APPENDIX H

CUMULATIVE EFFECTS ASSESSMENT

BOGUE BANKS
MASTER BEACH NOURISHMENT PLAN

ENVIRONMENTAL IMPACT STATEMENT

CUMULATIVE EFFECTS ASSESSMENT

DRAFT

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1.0 INTRODUCTION

Council on Environmental Quality's (CEQ) regulations [40 Code of Federal Regulations (CFR) §§ 1500 – 1508)] implement the procedural provisions of the National Environmental Policy Act (NEPA) of 1969, as amended [42 United States Code (U.S.C.) §§ 4321 et seq.)]. Those regulations define *cumulative effects* as:

> *The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions (40 CFR § 1508.7).*

The CEQ (1997) further characterizes cumulative impacts and describes the cumulative impact analysis process. Cumulative impacts

> *…result from spatial (geographic) and temporal (time) crowding of environmental perturbations. The effects of human activities will accumulate when a second perturbation occurs at a site before the ecosystem can fully rebound from the effect of the first perturbation…Cumulative effects analysis, an iterative process, repeatedly assesses consequences following incorporation of avoidance, minimization, and mitigation measures into the alternatives to achieve a particular goal. Monitoring is the last step in determining the cumulative effects that ultimately results from the action. The significance of cumulative effects depends upon the ecosystem, resource baseline conditions, and relevant resource stress thresholds.*

This analysis follows the 11-step process outlined by the CEQ in their 1997 publication Considering Cumulative Effects Under the National Environmental Policy Act (Table 1).

Table 1. Steps in the Cumulative Effects Analysis (as adapted from CEQ 1997).

Environmental Impact Assessment Components	CEA Steps
I. Scoping	a. Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. b. Establish the geographic scope for the analysis. c. Establish the time frame for the analysis. d. Identify other actions affecting the resources, ecosystems, and human communities of

Environmental Impact Assessment Components	CEA Steps
	concern.
II. Describing the Affected Environment	a. Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. b. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds. c. Define a baseline condition for the resources, ecosystems, and human communities.
III. Determining the Environmental Consequences	a. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. b. Determine the magnitude and significance of the cumulative effects. c. Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. d. Monitor the cumulative effects of the selected alternative and adapt management.

2.0 SCOPING

2.1 Significant Cumulative Effects Issues

This assessment of cumulative impacts will focus on significant coastal shoreline resources and the impacts associated with inlet management, offshore dredging activities and the placement of compatible sediment on the beach. Depending upon specific project location and design, beach disposal/nourishment projects have the potential to beneficially or adversely affect the following resources, ecosystems and communities:

1) Beaches and Dunes including those species that occur within this habitat such as shorebirds and waterbirds (including the federally-protected piping plover and its critical habitat, and the red knot); seabeach amaranth; nesting sea turtles;
2) Marine waters including water column and water quality
3) Intertidal and nearshore zones including benthic assemblages;
4) Offshore Borrow Areas
5) Other resources including sand transport and human communities

These resources may be affected via the interactive or additive effects of a single project or of multiple projects occurring within an identified geographic and temporal scope. In discussing the potential cumulative impacts of offshore borrow area dredging and beach nourishment, we consider time crowded perturbations, and space crowded perturbations, as defined below, to be pertinent to this action.

- ***Time crowded perturbations*** *– repeated occurrence of one type of impact in the same area.*
- ***Space crowded perturbations*** *– a concentration of a number of different impacts in the same area.*

In the above, temporal-crowded perturbations refer to repeated occurrence of one type of impact in the same area, and spatial-crowded perturbations refer to a concentration of a number of different impacts in the same area. Each of the resources identified above will have different exposures and tolerance levels for actions associated with the type of project proposed. Cumulative effects may arise from various stressors or impacts including: loss or disturbance to habitat; disturbance from mechanical operations of the dredge equipment and heavy machinery; indirect effects associated with short-term elevation of turbidity levels; expansion of supratidal beachfront; and inlet stability resulting from the management of Bogue Inlet. These effects (and others) are evaluated in Section 5.0 of the EIS.

