	3.1	0.300	0.1	5.7
1590+00	Swash	0.731	6.1	8.3	0.506	5.4	13.8	0.381	1.9	0.0	0.460	1.1	0.0	0.729	1.3	9.9	0.389	0.7	8.4
1600+00	Toe of Dune	0.310	0.1	1.7	0.425	3.9	13.4	0.401	1.1	0.1	0.377	0.1	0.0	0.424	1.1	7.0	0.365	0.4	8.4
1600+00	Beach Face	0.429	1.5	5.3	0.277	0.0	2.7	0.311	0.0	0.1	0.425	0.4	0.0	0.363	0.0	3.0	0.290	0.2	3.2
1600+00	Swash	1.068	11.3	11.5	0.451	1.1	15.6	0.320	0.3	0.1	0.497	3.8	0.0	0.518	5.2	6.4	0.691	2.6	17.6
1610+00	Toe of Dune	0.284	0.0	0.5	0.390	1.9	32.0	0.365	0.1	0.1	0.353	0.0	0.0	0.342	0.2	3.9	0.368	0.0	4.8
1610+00	Beach Face	0.574	2.1	12.5	0.289	0.1	3.9	0.367	0.1	0.1	0.396	0.0	0.0	0.328	0.1	6.0	0.394	0.3	7.2
1610+00	Swash	0.817	4.2	9.0	0.571	6.7	17.7	0.298	0.0	0.2	0.347	0.4	0.0	0.397	0.6	7.9	0.403	2.2	5.2
1620+00	Toe of Dune	0.389	0.2	3.4	0.403	5.0	9.1	0.407	0.9	0.1	0.378	0.2	0.0	0.433	0.0	4.8	0.390	0.0	4.3
1620+00	Beach Face	0.374	0.0	1.8	0.231	0.0	2.0	0.338	0.0	0.1	0.426	0.0	0.0	0.326	0.0	2.9	0.323	0.1	6.6
1620+00	Swash	0.600	3.7	4.1	0.858	18.7	18.2	0.330	0.0	0.1	0.536	2.4	0.0	0.688	5.2	9.7	0.369	0.8	5.9
1630+00	Toe of Dune	0.277	0.0	1.8	0.470	0.7	5.5	0.367	0.0	0.1	0.334	0.1	0.0	0.385	0.2	5.7	0.397	0.0	4.9
1630+00	Beach Face	0.466	0.3	4.0	0.263	0.0	2.7	0.253	0.0	0.1	0.410	0.0	0.0	0.310	0.1	2.6	0.334	0.1	4.5
1630+00	Swash	0.647	2.2	7.2	0.298	0.2	3.6	0.308	0.0	0.1	0.472	3.9	0.0	0.490	3.1	7.4	0.326	0.0	4.0
1640+00	Toe of Dune	0.378	0.0	1.9	0.456	1.1	4.7	0.366	0.1	0.1	0.348	0.0	0.0	0.388	0.8	6.0	0.369	0.1	6.5
1640+00	Beach Face	0.388	0.0	2.8	0.279	0.0	2.5	0.316	0.1	0.1	0.380	0.0	0.0	0.323	0.2	3.3	0.455	0.4	10.3
1640+00	Swash	0.496	2.2	5.8	0.659	6.3	15.9	0.346	0.4	0.1	0.318	0.1	0.0	0.352	1.0	5.0	0.390	0.4	6.6
1650+00	Toe of Dune	0.378	0.1	4.0	0.367	1.0	13.7	0.339	0.1	0.0	0.390	0.1	0.0	0.383	0.0	4.0	0.432	0.0	9.1
1650+00	Beach Face	0.302	0.0	2.0	0.290	0.0	3.9	0.320	0.1	0.1	0.346	0.0	0.0	0.409	0.1	4.9	0.349	0.2	5.9
1650+00	Swash	0.469	4.6	4.1	0.690	1.0	12.7	0.336	0.2	0.1	0.331	0.1	0.0	0.474	2.1	6.4	0.306	0.0	4.2
1660+00	Toe of Dune	0.412	0.3	3.0	0.411	1.4	7.9	0.382	0.6	0.0	0.317	0.0	0.0	0.373	0.7	2.3	0.408	0.0	6.0
1660+00	Beach Face	0.301	0.0	1.9	0.366	0.0	4.7	0.283	0.1	0.1	0.401	0.1	0.0	0.324	0.0	3.3	0.342	0.5	4.8
1660+00	Swash	0.528	2.8	3.4	0.985	12.5	17.8	0.315	0.0	3.4	0.342	0.3	0.0	0.410	1.5	6.3	0.310	0.4	3.8
1670+00	Toe of Dune	0.232	0.0	0.3	0.455	5.5	10.6	0.376	0.0	5.1	0.360	0.1	0.0	0.385	0.4	5.0	0.385	0.2	5.6
1670+00	Beach Face	0.279	0.0	1.7	0.382	0.2	3.6	0.306	0.0	2.9	0.432	0.1	0.0	0.345	0.1	3.8	0.303	0.2	3.7
1670+00	Swash	0.622	2.2	8.1	0.760	4.6	8.7	0.347	0.1	3.8	0.376	0.0	0.0	0.456	1.4	5.7	0.342	0.3	5.3
1680+00	Toe of Dune	0.386	0.0	2.3	0.444	1.3	3.9	0.358	0.5	3.6	0.355	0.1	0.0	0.456	1.3	6.9	0.368	0.0	4.7
1680+00	Beach Face	0.381	0.0	1.4	0.344	0.2	2.6	0.371	0.0	5.3	0.419	0.3	0.0	0.380	1.5	5.7	0.355	0.2	4.3
1680+00	Swash	0.607	3.5	8.5	0.675	3.3	8.8	0.393	1.2	7.8	0.325	0.1	0.0	0.361	1.9	5.8	0.447	1.8	8.1
ALL	Toe of Dune	0.331	0.1	2.0	0.397	1.8	8.1	0.362	0.4	0.7	0.370	0.4	0.0	0.400	0.4	4.4	0.375	0.2	4.9
ALL	Beach Face	0.375	0.5	3.1	0.288	0.0	3.3	0.334	0.1	0.7	0.408	0.2	0.0	0.378	0.2	3.4	0.324	0.4	5.2
ALL	Swash	0.635	3.8	8.3	0.519	4.2	13.2	0.343	0.5	1.1	0.407	1.2	0.0	0.528	3.8	6.6	0.388	0.8	7.1
ALL	ALL	0.420	1.3	4.5	0.389	2.0	8.2	0.346	0.3	0.8	0.395	0.6	0.0	0.430	1.5	4.8	0.361	0.4	5.7

TABLE 4.2b. Geotechnical data summary for Buxton, including before- and after-project data along with quarters 1 through 4 of Year 2.

