

# BEACH NOURISHMENT AND SEDIMENT MANAGEMENT FRAMEWORK FOR HATTERAS ISLAND, NORTH CAROLINA, USA

Haiqing Liu Kaczkowski<sup>1</sup>, PhD, PE and Stephen Kaczkowski<sup>2</sup>, PhD

Hatteras Island features 85 kilometers (km) of developed and undeveloped shoreline and the beaches exhibit a range of conditions from accreting segments to retreating ones. NC Highway 12 (NC 12) is the only north-south highway along Hatteras Island and serves as the primary route for local access, emergency response, and connectivity to state and federal facilities. NC 12 at Hatteras Island has suffered repeated damage from erosion and dune breaches over the past thirty years. To address these challenges, the National Park Service (NPS), in collaboration with state and federal agencies, developed a sediment management framework (Framework) in 2022. This Framework outlines anticipated methods, locations, and frequencies for sediment management actions over the next 20 years, with beach nourishment as one of the main engineering solutions. By adopting this comprehensive approach, the Framework allows for the cumulative impacts of multiple sediment management actions to be considered, enhancing resilience to climate change effects. Following the Framework's guidelines, the first two beach nourishment projects were completed in Avon and Buxton in summer 2022, targeting the most vulnerable sections of the island. These efforts followed an earlier nourishment project in Buxton in 2017-2018. Collectively, these projects have placed approximately 3.692 million m<sup>3</sup> (4.8 million cubic yards) of beach-quality sand along an 8.7-km stretch of oceanfront, at a total construction cost of over \$48 million to the local government – Dare County. These nourishment efforts have significantly reinforced the island's shoreline, enabling it to withstand multiple hurricanes and storms without major damage to NC 12 or oceanfront properties since their completion.

*Keywords: Hatteras Island, North Carolina, Dare County, NPS, NC Highway 12, Sediment Management, Beach Nourishment, STWAVE, GenCade*

## PROJECT BACKGROUND

Hatteras Island, located in Dare County and Hyde County, North Carolina (NC), is a classic example of a micro-tidal, wave-dominated barrier island, formed by the shaping of littoral sands from the inner continental shelf into a narrow, elongated landform. As part of the North Carolina's Outer Banks, it includes 25 kilometers (km) of developed oceanfront and 60 km of undeveloped shoreline within the Cape Hatteras National Seashore (Seashore). Established as the nation's first national seashore in 1937, it was reauthorized as the Cape Hatteras National Seashore Recreational Area in 1940 and officially designated in 1953. The area is renowned for its rich recreational, natural, and cultural offerings, including historic landmarks such as the Cape Hatteras Lighthouse. Standing at 64 meters (210 feet), it is the tallest brick lighthouse in the United States and the second tallest in the world. With its local and regional appeal, the Seashore attracts over 2 million visitors annually, offering opportunities to explore both ocean and sound-side beaches. Despite its appeal, Hatteras Island faces significant coastal challenges. It is one of the most hazardous sections of the Atlantic Coast due to the 12-mile-long sandbar, Diamond Shoals, where the Gulf Stream meets the Virginia Drift. This collision has caused numerous shipwrecks, earning the area its nickname, "*Graveyard of the Atlantic*." Coastal erosion has been a persistent issue along the Seashore, leading to road closures and even island breaches in the past, posing serious risks to public safety as well as state and federal infrastructure.

## NC Highway 12 Task Force

NC Highway 12 (NC 12) serves as the sole north-south highway on Hatteras Island, providing vital access for communities, emergency vehicles, and National Park facilities. Over the past 30 years, NC 12 has suffered repeated damage from erosion and dune breaches, with various sections forced to close due to weather events such as storms, nor'easters, and hurricanes. These events often result in overwash or complete washouts of portions of the roadway, causing significant disruptions to the lives, health, safety, and welfare of Hatteras Island residents and visitors.

In late 2020, representatives from Dare County, Hyde County, the National Park Service (NPS), and other state and federal agencies formed the "NC 12 Task Force." The task force's mission is to develop a long-term, prioritized plan for NC 12, focusing on identifying vulnerable highway locations ("hotspots"), projecting future challenges such as erosion, storms, and sea-level rise, and recommending location-specific solutions. Additionally, the plan includes funding strategies and a timeline for implementation. Under the task force's leadership, seven erosion "hotspots" were identified, including the narrow isthmus areas near Avon and Buxton (Figure 1).

## 2017-2018 Buxton Beach Nourishment

The Village of Buxton is situated on Hatteras Island near the cape where NC 12 curves. It is bordered by the Atlantic Ocean to the east and Pamlico Sound to the west. The narrow section immediately north of Buxton has previously experienced breaches and remains highly vulnerable to future breaches. Erosion