2.2 Primary Resources of Concern

The primary concerns pertaining to proposed dredging and beach disposal are direct and indirect impacts to macro-invertebrates, fish, shorebirds, and threatened and endangered species, as introduced above. Federally listed threatened or endangered species which could be present along the North Carolina coast are the blue whale, finback whale, humpback whale, North Atlantic right whale, sei whale, sperm whale, West Indian manatee, green sea turtle, hawksbill sea turtle, Kemp's Ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, shortnose sturgeon, Atlantic sturgeon, piping plover, and seabeach amaranth. Impacts to all listed species are summarized below and include, but are not limited to, mortality, reduction in forage, habitat alteration, and disturbance during construction activities (that may affect behavior or physiology). Also discussed are the benefits of periodic renourishments, which are expected to enhance nesting habitat of sea turtles and to provide additional habitat for sea beach amaranth and piping plover. In relation to dredging of offshore sites for material, primary concerns include potential impacts to benthic organisms and fishes associated with borrow areas (USACE 2014).

Detailed discussions of all significant resources and associated impacts considered in this assessment are included in the main body of the EIS. Effects discussed below are included here as they may occur on a statewide scale due to typical beach nourishment projects.

2.2.1 Beaches and Dunes

Terrestrial habitat types of concern include sandy beaches, which are usually sparsely if at all vegetated, and vegetated dune communities. Mammals occurring within this environment are opossums (*Didelphis virginiana*), eastern cottontail rabbits (*Sylvilagus floridanus*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), feral house cats (*Felis catus*), shrews (*Sorex* spp.), moles (Scalopinids), voles (Arvicolinids), and house mice (*Mus musculus*). Ghost crabs (*Ocypode quadrata*) are important invertebrates of the beach/dune community. The beach and dune also provide important nesting habitat for loggerhead and green sea turtles as well as habitat for a number of shorebirds and many other birds, including resident and migratory songbirds (USACE 2014).

Common vegetation of the upper beach includes beach spurge (*Euphorbia polygonifolia*), sea rocket (*Cakile edentula*) and pennywort (*Obolaria virginica*). The dunes are more heavily vegetated, and common species include American beach grass, panic grass (*Panicum* spp.), sea oats (*Uniola paniculata*), broomstraw (*Andropogon virginicus*), seashore elder (*Iva imbricata*), and salt meadow hay (*Spartina patens*). Seabeach amaranth (*Amaranthus pumilus*), a federally listed threatened species, is present throughout many of North Carolina's beaches (USACE 2014).

Placement of material along the ocean beach enhances and improves important habitat for a variety of plants and animals, and restores lost habitat in the areas of most severe erosion. This is especially important for nesting loggerhead sea turtles, piping plovers (*Charadrius melodus*), and seabeach amaranth. Historic nesting data from the study area beaches indicate that sea turtles continue to nest on disposal beaches with hatch rate successes similar to non-disposal beaches. Furthermore, new populations of seabeach amaranth have been observed subsequent to sand placement on beaches (e.g., Wrightsville Beach) (USFWS 1996b, CSE 2004). Individually and cumulatively, in addition to providing important habitat, beach nourishment projects protect public infrastructure, public and private property, and human lives (USACE 2014).

2.2.2 Marine Waters

North Carolina marine waters provide habitat for a variety of fishes and are important commercial and recreational fishing grounds. Kingfish, spot, bluefish, weakfish, spotted seatrout, flounder, red drum, king mackerel, and Spanish mackerel are actively fished from boats, the beach, and piers. Offshore marine waters serve as habitat for the spawning of many estuarine-dependent species that following recruitment migrate along the shores or in offshore areas. Larger, pelagic nekton located offshore of North Carolina are composed of a wide variety of bony fishes, sharks, and rays, as well as marine mammals and sea turtles, all of which may be present at the offshore borrow sites.

