CHAPTER 2 – ALTERNATIVES

This chapter describes the No-Action alternative and two action alternatives. The two action alternatives are for beach restoration along the Cape Hatteras National Seashore (Seashore) and the village of Buxton. The action alternatives were designed to augment the natural supply of sand along the ocean beach and reduce the frequency of dune breaches and storm damages to NC 12 and community infrastructure. The Environmental Assessment examines three alternatives:

- Alternative 1–No-Action
- Alternative 2–Winter Construction
- Alternative 3 (Preferred Alternative)–Summer Construction

Additional alternatives were considered during the early stages of planning, but were dismissed from further analysis for the reasons documented below.

DEVELOPMENT OF ALTERNATIVES

Guiding Principles

The Council on Environmental Quality regulations for implementation of the National Environmental Policy Act call for alternatives in a document to include a no-action alternative (i.e. Alternative 1). The description and evaluation of the No-Action Alternative provides a baseline against which the action alternatives can be compared.

Alternative 2–Winter Construction and Alternative 3–Summer Construction were developed based on the objective of Dare County (Applicant) to implement a project which mitigates erosion, restores the Buxton beach, reduces the frequency of dune breaches and storm damage to NC 12, and provides effective beach widening and storm-damage reduction for a period of up to ten years. The project would be funded by Dare County without imposing additional costs on the state of North Carolina or the US Government. It would be consistent with federal and state regulations for construction activities in the coastal zone, specifically the beach area, and seek to minimize the impact on marine and wildlife species during construction.

An objective of the Applicant is to implement a project which is indistinguishable from a natural beach while providing a wider buffer and expanded habitat areas between the ocean and threatened structures. Under current North Carolina CZM regulations, only three alternatives are allowed to deal with severe beach erosion: No Action (ie abandonment), Retreat and Relocation, and Beach Nourishment. Under the same state regulations, hard erosion-control structures are not allowed.

In addition to these guiding principles, NPS Management Policies (NPS 2006) were also considered. Specific and applicable policies are described below.

Protection of Geologic Processes

Geologic resources (both features and processes) are integral components of park natural systems. The National Park Service prefers natural geologic processes to proceed unimpeded except under certain circumstances (NPS 2006, Section 4.8.1). With respect to this project, *three* such exceptions are applicable:

- The project is necessary to respond to emergencies that threaten human life and property.

- The natural area has been previously modified or manipulated.
- No other feasible way exists to protect natural resources, park facilities, or historic properties.

Shoreline and Barrier Islands

Natural shoreline processes should be allowed to continue without interference where possible (NPS 2006). Manipulation of the shoreline may be approved only after an analysis of the degree to which such measures would impact natural resources and processes, so that an informed decision can be made through an assessment of alternatives. This Environmental Assessment represents such an assessment. NPS guidelines also require minimization of impacts outside the action area.

Barrier islands are formed and shaped by waves, tidal currents, and winds. At geological time scales (>1000s of years), they are ephemeral, temporary landforms dependent on the available sediment supply and specific position of sea level. At decadal to century time scales (time scales relevant for community planning), barrier islands exhibit a continuum of shoreline changes ranging from high erosion to high accretion. The majority of US East Coast barrier islands are changing at <1 meter per year at century time scales (Dolan et al. 1990).

Permanent infrastructure is not possible at geological time scales on barrier islands or over much of the coastal plain, but has been essential for some coastal islands at century time scales. Barrier island development has been a critical driver of the tourism economy in the US (Houston 1995, 2002, 2013). Fortunately, not all barrier islands are developed and large percentages (>50%) of the ocean coasts of Virginia, North Carolina, and South Carolina remain undeveloped.

The development of alternatives took into account the fact that relocation of NC 12, existing development and community infrastructure is not possible by the Applicant for a number of reasons:

- Dare County has no authority over private property, utility lines, and NC 12, a state road maintained by the NC Department of Transportation.
- Community infrastructure including NC 12 were previously relocated in the Buxton Action Area and are presently situated as far landward as practicable, without encroaching on USACE jurisdictional wetlands (salt marsh) along Pamlico Sound.
- There is a limited right-of-way corridor established through Easement agreements for location of infrastructure.

The NPS Management Policies (NPS 2006) recognize instances where resource management practices may influence alternatives available for decisions. In developing potential nourishment approaches for coastal areas, the Management Policies provide:

> *Where human activities or structures have altered the nature or rate of natural shoreline processes, the Service will, in consultation with appropriate state and federal agencies, investigate alternatives for mitigating the effects of such activities or structures and for restoring natural conditions. The Service will comply with the provisions of Executive Order 11988 (Floodplain Management) and state coastal zone management plans prepared under the Coastal Zone Management Act of 1972. Any shoreline manipulation measures proposed to protect cultural resources may be approved only after an analysis of the degree to which such measures would impact natural resources and processes, so that an informed decision can be made through an assessment of alternatives. Where erosion control is required by law, or where present developments must be protected in the short run to achieve park management objectives, including high-density visitor use, the Service will use the most effective method feasible to achieve the natural resource management objectives while minimizing impacts outside the target area. (4.8.1.1)*

The action alternatives selected for analysis are expected to mimic natural processes and have negligible effects on coastal processes, while restoring the beach and reducing the frequency of such emergency actions as road closures, dune reconstruction, and emergency sand bagging.

Beach Nourishment Implementation Options

Beach nourishment—the addition of beach quality sand to the littoral zone from non-littoral sources (NRC 1995)—can be accomplished by a number of methods including truck hauling and dredging via suction-cutter head dredge or trailing-arm hopper dredge. Cost is generally a function of the distance between the borrow source and the placement area and the means of conveyance. Therefore, nearby sources are favored for economic reasons. The Applicant considered alternate borrow sources, construction methods, and placement configurations. This EA addresses methods and sources deemed feasible and most advantageous with respect to project longevity and environmental protection given a fixed construction budget established by the Applicant. Beach nourishment performance and longevity is highly dependent on sediment quality and project length (NRC 1995, Dean 2002). Accordingly, certain construction methods and sand sources were eliminated from further consideration as discussed later in this chapter.

ALTERNATIVE 1–NO-ACTION

Under the No-Action Alternative, the US Army Corps of Engineers and National Park Service would not issue permits to Dare County for beach nourishment along the shoreline in Cape Hatteras National Seashore and the Village of Buxton Beach.

The No-Action Alternative provides a basis for comparing management direction and environmental consequences of the action alternatives. Should the No-Action Alternative be selected, Dare County, the State of North Carolina, and local entities would respond to future maintenance needs associated with the current natural conditions of unabated erosion in the Buxton Action Area. Current responses to that erosion by the NC Department of Transportation would continue, including sand scraping and road repairs. As erosion progresses and sufficient room to maintain a protective dune no longer exists, the state and individual property owners are likely to implement short-term emergency measures such as sand-bagging. This alternative assumes that a high potential exists for NC 12 to be closed due to major storm damage and that NCDOT would carry out repairs as needed to reopen the road. Possible emergency repair options to reopen the road would include a temporary bridge or emergency beach nourishment, as were completed in 2012 at the Pea Island breach and in 2014 north of Rodanthe.

If a breach occurred as feared during a major storm(s), Hatteras communities, as in the past, could be isolated from the mainland until the road was reopened. Emergency services would have to seek alternative ways of transporting sick or injured people off the island until repairs could be made. The normal transport of food and goods for families and materials to repair damaged houses and businesses would be interrupted. Other than helicopter lifts and boat traffic, travel would cease and transporting of goods and services would likely occur by ferry or small plane.

ALTERNATIVE 2–WINTER CONSTRUCTION

Alternative 2–Winter Construction consists of beach nourishment in the winter time via dredge using an offshore borrow area and placement of up to 1.3 million cubic yards of sand along ~15,500 linear feet of shoreline along Cape Hatteras National Seashore and the Village of Buxton; ie the Buxton Action Area (see Fig 1.1). Alternative 2–Winter Construction requires contracting with a professional dredging company experienced and equipped to conduct a project of this type and scale. The specific design, plans, and specifications of the nourishment project on which dredging companies would provide bids for construction would be prepared by the Applicant's consultant, a registered engineering firm with demonstrated experience in these types of projects. If permitted, the Applicant, its consulting engineer, and the dredging company would coordinate the work closely with representatives of the US Army Corps of Engineers and the National Park Service to ensure the project complies with federal and state permits for construction.

Beach nourishment by dredge involves hydraulic excavations of a borrow area, pumping via pipeline, and discharge of a sediment-water slurry along the beach. Water drains, leaving the sediment in place to be shaped by land-based equipment such as bulldozers. A nourished beach is typically constructed in sections, adding sand to the active beach zone working parallel to shore. Bulldozers distribute the sand from the pumpout point to elevations and slopes typical of a natural beach (Dean 2002). Surveys before and after sand placement are used to confirm how much sand has been added in each section and whether the elevation and slope of the new beach conform with the plans and specifications for the project which reflect the approved profiles in the permits.

Alternative 2–Winter Construction would involve excavation of sand by ocean-certified dredges from a borrow area ~1.7 miles seaward of the Cape Hatteras Lighthouse (see Fig 1.1). The dredges would be either cutter head dredges or self-propelled hopper dredges. If traditional suction cutter head dredges are used, excavations would be limited to ~7 feet below the substrate and would be pumped directly onto the beach via submerged pipeline. Sections of pipe (typically 40 feet long) would be added as construction progressed along the beach. Approximately 200–300 feet of beach would be nourished over a 24-hour period, working from one of two landing points for the submerged pipeline. The landward limit of sand placement would be seaward of the foredune along the existing dry-beach area. Initially, the material would be shaped to form a gently sloping berg at or below the normal dry-beach level in the action area. The seaward edge of the nourishment would be sloped by dozers to match a typical beach slope in the swash zone, the area over which waves break and run up the shore. After project completion, the nourished profile would generally adjust to waves as illustrated in Figure 2.1.

If hopper dredges are used, excavation depths would be shallower, but would not exceed ~7 feet in the aggregate (after multiple passes) within the designated borrow Area. Hopper dredges tend to leave some undisturbed Areas. Hopper dredges are self-propelled vessels which pump sand into the hopper of the ship then motor to a pumpout point where a length of submerged pipe extends ~1,500 feet offshore from the beach. Sand in the hopper is pumped to shore and distributed by the same methods used for cutter head dredge discharges. The environmental impacts of such cutter head and hopper dredges are essentially the same on the beach, but vary at the borrow Area as discussed later.

Using either type of dredge, excavations would be restricted to the approved offshore borrow Area and would avoid cultural resources, shipwreck debris, or obstructions that may be present. Further, the borrow Area would be chosen based on having sand that closely matches the existing sand in the action area. Along the beach, no sand would be placed on the foredune or private property. Upon completion, the nourished beach would be left to equilibrate under wave action—that is, even out and develop a profile and slopes typical of a natural beach.

Work under Alternative 2–Winter Construction would be completed during winter months within particular environmental windows for construction prescribed by USFWS and NMFS. The assumed window is December 1 through March 31, based on the 1997 South Atlantic Regional Biological Opinion (NMFS 1997). The location of the action area is about 110 miles from the nearest safe harbor that can accommodate large ocean-certified dredges. Oregon Inlet (~36 miles from the Proposed Action Area) is too shallow for entry by large hopper dredges (typical draft unloaded is ~15 feet). The Bonner Bridge (fixed-span) at Oregon Inlet further precludes entry into sheltered waters by large vessels.