Survey Period > Survey Date>		BD 16-Jun-22			AD 31-Aug-22			Y2Q1 29-Nov-23			Y2Q2 13-Feb-24			Y2Q3 30-May-24			Y2Q4 14-Oct-24		
Station	Interval	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %
1770+00	Toe of Dune	0.257	0.0	0.9	0.357	0.1	5.1	0.350	0.0	5.3	0.311	0.0	0.0	0.337	0.0	5.0	0.408	0.0	9.4
1770+00	Beach Face	0.505	2.3	9.5	0.351	0.1	4.3	0.325	0.2	4.6	0.363	0.3	0.0	0.227	0.0	1.2	0.372	0.0	5.3
1770+00	Swash	0.857	16.0	18.3	0.757	5.1	16.5	0.272	0.0	2.5	0.411	3.4	0.0	0.245	0.0	2.6	0.685	11.8	14.2
1780+00	Toe of Dune	0.306	0.1	0.0	0.343	0.3	3.9	0.313	0.0	4.2	0.378	0.2	0.0	0.338	0.3	5.9	0.364	2.8	4.8
1780+00	Beach Face	0.641	1.3	9.9	0.340	0.1	3.2	0.310	0.0	4.0	0.346	0.0	0.0	0.250	0.0	2.3	0.405	0.9	8.0
1780+00	Swash	0.899	6.7	12.8	0.630	5.3	14.0	0.456	3.7	9.0	0.306	0.5	0.0	0.259	0.1	3.0	1.046	24.4	17.8
1790+00	Toe of Dune	0.306	0.1	2.2	0.467	3.4	8.8	0.382	1.8	9.9	0.338	0.2	0.0	0.324	0.1	2.8	0.374	0.0	5.0
1790+00	Beach Face	0.344	0.1	3.7	0.403	0.1	4.2	0.409	0.1	6.8	0.381	1.4	0.0	0.263	0.0	2.4	0.389	0.3	7.3
1790+00	Swash	0.715	7.2	11.6	0.736	7.1	17.4	0.274	0.0	2.0	0.495	3.7	0.0	0.343	0.3	4.8	0.635	21.3	16.8
1800+00	Toe of Dune	0.392	0.0	3.9	0.407	0.1	4.4	0.314	0.3	4.4	0.434	0.2	0.0	0.351	5.4	9.6	0.402	1.9	5.7
1800+00	Beach Face	0.384	0.2	4.3	0.354	0.1	4.6	0.273	0.0	3.6	0.372	0.4	0.0	0.300	0.3	4.6	0.355	0.7	7.4
1800+00	Swash	0.927	11.2	18.6	0.584	5.6	26.6	0.282	0.1	3.2	0.509	4.6	0.0	0.295	0.3	6.5	0.296	0.9	3.9
1810+00	Toe of Dune				0.455	0.4	7.4	0.283	0.0	2.8	0.385	0.0	0.0	0.320	0.1	4.1	0.469	1.7	12.7
1810+00	Beach Face	0.377	0.1	3.5	0.428	0.7	7.0	0.537	6.4	14.0	0.336	0.0	0.0	0.292	0.1	3.3	0.324	0.0	4.3
1810+00	Swash	0.890	10.0	13.9	0.567	3.0	18.6	0.270	0.3	3.4	0.315	0.6	0.0	0.479	2.9	10.9	0.309	1.0	10.0
1820+00	Toe of Dune				0.404	3.4	5.6	0.322	0.0	5.1	0.297	0.0	0.0	0.393	1.0	8.1	0.297	0.2	4.2
1820+00	Beach Face	0.417	0.3	4.5	0.370	0.2	4.8	0.311	0.3	4.6	0.417	0.6	0.0	0.331	0.3	4.3	0.340	0.1	5.9
1820+00	Swash	1.468	37.2	22.9	0.561	2.5	20.8	0.302	0.0	4.0	0.370	0.1	0.0	0.334	0.2	3.9	0.355	0.1	5.9
1830+00	Toe of Dune				0.419	0.7	4.7	0.349	0.0	6.2	0.337	0.0	0.0	0.297	0.0	3.0	0.285	0.2	3.2
1830+00	Beach Face	0.617	0.7	9.3	0.407	0.1	5.0	0.319	0.0	3.3	0.285	0.0	0.0	0.402	0.5	6.7	0.356	0.0	4.8
1830+00	Swash	0.954	12.7	17.2	0.637	3.7	16.1	0.300	0.0	3.0	0.433	5.0	0.0	0.471	3.9	8.2	0.401	0.9	8.3
1840+00	Toe of Dune	0.359	0.1	6.9	0.458	1.8	7.7	0.352	0.0	6.2	0.326	0.3	0.0	0.368	0.5	5.4	0.335	0.4	4.8
1840+00	Beach Face	0.355	0.1	4.4	0.380	0.0	4.4	0.447	0.7	7.7	0.502	1.9	0.0	0.297	0.1	3.3	0.319	0.0	3.8
1840+00	Swash	0.494	2.2	10.8	0.634	1.6	16.1	0.495	9.6	10.6	0.481	7.7	0.0	0.642	7.6	14.0	0.533	5.6	13.8
1850+00	Toe of Dune	0.415	0.0	5.3	0.457	0.4	5.4	0.330	0.1	4.8	0.372	0.2	0.0	0.341	0.8	4.6	0.279	0.4	3.6
1850+00	Beach Face	0.365	0.0	4.7	0.362	0.0	4.9	0.314	0.0	3.3	0.432	0.1	0.0	0.358	0.2	8.3	0.347	0.0	4.8
1850+00	Swash	0.509	2.8	10.6	0.634	3.1	19.8	0.405	0.0	6.7	0.376	0.6	0.0	0.493	9.1	10.3	0.466	4.7	10.7
1860+00	Toe of Dune	0.352	0.0	4.7	0.395	0.0	4.0	0.338	0.0	5.5	0.336	0.1	0.0	0.290	0.0	3.0	0.275	0.0	2.5
1860+00	Beach Face	0.384	0.1	4.8	0.365	0.0	4.9	0.384	0.1	5.3	0.459	0.1	0.0	0.327	0.1	5.0	0.320	1.1	4.5
1860+00	Swash	0.391	1.6	6.7	0.544	1.8	18.0	0.274	0.0	2.4	0.353	0.0	0.0	0.266	1.7	7.3	0.465	0.6	7.7
1870+00	Toe of Dune	0.512	0.4	4.5	0.439	3.3	9.3	0.327	0.0	4.3	0.335	0.1	0.0	0.306	0.0	3.5	0.323	0.0	3.8
1870+00	Beach Face	0.618	0.9	11.6	0.339	0.0	4.1	0.276	0.1	2.4	0.506	1.3	0.0	0.583	1.2	14.0	0.340	0.1	3.9
1870+00	Swash	0.372	0.8	6.0	0.519	4.1	22.0	0.372	0.0	5.2	0.497	4.6	0.0	0.365	1.6	6.0	0.539	10.2	12.1
1880+00	Toe of Dune	0.321	0.0	3.7	0.346	0.5	5.6	0.312	0.0	3.6	0.390	0.1	0.0	0.308	0.0	3.2	0.309	0.0	3.8
1880+00	Beach Face	0.343	0.1	4.3	0.346	0.0	4.5	0.277	0.0	2.1	0.297	0.0	0.0	0.303	0.2	4.4	0.234	3.1	2.6
1880+00	Swash	0.324	0.0	12.7	0.484	0.7	12.7	0.379	0.1	5.4	0.483	8.2	0.0	0.379	3.8	7.4	0.356	0.9	8.1
1890+00	Toe of Dune	0.296	0.0	2.7	0.475	1.9	16.0	0.338	0.0	4.1	0.252	0.0	0.0	0.309	0.1	3.5	0.392	0.1	5.8
1890+00	Beach Face	0.302	0.0	3.6	0.345	0.0	4.7	0.369	0.0	5.6	0.431	3.6	0.0	0.324	0.1	4.4	0.275	0.0	2.8
1890+00	Swash	0.499	3.0	9.6	0.544	2.0	21.5	0.342	0.1	3.9	0.416	4.1	0.0	0.300	0.0	4.6	0.386	0.3	7.4
1900+00	Toe of Dune	0.371	-0.2	4.1	0.506	3.1	28.9	0.287	0.0	2.6	0.287	0.0	0.0	0.301	1.6	4.0	0.302	0.0	3.4
1900+00	Beach Face	0.293	0.1	3.5	0.528	2.7	4.2	0.274	0.0	2.8	0.463	1.1	0.0	0.463	4.0	7.1	0.293	0.0	3.1
1900+00	Swash	0.357	3.1	6.0	0.413	1.6	16.2	0.376	0.6	6.5	0.362	5.0	0.0	0.469	3.0	10.6	0.549	8.1	8.1
1910+00	Toe of Dune	0.406	0.0	4.7	0.556	1.4	22.5	0.309	0.0	3.5	0.374	1.4	0.0	0.264	0.0	2.7	0.284	0.0	2.7
1910+00	Beach Face	0.355	0.3	4.4	0.441	1.7	18.1	0.294	0.0	2.7	0.490	2.8	0.0	0.294	0.5	4.3	0.388	0.4	6.8
1910+00	Swash	0.931	14.9	18.2	0.535	1.5	21.9	0.506	1.8	9.8	0.362	0.3	0.0	0.392	0.1	7.6	0.499	15.1	16.6
1920+00	Toe of Dune	0.518	1.7	8.5	0.536	1.1	6.0	0.300	0.1	2.9				0.250	0.1	2.5			0.0
1920+00	Beach Face	0.338	0.0	3.3	0.541	2.2	14.6	0.303	0.1	3.9				0.756	10.8	12.1			0.0
1920+00	Swash	0.583	2.2	12.0	0.482	0.1	12.2	0.409	0.2	5.7				0.383	7.2	8.2			0.0
ALL	Toe of Dune	0.363	0.2	3.3	0.434	1.4	9.1	0.324	0.1	4.7	0.341	0.2	0.0	0.317	0.6	4.4	0.335	0.5	4.7
ALL	Beach Face	0.402	0.4	5.6	0.389	0.5	6.1	0.332	0.5	5.2	0.395	0.9	0.0	0.342	1.1	7.2	0.334	0.5	10.0
ALL	Swash	0.616	7.5	13.0	0.572	3.0	18.1	0.349	1.0	4.8	0.406	3.2	0.0	0.369	2.6	5.8	0.474	7.1	5.0
ALL	ALL	0.450	2.7	7.3	0.458	1.6	11.1	0.335	0.6	4.9	0.380	1.4	0.0	0.342	1.5	5.7	0.376	2.7	6.5