Dredging and placement of beach fill may impact the marine water column in the immediate vicinity of the activity, potentially affecting the surf zone and nearshore ocean. These impacts may include minor and short-term suspended sediment plumes and related turbidity, as well as the release of soluble trace constituents from the sediment. Overall water-quality impacts for any given project are expected to be short-term and minor. Cumulative effects of multiple, simultaneous beach nourishment operations could potentially impact fishes of the surf zone. However, the high quality of the sediment selected for beach fill and the small amount of beach affected at any point in time would not suggest that this activity poses a significant threat (USACE 2014).

2.2.3 Intertidal and Nearshore Zones

The intertidal zone serves as habitat for invertebrates including mole crabs, coquina clams, amphipods, isopods, and polychaetes, which are adapted to the high energy, sandy beach environment. These species are not commercially important, but they provide an important food source for surf-feeding fish and shore birds. The surf zone is an important migratory area for larval/juvenile fish moving in and out of inlets and estuarine nurseries (Hackney et al. 1996). Disposal operations along the beach can result in increased turbidity and mortality of intertidal macrofauna listed above, which serves as forage for various fish and bird species. Therefore, feeding activities of these species may be interrupted in the immediate area of beach sand placement. These mobile species are expected to temporarily relocate to other areas as the project proceeds along the beach. Though a short-term reduction in prey availability may occur in the immediate disposal area, only a small area is impacted at any given time, and once complete, organisms can recruit into the nourished area. The anticipated construction timeframes for beach projects are typically from December 1 to March 31 and avoid a majority of the peak recruitment and abundance time period of surf zone fishes and their benthic invertebrate prey source. Therefore, the impacts of beach renourishment on the intertidal and nearshore zones are considered temporary, minor and reversible. Cumulative effects of multiple simultaneous beach nourishment operations could be potentially harmful to benthic invertebrates in the surf zone. However, the high quality of sediment selected for beach fill and the small amount of beach affected at any point in time would suggest that this activity would not pose a significant regional or population-level threat (USACE 2014).

2.2.4 Offshore Borrow Areas

Borrow area Y and the ODMDS are located 1-5 miles off the shore; the former being in state waters and the latter state and federal. Changes in geophysical conditions associated with dredging activities may affect the resources that inhabit these areas due to changes in sediment characteristics, bathymetry, habitat complexity, prey availability, etc. (Diaz et al. 2004, Slacum et. al. 2010). Though bathymetric changes will immediately result from dredging, it is anticipated that the areas will infill and re-establish their structure (Dibajnia and Nairn et. al. 2011) and post-dredging surface sediments will be consistent with the adjacent and pre-dredging sediment; thus maximizing macroinvertebrate recruitment and recovery. As discussed above, post-dredging recovery of the benthic resources and the organisms that rely on them could take 1-4 years depending on the magnitude and duration of the perturbation and local rates of recruitment. Assuming that physical changes to the system are not significant following dredging, macroinvertebrates are expected to recruit rapidly. However, reestablishment of pre-dredging species composition may take longer (USACE 2014).

2.3 Other Resources of Concern

2.3.1 Shoreline Morphology and Sand Transport

Wind, waves, and currents drive littoral transport of sand both along shore and cross-shore. The proposed project along Bogue Banks will not modify these drivers, but other regional projects may affect sand budgets. The proposed project does not include placement of sand within the inlet complexes and it is not anticipated that the small relative quantities relocated from the Bogue Inlet maintenance activities would influence the large-scale physical drivers of the inlet system.

2.3.2 Human Resources

It is assumed that coastal areas of North Carolina will continue to be developed and expand both with and without beach nourishment projects. However, no increase in storm-damage due to induced development is anticipated due to the proposed action. Development of vacant lots is limited to lots buildable under the regulations set forth by CAMA, flood plain regulations, state and local ordinances, and applicable requirements of the Federal Flood Insurance Program.