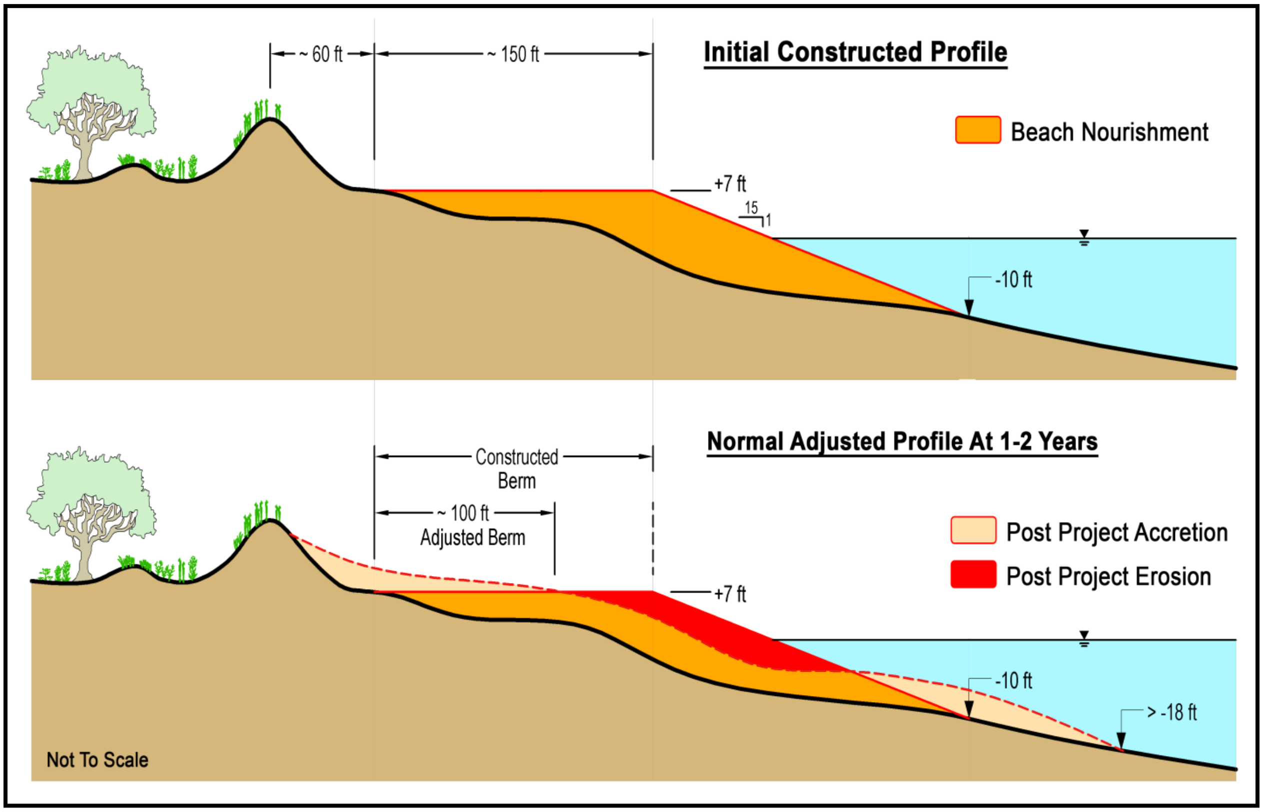

Figure 2.1. Idealized initial nourishment profile for sand placement seaward of the foredune and upper beach. Upon project completion, storm waves and winds would quickly shift some nourishment sand toward the dune, as well as into deeper water. The resulting ``equilibrated`` profile would exhibit a narrower berm (i.e. ``dry sand beach``) as illustrated. Note the initial constructed profile (berm width) would vary between ~150 feet and 350 feet according to the specific sand deficit and erosion rate at a particular segment of beach. The area of intertidal wet sand is expected to remain constant but be displaced seaward after initial equilibration of the nourishment sand.

Normal safe operations require dredging equipment and personnel to move to a safe harbor before a storm event occurs. Operations can only resume after seas return to operational conditions.

Due to the sailing time from the Proposed Action Area to the nearest safe harbor in the Norfolk, Virginia, area, each northeast storm event is likely to suspend dredging operations for a minimum of three days. Based on average storm frequencies of 1 per 6 days during winter months in the action area, dredging efficiency is expected to be <50% for either hopper or suction cutter head dredges. When common winter storms pass through the Buxton area, pipe on the beach may have to be removed temporarily and stored on high ground.

The scale and scope of Alternative 2–Winter Construction would be dependent on the number of operational days that are possible in the action area within the assumed four-month window for construction. Winter construction would be limited to those days when waves are less than the threshold for safe operating conditions (Fig 2.2). Factors to consider are the average frequency of northeasters and tropical storm (1per 6 days) (USACE 2010), projections of efficiencies for winter dredging in the northern Outer Banks (USACE 2000, 2010), and experience within similar settings (CSE 2012, 2014). Under Alternative 2–Winter Construction, construction would involve 2–3 days per week of 24-hour operations pumping sand, interrupted by moving the dredge(s) to a safe harbor during storm forecasts. The scale, scope, and construction duration for Alternative 2–Winter Construction is based on a fixed budget established by the Applicant. Based on preliminary planning and design, and the assumptions of dredging efficiency, Alternative 2–Winter Construction would involve excavation and placement of up to 1.3 million cubic yards in the Buxton Action Area. This equates to a maximum average fill density of ~84 cubic yards per foot along 15,500 linear feet. It can be shown that a fill density of this magnitude equates to a maximum average beach width increase of ~70 feet in this setting (Overton & Fisher 2005, Kana et al. 2015). It would take 65 dredging days averaging 20,000 cubic yards per dredge per day to accomplish the work. At <50% production efficiency, more than a four-month construction duration would be required if only a single, ocean-certified dredge is used. To accomplish up to 1.3 million cubic yards, more than one ocean-certified dredge would likely be required part of the time. The proposed borrow area is large enough to accommodate two dredges operating at the same time.

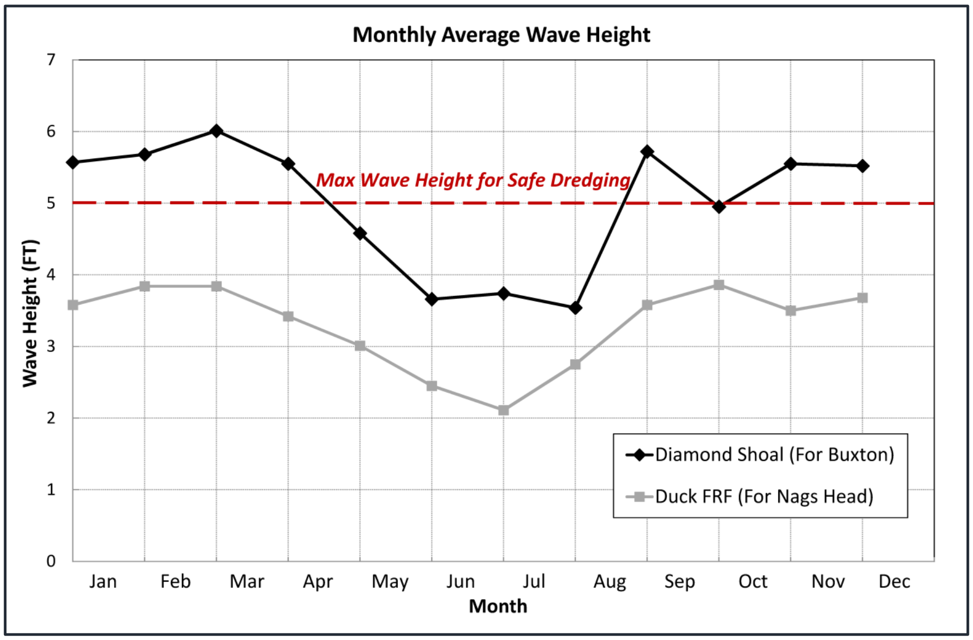

Figure 2.2. Graph showing the monthly average wave climate from 2003–2013 at NDBC Wave Buoy Station 41025 at Diamond Shoals (NC) near Buxton compared with the wave climate at the USACE Field Research Facility at Duck (NC). The criteria for safe dredging apply to hopper-dredge operations using ocean-certified equipment per informal guidance by dredging contractors. Suction-cutter head dredges generally cannot operate safely in waves >3 feet (USACE 2010). The graph shows that average monthly wave height exceeds 5 feet from September to April in the Proposed Action area. Calmest conditions occur in June and July when average wave heights are ~3.7 feet. The bars at the bottom of the graph show approximate range of dates when certain protected species may be present in or near the Action area. (Source: NDBC)

The total nourishment volume that would be accomplished under Alternative 2–Winter Construction would be about 40% greater than the existing sand deficit estimated by CSE (2013b) (ie ~900,000 cubic yards). The difference provides advance nourishment (USACE 2008) to accommodate average annual beach losses in the range 115,000–130,000 cubic yards per year (CSE 2013b). Thus, Alternative 2–Winter Construction would provide ~3 years of erosion relief, offsetting average annual losses before the beach reverts back to a deficit volume.

Alternative 2–Winter Construction would require a staging area for mobilization of equipment and temporary storage of shore pipe, which are typically 40-foot lengths of 30-inch-diameter steel pipe. As beach building occurs, the equipment and pipe would be stored on the newly constructed beach and would move with the active work area. For the Buxton Action Area, two landing points are likely to be used. One would be ~4,000 feet south of the Haulover Day Use Area on Seashore property, which marks the approximate north limit of the Proposed Action. The other would be positioned near the north boundary of the village of Buxton. Pumping onto the beach would begin at these landing points and proceed northerly or southerly for up to ~4,000 feet, adding shore pipe as the beach is built. Upon completion of an ~4,000-foot section of the project, pipe would be removed and shifted to the next work area, proceeding in the other direction from the landing point. At any point in time, there would be between ~100 feet and 4,000 feet of beach impacted by the presence of the pipeline.

The active beach pumping area would extend ~500 feet alongshore on a given day. Pipe-loading equip-mint, support vehicles, fuel barge, and a portable office and shelter for workers would move with the active work zone and would be cordoned off from the public. The active work area would be marked by flagging ribbon and would be limited to hard-hat personnel who have completed safety briefings. Dredge safety personnel would be stationed at the safety fence to prevent unauthorized entry and safeguard the public from areas where heavy equipment is operating. Upon completion of construction, all equipment and supplies would be removed from the site. The beach would be graded to eliminate tire tracks, depressions, and mounds. The staging area(s) would be restored to pre-project conditions. If compaction measurements show values above USFWS thresholds after project completion, the Applicant would seek guidance whether tilling of the beach should be performed and implement tilling at the direction of state and federal resource agencies.

PREFERRED ALTERNATIVE 3 – SUMMER CONSTRUCTION

Alternative 3 – Summer Construction consists of beach nourishment during summer months via dredge using an offshore borrow area and placement along up to 15,500 linear feet of shoreline along Cape Hatteras National Seashore and the Village of Buxton (ie, the Buxton Action Area) (see Fig 1.1). It differs from Alternative 2–Winter Construction in terms of the amount of sand placed and the season of construction. Sand excavation and placement would be as described under Alternative 2–Winter Construction. However, the project would be constructed during fair-weather months in summer when dredging efficiency can be maximized in the action area.

Under a fixed budget established by the Applicant, Alternative 3 – Summer Construction would provide up to ~2.6 million cubic yards of sand, which is equivalent to a maximum average fill density of ~168 cubic yards per foot. This quantity of nourishment sand would widen the beach by ~140 feet after normal adjustment of the profile (see Fig 2.1). The higher volume (approximately twice that of Alternative 2–Winter Construction) would be nearly three times the present sand deficit estimated by CSE (2013b). The additional sand would increase project longevity to ~10 years before the beach returned to a deficit condition. Factoring out the deficit volume (~900,000 cubic yards), Alternative 3 provides up to ~1.7 million cubic yards to erode under normal yearly processes (annual loss rates in the range 115,000–130,000 cubic yards per year, CSE 2013b) before the Proposed Action Area returns to a deficit condition. Given the uncertainty in the erosion rates after the project, this additional volume may last somewhat more or less than ten years.

Because beach nourishment has not been conducted in the Proposed Action Area since the 1970s (Dolan et al. 1974), experience from prior projects is limited. As a result, dredging costs for such a project are uncertain, and no comparative volumetric erosion data spanning years to decades exists. Thus, the final scale of Alternative 3 – Summer Construction is uncertain. The Applicant has considered this and has determined the project may be reduced by up to 25%, which would yield a total volume of ~1.9 million cubic yards. The higher volume (2.6 million cubic yards) is referenced with respect to the permitted quantity desired by the Applicant. Because the Proposed Action is intended to replace sand losses and provide benefits for a minimum of five years, any volume within the range of 1.9–2.6 million cubic yards is considered viable to meet the project goals. The volume of 2.6 million cubic yards is used as a basis to evaluate project impacts. [Note: References to 2.6 million cubic yards in other sections of this EA reflect the maximum possible volume that may be applied under a fixed budget.]

Alternative 3 – Summer Construction would be performed by trailing arm suction hopper dredges or traditional hydraulic cutter head dredges with booster pumps. The dredges would reach from the borrow area to the furthest segment of project beach, a distance of ~18,000 linear feet. (The two dredge types were generally described under Alternative 2–Winter Construction.) The Applicant desires permits which allow both hopper and hydraulic dredges to be used at the discretion of the dredging contractor. Allowing both types provides the most flexibility to accomplish the work in the shortest time. It also allows the contractor to use the resources he determines to be the most advantageous to minimize the environmental risks and maximize dredging efficiency. One or more hopper dredges and a hydraulic dredge may work on the project at the same time. The objective is to complete the project in one season and in the shortest time possible.

As a result of prior correspondence from the Dredging Contractors of America (USACE 2010) and discussions with qualified dredging contractors, the Applicant has concluded that the Proposed Action could not be accomplished safely or cost-effectively during fall or winter in the Buxton Area by either cutter head or hopper dredges. In the summer, cutter head dredges are less preferred, because offshore mean wave heights exceed threshold conditions for that type of dredge (Fig 2.2, also Appendix A - *Littoral Processes*). The use of hopper dredges in the summer, with the cutter head as an option during calmer seas, is the Applicant's preferred approach to ensure the Proposed Action is achievable.