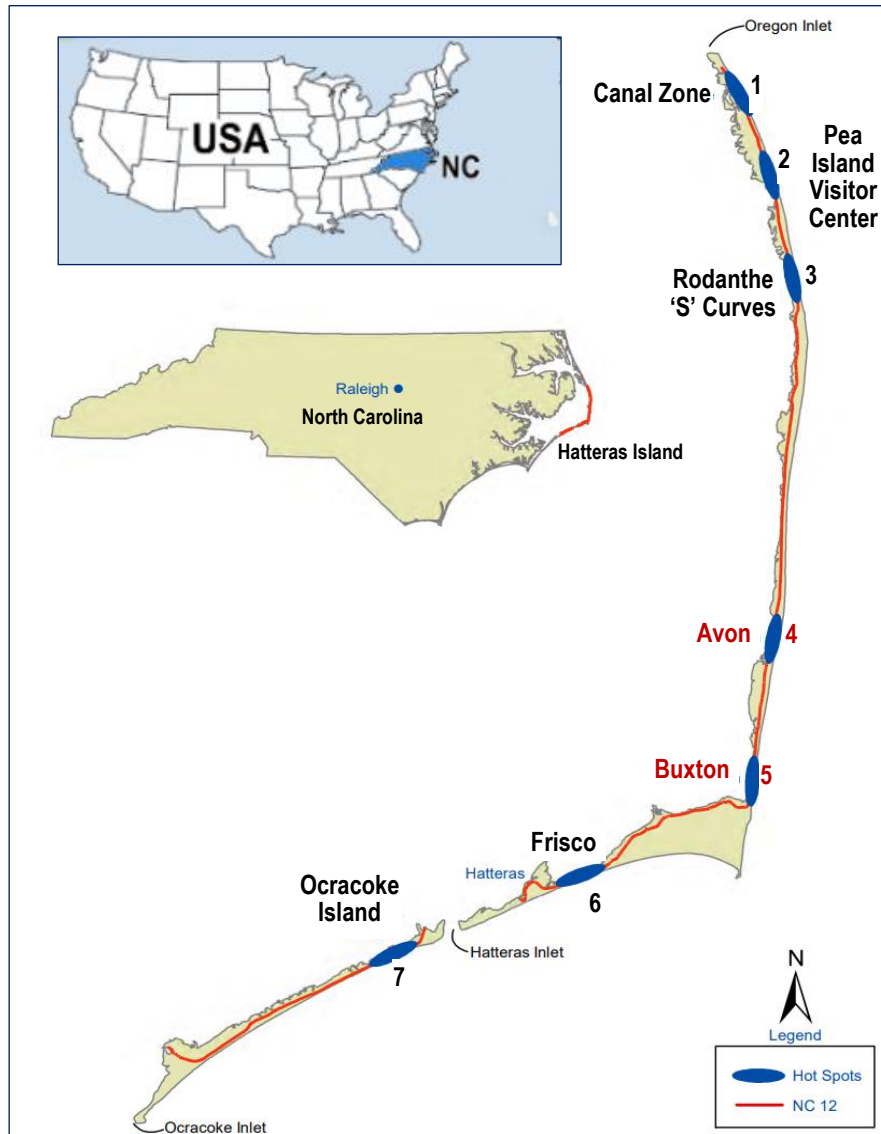
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<sup>1</sup> South Carolina Governor's School for Science & Mathematics, USA.

<sup>2</sup> South Carolina Governor's School for Science & Mathematics, USA.

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has also undermined oceanfront houses and motel units along the eastern shore of Buxton, prompting emergency measures such as sand-bagging to protect structures along approximately 450 meters of oceanfront at the south end of the Buxton area. While temporarily safeguarding structures, sandbags have eliminated a recreational beach and associated habitats. The series of photos in Figure 2 show flooding of NC 12 and damaging waves along the Buxton oceanfront during a northeaster on 8 Dec 2014 before the 2017-2018 nourishment project. Erosion has left little sand on the beach.



**Figure 1. Hatteras Island (North Carolina, USA) and its seven erosional “hotspots” identified by the NC 12 Task Force – a collaborative effort by the local government and the state and federal resource agencies. Avon (#4) and Buxton (#5) are the two sites that were nourished in summer 2022.**



**Figure 2. Flooding of NC 12 and damaging waves along the Buxton oceanfront properties during a northeaster on 8 December 2014 (NPS/USACE 2015).**