2.4 Geographic Scope

This analysis will consider the impacts associated with dredging an offshore borrow area and beach placement of sediment along approximately (~) 18 miles of Bogue Banks Beaches, Carteret County, relative to the cumulative nature of these activities along the entire North Carolina coastline. It will focus on cumulative impacts within the project area since all of affected beaches under the current proposal have received beach placement of sediment in the past, the proposed action represents zero additional miles of North Carolina beaches affected by sand placement. Additionally, this analysis will study the cumulative impacts within the project area associated with increased offshore borrow area use and inlet management of Bogue Inlet.

2.5 Temporal Scope

This CEA considers known past, present and reasonable foreseeable future projects (RFFP) that may occur within the defined geographic scope above. This analysis will consist of relevant actions (dredge and fill) occurring within the past 50 years, current projects, and projects that may be implemented over the next 50 years. The long-term time period was chosen as it covers the initial nourishment of Wrightsville Beach in 1965. Since that time, numerous dredge and fill projects have occurred within the geographic scope of this proposed project. A time-frame extending into the future 50 years will incorporate existing non-federal and federal projects where planning and implementation includes a 50-year period. Under the preferred alternative, the County, through an interlocal agreement with all of the island municipalities, would manage all of the ~18 miles of beaches along Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle through the implementation of a comprehensive 50-year beach nourishment and non-structural inlet management project.

Additional non-federal projects will likely be pursued beyond 2017, but for the purposes of this assessment, it is assumed that these actions will be re-occurring within areas that had already been previously permitted and constructed (non-federal) or authorized (federal). This cumulative analysis also considers the potential that future federal and non-federal Coastal Storm Damage Reduction (CSDR)/beach nourishment projects under study could be constructed.

2.6 Other Actions Affecting Resources of Concern

Cumulative effects analysis not only considers the impacts of past, present and RFF actions on the identified resources, but also the impacts from unrelated actions occurring in the vicinity of the project area. Anthropogenic actions affecting resources of concern are inlet management and maintenance, maintenance of navigation channels, beach (re)nourishment projects, beach scraping, dune enhancement, placement of hard structures along shoreline, placement of soft structures along shoreline, population increase, continued residential, commercial, and light industry development on barrier islands, and commercial and recreational fishing activity.

Natural actions affecting resources of concern are seasonal and sea level rise, and natural barrier island and inlet processes influenced by wind, currents and tidal energy. The potential for the increase in the rate of damaging storms and hurricanes in light of global climate change has been the source of debate within the scientific community. The International Panel on Climate Change (IPCC 2007) concluded that global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century. Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC 2007). This rate is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft) to 1.4 m (4.6 ft) above the 1990 level. According to National Oceanic and Atmospheric Administration (www.tidesandcurrents.noaa.com), the regional trends in North Carolina show an increase of 0 to 3 mm/yr (0 to 0.00984 ft/yr), or a 0 to 1 ft/century. With measured rates of shoreline change ranging between 2 and 5 ft per year, sea level has very little impact on shoreline change. In 2012, the State of North Carolina passed legislation (House Bill 819) declaring that only "historic rates of sea-level rise may be extrapolated to estimate future rates of rise but shall not include scenarios of accelerated rates of sea-level rise unless such rates are from statistically significant, peer-reviewed data and are consistent with historic trends." As such, the State of North Carolina has not adopted a planning benchmark for sea level rise, and no such benchmark is currently under consideration.

The minimal impact of increased sea level rise has been noted through the performance of the Wrightsville Beach and Carolina Beach federal storm damage reduction projects. Both of these projects have been in existence since 1965 and have been subjected to the same rate of sea level rise applicable to Bogue Banks. A review of the nourishment rates for these two projects shows no significant changes in the volume or frequency of periodic nourishment needed to maintain the projects.

The following is a summary of activities that have or potentially could impose cumulative impacts on Bogue Inlet, Beaufort Inlet and the oceanfront shoreline of Bogue Banks and adjacent islands including Bear Island and Shackelford Banks.