TABLE 4.2c. Geotechnical data summary for the control site at Salvo, including before- and after-project data along with quarters 1 through 4 of Year 2.

Survey Period >		BD			AD			Y2Q1			Y2Q2			Y2Q3			Y2Q4		
Survey Date >		22-May-22			31-Aug-22			29-Nov-23			13-Feb-24			30/05/2024			14-Oct-23		
Station	Interval	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %	Mean mm	Granule %	Shell %
980+00	Toe of Dune	0.355	0.1	1.7	0.241	0.0	0.8	0.229	0.0	2.0	0.245	0.0	0.0	0.321	0.2	0.8	0.379	7.6	1.9
980+00	Beach Face	0.361	0.0	0.5	0.280	0.0	1.0	0.299	0.1	1.1	0.367	0.7	0.0	0.295	0.1	0.7	0.267	2.4	0.9
980+00	Swash	0.980	0.0	5.0	0.733	6.7	3.3	0.359	0.3	1.3	0.440	2.5	0.0	0.430	1.0	1.8	0.354	9.4	2.6
990+00	Toe of Dune	0.323	0.0	1.5	0.323	0.3	0.9	0.201	0.0	0.4	0.273	0.0	0.0	0.303	0.3	1.1	0.318	2.6	0.6
990+00	Beach Face	0.314	2.6	0.6	0.349	0.9	2.7	0.348	0.0	1.0	0.384	0.3	0.0	0.397	0.3	1.4	0.274	1.2	1.3
990+00	Swash	0.603	5.4	6.1	0.582	6.6	3.0	0.267	0.1	1.2	0.382	0.0	0.0	0.396	0.5	2.2	0.315	4.5	1.0
1000+00	Toe of Dune	0.245	0.0	0.3	0.338	0.0	0.9	0.226	0.0	0.4	0.297	0.0	0.0	0.315	0.0	1.2	0.399	17.5	0.7
1000+00	Beach Face	0.409	3.4	5.1	0.258	0.0	3.5	0.263	0.3	0.7	0.352	0.0	0.0	0.383	1.7	1.7	0.272	0.7	0.6
1000+00	Swash	0.778	3.1	11.5	0.704	10.8	4.2	0.265	0.0	1.1	0.398	0.3	0.0	0.475	0.6	4.1	0.296	6.5	1.4
1010+00	Toe of Dune	0.222	0.1	0.7	0.306	0.0	0.8	0.235	0.0	0.4	0.254	0.0	0.0	0.325	0.0	0.5	0.305	1.5	0.7
1010+00	Beach Face	0.492	3.9	8.8	0.329	0.0	1.0	0.297	0.0	0.7	0.333	1.0	0.0	0.294	0.0	0.9	0.335	6.4	1.0
1010+00	Swash	1.091	18.3	13.5	0.493	3.5	4.6	0.273	0.5	1.4	0.358	0.0	0.0	0.356	0.2	2.1	0.316	7.0	1.4
1020+00	Toe of Dune	0.210	0.0	0.6	0.287	0.0	0.8	0.232	0.0	0.4	0.243	0.0	0.0	0.240	0.0	0.7	0.274	0.5	0.5
1020+00	Beach Face	0.366	0.1	1.4	0.436	0.6	3.0	0.276	0.0	0.5	0.310	0.0	0.0	0.333	0.0	1.2	0.306	4.9	1.3
1020+00	Swash	0.506	0.0	1.9	0.307	19.1	3.5	0.254	0.0	1.2	0.382	0.2	0.0	0.466	1.6	3.1	0.290	4.5	1.5
1030+00	Toe of Dune	0.239	0.0	0.6	0.360	0.5	1.0	0.261	0.0	0.3	0.246	0.0	0.0	0.301	0.5	2.9	0.296	2.7	0.8
1030+00	Beach Face	0.554	5.1	2.1	0.344	0.2	1.6	0.230	0.0	0.6	0.307	0.0	0.0	0.364	0.1	1.4	0.378	11.3	1.6
1030+00	Swash	0.686	3.7	10.9	0.983	43.7	13.4	0.247	0.0	0.8	0.396	0.2	0.0	0.371	0.5	2.8	0.315	6.7	1.6
1040+00	Toe of Dune	0.341	0.0	0.7	0.394	0.1	1.6	0.277	0.0	0.5	0.313	0.0	0.0	0.323	1.7	1.2	0.282	4.0	1.0
1040+00	Beach Face	0.345	0.0	0.9	0.295	0.0	1.2	0.277	0.0	0.7	0.329	0.0	0.0	0.312	0.0	1.0	0.287	2.1	1.2
1040+00	Swash	0.545	5.1	3.2	0.417	3.5	4.5	0.239	0.0	1.0	0.364	0.1	0.0	0.387	1.1	2.7	0.296	1.0	1.1
1050+00	Toe of Dune	0.237	0.1	0.3	0.441	1.0	3.0	0.292	0.0	0.4	0.280	0.0	0.0	0.275	0.0	1.5	0.301	2.5	1.3
1050+00	Beach Face	0.468	1.1	3.4	0.259	0.0	1.9	0.266	0.0	0.7	0.260	0.0	0.0	0.282	0.1	1.4	0.308	3.3	1.1
1050+00	Swash	0.714	0.0	6.3	0.855	30.9	8.8	0.241	0.0	0.8	0.332	0.1	0.0	0.382	1.3	4.3	0.282	2.1	1.1
1060+00	Toe of Dune	0.247	0.1	0.4	0.285	0.3	0.8	0.321	0.1	0.0	0.358	0.9	0.0	0.306	1.0	2.5	0.276	1.5	0.7
1060+00	Beach Face	0.430	1.6	2.1	0.282	0.1	1.4	0.273	0.0	0.0	0.264	0.0	0.0	0.267	0.1	1.6	0.242	0.7	1.1
1060+00	Swash	0.549	0.0	4.2	0.612	12.1	4.2	0.255	0.0	0.1	0.320	0.1	0.0	0.357	2.4	3.1	0.272	1.7	1.2
1070+00	Toe of Dune	0.315	0.1	0.5	0.278	0.0	0.6	0.347	0.0	0.0	0.325	0.0	0.0	0.278	2.1	1.5	0.342	5.2	1.1
1070+00	Beach Face	0.347	0.0	0.6	0.249	0.0	0.8	0.282	0.0	0.0	0.300	0.1	0.0	0.389	1.4	2.2	0.254	0.8	1.1
1070+00	Swash	0.498	5.9	4.1	0.856	14.4	7.0	0.256	0.0	0.1	0.363	0.4	0.0	0.309	1.1	3.3	0.289	3.4	1.6
ALL	Toe of Dune	0.269	0.0	0.7	0.321	0.2	1.0	0.258	0.0	0.5	0.281	0.1	0.0	0.298	0.6	1.4	0.314	4.5	0.9
ALL	Beach Face	0.402	1.8	2.3	0.304	0.2	1.6	0.280	0.0	0.9	0.318	0.2	0.0	0.329	0.4	2.9	0.290	3.4	1.4
ALL	Swash	0.647	4.5	6.7	0.575	13.5	5.6	0.264	0.1	0.6	0.372	0.4	0.0	0.390	1.0	1.6	0.301	4.6	1.2
ALL	ALL	0.402	2.0	3.3	0.393	4.2	2.9	0.267	0.1	0.7	0.322	0.2	0.0	0.337	0.7	1.9	0.302	4.2	1.2