The Proposed Action involves dredging and placement of up to 2.6 million cubic yards on the target beach. The average production per day varies according to sailing distance from the borrow area to the beach, as well as weather and environmental restrictions placed on the project. Based on project experience at Nags Head (CSE 2012), one hopper dredge can excavate and place from 15,000 to 30,000 cubic yards per day (24-hour period). Under ideal conditions, a hydraulic dredge can excavate up to 60,000 cubic yards per day. That volume would go down with increased wave heights and work stoppages as well as relocation due to severe weather. Therefore, project duration is dependent on average daily production.

A single hopper dredge operating at an efficiency of 80% and a daily production of 25,000 cubic yards per day would require 130 calendar days (~4 months) to complete the project. Efficiency is measured as the actual dredging time divided by the total time available. Giving the contractor flexibility to use both hopper and hydraulic dredges, with an average (net) production of 40,000 cubic yards per day, the project would require 65 days (~2 months) to complete. Net production at Nags Head was ~42,000 cubic yards per day with two dredges, one hopper dredge and one suction cutter head dredge, operating May 27 to August 27. Net production dropped to ~13,000 cubic yards per day between August 27 and October 27 with two smaller hopper dredges operating (CSE 2012). The downtime associated with shutdown and redeployment of the dredges during weather events is the main factor contributing to efficiency and construction duration of the Proposed Action.

May to August is a period of relative calm compared to fall and winter months (October to March) in the Proposed Action Area. Permitting the dredges to work over the warm and calm weather months (May to August), along with allowing both hopper and hydraulic dredges, would mitigate some of the risks to man and machine and would provide conditions where the work could be completed in a much shorter time period, thus reducing the duration of environmental impacts. The production efficiencies for Nags Head (2011) was close to 80% from June through August, a rate that incorporates downtime due to Hurricane Irene and other weather events (CSE 2012). Projections of dredging efficiency under Alternative 3 take into account the possibility of hurricanes and other high wave events during summer in the action area. Equipment requirements and operations under Alternative 3–Summer Construction would be the same as Alternative 2–Winter Construction. However, work during summer months, when threatened or endangered species may be present, would require modification of operations as follows:

- Endangered species observers would be stationed on dredges to alert dredging personnel and record encounters. This would include authority to suspend operations while wildlife resources officials are contacted in the event of a take as defined under the Biological Opinion applicable for the Proposed Action.
- Certified trawlers would be retained to trawl for sea turtles ahead of operating hopper dredges and relocate turtles if encountered, or operate as non-capture trawling per final recommendations of NMFS.
- Continuous nightly beach patrols would be performed by certified monitors to locate any turtles that are stranded behind the dredge pipe on the beach and relocate them to the waters' edge or deal with them according to directives by and in consultation with USFWS and North Carolina Wildlife Resources Commission (NCWRC).
- Vehicle ingress and egress at night would be with escorts by certified, endangered species observers.
- Lighting at the Action Work Area on the beach would be minimized in conformance with USFWS requirements for beach lighting.
- Use of bulldozers at night would be reduced to the minimum required for safe operations as sand is being discharged.
- The order of work (sections to be filled) would be accomplished in close coordination with NPS officials so that there would be the least practicable disruption to bird-nesting activities along Seashore lands.
- No-work buffers along the beach would be established around the turtle or bird nests in coordination with USFWS, NCWRC, and NPS officials.
- Other operations modifications as may be recommended by federal and state resource agencies.

Placement Options — Beach nourishment may be placed in a number of configurations, depending on the goals and objectives of the project, as well as various environmental protection requirements (NRC 1995, Dean 2002). In some instances, particularly after major storms, emphasis may be to restore a protective dune and place a majority of the fill above the high watermark. Other projects have emphasized placement in the active beach zone seaward of the dune. In a few projects (Douglass 1997), nourishment sediment was placed in the near shore with the hope of eventual onshore migration of material. Each type of placement has advantages and disadvantages from an operational standpoint. Intermittent nourishment alongshore has also been suggested under the assumption that undisturbed areas between fill sections would help accelerate recruitment of benthic organisms into impacted areas (Peterson and Bishop 2005). Each of these placement options has been evaluated and ranked by the Applicant in terms of how well each meets the goals and objectives of the Proposed Action and with consideration of environmental protection requirements for projects within the Seashore boundary. Alternative 3 would involve two of the placement options (Fig 2.3).

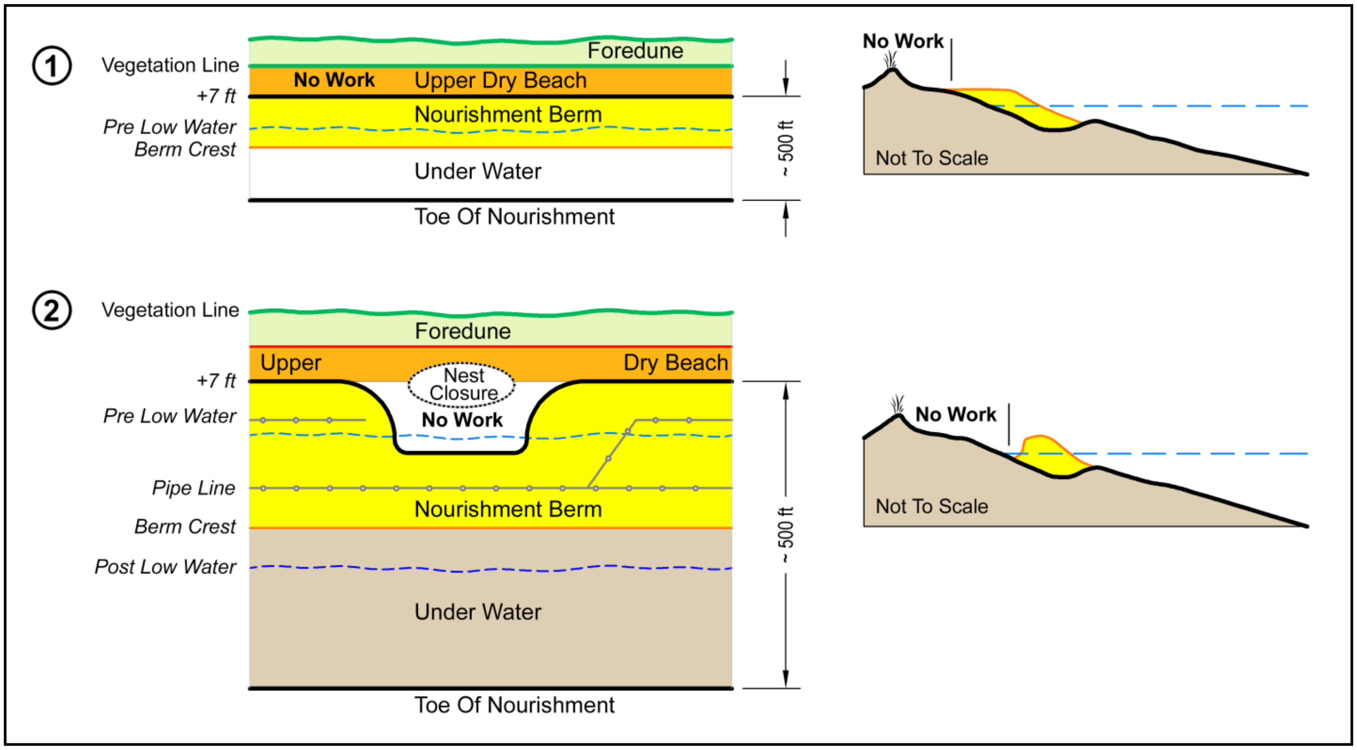

Figure 2.3. Diagram showing two beach-nourishment placement options in plan view (left) and section view (right) considered for the Buxton nourishment project under Alternative 3 – Summer Construction. The dashed blue line references mean low water (MLW). Option 1 (Continuous Placement) would leave a no-work area along the upper beach between the foredune and the (~)+7-foot NAVD contour. Option 2 (Modified Continuous Placement) is the preferred option if there are unavoidable, shorebird nest closure areas delineated by park biologists during project implementation. Option 2 would leave buffer areas along the dry-sand beach and place material seaward of low water for limited distances along the project area. This would leave a small pond between the existing beach and nourishment berm in the area labeled no work in the lower left-hand diagram. Over time, upon project completion, the low swales left along no-work areas would infill naturally by wave swash and washover deposits.

1) *Continuous placement* along the active beach zone at or below the +7 ft NAVD contour at grades and slopes matching the existing dry-sand and wet-sand beach.
2) *Modified continuous placement* along the active beach zone at or below the +7 ft NAVD contour extending across the inner surf zone (ie inside the outer bar), leaving isolated undisturbed areas landward of the approximate low watermark.

Placement Option 1 is a typical method of beach construction. It produces a berg at the normal dry-sand beach level over which the equipment can proceed down the beach without impact to existing dunes or vegetation. The +7-foot NAVD contour is chosen as an optimal berg elevation for the Proposed Action Area—berms vary in elevation from (~)+5 feet to (~)+9 feet NAVD (CSE 2013b). By limiting the fill to the 7-foot contour, a narrow no-work area would be maintained between the foredune and the active work area. This would allow public ingress and egress as the project proceeds. While it is not possible to control the underwater slope at placement, the final design would assume slopes typical of hydraulic placement using medium-coarse sand in this setting (~1 on 15) following the experience at Nags Head (CSE 2012). Placement of elevations close to the natural elevation of the native beach increases the likelihood and frequency of wave overtopping and runup across the dry-sand beach. This allows the nourished beach to take on a more natural character soon after construction, particularly if a project is completed in summer and then exposed to the high waves of fall and winter.

Placement Option 2 is proposed by the Applicant to provide limited no-work buffers around critical habitat areas at the time of construction yet maintain efficient operation and complete the project in the shortest time possible. *Modified continuous placement* would entail the same placement configuration as described under Option 1 for the majority of the Proposed Action Area. If NPS biologists identify active nesting areas for migratory birds, the Applicant proposes to postpone fill placement near that area(s) as long as practicable.

If nesting activity remains as construction progresses near the area (provided no areas remain where operations can be shifted), the Applicant proposes to place nourishment seaward of mean low water over the length of the nest closure area to keep equipment as far as possible from species of concern. This concept is illustrated in Figure 2.3. The resulting fill configuration would be continuous along the outer beach, but would leave a swale between the nourished berm and existing beach. This swale would become a temporary pond until the seaward nourishment berg overwashes and infills the area. A similar fill configuration was used for a short segment of the 2011 Nags Head project (Fig 2.4). Fall 2011 storms overtopped the completed berm and filled in the pond with sand within several months of nourishment along that section of beach.

Figure 2.4. Oblique aerial photographs looking west across south Nags Head. Note row of 8–9 condemned houses initially positioned seaward of the dune line in the active surf zone.

[UPPER LEFT] Before nourishment on 23 February 2011.

[UPPER RIGHT] After nourishment on 2 September 2011 (note pond).

[LOWER LEFT] After northeast storm on 21 November 2011 (note infilled pond).

Fill placement was modified for this section of beach to avoid nourishment landward of the low-tide mark. This left a temporary pond in front of the condemned houses which was infilled naturally by overwash deposits. Fill placement Option 2 for the Buxton proposed project would be similar to sand placement illustrated here.

For a project of the scale of Buxton, it is likely the contractor would elect to use a minimum of two submerged, pipe-landing points from which sand pumping would proceed in both directions. This means work would likely be divided into four beach segments 3,000 feet long to ~4,000 feet long with nearly all activities occurring within one segment for about 2–3 weeks before shifting equipment to the next segment. This sequencing provides opportunities to avoid nest closure areas for a significant portion of the project duration. Based on production rates at Nags Head, the assumed duration of construction impacts under Alternative 3 is 2.5 months.

For reasons of safety, construction efficiency, project longevity, and duration of construction impacts, Alternative 3 - Summer Construction (Nourishment with Offshore Sand Source) is the Preferred Alternative.

Alternatives 1, 2, and 3 are retained for further analysis in this Environmental Assessment.

ALTERNATIVES ELIMINATED FROM FURTHER STUDY

Several alternatives were identified during the planning process and internal and public scoping. Some of these alternatives were determined to have unacceptable impacts or to be technically or economically infeasible. Other alternatives identified during initial scoping were determined to be outside the project purpose, not allowed under existing North Carolina laws, or beyond the means of the Applicant.

The following alternatives eliminated from further study are presented in several categories:

1) Alternate nourishment borrow sources,
2) Erosion control methods designed to retain sand, and
3) Shore-protection methods involving hard structures.

Rationale for Dismissing Nourishment Using Non-Offshore Sand Sources

Based on previous practice along the US East Coast, the following classes of borrow sources have been used for beach nourishment (CERC 1984):

– Lagoon sediments	– Offshore deposits	– Inland deposits
– Inlet shoals	– Recycled spoil sediments	– Freshwater pond deposits
– Near shore bars	– Accreting spits/beach deposits	– Imported material

In general, economics favor the borrow source(s) that matches the native beach quality, involves the shortest transportation distance, and minimizes environmental impacts. Large-scale projects, such as the Buxton nourishment project, require large volumes of material which may not be available in only one offshore deposit.