2.6.1 Local Maintenance Activities

Under existing condition, the project area is subjected to repeated and frequent disturbance due to maintenance activities by individual homeowners and local communities following major storm events, such as the Post-Irene FEMA Renourishment Project constructed in 2013. These efforts are primarily made to protect adjacent shoreline property. Such repairs consist of dune rebuilding using sand from beach scraping and/or sand fencing. Limited fill and sandbags are generally used to the extent allowable by CAMA permit. Such frequent maintenance efforts could keep the natural resources of the barrier island ecosystems from re-establishing a natural equilibrium with the dynamic coastal forces of the area.

2.6.2 Non-Federal Beach Nourishment

Several large local beach nourishment efforts have been conducted or are in the permitting process throughout NC. The number of locally funded beach nourishment activities has increased significantly in the last ten years. Though non-federal beach nourishment efforts continue to increase, many of these projects are being pursued as one-time interim efforts until a federal beach nourishment project can be implemented. Therefore, this increase in permitted non-federal projects does not necessarily reflect a subsequent increase in resource acreage impacts; many of the non-federal projects occur within the limits of federal projects which are already authorized but un-funded (e.g., Dare County Beaches) or projects that are under study (i.e. Bogue Banks). These projects (i.e., non-federal) total approximately 93 miles of beach or 29 percent (%) of North Carolina beaches (USACE 2014). These frequent maintenance efforts could inhibit the natural resources of the barrier island ecosystems from reestablishing a natural equilibrium with the dynamic coastal forces of the area.

2.6.3 Federal Beach Nourishment

Federal beach nourishment activities typically include the construction and long-term (i.e., 50-year) maintenance of a berm and dune. The degree of cumulative impact would increase proportionally with the total length of beach nourishment project constructed and the frequency of maintenance operations. The first federal North Carolina beach nourishment projects were constructed at Carolina and Wrightsville Beaches in 1965 (comprising approximately 6.4 miles). An additional 3.8 miles of federal beach nourishment project was constructed in 1975 at Kure Beach. In 2004, a CSDR project along 14 miles of Dare County Beaches was authorized, but has not yet been constructed. Most of the remaining developed North Carolina beaches are currently under study by the Wilmington District for potential future beach nourishment projects or are awaiting authorization and/or appropriation. Individually, these existing or proposed federal projects total approximately 122 miles of beach or 38% of North Carolina beaches (USACE 2014). Considering all existing and proposed federal and non-federal nourishment projects, and recognizing that some of the projects are overlapping or represent the same project area, approximately 112 miles or 35% of the North Carolina coast could have private or federal beach nourishment projects by the close of 2015.

2.6.4 Beach Disposal Resulting from Federal Navigation Dredging

Material from maintenance dredging the AIWW, inlets, and connecting channels in the vicinity of study area has historically been disposed within authorized disposal limits along the beach. The design of beach placement sites generally extends the elevation of the natural berm seaward. Throughout North Carolina, a total of approximately 41 miles of beach (~13% of North Carolina beaches) are authorized for disposal of beach-quality dredged material from maintenance dredging of navigation channels (USACE 2014). However, not all of these projects are routinely dredged, and a majority of the authorized disposal limits are not actually filled to capacity. Additionally, many of the authorized disposal limits overlap with existing federal or non-federal beach projects. Therefore, if overlapping beach projects are not counted twice, navigation-dredged material is placed along approximately 19 miles, or 6% of North Carolina beaches (USACE 2014). The Wilmington District currently uses about 50 percent of the length of beach in North Carolina that is approved for this purpose and does not anticipate significant increases in beach disposal in the foreseeable future.

Beach-quality sand is a valuable resource that is highly sought by beach communities to provide wide beaches for recreation and tourism, as well as to provide hurricane and wave protection for public and private property in these communities. When beach-quality sand is dredged from navigation projects, it has become common practice for the USACE to facilitate use of this resource to beach communities when applicable laws, regulations, funding, and other considerations allow. Placement of this sand on beaches represents return of sediment to the littoral system.