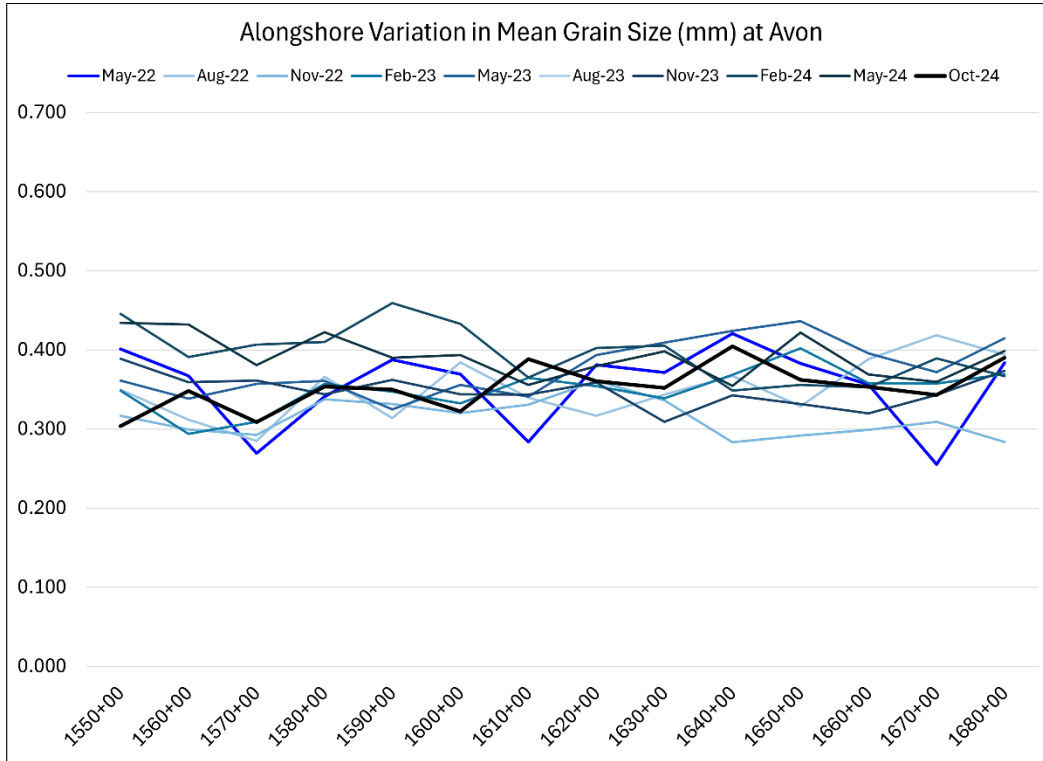


FIGURE 4.11a. Alongshore variation in mean grain size at Avon throughout Year 1 and Year 2.

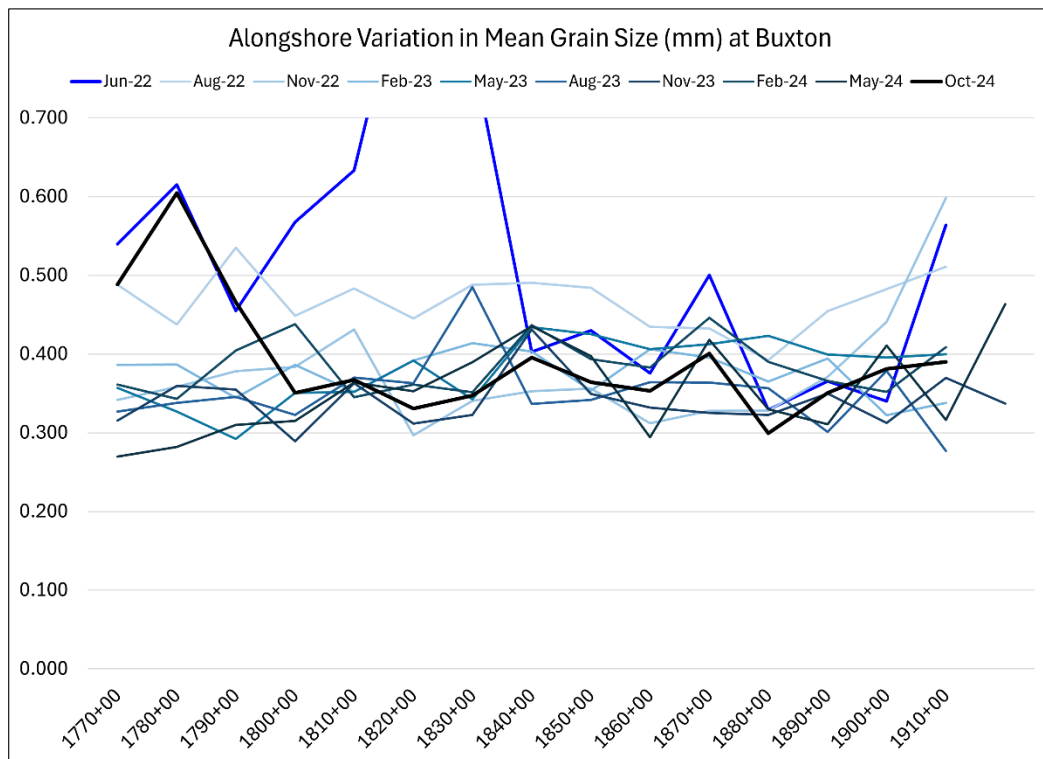


FIGURE 4.11b. Alongshore variation in mean grain size at Buxton throughout Year 1 and Year 2.