The following sediment sources are considered unacceptable for the Proposed Action.

Lagoon Deposits in Pamlico Sound – Generally, sand in the sound is much finer than sand on the beach and contains levels of mud and silt unacceptable for beach nourishment. Additionally, the environmental impacts of a large-scale dredging project (up to 2.6 million cubic yards) in Pamlico Sound would be high because of the greater diversity of estuarine organisms and submerged vegetation present. In a US Geological Survey (USGS) paper written in cooperation with the National Park Service, Dolan and Lins (1986) discussed the use of beach nourishment for shoreline stabilization, stating:

> *. . . artificial beach nourishment . . . has long been considered the most desirable method of protection because (1) placement of sand on a beach does not alter the suitability of the system for recreation, (2)*

nourishment cannot adversely affect areas beyond the problem area, and (3) if the design fails, the effects . . . are soon dissipated.

Perhaps the greatest disadvantage of artificial nourishment is that great quantities of sand of suitable quality (type and size) are not readily available. In the past, sand was dredged from sounds and bays immediately inland from the beach or transported from inland sources. Because of recent concern about estuarine ecology, however, and because materials dredged from sounds and bays are generally too fine to be effective in beach nourishment, estuarine and bay sources have been less desirable and are no longer readily available. The only future source of large quantities of sand for nourishment of the Outer Banks appears to be offshore areas, such as Diamond Shoals and coastal inlets [Dolan and Lins (1986), pg 34].

Inlet Shoals (Inshore) — Significant accumulations of sand occur in the ebb- and flood-tidal delta shoals of Oregon Inlet ~36 miles north of the project site. The mean grain size of these deposits tends to be much finer than native beach sand. The flood shoals are located inshore of the Oregon Inlet bridge and would have to be pumped either directly to the project site with the aid of many booster pumps or pumped offshore to hopper dredges which could transfer and pump out the material after sailing nearly 80 miles (roundtrip) to the project site. Additionally, these ephemeral flood-tidal delta shoals are habitat for a number of protected shorebird species. The environmental consequences, level of coordination required, the potential for disapproval by conservation groups and regulatory agencies, the cost implications due to pumping distances, and the unsuitable sediment size make this source of sand infeasible when compared to the offshore borrow sources.

Significant deposits of sand are available from the ebb-tidal delta shoals of Oregon Inlet. The navigation channel across the outer bar is dredged frequently by the USACE. Typically, the dredged material is disposed of on the beaches at the northern tip of Pea Island adjacent to Oregon Inlet. CSE (2011) determined the location of the placement of the dredge spoil, sampled the material, and analyzed the sand samples for texture and suitability for beach nourishment. The material is generally fine-grained sand (<0.25 millimeter mean diameter) and was determined to be much finer than native beach sand along Nags Head. The Buxton beach sand is slightly coarser than Nags Head (CSE 2013a) (Appendix C - *Geotechnical Data*). It can be shown that placement of finer sand on a beach typically leads to rapid dispersal into the underwater part of the beach zone (Dean 2002). This lessens the benefit of nourishment (narrower dry-sand beach) and reduces wave attenuation relative to sediment sizes that match the visible beach.

Nearshore Bar(s) Along the Project Area — Sand stored in nearshore bars (water depths <20 ft) is part of the active beach profile and is an important component in the beach system that provides wave dissipation. Access to the material would be difficult by deep-draft hopper dredges. Additionally, the material in longshore bars is generally too fine for retention on the dry beach and is inappropriate for beach nourishment. Grain size data for samples in the Buxton Action Area support this finding (see Appendix C – *Geotechnical Data*).

Accreting Spits/Beach Deposits — Major deposits of beach sand are accumulating on Cape Point within Seashore jurisdiction (Fig 2.5). Excavation of these deposits would involve significantly more environmental consequences than offshore deposits because Cape Point is designated as critical habitat for the piping plover.

Figure 2.5. Oblique aerial photos of Cape Point, a highly accretional cuspate foreland which accumulates sediment eroded from the east and south Buxton oceanfront's. Cape Point is an important habitat for endangered and threatened species, such as the piping plover. The left image is looking north with Cape Point in the foreground and the Village of Buxton along the top. The right image is looking west across the Cape Point foreland with the east-facing beach along the lower edge of the picture and the broad south-facing beach arcing toward the top left corner of the picture. [Images by CSE on 10 September 2014]

Inland Deposits — Material imported from sand mines in Currituck County (~75 miles from Buxton) was used for building dunes in Nags Head and Kitty Hawk after Hurricane *Isabel*. No known sand mines are available in the Buxton Action Area which could provide sufficient quantities to complete the proposed nourishment project. Use of distant sand mines would be cost-prohibitive, based on trucking costs for much shorter haul distances between Currituck spit and Kitty Hawk (~16 miles). Dune-building projects at Nags Head and Kitty Hawk were $16.00 per cubic yard and $15.15 per cubic yard (respectively) in 2005 following Hurricane *Isabel* (CSE 2005a). This represents nearly twice the unit costs of nearby offshore borrow areas (including pumping and mobilization and demobilization costs). Under a fixed budget established by the Applicant, a doubling of transportation costs would result in a major reduction in the total project volume, which would reduce the project longevity and would not accomplish the goals and objectives of the Applicant.

Freshwater Pond Deposits — No known freshwater ponds are nearby that require maintenance excavations or that could provide the quantities of beach-compatible sediment required for the Proposed Action.

Recycled Spoil Sediments — No feasible sources of dredge spoils are available to be pumped to the beaches of Buxton.

Primarily for reasons of sediment quality, environmental impacts, economics, or unavailability within economic transportation distances, the alternative borrow sources discussed herein are not deemed acceptable for the Buxton beach nourishment project. **The alternative of nourishment using non-offshore sand sources is not considered for further analysis in this EA.**

Rationale for Dismissing Sand-Retaining Structures and Techniques

A number of erosion-control methods can be used to intercept mobile sands in the beach zone. These include three general types of sand-retaining structures—jetties, groins, and breakwaters—and one technique—beach dewatering systems. Jetties and groins are shore-perpendicular barriers extending from the upper beach/toe of dune to some distance offshore. They may be constructed of timber, steel sheet piles, quarry stone, pre-cast concrete units, or sand bags. In the presence of a predominant transport direction (north to south along the beach in the action area), sand tends to accumulate along the upcoast (north) side of the structure, producing a salient (bulge) in the shoreline related in size to the length of the structure. When the groin is filled to capacity, excess sand would be transported by waves around or over the structure to the downcoast (south) shoreline, leaving a salient in place. The beach along the upcoast side of the groin or jetty would generally be wider than the beach downcoast for some distance in either direction, which is also a function of groin length (ASCE 1994). Commonly, observable modification of the shoreline due to the presence of groins or jetties can be detected 10–20 times the groin length depending on numerous factors (CERC 1984).

Groins, jetties, and breakwaters are a proven method for reducing sand losses along beaches on the upcoast side of a structure and have been used previously in the Buxton Action Area to protect the US Navy Facility and Cape Hatteras Lighthouse (Machemehl 1979, NPS 1980, USACE 1996, NPS 2013). Intermittent breakwaters and nourishment have been incorporated into a shore-protection plan for Colonial National Historical Park in Virginia (NPS 2012b). Figure 2.6 shows existing groins at the south end of the proposed Buxton project and their impact on the shoreline near Cape Hatteras Lighthouse. The groins were constructed in 1969 (Machemehl 1979) and have produced a salient (bulge) in the shoreline along Buxton Village. The salient results from the groins holding a segment of beach in place while the beaches north and south of the groins continue to erode.

While groins, jetties, and breakwaters combined with nourishment may reduce sand losses and improve project longevity, they are not permissible under existing North Carolina CZM rules and regulations.

Groins and jetties are not evaluated further in this EA because they are not allowed along the northern Outer Banks under present state CZM rules and regulations.

Breakwaters are shore-parallel structures placed close to the beach to modify and reduce wave energy and sand transport along the coast. In the sheltered lee of breakwaters, sediment falls out of suspension and accumulates in the form of a salient. In extreme cases, sand would build out to the breakwater, forming a tombolo spit of high ground between the beach and the structures.

Breakwaters are not evaluated further in this EA because they are not allowed along the North Carolina coast under present state CZM rules and regulations.

Beach dewatering is a technique for sand retention whereby wave swash is withdrawn by suction through a system of pipes and vacuum pumps. The water is discharged offshore or in holding ponds for gradual percolation into the ground. By drawing off part of the swash before it runs back down the sloping part of the beach, less sand moves in the return flow. The result is accumulation and retention of sand in the dry beach zone in the area where pipe is in place. Results are mixed and depend on many factors (Turner & Leatherman 1997). Such a system is not considered viable for the project at Buxton for several reasons:

FIGURE 2.6. **[UPPER]** Oblique aerial photograph looking north along the Buxton Action Area with the moved Cape Hatteras Lighthouse at the lower left side of the image and the Village of Avon at the top right corner of the image. White foam lines of breaking waves over the near shore bar parallel the beach. The east-facing shoreline bulges seaward in the middle of the image. This bulge marks the location of three groins fronting the former US Naval Facility and former location of the Cape Hatteras Lighthouse. The salient (bulge) visible to the north (upper right) is Rodanthe and Salvo. [Image courtesy of USACE–Wilmington District taken 9 September 2000]

[LOWER] Ground photo looking south of two of the groins at former location of the Cape Hatteras Lighthouse. The structures extend into the ocean from right to left and are constructed of pre-cast concrete sheet piles linked by timber whalers. Some sheets have collapsed or washed out as indicated by the gaps in the structure along the top edge of the image. [Image taken 4 November 2013 by Coastal Science & Engineering]

1) Beach dewatering requires an extensive network of perforated pipe to be buried close to the surface of the beach—a permanent installation (which would potentially interfere with turtle nesting activities).
2) The system requires pumps, infrastructure, and discharge points which are not available.
3) The sand deficit along the action area greatly exceeds the scale of the existing beach where such a system would be installed.
4) Dare County and the Park Service do not wish to install permanent infrastructure (piping) along high-energy beaches subject to significant seasonal fluctuations in width and elevation.
5) Beach dewatering does not augment the sand supply in the beach zone, but rather captures some fraction of sand moving downcoast at the expense of adjacent areas.

Beach dewatering systems are not evaluated further in this EA because they are not likely to meet the purpose of the project or they are not allowed under present state CZM rules and regulations.

Rationale for Dismissing Other Potential Alternatives

Other potential alternatives considered and dismissed include:

- Structural shore protection—including seawalls, revetments, and bulkheads.
- Structure relocation—including NC 12 realignment.
- Structure abandonment.
- Alternative transportation system.
- Nourishment along other erosion hotspots such as the Hatteras Village reach west of Buxton, which is narrow and vulnerable to another breach.

As previously described, hard erosion-control structures are prohibited under North Carolina CZM rules and regulations. Installation of a protective seawall along the most vulnerable sections of NC 12 would also not meet the purpose and needs of the project.

The Applicant (Dare County) has no authority to move, elevate, or abandon NC 12. The road alignment is as far landward as practicable without encroaching on existing tidal wetlands at the margin of Pamlico Sound. Such alternatives would not meet the purpose and needs of the project. NCDOT is preparing a feasibility report (in preparation – NCDOT, J. Jennings, Regional Director, pers. comm., July 2015) to evaluate 5-year and 50-year alternatives for NC 12 in the Buxton Canadian Hole area. That report is expected to contain additional information of relevance to the present project. However, implementation of NCDOT plans is likely to require several years before final design can be approved. The Applicant desires to proceed with the Proposed Action, Alternative 3 – Summer Construction, given the urgency of the erosion problem and need to widen the beach to reduce storm damages.

Relocation or abandonment of existing buildings, infrastructure, and sand-trapping structures would not meet the purpose and needs of the project. Dare County has no jurisdiction over existing private structures and cannot remove them under present state law even if they are condemned by the State. The County does not own the existing groins which are functioning to maintain the shoreline salient at Buxton to some unquantified degree. Removal of the groins, emergency sand bags, and several rows of houses would be exceedingly costly as a result of (1) the high value of beach resort property, (2) the cost of litigation necessary to force property owners to abandon homes and businesses if they do not agree to buyouts at market prices, (3) loss of tax revenue, and (4) loss of rental income and its ripple effect on the local economy.

Property abandonment and relocation associated with ongoing beach erosion is encouraged under existing state CZM regulations. Considering present property values, the economic costs of property abandonment are exceedingly high and generally involve extensive litigation, as demonstrated by a recent case at Nags Head (Sansotta vs Town of Nags Head, US District Court–Eastern District of North Carolina 2:10-CV-29-D). The Town of Nags Head recently settled with a property owner and agreed to pay the owner $1.5 million for six houses that had been sitting in the surf zone for nearly ten years and were rendered uninhabitable.