2.6.5 Other Activities

Many factors unrelated to placement of sand on the beach may cumulatively affect beach resources such as benthic invertebrate resources, shorebird populations, and fisheries. The factors can be a result of favorable or negative conditions including droughts, floods, La Niña, El Niño, and major storms or hurricanes. A primary anthropogenic factor affecting shorebird populations is beach development resulting in: (1) a loss or disturbance of nesting habitat and (2) invasion of domesticated predators (USACE 2014). Primary anthropogenic factors affecting fish stocks are over-fishing and degradation of water quality due to pollution.

Ssimilar dredge and beach nourishment/disposal projects occurring within the geographic scope of this analysis are further described below. These projects are applicable for this evaluation given the type of activity and the potential for disturbance to identified resources. The cumulative direct and/or indirect effects of these projects have been evaluated in the context of each resource type. The compilation of projects represents those recent, current, and RFF projects that are either federally-funded or are sponsored via local initiatives.

3.0 RESOURCE RESPONSE TO CHANGE AND CAPACITY TO WITHSTAND STRESSES

Beaches and Dunes

Shoreline stabilization projects may affect shorebirds by altering the dynamic coastal processes that create and maintain their required habitats. Sand placement projects typically include the construction of berms and continuous artificial dunes that impede natural ocean-to-sound overwash. Ocean-to-sound overwash is responsible for the creation of new sparsely-vegetated interdune habitats that are used for nesting and roosting and back-barrier intertidal flats that are used for foraging. The loss of overwash-driven sediment deposition along the back-barrier shoreline may also affect piping plovers by impeding natural barrier island migration. Barrier islands respond to sea level rise by migrating landward. The principal mechanisms of landward migration involve sediment deposition along the back-barrier estuarine shoreline via overwash events and inlet processes. In the absence of sufficient back-barrier sediment deposition, the long-term consequence of rising sea level is simultaneous ocean and back-barrier shoreline erosion, resulting in island narrowing (Riggs et al. 2009). Shoreline erosion and island narrowing may reduce the availability of suitable habitats for piping plovers. Sand placement projects may also affect piping plovers through direct impacts on existing habitats and prey resources within the immediate placement area. Placement and grading may eliminate important microhabitats such as wrack lines, tidal pools, and isolated clumps of vegetation. Sand placement projects temporarily eliminate most of the intertidal benthic infaunal invertebrates within the placement footprint, thus temporarily reducing the availability of potential prey resources for piping plovers (USFWS 2009).

Infaunal species inhabit a highly dynamic environment. Infaunal species respond to shoreline erosion and accretion by migrating with shoreline spatial fluctuations. The initial effects of sand placement would include the loss of most intertidal benthic invertebrates within the placement areas. Reductions in the availability of invertebrate prey may negatively affect the energy budgets of breeding and non-breeding shorebirds including plovers and red knots; potentially resulting in reduced survivability and productivity. Sand placement projects would employ conservation measures to minimize the duration of direct effects on benthic invertebrate communities; including the use of beach compatible sand and the completion of construction activities prior to the onset of peak benthic invertebrate recruitment periods. Most benthic recovery studies have reported relatively rapid recovery (≤1 year) when highly compatible beach fill sediments were used and peak larval recruitment periods were avoided (Burlas et al. 2001; Jutte et al. 1999; Van Dolah et al. 1994, 1992; Gorzelany and Nelson 1987; Salomon and Naughton 1984; Parr et al. 1978; Hayden and Dolan 1974).

Sand placement projects may affect sea turtles through direct effects on dry beach nesting habitat; including modification of beach morphology and/or changes in substrate properties. Observed declines in nesting on nourished beaches have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile (Crain et al.