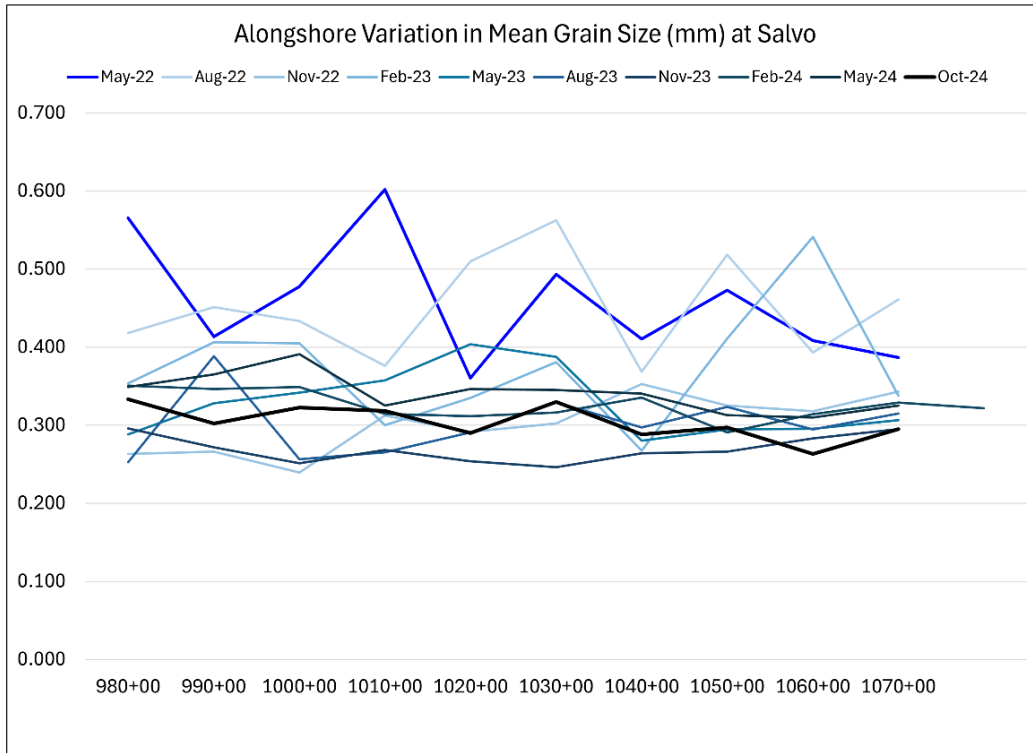


FIGURE 4.11c. Alongshore variation in mean grain size at Salvo throughout Year 1 and Year 2.

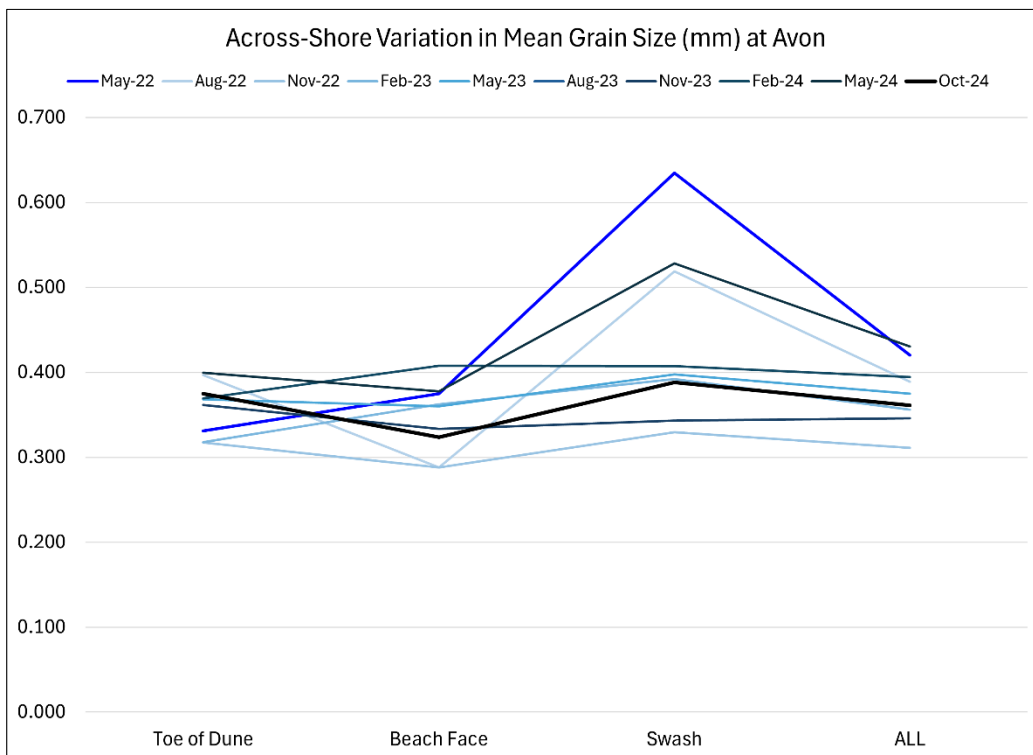


FIGURE 4.11d. Across-shore variation in mean grain size at Avon throughout Year 1 and Year 2.

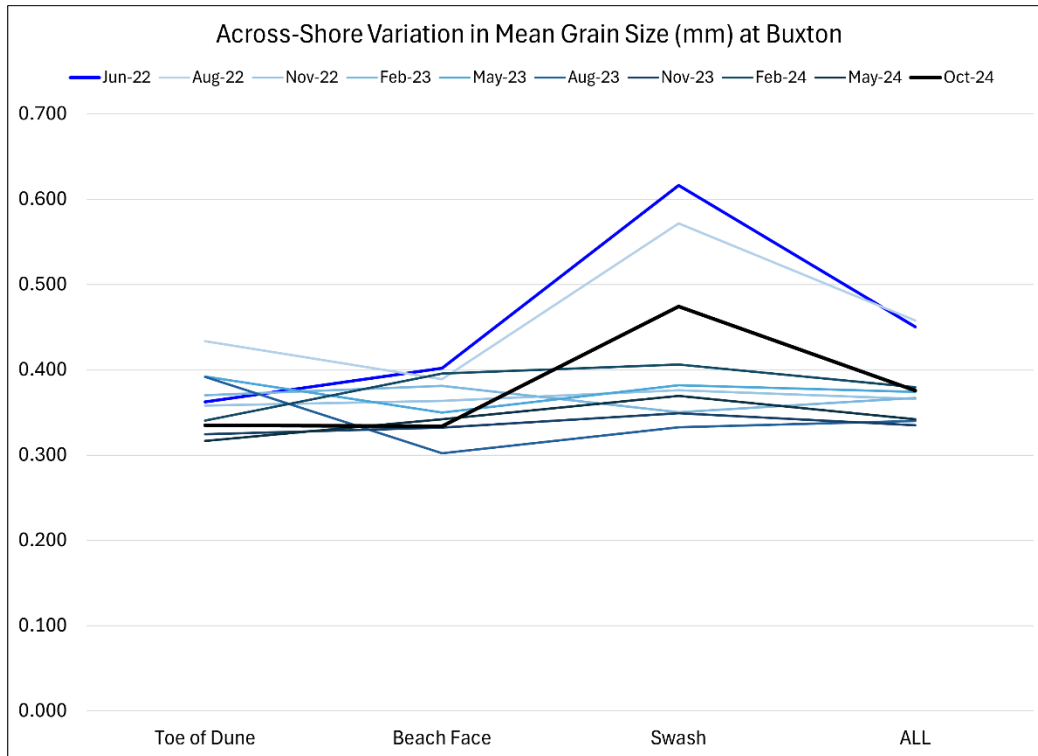


FIGURE 4.11e. Across-shore variation in mean grain size at Buxton throughout Year 1 and Year 2.