Along the Buxton Action Area, abandonment and removal of existing groins would lead to rapid erosion of the salient. Figure 2.7 illustrates the likely eventual adjustment of the shoreline if the groins and developed properties were removed. A new shoreline would equilibrate between the Canadian Hole (middle right side of image) and Cape Point (upper part of image). Such abandonment or removal of groins would ultimately lead to shoreline recession of hundreds of feet, taking out a length of NC 12 in the approach to Buxton Village and multiple rows of houses, hotels, and businesses. The aggregate value of properties lost would be at least an order of magnitude greater than the Applicant's budget for the proposed project (ie >$250 million). Associated with abandonment would be even greater economic impacts of the road closure, loss to tax base, loss of business revenues, and other disruptions to the life and well-being of the communities at the Cape.

For reasons stated above and other practical considerations, structural alternatives, structure relocation, and structure abandonment are eliminated from further study because they do not meet the purpose and needs of the project, or Dare County has no authority to impose them, or they are not allowed under state law.

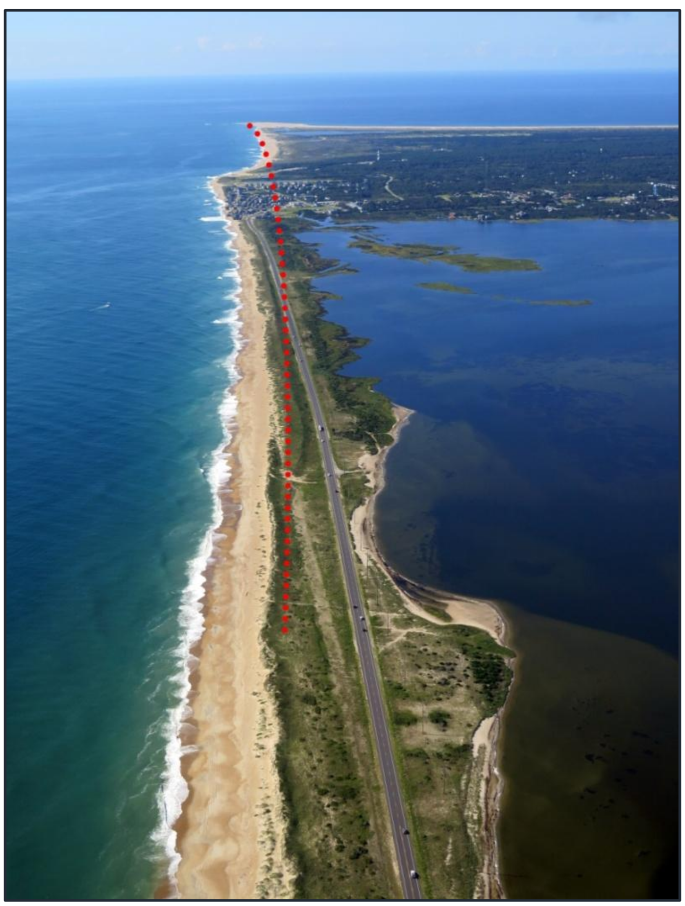

Figure 2.7.

Oblique aerial photograph on 10 September 2014 looking south along the Proposed Action Area with the Canadian Whole area of the Seashore in the middle and Cape Point at the top of the image. The Village of Buxton is marked by the pronounced salient (bulge) in the shoreline.

A dashed line extending landward along the shoreline marks the projected alignment of the dune line if the groins were removed. The equilibrated shoreline would be straighter, but at the cost of losing a long segment of NC 12 and several rows of houses and businesses in Buxton.

The predicted shoreline (dashed line) represents the anticipated impact after several decades of erosion. As the salient along Buxton erodes, the east shore of Cape Point would accrete as implied by the dashed line positioned seaward of the existing dune line at the top of the image.

[Image by Coastal Science & Engineering 2014.]

Nourishment Construction Alternatives Eliminated from Consideration

In addition to the two nourishment placement alternatives retained for further analysis (previous section of EA), four alternative placement methods were considered (Fig 2.8).

Placement Option 3 entails intermittent placement, leaving some gaps along the shoreline. Sometimes this is done to concentrate the nourishment volume where it is needed most for shore protection or recreation as in the case of Hunting Island, South Carolina, in 1991 (Kana & Mohan 1998). However, it has also been recommended under the assumption that it is a way to maintain a benthic community in close proximity to nourished areas from which organisms can rapidly colonize the new beach (Peterson & Bishop 2005, Peterson et al. 2006, NPS 2012a). No documented cases of intermittent nourishments are known to exist whereby this theory can be evaluated using quantitative measurements of the benthic community structure. If this alternative were implemented at Buxton, a number of effects would have to be considered. First, the no-work gaps would require fill sections to be much wider along work areas to accommodate the design volume. The total project length is relatively short at ~3 miles. If two 0.5-mile gaps were added to the project, the average fill density of nourished sections would increase by 50%. At initial placement, the project sections would have to be over 500 feet wide, tapering rapidly to no added beach width. If gradual tapers on the order of 1,500 feet were provided, little space would be left for full sections. This would produce a highly scalloped shoreline and lead to erosional end effects (Dean 2002). It would also increase the vulnerability of the foredune along the unnourished segment until sand spread into the gap. The process of sand spreading into the gaps occurred over several years after the 1991 Hunting Island project (Kana & Mohan 1998).

Nags Head (2011) was a continuous nourishment, using offshore borrow areas along 10 miles without gaps. Within the first three months after completion, pre- and post-project benthic monitoring documented rapid recovery of the benthic community to comparable levels as the adjacent unnourished areas (CZR-CSE 2014, Appendix E- *Biological Monitoring*). Other projects have similarly documented rapid recovery of benthic communities within weeks to months after large-scale continuous beach fills (Van Dolah et al. 1994, Burlas et al. 2001, Jutte et al. 2002).

For the reasons outlined above, Placement Option 3 is no longer considered for the Buxton nourishment project.

Placement Option 4 has been used after storms in many localities because it incorporates dune nourishment with berm nourishment. Many federal projects incorporate some form of protective dune or storm berm above the normal dry beach level. This alternative necessarily requires placement on the face of existing dunes leaving no undisturbed area seaward of the vegetation line as construction proceeds. The Buxton project is situated in a part of the coast subject to strong winds. As the Nags Head (2011) project demonstrated, a significant volume of sand shifted landward by natural processes after project completion. Post-construction measurements documented upwards of 800,000 cubic yards (~17% of the total nourishment volume) shifted into the foredune and upper beach area within three years of project completion (CSE 2014). The average post nourishment dune accretion rate at Nags Head was ~4.2 cubic yards per feet per year for the first three years of the project (CSE 2014). Dune growth was aided by strategic placement of sand fencing in many areas. Where existing dunes were relatively high, foredune vegetation served as a barrier to trap wind-blown sand, mimicking the natural process of dune growth along stable barrier beaches. Sand fencing is not part of the Preferred Alternative, but it may be considered by individual property owners at a later date after construction. The rapidity of dune growth along Nags Head provides a realistic measure of likely dune growth rates at Buxton after nourishment, given the proximity and similar exposure to winds at both sites.

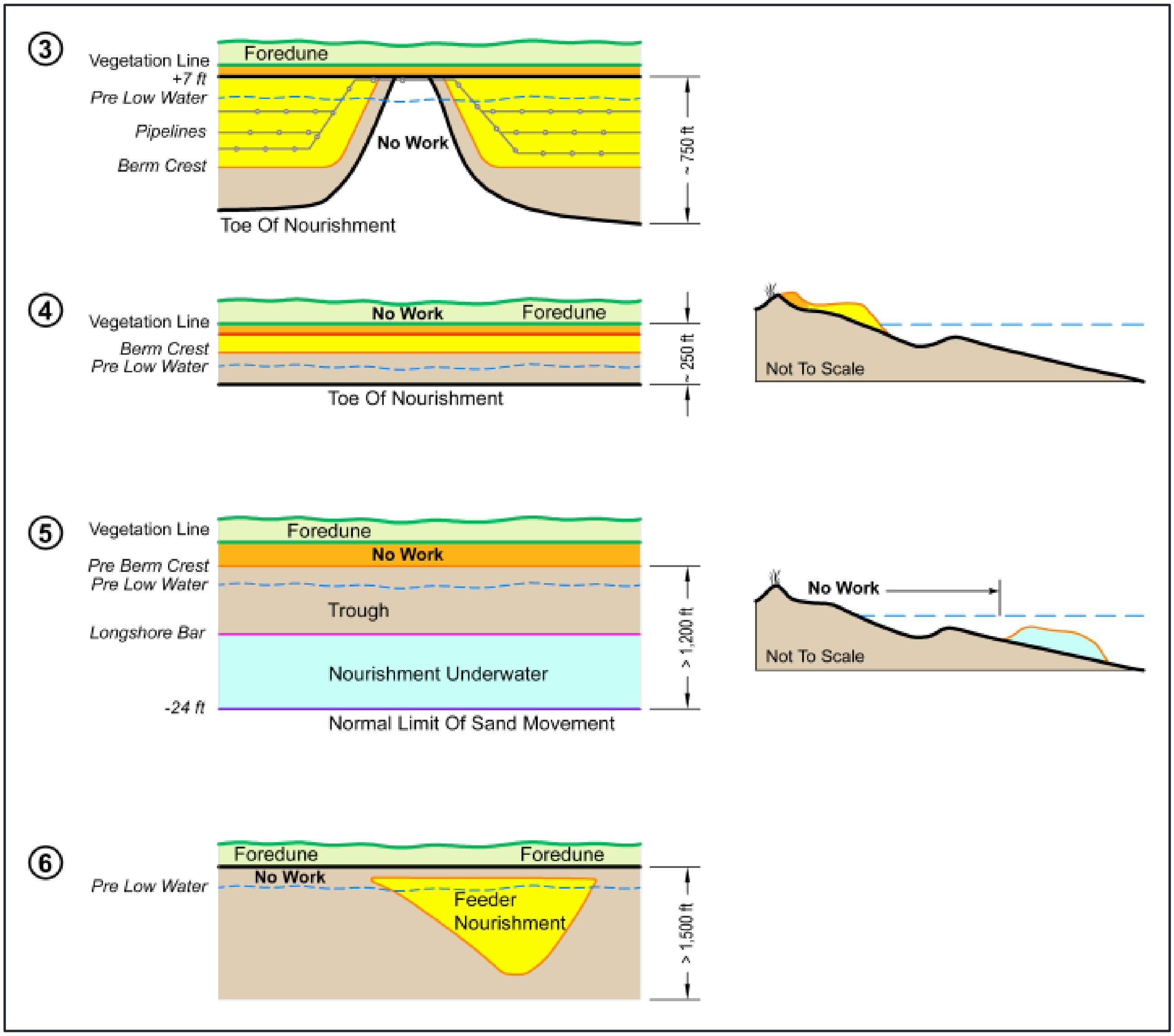

FIGURE 2.8. Diagram showing four beach-nourishment placement options which are rejected from further analysis for the proposed project at Buxton.

[UPPER] Labeled 3 – This diagram illustrates the concept of intermittent fill whereby no-work gaps are left between nourished sections. As discussed in the text, this placement option is not feasible for the relatively short length and high volume of nourishment needed at Buxton.

[SECOND] Labeled 4 – This diagram and an associated cross-section to the right show nourishment incorporating a dune and berm with most of the material placed above the low water contour. The preferred alternative is to minimize sand placement on the dune or back beach area so as to avoid turtle-nesting areas of the beach.

[THIRD] Labeled 5 – This diagram and an associated cross-section to the right show nourishment placed underwater seaward of the outer bar. In theory, such placement would eventually result in sand shifting landward toward the beach. However, it is difficult to control underwater placement, and an unacceptable delay occurs before the added sand provides direct benefits in the form of a wider beach.

[LOWER] Labeled 6 – This diagram illustrates the concept of feeder nourishment whereby all the fill is placed near the upcoast end of the project. Over time, the material is expected to migrate downcoast, replacing lost sand. This option is rejected because the feeder beach would extend so far offshore that it would modify wave patterns and potentially cause erosion at the flanks of the feeder beach before sand spread downcoast (Dean 2002).

A disadvantage of Placement Option 4 is that the majority of nourishment volume is initially perched on the existing beach above low water. This configuration is unstable and subject to large-scale erosion (profile adjustment) until sufficient volume shifts underwater to form a stable base for the fill. Erosional escarpments in the berm tend to persist, particularly where the berm elevation is set well above the normal wave uprush limit. A small federal project at Hunting Island, South Carolina, designed to provide emergency dune protection, set the berm elevation at (~)+11 feet NAVD. This was roughly 4 feet higher than the normal dry-sand beach in the area (USACE–Charleston District, C. Mack, coastal engineer, pers. comm., December 2003) (CSE 2005b). As this highly eroding section of beach receded, escarpments 4–5 feet high persisted for months, inhibiting turtle nesting activities, which were severely limited before nourishment due to the highly eroded condition of the beach.