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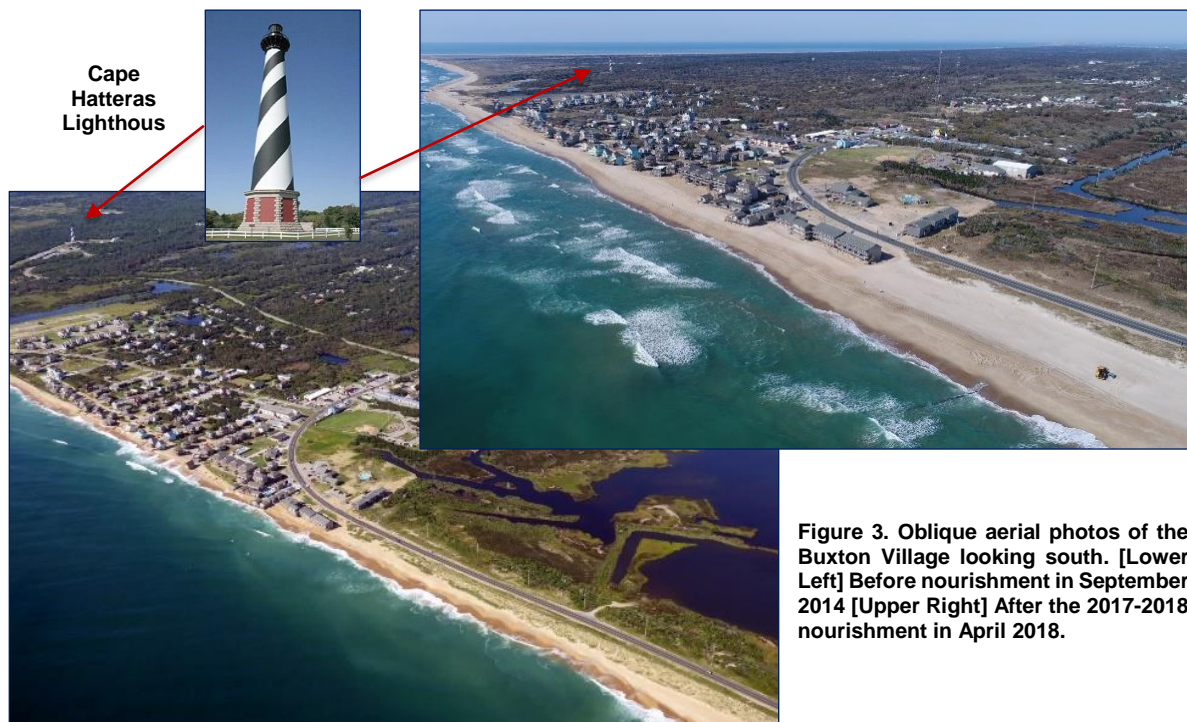
A feasibility study to evaluate erosion, develop potential solutions, and assess the environmental impacts of beach restoration alternatives and potential impacts was completed in 2015 (NPS/USACE 2015). Using official long-term erosion rates published by NCDENR (2012) and beach condition surveys conducted between 2012 and 2014, the study estimated an average annual erosion rate of 88,000 m<sup>3</sup> (114,500 cy) per year for 4,700-meter (15,500-ft) project area. Numerical models of wave and shoreline evolution were utilized to optimize the nourishment design, evaluate project's longevity, and analyze its impact on the wave field. Funded entirely by the local government (Dare County), a 2-million cubic meter (m<sup>3</sup>) beach nourishment project utilizing an offshore borrow area was planned and permitted.

Summer dredging was allowed for beach nourishment projects in the northern Outer Banks to avoid the inclement wave conditions typical in winter. The Contractor, Weeks Marine, elected to use a cutterhead dredge (*CR McCaskill*) to start the nourishment on 21 June 2017. However, progress was slow, mainly due to rough sea conditions that frequently halted operations and caused mechanical issues. By 22 August 2017, approximately 845,000 m<sup>3</sup> (1.1 million cy) of sand, about 42 percent of the total contract volume, was placed on the beach by the *CR McCaskill*.

In September 2017, four named hurricanes (*Irma, Jose, Katia, and Maria*) affected the project area, producing wave heights that exceeded the safe operating limits for a cutterhead dredge. As a result, construction was halted for over 50 days. On 11 October, the Contractor resumed operations using a hopper dredge (*RN Weeks*).

Weeks Marine's newly constructed hopper dredge, *Magdalen*, passed sea trials and received its operation certificate just in time in January 2018, when approximately 80 percent of the project was finished. With double the capacity of *RN Weeks*, the *Magdalen* completed the remaining 385,000 m<sup>3</sup> of work. The final load was delivered at 1:30 pm on 27 February 2018, nearly 5 months behind the Contractor's original schedule. During the summer months (June through August), the average daily production rate was approximately 13,850 m<sup>3</sup> per day (m<sup>3</sup>/day), while in the fall and winter months (September to February), it dropped to about 6,150 m<sup>3</sup>/day.

Despite the delays, the project was successfully completed without any sea turtle fatalities or other environmental incidents. Nourishment in front of the narrow isthmus of NC Highway 12 was completed, and the highly vulnerable section of the road was protected (Figure 3). The Buxton project offers valuable insights for future renourishment efforts. Without the allowance for summer dredging, construction could have taken even longer, potentially leaving the road vulnerable to breaches during hurricanes and storms.



**Figure 3. Oblique aerial photos of the Buxton Village looking south. [Lower Left] Before nourishment in September 2014 [Upper Right] After the 2017-2018 nourishment in April 2018.**

### NPS SEDIMENT MANAGEMENT FRAMEWORK

Following the successful completion of the 2017–2018 Buxton beach nourishment project, the National Park Service (NPS) took the lead in conducting a shoreline assessment and sediment management study for the entirety of Hatteras Island. Working in collaboration with state and federal agencies, they finalized a Sediment Management Framework (Framework) in June 2021 (NPS 2021). The Framework aims to guide the issuance of special use permits for sediment management at the Seashore, addressing the impacts of human-altered shoreline processes while aligning with NPS management policies and missions. It outlines the anticipated methods, locations, and frequency of sediment management actions that may be implemented over the next 20 years (Figure 4).

The development of the Framework enables the Seashore to evaluate the long-term, cumulative impacts of multiple sediment management actions over many years within a comprehensive context, enhancing resilience to climate change. Guided by the Framework, the NPS could allow agencies, municipalities, and other entities to conduct sediment management activities—such as sound-side and ocean-side beach nourishment, dune restoration, and filling island breaches—under specific conditions.