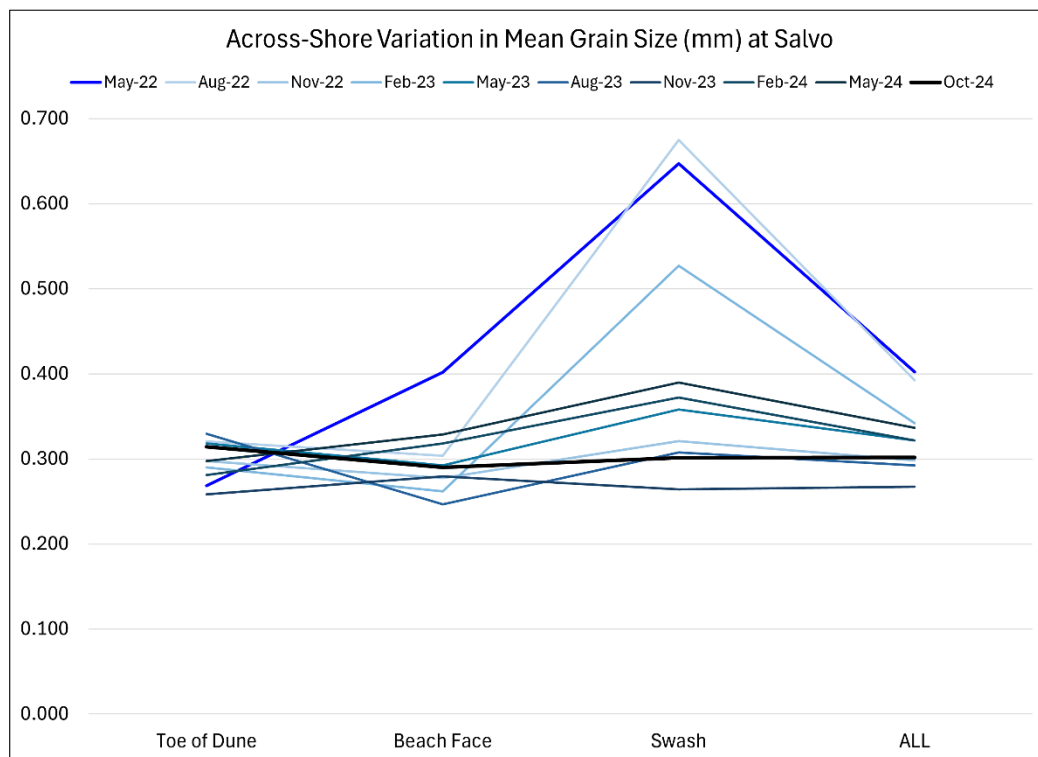


FIGURE 4.11f. Across-shore variation in mean grain size at Salvo throughout Year 1 and Year 2.

5.0 COASTAL RESILIENCY UPDATE

5.1 Weather and Climate Conditions, September 2023 to October 2024

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 September 2023 to October 2024 (the same as the survey data presented herein).

Wind data are compared to historical data covering the period from 1957 to 2024. 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 2024, <http://mrcc.purdue.edu/>). The closest operational station is located at Billy Mitchell Airport, in Hatteras. Wave data are recorded by the National Data Buoy Center (NDBC) Station 41025 (Diamond Shoals), ~15 and 25 nautical miles (nm) south of Buxton and Avon, respectively (https://www.ndbc.noaa.gov/station_page.php?station=41025).

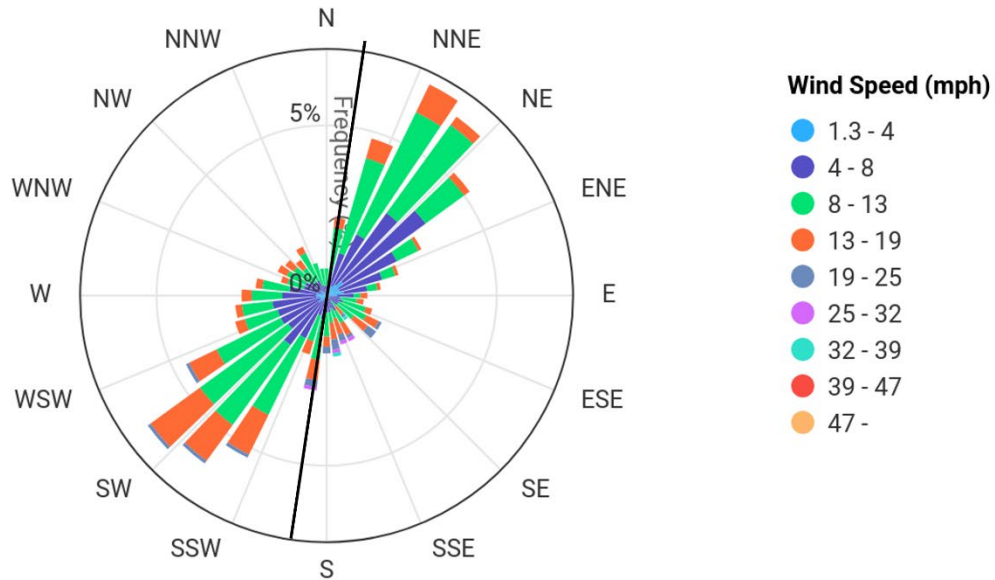
The average wind speed and direction* during the survey period was ~19.2 miles per hour (mph) from ~178° (approximately south-southeast, Fig 5.1). This is slightly higher than the longer-term data record, which dates back to 2010 (17.2 mph from ~185.5°). The peak observed wind speed was a gust to 69.8 mph from ~139° (approximately southeast) on 17 December 2023, during the passage of a nor'easter.

According to data from MRCC-NOAA, wind directions during the study period were similar to longer-term trends. The proportion of winds from the northeast (0°–90°) and northwest (270°–360°) quadrants represents 52.6% of the total from 1957 to 2024; between September 2023 and October 2024, these quadrants represented 48.4% of the total incoming winds.

The average wave height from September 2023 to October 2024 at Station 41025 was ~5.0 ft, with an average wave period of ~5.4 seconds. The maximum observed wave height was 28.8 ft during the passage of a nor'easter on December 17–18, 2023 (Fig 5.2). The average wave direction was ~151°, southeast. From 2010 to 2024, the maximum observed wave height was ~29.4 ft (Hurricane *Florence*, September 2018), while the maximum wind speed was a gust to 87.5 mph (Hurricane *Dorian*, September 2019). Peak conditions from 2023 to 2024 were comparably severe to those observed in the long-term record, suggesting this survey period represents relatively high-energy conditions compared to the last 15 years.