For the reasons outlined above, Placement Option 4 is rejected for the Buxton nourishment project.

Placement Option 5 involves nourishment along the lower foreshore well beyond the inner surf zone. Ideally, the sediment would be deposited in water shallow enough to eventually migrate onshore and add to the beach volume. If material is placed too far offshore, it would likely not move into the active beach zone, as was the case for a project off the barrier beaches flanking Mobile Bay, Alabama (Douglass 1997). Placement control is difficult under this alternative because it is analogous to emptying a dump truck without spreading the material evenly along the action area. In the case of the Mobile project, near shore disposal was constrained by water depths needed for loaded hopper dredges. Placement was, by necessity, in water exceeding 25 feet deep, the approximate operational depth of the loaded vessel. This placed the material beyond the active littoral zone with little associated nourishment benefit (Douglass 1997). The risks of such fill placement being able to meet the goals and objectives of the project are considered unacceptably high by the Applicant.

For reasons outlined above, Placement Option 5 is rejected for the Buxton nourishment project.

Placement Option 6 involves nourishment along one short segment of beach at the upcoast (i.e. north) end of the project. All fill would be concentrated in that area, with the expectation of gradually feeding the downcoast action area. Feeder beaches have been used adjacent to inlets and navigation projects (CERC 1984) for reasons of economy and size of dredge. Small harbor dredges working channels may only be able to pump a distance of 2,000–4,000 feet. Therefore, the dredge spoil is placed as far away from the inlet as practical, but not extended over long distances downcoast to other areas that may need sand. Oregon Inlet disposal along Pea Island is an example of a feeder beach repeatedly nourished to provide sand gradually to downcoast areas (Dolan & Lins 1986).

This concept is problematic for the Buxton project for two reasons. First, the scale of the Buxton project (~2.6 million cubic yards) greatly exceeds the volumes typically removed from inlet and harbor entrances where feeder beaches have been used. A Buxton feeder beach would produce a very large salient (bulge) in the shoreline extending over 1,000 feet offshore for a limited length of beach. This would alter wave patterns and lead to focused erosion at the ends of the feeder, with the degree of erosion related to the scale of the feeder beach. This interruption of normal transport would increase the likelihood of a dune breach associated with end effects of the nourishment (NRC 1995, Dean 2002). A breach of the foredune would damage NC 12 and infrastructure.

A variation on the feeder beach concept would stockpile a large portion of the sand somewhere along the action area for later distribution by mechanical means after the turtle or bird nesting period or storm emergencies. The primary issue with stockpiles is the lack of room along the existing dry-sand beach or backshore area within the action area for a large stockpile. For example, if 50%, or ~1,300,000 cubic yards, of the project volume were retained in a stockpile, ~800 acre-feet of storage capacity would be required. Such a stockpile would average 40 feet high and require over 20 acres of land, which would not be practical for the Proposed Action. Also, such a stockpile for later placement along the beach would significantly increase the project costs (or reduce project volume) due to the need for double handling of the nourishment sand.

For reasons outlined above, Placement Option 6 is rejected for the Buxton nourishment project.

MITIGATION MEASURES

To prevent and minimize potential adverse impacts associated with the Proposed Action, certain management and mitigation measures would be implemented during construction. Upon project completion, the action area would be left to adjust naturally and no further maintenance or manipulation of the beach would be involved. Additional monitoring activities before, during, and after construction are anticipated in conformance with the Biological Opinion for the project (to be issued at a later date). The Applicant should anticipate that state and federal permits required before this Proposed Action proceeds with construction would include a variety of conditions specifically related to the protection of water quality and natural resources from construction-related impacts. If the National Park Service decides to permit this Proposed Action, then the following mitigation would be incorporated into the terms and conditions of the NPS Special Use Permit.

Coastal Resources and Soils/Wetland Resources/Wildlife and Wildlife Habitats

- A pre-construction environmental meeting would be convened with resource and regulatory agencies, the National Park Service, the contractor, and the engineer to review protocols and environmental protection measures mandated under the permits.
- Equipment mobilization and use would be via designated beach accesses and along the constructed berm so as to avoid impacts to vegetated areas.
- Pipe and material along the beach would be moved under escort by NPS biologists so as to avoid any nesting activity or sensitive habitat designated by the National Park Service.
- Appropriate measures would be employed to prevent or control spills of fuels, lubricants or other contaminants from entering waterways or sensitive areas. Actions would be consistent with state water quality standards and the Clean Water Act Section 401 certificate requirements. A hazardous spill plan would be approved by the National Park Service and appropriate resource agencies prior to construction. This plan would state what actions would be taken in the case of a spill, notification measures and prevention measures to be implemented, such as the placement of refueling facilities, storage and handling of hazardous materials.
- Equipment on the beach would be moved to a safe location within the vicinity of the action area upon a weather forecast of high wave and water conditions.
- The contractor would not leave vehicles idling for excessive periods when parked or not in use.
- Sea turtle nests lay immediately prior to or during construction within the project Area would be relocated by trained observers under the guidance of USFWS, NPS and NCWRC officials.
- Wildlife collisions would be reported to federal and state resource personnel.
- Injury or death of wildlife would be reported to USACE, NPS personnel and other applicable agencies, such as the USFWS and NCWRC.

Vegetation

- No construction activities or equipment storage would occur on vegetated areas.
- Post-project dune planting or sand fencing are not included in project plans. Such activities would be possible at the discretion of the National Park Service or individual property owners in Buxton Village. The Applicant believes the appropriate time to implement dune planting or sand fencing is after the nourished beach undergoes natural equilibration (months to year timeframe).

Threatened and Endangered/Special Status Species

- The Applicant would coordinate with the National Park Service and resource agencies (USFWS, NCWRC) regarding the need to restrict construction in the vicinity of active nest building by sea turtles, shorebirds, or nesting water birds. (For more detailed discussion regarding mitigation procedures to protect these species, see Chapter 4.)
- The Applicant would coordinate during dredging operations with NMFS and the National Park Service regarding specific restrictions, operations procedures, and protection of turtles, Atlantic sturgeon, whales, and other marine mammals.
- The Applicant would comply with no-work buffers established by the National Park Service around active nests or other designated habitat requiring protection.

Cultural Resources

- Construction would be stopped if cultural resources are encountered, and the contractor would coordinate protective measures to minimize disturbance with the State Historic Preservation Office (SHPO).
- Potential cultural resources detected in the offshore borrow area (see Appendix F- *Cultural Resources*) would be avoided during dredging operations by establishing no-work buffers around the objects. Planning is being conducted for additional Phase 2 surveys to identify a possible abandoned cable running across the borrow area.

SUMMARY COMPARISON OF ALTERNATIVES

Table 2.1 provides a summary comparison of the alternatives presented in this chapter.

Table 2.1 Summary of Alternatives

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
NPS Beach – Reach 1	The ~11,500 feet of seashore beach north of the Village of Buxton (Reach 1) would continue to erode at historical rates of up to 10 feet/year. The beach would narrow and the dune would erode during storms. Dune breaches would occur with increasing frequency as the beach degrades. Emergency measures to repair the dune or place emergency sand bags to protect infrastructure would be implemented. Transportation and infrastructure would be adversely impacted by major storms. The chance of a breach inlet during storms would increase as the beach continues to narrow.	Reach 1 along the Seashore would be nourished by a sand volume that is about half the amount of the Preferred Alternative during a four-month construction window. The volume of sand would replace the estimated deficit volume of sand (ie minimum volume that must be added to bring the beach profile to a stable condition). This would only provide a few years' worth of extra sand to accommodate annual erosion. Project longevity would be relatively short (several years) before the beach volume is again in deficit.	Reach 1 would be nourished at the maximum sand volume allowable under the Applicant's fixed budget. Summer dredging and nourishment would result in much greater efficiencies and production, shorten-in the duration of construction to ~2.5 months while doubling the volume. The increased volume would provide a much wider beach and increase longevity to ~10 years. This would provide protective benefits for a much longer period and reduce the frequency and magnitude of damages to dunes, NC 12 and infrastructure during storms.
Village of Buxton Beach – Reach 2	The ~4,000-foot length of seashore beach fronting the Village of Buxton would continue to erode at historical rates of up to ~12 feet per year. Beach width would continue to decline and normal waves would impact existing homes and businesses. Property owners would use more emergency sand bags to protect property. Wave runup would be higher at the sand bags without a beach to dissipate waves gradually. High runup and overwash would flood property and NC12 with increasing frequency, cutting off transportation to surrounding communities.	Reach 2 along the village shoreline would be nourished by sand volume that is about half the amount of the Preferred Alternative. Winter construction would be halted numerous times, leaving incomplete sections vulnerable to end losses before construction resumes. The nourishment volume would offset the deficit volume, but only provide for a few years of extra sand to accommodate annual erosion. Project longevity would be short (a few years) before the beach volume is in deficit.	Reach 2 would be nourished at the maximum sand volume allowable under the Applicant's fixed budget. Summer dredging and nourishment would result in much greater efficiencies and production, shortening the duration of construction impacts while doubling the volume. End losses due to temporary construction stoppages would be reduced. The increased volume would provide a much wider beach and increase longevity to ~10 years. This would provide protection benefits for a much longer period and reduce the frequency and magnitude of damages to existing property and infrastructure.
Meets Purpose & Need	No. Present conditions along the action area have deteriorated to the point that minor storms directly impact developed property and cut back the toe of the artificial dune. Future dune breaches are expected at increasing frequency. This would lead to repeated property damage and road closures and would necessitate emergency actions to restore the area.	Yes. Nourishment at about half the amount of the Preferred Alternative would provide improved storm-damage reduction and protection of infrastructure and existing development. A wider beach would reduce wave runup and erosion of the dune, lessening the frequency of breach events. Project longevity would be limited to ~3 years before the action area returns to a deficit volume condition.	Yes. Nourishment at the maximum quantity allowable within the Applicant's budget would provide protection to infrastructure and existing development for up to ten years. Dune-breaching frequency would be reduced, and the wider beach would feed sand to the dune allowing for natural dune growth. Storm damages would be reduced and the probability of a breach inlet forming would diminish.

Table 2.1 (continued) Summary of Alternatives

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Anticipated Sea Level Rise	Beaches respond to sea level rise by profile adjustment under waves and changing water levels. The adjustment is rapid and imperceptible. An associated net recession of the shoreline occurs with sea level rise, which in the case of the Buxton action area is dwarfed by other underlying causes of erosion. Sea-level rise in the range 3–6 millimeters per year (recent scenarios) equates to beach recession of ~2–4 inches per year in the Buxton area. The average natural recession rate in the area is ~10–12 feet per year.	The nourished beach would adjust rapidly to sea level rise just as a natural beach. The volume of nourishment and seaward displacement of the shoreline would greatly exceed the recession due to sea level rise at decadal scales. The shoreline advance due to nourishment would be 20–40 times the potential recession due to sea level rise over a 3–5 year period.	Greater nourishment volumes under the Preferred Alternative would provide longer term benefits, more than offset recession due to sea level rise and reduce runup levels which are a function of beach width and steepness of the profile. The shoreline advance due to nourishment would be 40–80 times the potential recession due to sea level rise over an ~10-year period.
Regulatory Implications	Continued erosion, breaches of the dune, damages to buildings, and emergency repairs to NC12 result in repeated need for emergency permits and such remedial measures as sand bagging that are generally discouraged under North Carolina CZM rules and regulations.	Nourishment is a soft-engineering solution to erosion generally approved or preferred by regulatory agencies compared with emergency sand bags or hard structures. Construction in winter months is generally preferred by resource agencies, so as to avoid disturbing sea turtles and other species.	Nourishment during summer months is discouraged or opposed by resource agencies, to avoid times of construction when threatened or endangered species may be present.
Site Constraints & Construction Logistics	The action area is generally considered to be a difficult place to work because of its remoteness and high wave energy. The nearest safe harbor for oceangoing dredges is >100 miles away.	Under Alternative 2, winter conditions pose high risks to contractors working offshore and along the beach. Potential exists for loss of equipment or human life. Production would be greatly diminished because of the number of days in which wave heights exceed operational conditions.	Under Alternative 3, summer conditions significantly reduce risk and improve safety for offshore work. Average wave heights are to operational limits of hopper dredges in the action area in June through August.
Existing Uses	Alternative 1 has no impact on existing uses, which include recreation, bird nesting, turtle nesting, surf fishing, surfing and observing nature. However, ongoing erosion is likely to lead to reduced walkable beach, more dune damages, and temporary highway closures while emergency repairs are performed.	Under Alternative 2, temporary and localized disruption of existing uses would occur during construction. Upon project completion, existing uses would resume with little change. Construction in winter would be less disruptive to threatened and endangered species, recreational users, and other activities.	Under Alternative 3, temporary and localized disruption of existing uses would occur during construction, with greater impacts than Alternative 2. The duration of construction impacts would potentially be shorter due to efficiencies of work during low-wave summer months and the relatively small beach area affected by active construction.