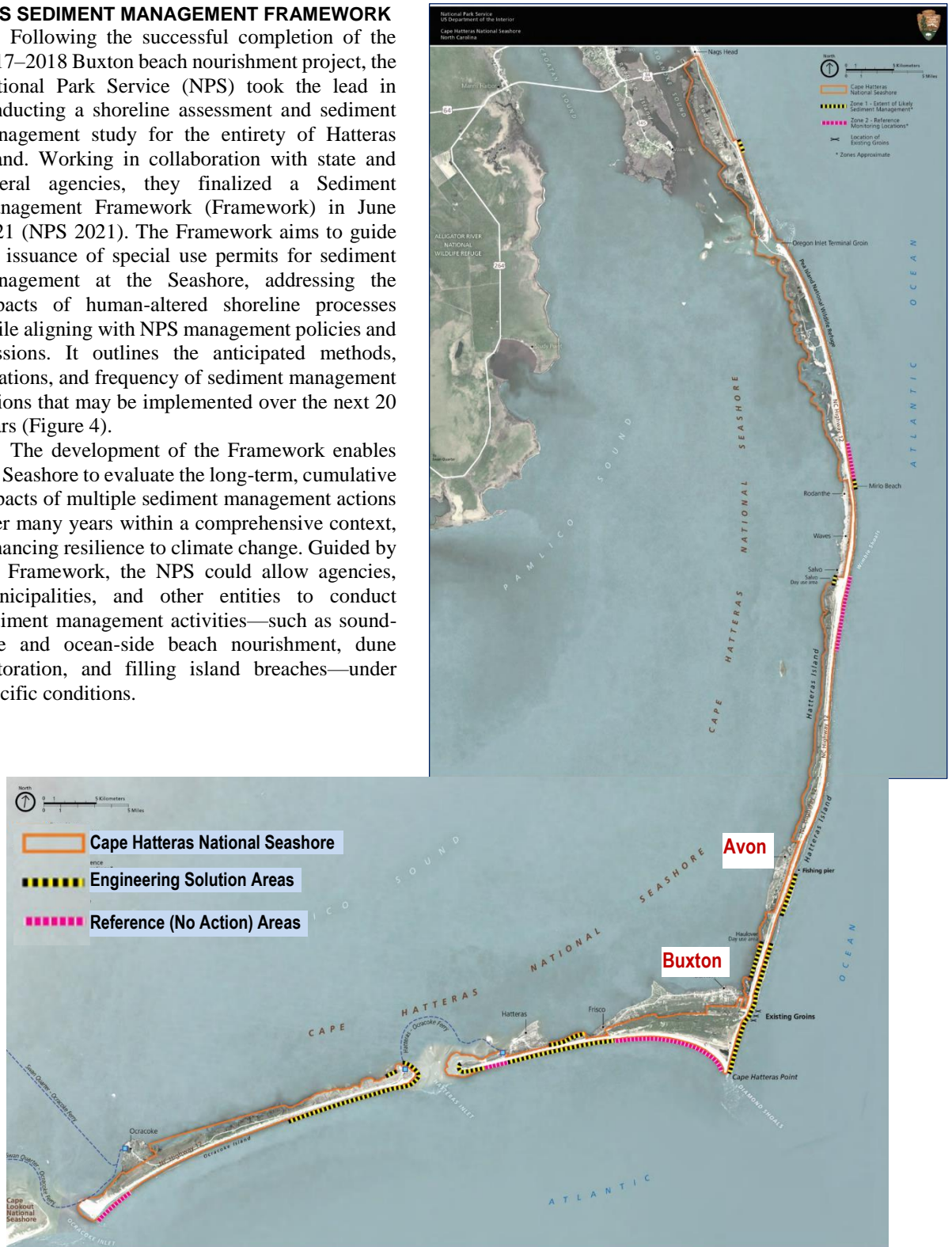


Figure 4. Areas of likely sediment management activities presented in NPS' Final Environmental Impact Statement (NPS 2021). Zone 1 (black and yellow bars) represents the likely sediment management areas over the next twenty years, and Zone 2 (red bars) represents the reference areas that would be excluded from consideration for sediment management activities unless there is an emergency.

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The NPS would require resource monitoring within its jurisdiction, and permitted activities would require mitigation measures to minimize impacts on park resources. Up to 10 km of the Seashore could undergo sediment management annually, with individual sites eligible for recurring work as frequently as every three years. In emergency situations, an additional 10 km of sediment management could be authorized. Monitoring would be conducted before and after sediment management projects, tailored to the resources at each project site, to gather insights and improve conditions for future projects.

Furthermore, the NPS would reserve five sections, totaling approximately 20 km of the Seashore (around 23% of the total shoreline, identified as Zone 2 in Figure 4), from sediment management activities under normal conditions. These areas, exempt except in emergencies, would serve as ecological study zones and reference areas for comparative studies with managed sites.