CAPE HATTERAS AP (NC) Wind rose

September 08, 2023 - October 31, 2024
Sub-Interval: January 1 - December 31, 0 - 24



CAPE HATTERAS AP (NC) Wind rose

March 01, 1957 - October 31, 2024
Sub-Interval: January 1 - December 31, 0 - 24

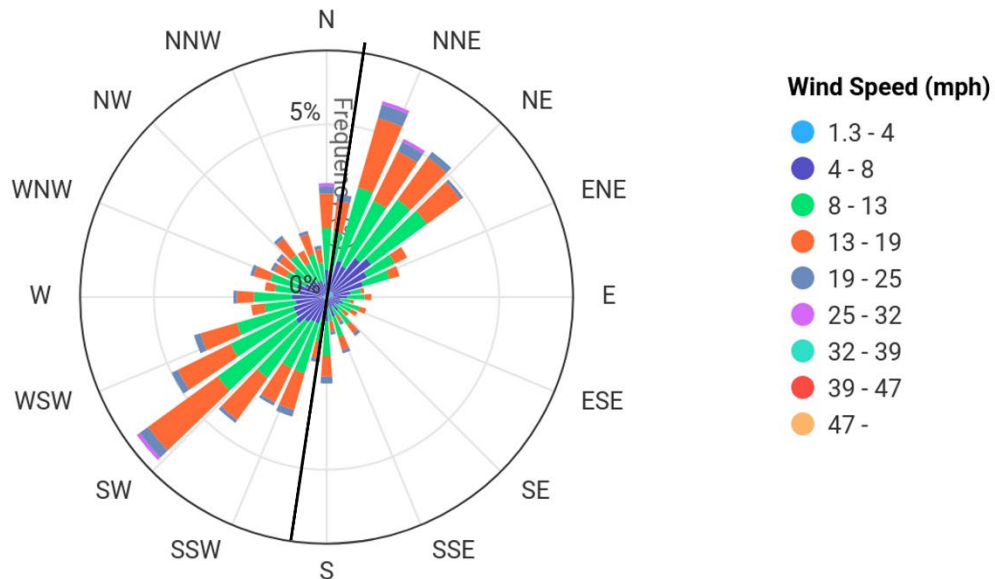


FIGURE 5.1. Wind roses showing direction and magnitude of winds measured at Billy Mitchell Airport from September 2023 to October 2024 [UPPER] and from March 1957 to October 2024 [LOWER]. The line across the wave rose indicates the average shoreline orientation along Hatteras Island between Cape Point and Avon (~10° N).

Other than during the passage of nor'easters, atmospheric pressure dropped below 1000 millibars (mb) six times from September 2023 to October 2024. This metric is used because most Category 1 hurricanes have a central pressure of ~980–990 mb, and many nor'easter-type storms will feature central pressures below 1000 mb. Similarly, wave height is an easy parameter for distinguishing the relative intensity of storm events. However, atmospheric pressure and wave height are imperfect measures because they 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 a high tide).

The fundamental driver of beach erosion is (are) variation(s) in sediment transport. An increase in erosion indicates more sand is being transported away from a location than toward it. Over time, this reduces beach volumes as measured via surveys (described in Section 3.2). Sand transport increases exponentially with shear stresses generated by currents and wave action, such that a doubling of tidal channel flow velocity or wave height will increase sediment transport rates several times over. This helps explain why even minor storms can exact significant erosional losses along the coast: a four-foot wave is four times more powerful than a two-foot wave.

Engineers and scientists use measurements of wave properties, such as height, length, and speed, to estimate the magnitude of energy exerted by a single wave crest. 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 generating southerly transport (ie – north to south) and northerly transport (ie – south to north) can be differentiated.

To visualize this on a graph, wave power can be calculated so that northerly south-to-north transport is measured above zero (positive) while southerly transport north-to-south is measured below zero (negative). The estimated wave power at Avon and Buxton from September 2023 to October 2024 is shown in Figure 5.3. The larger-magnitude positive wave power values in the winter months represent the passage of low-pressure tropical cyclones and nor'easters.

The most powerful wave from September 2023 to October 2024 occurred on 17 December, with 11.8 kW/m of wave power directed in a northerly direction during the passage of a nor'easter. If individual wave observations are counted as discrete events, southerly-directed wave energy is slightly dominant from September 2023 to October 2024 (eg – ~7,319 observations from south to north versus ~8,924 observations from north to south). The total wave power of northerly-directed

energy at both Avon and Buxton from September 2023 to October 2024 was ~7,113 kW/m, while southerly-directed wave power was -5,124 kW/m.

At the buoy, northerly waves occur more frequently and stronger. From 2010 to 2024, ~56% of wave observations were northerly, but the average power of a southerly wave was ~53% greater. In many locations along the South Atlantic Bight, this observation aligns with long-term anecdotal evidence that documents more frequent wave events approaching from the south, but the strongest events approaching from the north.

The difference between offshore and nearshore measurements is important to consider when interpreting these data. Sediment transport is primarily influenced by wave height, which is modified by the refraction of wave energy around bars and shoals in the nearshore and shallow offshore zones. Moreover, Station 41025 is located along the southern flank of Diamond Shoals, which means it is shielded from the southerly wave energy that can dominate winter and spring months along Hatteras Island.

All this is to say, offshore buoy data are an imperfect representation, but remain valuable for comparing long-term records against beach volume measurements. Plotting the data as a time series (Fig 5.3) helps visualize the relative frequency and magnitude of northerly- and southerly-directed wave events. Looking across the entire Year 2 survey period, there is a period of distinct northerly flow (positive values) from ~September 2023 through March 2024. Over the long term, total southerly wave energy tends to outpace northerly wave energy over every month other than March, October, and November. Over the 14 months from September 2023 to October 2024, net northerly wave energy is greater for nearly 50% of the time.

Collectively, these results indicate that wave heights and directions from September 2023 to October 2024 remained similar to long-term trends. However, the distribution and timing of heights and directions were more strongly skewed towards a northerly flow than typical. This pattern would generate a south-to-north net longshore sediment transport direction along both Avon and Buxton. Although the long-term sediment transport direction along much of the northern Outer Banks is from north to south, periodic reversals related to prevailing wind and wave patterns in a given year have been documented (Park and Wells 2005, Smallegan 2012, Kana and Kaczowski 2012). The apparent net sand transport away from the Buxton project towards the north is a strong indicator of such a reversal; once conditions return to a more 'normal' balance of transport, that trend should reverse.