SUMMARY COMPARISON IMPACTS OF ALTERNATIVES

Table 2.2 provides a summary of the impacts related to each alternative. A more detailed explanation of the impacts is presented in Chapter 4 – Environmental Consequences.

Table 2.2 Summary of Impacts of Alternatives

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Coastal Resources	Under Alternative 1, erosion and sand loss from the action area would continue to be the dominant process. With continued erosion, the foredune would breach, leading to a further reduction in sand supply along the beach. Because NC12 is a fixed structure and lifeline to the communities of Hatteras Island, emergency highway maintenance would likely continue. Emergency measures would further manipulate the beach/dune system, introduce more emergency sandbags, modify the profile and narrow the recreational beach. The available sand supply to downcoast areas would be reduced. **Project Impact:** Minor to moderate, long-term adverse impacts. **Cumulative Impact:** Contributes a noticeable, adverse increment to a long-term, regional, cumulative adverse impact.	Alternative 2 would augment the sand supply and have negligible impact on littoral processes. A wider beach would reduce runup levels and help promote natural dune growth which depends primarily on wind speed and the width of the dry sand beach. The adjusted profile after construction is expected to retain similar slopes and morphology as other stable beaches in the vicinity of the action area. Excavations in the borrow area would produce short-term local adverse impacts. Alternative 2 benefits would last for several years. **Project Impact:** Long-term (several years) beneficial impacts. **Cumulative Impact:** Contributes a noticeable beneficial increment to a long-term, regional, cumulative adverse impact associated with erosion and dune manipulation along the coast.	Alternative 3 would augment the sand supply by at least twice the amounts under Alternative 2. This would provide similar impacts for dune building without significant modification of littoral processes. The wider beach would allow natural processes of erosion and accretion to occur without frequent adverse impacts to the dune system. Alternative 3 benefits would extend up to one decade. **Project Impact:** Long-term (decade) beneficial impacts. **Cumulative Impact:** Contributes a noticeable, beneficial increment to long-term, regional, cumulative, adverse impact associated with erosion and dune manipulation along the coast.
Sand Resources	Alternative 1 would impact sand resources by continuing to remove sand from the action area. As erosion continues and emergency shore protection is implemented, beach and dune sediments tend to become coarser than normal. Scraping of washovers across NC12 introduces coarser sands and chunks of asphalt into the repaired dune. The narrower and coarser-grained beach tends to steepen, thus modifying the characteristics of the surf. Steep beach faces produce a plunging wave form at the shore, dangerous for surfers and swimmers. **Project Impact:** Minor long-term adverse impacts. **Cumulative Impact:** Contributes a noticeable adverse increment to long-term, beneficial, cumulative impacts of sand additions along other Dare County beaches.	Alternative 2 would augment sand resources on the beach, while reducing sand resources in the offshore borrow area. The impacts would be the same, but lower in magnitude compared with Alternative 3. **Project Impact:** Long-term (several years) beneficial impacts on beach; moderate adverse impacts in borrow area. **Cumulative Impact:** Contributes a minor, adverse increment to long-term, minor, regional, adverse cumulative impacts of offshore sand excavations. Contributes a noticeable, beneficial increment to long-term, beneficial, cumulative impacts of sand additions along other Dare County beaches.	Alternative 3 would provide the largest addition of new sand to the beach under a fixed budget. Sand quality is expected to closely match other native beaches in the area and be incrementally finer than some sections in the action area, which are coarse for the reasons given under Alternative 1. By augmenting the littoral sand supply, the normal processes of erosion and accretion would occur with less direct impacts to the dune, NC 12, and existing structures. Breach events would be less frequent and dune building would occur via natural aeolian processes for the life of the project, rather than via artificial manipulation after storms. The offshore borrow area is an isolated shoal, which would be reduced in height by several feet upon excavation. Data indicate the underlying sediments match the borrow sediments. Thus, little change in substrate conditions should occur upon project completion. **Project Impact:** Long-term (decade), beneficial impacts on beach; moderate, adverse impacts in borrow area. **Cumulative Impact:** Contributes a minor, adverse increment to long-term, minor, regional, adverse cumulative impacts of offshore sand excavation.Contributes a noticeable, beneficial increment to long-term, beneficial, cumulative impacts on the beach.

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Water Quality	Continued erosion would increase the frequency of dune breaches, property damage, and overwash onto NC12. Emergency repairs would introduce incompatible materials, such as asphalt, oil and grease, into the reconstructed dune with possible minor adverse impacts to water quality. Turbidity in the littoral zone would be unchanged. **Project Impact:** Negligible to minor, long-term adverse impacts. **Cumulative Impact:** Contributes an imperceptible adverse increment to long-term, negligible adverse cumulative impacts.	Dredging operations would produce localized, short-term increases in turbidity at the borrow area and the slurry discharge area along the beach. The proposed borrow area consists of medium to coarse sand (mean grain size), with trace amounts of mud. Nearly all the sediment would settle rapidly (order of seconds to minutes) based on the fall velocity of sandy materials. Turbidity impacts would be limited temporally and spatially due to the texture of the sediments. **Project Impact:** Transient, short-term, adverse impacts during construction. **Cumulative Impact:** Contributes an imperceptible adverse increment to long-term, negligible adverse cumulative impacts.	Same as Alternative 2, but of incrementally greater magnitude in relation to the higher volume of nourishment that may be accomplished. **Project Impact:** Transient, short-term adverse impacts during construction. **Cumulative Impact:** Contributes an imperceptible adverse increment to long-term, negligible adverse cumulative impacts.
Essential Fish Habitat (EFH)	Under the No-Action Alternative, continued erosion would likely increase the amount of shoreline that is armored with emergency sand bags. This would modify the profile and reduce the area of unconsolidated/shallow subtidal bottom EFH for certain benthic organisms which serve as prey for the surf fishery. There would be no impact in offshore shoal areas. If a breach occurs, it offers transient, potential beneficial impacts of additional estuarine emergent wetlands EFH and estuarine intertidal flats EFH on back barrier due to overwash deposits. Length of benefit would depend on whether and how fast the breach closed and whether or not the breach was bridged. **Project Impact:** Site-specific to local, long-term, minor to moderate adverse impacts to nearshore EFH. Site-specific short-to long-term potential beneficial impacts. **Cumulative Impact:** Contributes imperceptible to noticeable increment to adverse cumulative impacts associated with ongoing erosion processes.	Dredging operations offshore would produce localized, short-term, adverse impacts to the existing population of benthic organisms, removing biomass and prey from the surficial layer of sediment in the Cape Hatteras sandy shoal HAPC and temporarily increase turbidity in marine water column EFH. Dredge operations may impact *Sargassam* habitat HAPC by entrainment. Excavations would leave undisturbed area and some irregular topography which may be attractive to some fish species and foster rapid recruitment of benthic organisms. Beach filling operations would bury sessile benthic organisms in the unconsolidated/ shallow subtidal bottom EFH, temporarily increase turbidity to marine high-salinity surf zone EFH, and/or bury sargassum EFH that may be floating in the area. The borrow area is expected to undergo rapid (order of months) recolonization by similar species because of the similarity between surficial sediments and under-lying sediments. The nourished beach area is expected to undergo rapid (order of weeks to months) recolonization by similar species because of the textural similarity between native and borrow sediments. See Appendix E (*Biological Monitoring*) for related project data from a nearby similar setting. **Project Impact:** Site-specific, short-term, minor to moderate, adverse impacts during construction to nearshore and offshore EFH/HAPC. **Cumulative Impact:** Contributes imperceptible to noticeable, adverse increment during construction to long-term, minor, adverse cumulative impacts of offshore sand borrow excavations and beach placement of excavated materials. It would contribute imperceptible increment to noticeable, long-term, beneficial, cumulative impacts associated with stable beaches.	Same as Alternative 2 but of incrementally greater magnitude in relation to the higher volume of nourishment that may be accomplished. Upon project completion, the greater longevity of Alternative 3 would allow the benthic communities to evolve unobstructed for a longer period of time before erosion returns the area to conditions where the profile is frequently manipulated and hatitat area diminishes for the reasons given under Alternative 1. **Project Impact:** Site-specific, short-term, minor to moderate, adverse impacts to nearshore and offshore EFH/HAPC. **Cumulative Impact:** Contributes imperceptible to noticeable, adverse increment during construction to long-term, minor, regional, adverse cumulative impacts of offshore sand borrow excavations and beach placement of excavated materials. It would contribute an imperceptible increment to noticeable long-term beneficial cumulative impacts associated with stable beaches.

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Biological Resources	Existing conditions of moderate to high erosion would continue to degrade the beach, produce dune breaches, damage existing development and NC12 and force emergency repairs, including dune rebuilding, with less than ideal sediment and road debris. Emergency sand bags would eliminate nesting habitat for threatened birds or turtles. As erosion proceeds, greater lengths of shoreline would be considered for protection by sand bags, particularly ~3,000 feet within Reach 2 (Buxton Village) and the southernmost ~1,000 feet of Reach 1 along the Seashore where NC 12 is closest to present mean high water. Because the action area represents a relatively small portion of similar habitat in the Cape Hatteras and Cape Lookout National Seashores, the overall impact would be minor. Storms would increase overwash habitats preferred by some protected birds and plants. Following a major storm, there could be significant observable adverse impacts to existing habitats, particularly if the barrier is breached. A storm breach would also provide certain benefits in the form of locally increased tidal flushing in Pamlico Sound and the formation of new intertidal shoals, habitats preferred by some protected birds. A breach would also provide short-term benefit to both sturgeon species and sea turtles if it was deep enough to provide access to back barrier habitats. Length of benefit would depend on whether and how fast the breach closed and whether or not the breach was bridged. **Project Impact:** Mixed beneficial and adverse short-term and middle-term, indirect impacts associated with ongoing erosion processes, which reduce some preferred habitats or render others less desirable **Cumulative Impact:** Contributes a minor adverse increment to long-term, moderate adverse cumulative impacts associated with ongoing erosion processes.	Nourishment would produce short-term (~4 months) adverse impacts to biota in the action area, particularly benthic organisms. During winter, species abundance tends to be lower, and impacts would be less than construction activities in summer months. There would also be short-term impacts to nesting or roosting activities of colonial sea birds that may be using the back beach area. Sea turtles are not likely to be present on the beach during winter months, but if water temperatures rise sufficiently during a portion of the construction period, could be present, along with Atlantic sturgeon and shortnose sturgeon in the offshore borrow area. Additional sand mitigates erosion and expands the area of dry-sand beach for the benefit of species that thrive in that zone, including ghost crabs and sea beach amaranth. Over time, nourishment sand feeds the foredune and provides expanded dune habitat for several years. Nourishment sand eventually buries emergency shore protection devices or migrates to downcoast areas, augmenting the natural sand supply. Adverse impacts to benthic organisms are expected to be short-lived in relation to the particular life cycle of each species present. If the borrow sediments are similar to native beach sediments, rapid recruitment of new biota should occur in the expanded habitat created by the project.During construction, beneficial and adverse impacts would occur in the form of nutrients and biota dislodged in the borrow area and beach zone. This may attract predators as well as eliminate benthic organisms for a short period (weeks to months). Upon project completion, new habitat would be available (wider beach) for the benefit of some organisms and barrier island vegetation. **Project Impact:** Site-specific, short-term, adverse and beneficial impacts, depending on the species (e.g. Atlantic sturgeon, shortnose sturgeon, and whales) may be adversely affected during dredging, and benthic organisms would be excavated or buried during construction, but benthic foraging habitat and sea turtle nesting habitat would be beneficially affected post-construction). See Appendices B – *Biological Assessment*, D – *Essential Fish Habitat*, and E – *Biological Monitoring* for more detail. **Cumulative Impact:** Contributes an imperceptible, adverse increment to long-term, moderate, adverse, cumulative impacts (construction). Post-construction contributes an imperceptible to noticeable, beneficial increment (wider beach) to moderate, adverse, cumulative impacts associated with ongoing erosion processes, which reduce some preferred habitats or render others less desirable.	Alternative 3 would produce shortest term (~2-3 months) impacts during construction, but greater impacts than Alternative 2 to certain biological resources because of the season. Benthic populations in summer tend to exhibit much greater abundance than winter populations. Sea turtles and certain colonial seabirds are more likely to be nesting or otherwise using the action area in summer. Therefore, shorter duration impacts under Alternative 3 would affect much greater biological activity during summer months. Adverse impacts during construction would include burial of benthic organisms and disruption of turtle nesting activities, or colonial seabird nesting and roosting activities. Following construction, Alternative 3 potentially produces much longer (decade) beneficial impacts in the form of expanded beach habitat. Duration of beneficial impacts would be a function of the scale and longevity of the project, but upwards of twice that of Alternative 2. During construction, beneficial and adverse impacts would occur in the form of nutrients and biota dislodged in the borrow area and beach zone. This may attract predators as well as eliminate benthic organisms for a short period (weeks to months). Upon project completion, new habitat would be available (wider beach) for the benefit of some organisms and barrier island vegetation. **Project Impact:** Site-specific, short-term, adverse and beneficial impacts, depending on species. Atlantic sturgeon may likely be adversely affected by dredging, and adverse impact would likely occur to sea turtles that may be trying to nest (particularly to loggerhead and greens) and less likely to Kemp's ridley) and to benthic organisms, which would be excavated or buried during construction (offshore and beach). All sea turtle nests in the project area would be relocated during construction; post-construction-nesting beach will be wider. Benthic foraging habitats would be increased post-construction, as would overwash habitats preferred by some protected plants and protected birds for nesting, foraging, and roosting. See Appendices B, D, and E for more detail. **Cumulative Impact:** Contributes an imperceptible, adverse increment to long-term, moderate, adverse, cumulative impacts (construction). Contributes an imperceptible to noticeable, beneficial increment (wider beach) to moderate, adverse, cumulative impacts associated with ongoing erosion processes, which reduce some preferred habitats or render others less desirable.