Comparisons between reference zones and action zones could lead to future adjustments in the frequency, timing, or methods of nourishment projects. In addition to reviewing and, where appropriate, permitting projects proposed by other entities, the NPS would collaborate with other agencies to utilize dredged sediment for habitat restoration. This effort would support nesting wildlife, including shorebirds, at the southern end of Hatteras Island and Green Island in Oregon Inlet.

### **NPS FRAMEWORK IMPLEMENTATION – THE FIRST TWO BEACH NOURISHMENT PROJECTS**

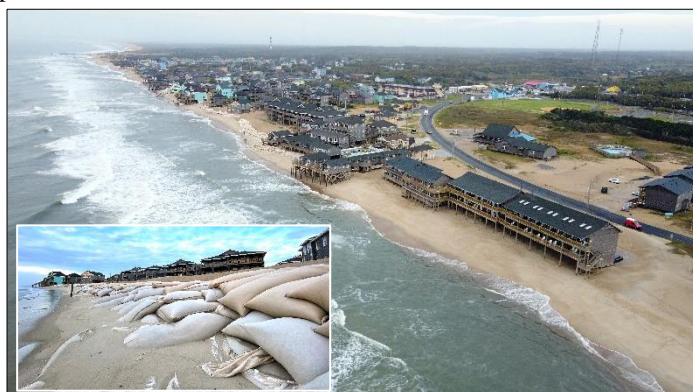
Following the guidelines of the NPS Framework, the first two beach nourishment projects were carried out in summer 2022 along two of the seven most vulnerable sections of Hatteras Island. Both projects utilized ocean-certified dredges to excavate sand from designated offshore borrow areas. Given the close proximity of the two project sites, approximately 2.5 km apart, a combined nourishment effort was undertaken, resulting in cost savings on dredge mobilization.

#### **2022 Buxton Beach Renourishment**

Following the completion of the 2017–2018 Buxton nourishment project, the newly restored beach successfully withstood multiple nor'easters in March 2018, two hurricanes in 2018 and 2019, and other severe weather events without disrupting traffic on NC 12. The widened dry-sand beach served as a feeder for dune growth after nourishment through aeolian transport (Kaczkowski et al, 2018), however, sand from the nourishment project was lost beyond the depth of closure (-7.3 m NAVD) after each weather event, moving outside the project area. By August 2020, less than 500,000 m<sup>3</sup> of the nourishment sand remained within the project area, approximately 25% of the volume originally placed during the 2017–2018 effort.

Between February 2018 and August 2020, the annual erosion rate in the Buxton project area was approximately 500,000 m<sup>3</sup>/year, significantly exceeding the historical average of 88,000 m<sup>3</sup>/year used in the design of the 2017–2018 project. Similarly, in recent years high erosion rates have been observed at Nags Head, which is located about 70 km northeast of Buxton in the northern Outer Banks. The unusually high erosion rate in the Buxton area during the first three years post-completion (2018–2020) can be attributed to several factors, including increased storm activity, the deteriorating condition of sand-retaining structures (e.g., groins) at the southern end of the project area reducing their sand-trapping effectiveness, and the migration of sand offshore beyond the depth of closure, influenced by the presence of a nearshore deep trough. Oblique aerial photos taken on April 15, 2021 (Figure 5), reveal a minimal dry-sand beach remaining along the Village of Buxton. Some previously buried sandbags have been re-exposed due to erosion, and new sandbags have been installed by property owners along the oceanfront as a temporary measure for shoreline protection. The loss of the dry beach has once again left NC Highway 12 vulnerable to flooding and potential breaches.

**Figure 5. Ground and aerial images taken on 15 April 2021 – looking south. The Village of Buxton north limit is located approximately at the end of the northernmost building shown near the bottom of the photo. Three years after the initial 2017–2018 beach restoration project, almost all nourishment sand was lost outside of the project limits beyond the depth of closure (USACE 2021a).**



A maintenance renourishment project along the same stretch of Buxton beach was planned in 2020-2021 (USACE 2021a), a total of 917,500 m<sup>3</sup> of sand was designed to be placed along the 4.7 km Buxton oceanfront. Numerical models (STWAVE and GenCade) were calibrated by the measurements after the 2017-2018 projects and used to optimize the renourishment design.

### 2022 Avon Beach Nourishment

The Village of Avon is located north of Buxton within the Cape Hatteras National Seashore. As an unincorporated community under the jurisdiction of Dare County, Avon is regarded as the largest and most active town on Hatteras Island. As with other communities on Hatteras Island, NC Highway 12 is the main route for public and emergency vehicle access to Avon. Avon, along with Buxton, is one of the seven erosion hotspots identified by the NC 12 Task Force (see Figure 1).

The Avon Ocean Pier, located near the center of the village, serves as a coastal landmark on maps. The shoreline north of the pier has remained relatively stable over the past 50 years (NCDENR 2012). In contrast, the approximately 2.5 km of shoreline south of the pier has experienced accelerated erosion since 2010 (Figure 6). In recent years, erosion rates along this critically eroded section of Avon's oceanfront have reached 5–6 meters per year.