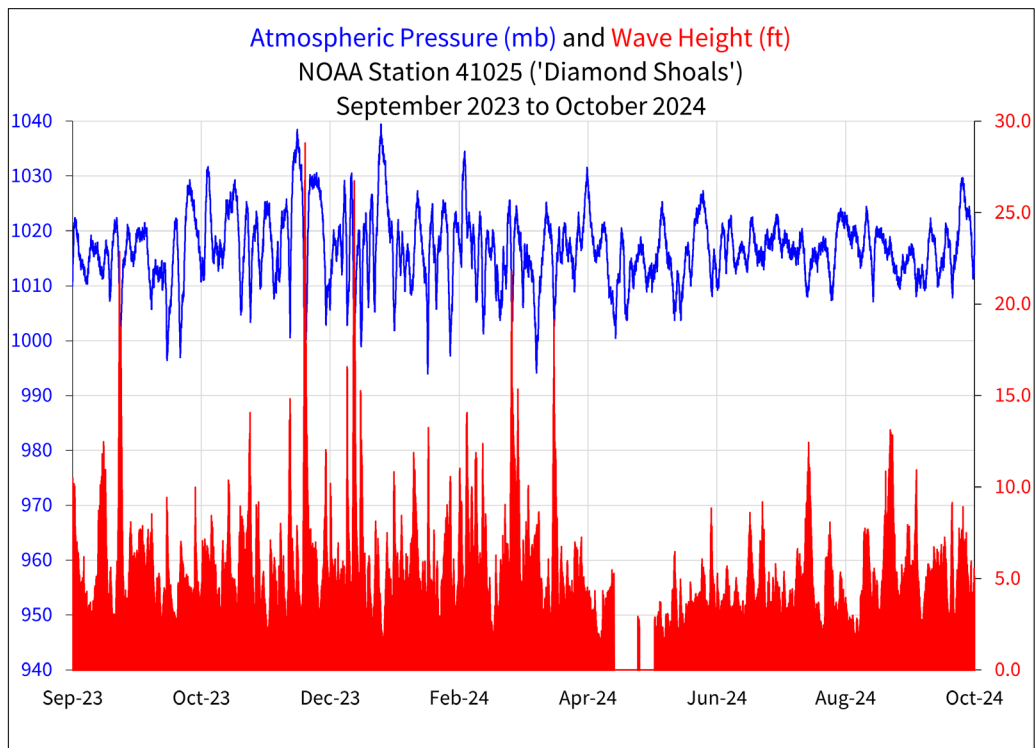


FIGURE 5.2. Atmospheric pressure and wave height at NDBC 41025 from September 2023 to October 2024. Conditions were relatively calm, compared to long-term averages.

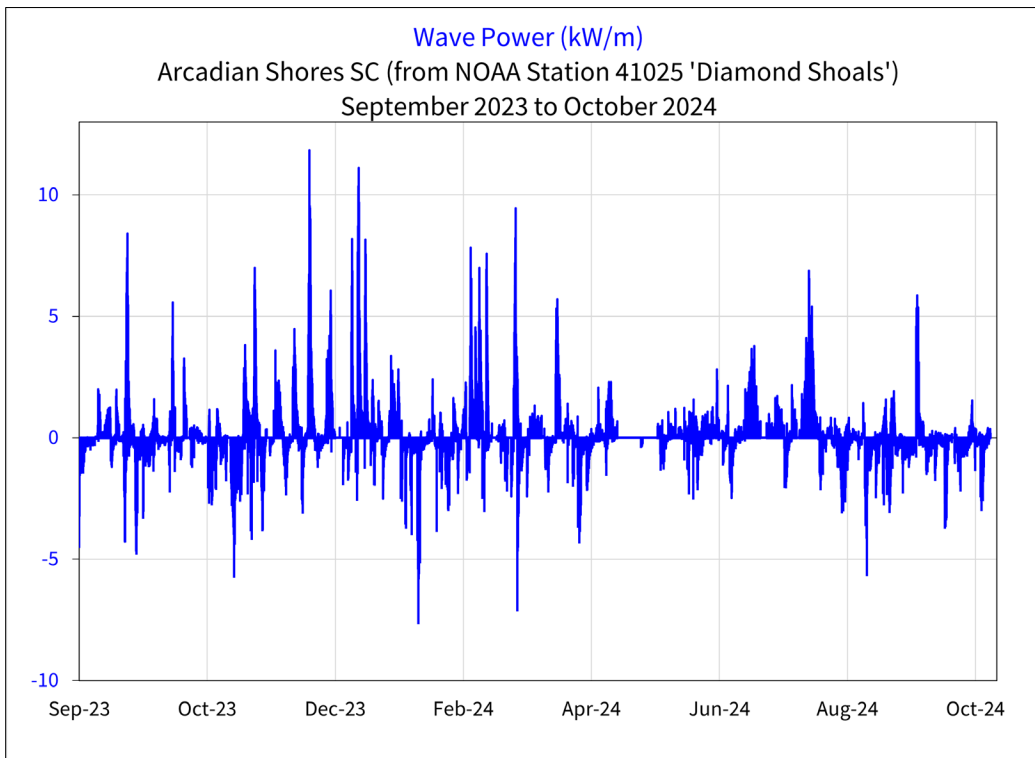


FIGURE 5.3. Wave power (in kW/m) for NDBC 41120 from September 2023 to October 2024. Wave power is a useful parameter for determining the relative magnitude and direction of wave energy in an alongshore direction along a beach. Positive values indicate waves move from south to north (ie, northerly transport), while negative values indicate predominance of north-to-south (ie, southerly) transport.

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6.0 SUMMARY OF FINDINGS

Two nourishment projects were completed at Avon and Buxton in the summer of 2022. These projects placed a total of 2,200,000 cy along 28,700 ft of beach. Along Avon, 1.0 million cy were placed along 13,200 ft, while along Buxton, 1.2 million cy were placed along 15,500 ft. Due to the proximity of the placement sites, both were completed in a single deployment by the same contractor working under a single agreement with Dare County.

This report documents changes at both sites over the course of the second year following project completion from September 2023 to October 2024. The changes reported herein were measured over a series of quarterly and annual surveys described in the post-project monitoring and mitigation plan submitted, along with the permit applications for each location. This plan was determined through coordination between Dare County and CSE based on guidance from NPS, USFWS, and CAMA personnel.

Results presented in this report and its appendices include:

- Beach and inshore profile surveys (2023 to 2024 – main report; see Sections 4.1 and 4.2)
 - The project area at Avon retains ~32% of the nourishment volume above –6 ft NAVD and 20% of the nourishment volume above –30 ft NAVD. This indicates the template is equilibrating to background wave conditions and continues to provide good storm wave height reduction without overwash or dune erosion along the entire project site.
 - The project area at Buxton retains ~28% of the nourishment volume above –6 ft NAVD and 4% above –30 ft NAVD. A temporary reversal in longshore sediment transport from 2023 to 2024 may have created an erosional arc on the north side of the old lighthouse site groins, leading to higher-than-expected erosion rates along the village.
 - These changes are described in more detail in Section 4.2.
- Aerial photography (2022 to 2024 – main report; see Section 4.3)
- Sand compaction (pre-project to 2024 – main report; see Section 4.4)
 - Compaction survey results collected quarterly over the course of Year 2 indicate both project sites are comparable to the ‘Control’ area south of Salvo. These results indicate that neither fill template caused an unnatural increase in compaction following project completion.
- Geotechnical characteristics of the fill material (2023 to 2024 – main report; see Section 4.5)
 - Sand samples collected quarterly over the course of Year 2 indicate both project sites exhibit comparable mean grain sizes and distributions as the ‘Control’ area south of Salvo. Variations observed at both sites over the course of Year 2 were also observed along the ‘Control’ area. Results indicate both templates were constructed using appropriate beach-quality sand with no remarkable differences between pre- and post-project conditions.
- Ecological monitoring (2023 and 2024 – Appendix D)

This is the second annual report in a five-year series following completion of the nourishment projects at Avon and Buxton. According to permit conditions, sand compaction measurements, visual inspections for escarpments, and a lighting survey are to occur only in Year 1 (2023), while ecological monitoring is to occur during Year 1 and Year 2 (2023 and 2024). So, the next report (Year 3 – 2025) will not include the compaction, escarpment, and lighting assessments.

Most survey profiles along both project areas retain more than 20% of the placed volumes above –30 ft NAVD. This indicates that templates continue to reduce storm damage by attenuating wave energy in the surf zone. However, erosion attributable to the nearshore trough and bar has been excessive over the past year. While it is not possible to know or say when this temporary increase in erosion rates will subside, the bar along both project areas is closer to the shoreline than in any previous survey at either site.

The Outer Banks and Hatteras Island in particular are among the most energetic wave-dominated settings on the US East Coast. Storm impacts from tropical and non-tropical cyclones are frequent and severe. CSE is closely monitoring beach conditions and will conduct the next annual survey data collection in August 2025.

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