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Cultural Resources	No shipwrecks are known to be in the area. However, continued shoreline recession potentially exposes remains of undetected, cultural artifacts buried along the barrier island. **Project Impact:** Negligible to minor, long-term, adverse impact to undetected cultural resources along the beach-dune system due to continued erosion. No impact at the borrow area. **Cumulative Impact:** Contributes an imperceptible, adverse increment to long-term, adverse impacts of erosion on undetected or detected, cultural resources along Dare County beaches.	Nourishment lessens the chance of undetected cultural artifacts being exposed on the beach. At the borrow site, cultural resources such as potential remains of shipwrecks would be avoided by placing no work buffers around any objects that may have historical value. Possibility of encountering and damaging undetected objects would be reduced by suspending operations and moving the dredge to other areas of the borrow site. **Project Impact:** Long-term (several years) beneficial impact along the beach and negligible to minor, adverse impact at the borrow site. **Cumulative Impact:** Contributes a beneficial increment to long-term, beneficial impacts associated with additional burial of undetected or detected cultural resources in the beach zone. Contributes a noticeable, adverse increment to overall cumulative impacts of encountering undetected cultural resources in offshore borrow areas.	Same as Alternative 2 with greater potential to expose undetected cultural resources in the borrow area. **Project Impact:** Long-term (decade), beneficial impact along the beach and negligible to minor, adverse impact at the borrow site. **Cumulative Impact:** Contributes a beneficial increment to long-term, beneficial impacts associated with additional burial of undetected or detected cultural resources in the beach zone. Contributes a noticeable, adverse increment to overall cumulative impacts of encountering undetected cultural resources in offshore borrow areas.
Socio-Economics	Developed property and NC 12 would sustain substantial socio-economic impacts in the form of road closures, loss of business, decline in visitation, and increased cost of supplies and emergency response. A breach of the barrier beach would necessitate costly emergency repairs such as construction of a temporary bridge, closure of the channel and restoration of the beach. The economic cost of road closures is high in the Hatteras communities because of their dependence on tourism. Road closures result in loss of business and tax revenues, inability of tourists to reach their destination, and substitute forms of transportation required to supply the community and safeguard life and property. **Project Impact:** Long-term, moderate, adverse impacts, depending on season, frequency, and magnitude of storms during the period. **Cumulative Impact:** Contributes an appreciable adverse increment to long-term, adverse cumulative impacts.	Reduces the frequency and magnitude of damages to NC 12, developed property and existing homes and businesses along the Buxton east coast, with associated substantial socio-economic benefits. Offsets costs of road closures and emergency repairs over the life of the project (several years) and preserves property values and the tax base within the community. Visitation and use of park facilities is maintained with negligible interruption. **Project Impact:** Long-term (several years), beneficial impacts over the life of the project. **Cumulative Impact:** Contributes a noticeable to appreciable, beneficial increment to long-term, beneficial, cumulative impacts.	The Preferred Alternative increases the duration of socioeconomic benefits to the project longevity (~1 decade). Benefits are otherwise the same as Alternative 2. The wider beach that is possible under Alternative 3 provides a significantly greater reservoir of sand to feed the dune system and reduces damaging wave runup at existing structures. Property damages would be reduced or minimized for the project's duration. The potential economic benefits in the form of reduced property damage, less frequent NC12 repairs, preservation of access for visitors, and preservation of the tax base and property values are likely to be an order of magnitude greater than the cost of the project over a decade. **Project Impact:** Long-term (decade), beneficial impacts over the project's life. **Cumulative Impact:** Contributes a noticeable, beneficial increment to long-term, beneficial, cumulative impacts.
Visitor Use & Experience	The No-Action Alternative would produce continued adverse impacts on visitor use and experience along the action area. Ongoing erosion would increase the frequency of dune breaches and road closures. Loss of beach along Buxton Village and installation of more emergency sand bags would inhibit or prevent direct beach access. Road damage and repairs would result in minor to major inconvenience for visitors and likely alter travel plans. Visitors to the Seashore and villages along Cape Hatteras are attracted to the area by the natural beauty, wildlife, and vistas of the coast. This experience would continue to be degraded by ongoing erosion and emergency road repairs and property protection measures. (continued next page)	Beach nourishment would produce short-term (months) adverse impacts to visitor use and experience during the period of construction due to dredge pipelines and equipment on the beach. Upon project completion, visitor experience would improve for several years by way of a wider recreational beach, less exposure of emergency sand bags, and less frequent dune breaches and road closures. **Project Impact:** Short-term, minor, adverse impacts in the active construction area, followed by long-term (years) beneficial impacts due to a wider beach and less frequent road closures. With fewer visitors in winter, fewer would be impacted by construction. (continued next page)	Similar impacts as Alternative 2, but would affect more people because visitation is highest during summer months. Post-construction benefits would last longer than Alternative 2. **Project Impact:** Short-term, adverse impacts in the active construction area, followed by long-term (decade) beneficial impacts due to a wider beach and less frequent road closures. With more people in summer, more people would be impacted by construction. **Cumulative Impact:** Contributes a noticeable increment to adverse, cumulative impacts during construction and beneficial impacts after construction for a decade. (continued next page)

Topic	Alternative 1: No-Action	Alternative 2: Winter Construction	Preferred Alternative 3: Summer Construction
Visitor Use & Experience (continued)	**Project Impact:** Moderate to major, adverse impact associated with road closures and emergency shore protection along Buxton Village properties. **Cumulative Impact:** Contributes an appreciable adverse increment to long-term adverse cumulative impacts.	**Cumulative Impact:** Contributes a noticeable increment to adverse, cumulative impacts during construction and beneficial impacts after construction for several years.	See above.
Public Safety	Current conditions within the action area would continue with increasing frequency of road closures as erosion continues. Road closures impact public safety, affecting emergency services, inhibiting evacuation of residents, and preventing patient transfers to regional hospitals. A potential breach of the barrier would produce extended adverse impacts over weeks to months as demonstrated by the breach events due to Hurricane *Irene* (2011). **Project Impact:** Regional, long-term, moderate, adverse impacts. **Cumulative Impact:** Contributes a noticeable, adverse increment to long-term appreciable, adverse cumulative impacts.	Reduces the frequency of road closures or the threat of a barrier breach and helps maintain unimpeded access via NC 12 during medical and other emergencies. Fire, police, and park service operations are favorably impacted for several years. **Project Impact:** Long-term (years), beneficial impacts in relation to the longevity of the project. Produces major, adverse impacts to worker safety associated with winter construction offshore. **Cumulative Impact:** Contributes a noticeable, beneficial increment to long-term, appreciable, cumulative impacts on public safety, with respect to maintenance of NC 12.	Produces the same benefits as Alternative 2 but for up to one decade in relation to the scale and longevity of the project. **Project Impact:** Long-term (decade) beneficial impacts in relation to the longevity of the project. Produces much lower adverse impacts to worker safety associated with summer construction compared with Alternative 2. **Cumulative Impact:** Contributes a noticeable, beneficial increment to long-term, appreciable, cumulative impacts on public safety, with respect to maintenance of NC 12.
Sustainability and Long-Term Management	NCDOT reports spending more money per mile maintaining NC 12 than any other road in the state. Maintenance is focused on several segments of the road where erosion has degraded the beach and encroached on the road. These erosion hotspots are limited in extent, but are a cause of frequent emergency actions to maintain the road. NCDOT is evaluating long-term (50-year) alternatives for the Buxton Canadian Hole hotspot. Until a plan can be agreed on and implemented, damages and emergency repairs would continue at increasing frequency. Existing conditions are neither sustainable nor practical for long-term management. **Project Impact:** Long-term, moderate, adverse impacts with the likelihood of increased frequency of emergency repairs and more difficult management of road closures and beach erosion. A breach of the barrier greatly magnifies the adverse impacts and management requirements associated with alternative transportation routes and methods. No-Action would indirectly, adversely impact the region. **Cumulative Impact:** Contributes an appreciable adverse increment to long-term adverse impacts of erosion.	Beach nourishment is sustainable at decadal scales in many areas provided there is a cost-effective source of beach-quality sand nearby and erosion rates are moderate. The action area was nourished between 1962 and 1973. Local observers report that those projects provided benefits due to better property protection and few road closures for ~2 decades. No nourishment has occurred in over 40 years. Alternative 2 would provide a sand volume of ~1.3 million cy, which would be comparable to the 1973 project. Alternative 2 is predicted to provide 3-5 years of erosion relief, due to the lower sand volume that a winter project would allow. The project would include performance monitoring to quantify nourishment longevity. Such information is needed to determine objectively whether nourishment is sustainable and cost-effective, relative to other shore protection or long-term (decades) property abandonment. **Project Impact:** Long-term (years) beneficial impacts. Project would provide site-specific performance data for evaluation of cost and sustainability. **Cumulative Impact:** Contributes an appreciable, beneficial increment to long-term, adverse, cumulative impacts of erosion.	The Preferred Alternative provides benefits similar to Alternative 2, but for at least twice as long in relation to the scale of the project. Alternative 3 would nourish the beach using up to ~2.6 million cy of sand, compared to Alternative 2 at ~1.3 million cy. Economies of scale make Alternative 3 more sustainable and cost-effective than Alternative 2. **Project Impact:** Long-term (decade) beneficial impacts. Project would provide site-specific, quantitative performance data for evaluation of cost and sustainability. **Cumulative Impact:** Contributes an appreciable, beneficial increment to long-term, adverse cumulative impacts of erosion.

ENVIRONMENTALLY PREFERABLE ALTERNATIVE

In accordance with Section 404b1(CFR 40 Part 230), the US Army Corps of Engineers must identify the Least Environmentally Damaging Practicable Alternative (LEDPA) before it can issue a permit. The National Park Service must also identify the environmentally preferable alternative in its NEPA documents for public review and comment [Sect. 4.5E (9)]. The LEDPA is the alternative that causes the least damage to the biological and physical environment and provides protection that best preserves and enhances historical, cultural, and natural resources. The LEDPA is identified by the Responsible Officer after weighing long-term environmental impacts against short-term impacts when evaluating and considering what is the best protection of the resources. In the case of beach nourishment in high-energy sites such as the Buxton Action Area, the environmentally preferred alternative (e.g. winter dredging) may not be the alternative under which the US Army Corps of Engineers or the National Park Service issues its permits, considering such other factors as safety.

Under Alternative 1–No Action, emergency measures are likely to be implemented with increasing frequency while the remaining beach would diminish in width. Alternative 1–No-Action is unlikely to provide a solution to the problem of ongoing erosion and does not address the urgency of the comments expressed to PEPC.

Alternative 2–Winter Construction and Alternative 3 (Preferred Alternative)–Summer Construction are beach nourishment projects designed to mimic the natural processes of accretion, which also occur along Hatteras Island within Seashore boundaries. Additions of sand by artificial means are generally more impactful than natural additions, mainly because of scale and rates of change to the profile. The added sand, if similar in texture to native sand, should be indistinguishable after equilibration of the beach.

The environmental impacts of Alternative 2–Winter Construction would be less than Alternative 3–Summer Construction because of the season of construction and the smaller scale. During Alternative 3–summer construction, the applicant acknowledges that disruptions to the environment would occur and the implementation of certain environmental protection measures would be needed. However, upon completion of construction, the environmental benefits of Alternative 2–Winter Construction would be less than Alternative 3–Summer Construction due to the project's shorter longevity and smaller volume of sand.

By comparison to Alternative 2, Alternative 3–Summer Construction would provide greater project longevity and environmental benefits resulting from a wider, longer-lasting beach. Until the NC Department of Transportation, the National Park Service, and other stakeholders can reach consensus on a long-term strategy for NC 12, Alternative 3–Summer Construction is considered to provide the most environmentally beneficial remedy for chronic erosion and the narrow beach in the high-energy coastal setting at Buxton. Therefore, Alternative 3–Summer Construction is the environmentally preferable alternative for the Proposed Action Area.

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