In 2020, the NC Division of Coastal Management (NCDCM) reported official erosion rates for Avon ranging from 0.6 m/year in an area north of the Avon Pier to 1.8 m/year along an approximately 1,200 m (4,000 ft) stretch of beach south of the pier. Erosion rates decrease to 1 m/year at the southern edge of the village. Based on these official erosion rates and beach condition surveys in 2020 and 2021, the long-term historical erosion rate for the 4 km (13,200 ft) Avon project area is estimated at 108,000 m<sup>3</sup>/yr (140,000 cy/yr). Restoring the project area for five years under normal weather conditions, would require approximately 764,500 m<sup>3</sup> (1 million cubic yards) of sand (USACE 2021b).

### Numerical Modeling – STWAVE and GenCade

Avon and Buxton experience coastal processes typical of northern North Carolina, including winds, waves, tides, and currents. The Outer Banks in this region is exposed to ocean-swell waves from the southeast and storm waves generated by nor'easters. The highest waves are usually associated with tropical storms and can align with hurricane surges. Hurricane waves may approach from various onshore directions as storms pass through the area. The spring tide range is approximately 1 m (3.5 ft) (NOAA-NOS 1983), with semi-diurnal tides.

Previous studies and geomorphic evidence indicate that net longshore sediment transport in this area predominantly moves southward (Inman & Dolan 1989). A detailed coastal processes study was conducted for Buxton during the 2017–2018 nourishment project (NPS/USACE 2015). Additionally, an updated littoral processes study was performed in 2022 for the Avon and Buxton nourishment projects, addressing specific questions about the potential impacts of the proposed work.

Utilizing an offshore borrow area can impact wave dynamics, altering local sand transport rates. The geometry of the borrow area may reduce wave heights in certain regions while increasing them in others. To evaluate the effects of the borrow area on wave conditions and sediment transport, wave heights over the proposed borrow site were analyzed, and were compared pre-dredge conditions to anticipated post-dredge scenarios. Sediment transport was assessed to understand how localized increases in wave energy density caused by the borrow area might influence regional sand transport potential.

The placement of nourishment sand on the beach can potentially affect sediment transport in other critical locations. For the 2017–2018 Buxton project, the depth of closure—defined as the approximate limit of measurable seabed changes over specific time scales—was analyzed as a key factor in selecting the borrow site (NPS/USACE 2015). Ideally, borrow sites should be positioned offshore beyond the depth of closure to ensure they remain separate from the littoral system on decadal time scales. Borrow



**Figure 6. Aerial photo taken on 15 July 2020 looking north, showing the highly eroded section of Avon south of the pier. The ground photo was taken by Daniel Pullen on 20 September 2020 during Hurricane *Teddy*. NC Highway 12 was closed for 5 consecutive days due to overwash caused by ocean swell generated by *Teddy* (USACE 2021b).**

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sites located landward of the depth of closure may only redistribute sediment within the littoral zone, having minimal effect on the overall net sand volume.

The steady-state spectral wave model (STWAVE) was used in this study to evaluate the changes of wave patterns before and after dredging of the proposed borrow areas. The generalized model for simulating shoreline change (GenCade) was used to evaluate the impact on sediment transport caused by the placement of nourishment sand. GenCade is a regional model for calculating coastal sediment transport, morphology change, and sand bypassing at inlets and engineered structures. It is a next-generation model combining previous long-term planform evolution of beach models GENESIS (GENERALized Model for Simulating Shoreline) with Cascade. Both models are developed and approved by the USACE and have been widely used by coastal engineers and community planners in predicting the behavior of shorelines and sediment transport. Information on each model is available in USACE (2001), Hanson and Kraus (1989), Larson et al (2006), and Frey et al (2012).

### Wave Climate

Offshore wave information is typically obtained from a wave gauge or a global/regional scale wave hindcast or forecast. For littoral processes study and the design of most coastal engineering projects, nearshore wave information is essential. Waves influence sediment transport, nearshore currents, wave setup and runup, harbor oscillations, and the stability of coastal structures. In some cases, the gradients in wave height and direction alongshore and cross-shore are as critical as their magnitudes for meeting specific coastal design criteria. A real-time wave buoy at Diamond Shoals, located approximately 19 miles offshore from Avon and Buxton, provided 18 years of wave data spanning from 2003 to 2020.

The wave height, dominant period, and direction analyses based on the real-time wave buoy data at Diamond Shoals are listed in Table 1. It shows that June, July, and August have the lowest wave heights compared to other months.

**Table 1. Monthly average wave climate from 2003 through 2020 at NDBC wave buoy station 41025 at Diamond Shoals (NC). [Source: NDBC] Wave direction uses meteorological convention. A direction of 0° corresponds to a wave arriving from True North. Similarly, a direction of 90° corresponds to a wave from due east. Wave direction records are available only for the period after 2012 at this station. Four years (2011, 2012, 2013, and 2019) have less than 65% of expected records.**

	18-Year Record (2003–2020) at Diamond Shoals		
	Wave Height (ft)	Dominant Wave Period (s)	Wave Direction (°)
January	5.91	7.96	119
February	6.00	7.93	127
March	6.27	8.59	121
April	5.74	8.04	113
May	4.82	7.60	130
June	3.94	7.27	145
July	3.94	7.05	155
August	3.58	7.75	135
September	5.54	9.19	104
October	5.15	8.45	100
November	5.64	8.28	102
December	5.68	8.03	116
<b>Average</b>	<b>5.18</b>	<b>8.01</b>	<b>122</b>

### Wave Modeling – STWAVE

The goal of using nearshore wave transformation models is to quantitatively characterize changes in wave parameters—such as height, period, direction, and spectral shape—as waves propagate from offshore to nearshore areas, typically at depths of 40 meters or less. STWAVE is a user-friendly, flexible, and robust half-plane model designed for simulating nearshore wind/wave growth and propagation (USACE 2001). For the Avon and Buxton nourishment project, including comparisons of pre- and post-dredging wave patterns and assessing the relative impacts of the proposed work, STWAVE has been deemed effective, as demonstrated in similar settings (Ekphitsuntsorn et al. 2010; Kuang 2010; Kaczowski & Kana 2012; NPS/USACE 2015).

Results from the STWAVE model indicate that borrow-area dredging will not affect wave patterns along the project beach; the impact will be localized to the dredged area and its immediate surroundings. The most significant change is an approximately 10% increase in local wave height, expected to occur at the center of the borrow area. The pre-project depth in the borrow area is 3–10 meters deeper than the estimated depth of closure (-7.3 meters or -24 feet NAVD), and the proposed maximum excavation of 1.8–3 meters (6–10 feet) is shown to have no significant effect on shoreward wave patterns, with only localized modifications within the borrow area. Additionally, the results indicate that the location of the borrow area will not significantly alter sand transport processes or rates over the excavation site, nor will it impede or modify normal onshore sand transport (USACE 2021a; USACE 2021b).

### Shoreline Evolution Modeling – GenCade

GenCade was utilized in this study to assess longshore sediment transport at various stages of the design life after the proposed beach nourishment project. The results were analyzed to determine the impact of the nourishment and borrow-area dredging on longshore sediment transport along the beach.

Both STWAVE and GenCade are operated within the Surface-water Modeling System (SMS) interface, which combines a georeferenced environment with access to other USACE numerical models. This platform enables the rapid assessment of multiple engineering alternatives within a robust, self-contained system, making it a cost-effective tool for analyzing shoreline changes.

To effectively use GenCade, calibration is necessary by adjusting model parameters to accurately replicate historical shoreline changes or longshore sediment transport rates over a specified time period. The core module of GenCade, GENESIS, was calibrated and verified during the 2017–2018 Buxton nourishment study. In that study, simulated rates of total volumetric erosion and net longshore sediment transport were compared with historical erosion rates (NPS/USACE 2015). Simulated net longshore sediment transport rates and total volumetric erosion rates for Avon were compared with the estimated historical erosion rate of 108,000 m<sup>3</sup>/year, and the results agreed closely. For the Buxton project area, the net longshore sediment transport rate predicted by the GenCade model can capture the higher-than-normal volumetric loss rates of ~500,000 m<sup>3</sup>/yr between 2018 and 2020. The calibrated model was used to simulate post-project longshore transport along Avon and Buxton shoreline segments. Results showed only minor differences compared to pre-project conditions, amounting to changes on the order of a few hundred cubic meters. The results suggest that nourishment and borrow-area dredging will have negligible impacts on longshore sediment transport rates. Any changes will be localized to the areas where beach fill is applied, with no significant effects observed 1 km north or south of the fill area.

### The Combined Avon and Buxton Nourishment Projects

The Avon and Buxton nourishment projects shared many similarities, including fill design, borrow area configurations, and construction methods. Combining these two projects resulted in significant cost savings, improved construction efficiency, and a shorter overall construction timeline, which also minimized environmental impacts. Figure 7 illustrates the comprehensive nourishment plan for these two projects, along with the offshore borrow areas.

Fully funded by Dare County, the 2022 beach nourishment projects at Avon and Buxton were successfully completed between June 19 and August 16, 2022, by Great Lakes Dredge & Dock Company (GLDD). Selected aerial photos before, during, and after nourishment are shown in Figures 8 and 9. Over 58 days of dredging and pumping operations, a total of 1.692 million m<sup>3</sup> (2.2 million cubic yards) of sand was placed along two stretches of beach, covering a combined length of 8.7 km (28,700 linear feet or 5.3 miles). GLDD, utilized two hopper dredges, *Ellis Island* and *Liberty Island*, to complete the work. The *Ellis Island*, the largest dredge in the United States, has a maximum capacity of 11,500 m<sup>3</sup> per load.

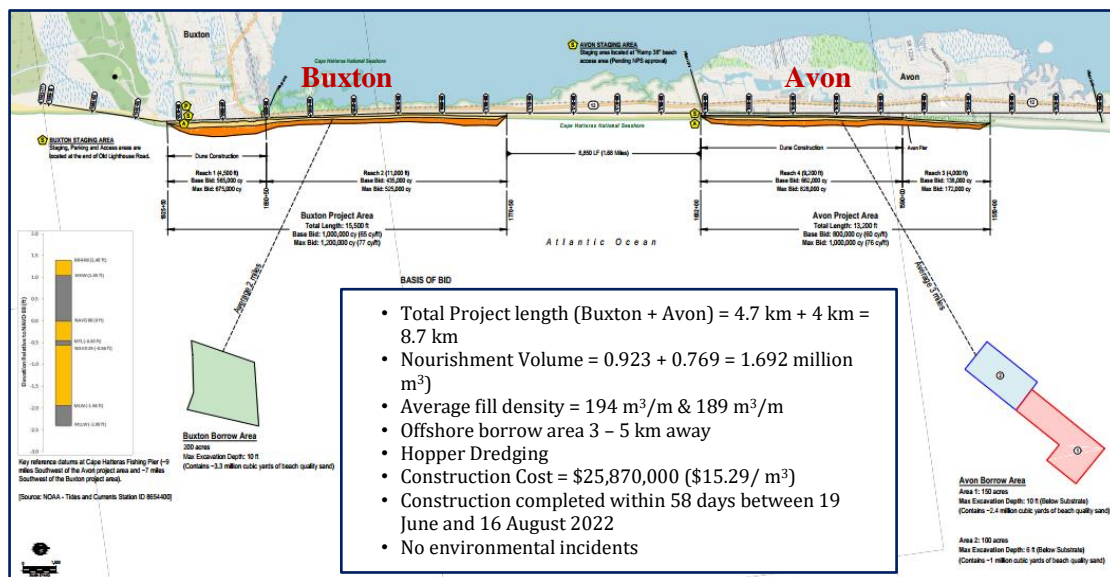


Figure 7. The overall plan of the first two nourishment projects following NPS' Framework.

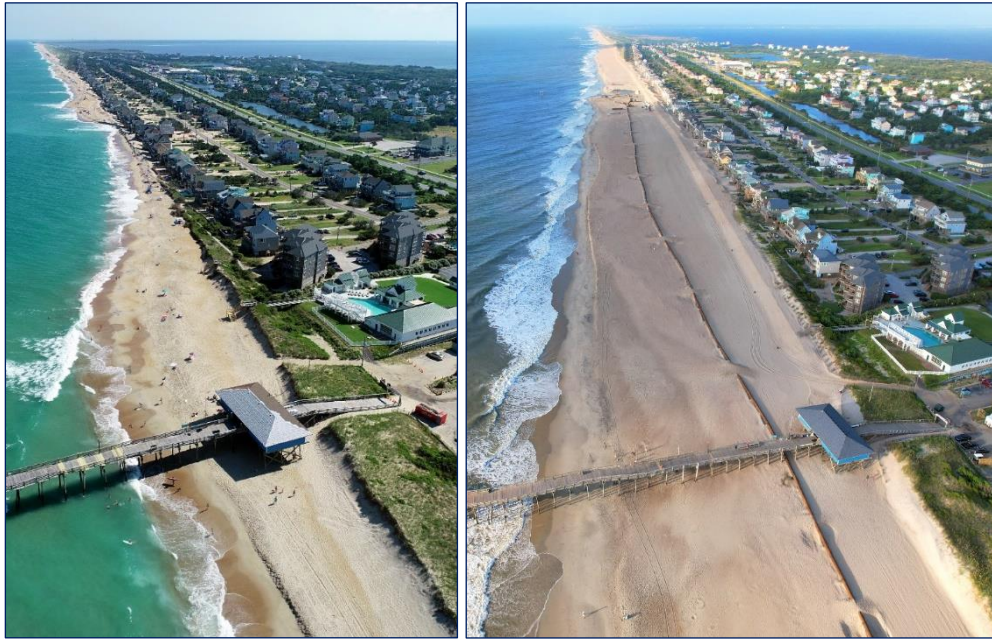


Figure 8. Oblique aerial images looking south showing the beach conditions before and after the 2022 Avon beach nourishment project. [Left] Before nourishment on 15 July 2020 [Right] During nourishment on 26 July 2022



Figure 9. Oblique aerial images on 5 August 2022 during construction of the 2022 Buxton beach renourishment project.

#### MONITORING AND MITIGATION PLAN

The NPS Framework, along with requirements from other state and federal resource agencies, mandates physical and ecological monitoring and mitigation measures for nourishment projects. Monitoring efforts include assessments of beach conditions and ecological monitoring conducted before

and immediately after construction, as well as seasonal monitoring for two years following nourishment. The monitoring program aims to evaluate project performance, assess the recovery of physical and biological components of the beach ecosystem, and identify any changes in beach characteristics, such as grain size and benthic organisms.

Specific monitoring activities involve comparing sediment properties (e.g., grain size, mineral content, and compaction) between reference zones and the nourished area, as well as analyzing the impacts on the abundance and distribution of selected swash zone benthic organisms, including mole crabs, coquina clams, amphipods, and polychaete worms.

## CONCLUSIONS

The primary goal of the 2022 Avon and Buxton nourishment projects was to widen the beach along severely eroding sections of the oceanfront on Hatteras Island, providing a protective buffer to mitigate chronic damage to NC Highway 12 and other federal, state, and county infrastructure. Wave and shoreline evolution models (STWAVE and GENESIS/GENCADE) were utilized to optimize the engineering design, assess project longevity, and evaluate potential impacts on downdrift areas. These projects represent the first set of engineering solutions implemented under the NPS 20-Year Sediment Management Framework. Their successful completion, along with post-project physical and ecological monitoring, will offer valuable insights for future management strategies on Hatteras Island.

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