1995; Steinitz et al. 1998; Ernest and Martin 1999; Herren 1999; Rumbold et al. 2001; Byrd 2004; and Brock et al. 2009). By design, sand placement projects typically construct a flat dry beach (aka berm) that gradually steepens to the natural equilibrium profile as the placed material is redistributed by wave and wind driven transport processes. This equilibration process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation. Sediment compaction and changes in sediment composition may also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988; Crain et al. 1995). Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment; potentially affecting embryonic development and hatching success (Nelson and Dickerson 1988; Nelson 1991; Ackerman et al. 1991; Crain et al. 1995; Ehrhart 1995; and Ackerman 1996).

Marine Waters

The water column resource is a dynamic and complex system; the quality of which is influenced by anthropogenic and natural inputs. In the nearshore environment and within inlets, this resource's quality is affected by nutrient loading, suspended sediment, and pollutant inputs. The capacity of the water column to accommodate inputs is related to the rates of flushing, exchange, and mixing. Within the inlets, a tidal prism functions to transport suspended sediment and turbidity originating from dredging events and other stresses. The relatively large sediment size of the material suspended by dredging operations within the inlet reduces the duration of the material in the water column and therefore reduces the duration of suspended material and turbidity.

Water column within inlet systems and along the ocean shoreline swash zone do experience frequent seasonal storms, along with routine strong winds, that constantly elevate TSS levels and increase turbidity. These environments are accustomed to higher ranges and are adaptable to natural increases, but these events have shorter duration periods than dredge and fill activities associated with channel maintenance and beach nourishment activities. Even with these activities, which operate as long as a 4-month period, sediment has shown to settle quickly due to the coarser material generally found in these environments and turbidity tends to be of short duration.

Intertidal and Nearshore Zones

Intertidal flats, shoals and nearshore zones are dynamic features within the inlet complex. This resource responds to changes imposed by anthropogenic and natural forces by altering composition (volume, grain size, infauna, vegetative cover) and spatial location. Of the 21 inlets in North Carolina, 11 are periodically maintained for navigational purposes. Federal authorization requires that maintenance occur within the deepest water of the channel, so realignment of the ebb tidal channel is not authorized. This requirement reduces direct impacts to intertidal and nearshore areas.

Each channel has its own authorized dimensions and range from 6-feet to 40-feet in depth and delegated widths ranging from 90-feet to 600-feet. The maintenance of these channels is generally annual, pending available funds. Species which utilize this habitat have generally adapted to the natural range of environmental conditions experienced in this habitat. This resource continually seeks to achieve dynamic equilibrium with the natural or man-induced forces affecting it.

Shorebirds that utilize the intertidal flats and shoals within the inlet complex have demonstrated the ability to respond to disturbances. In 2002, Mason Inlet was relocated approximately 3,000 ft. to the north. Piping plover spring migrants (but not winter residents) in the Mason Inlet area were disrupted by the construction phase of the relocation project, but these birds apparently continued on to Rich Inlet before stopping to rest and forage. Migrants appeared to have an aversion to the Mason Inlet area the following autumn (four months later), but numbers then returned to preconstruction levels by the beginning of winter (eight months later). By 2003, Mason Inlet had become an important foraging and resting site for migrating and over-wintering piping plovers (Webster, 2005).

Subsequent to the initial placement of sand, the beach profile equilibration process would result in some of the material being transported seaward and deposited on nearshore soft bottom habitats located seaward of the beach fill footprints. However, based on the opportunistic nature of the dominant benthic taxa and the gradual pace of the equilibration process (approximately six months), it is expected that benthic community adjustments would occur with only minor, short-term reductions in community levels of abundance, diversity, and biomass. Losses of benthic invertebrates may negatively affect the foraging activities of demersal surf zone fishes (e.g., flounders, rays, spots, and croakers), potentially inducing demersal fishes to seek out alternative soft bottom foraging habitats. However, it is anticipated that the effects of prey loss on demersal fishes would be localized and short-term based on: 1) the ability of some infaunal species to tolerate shallow sediment deposition, 2) the anticipated rapid rates of benthic community recovery in the surf zone, 3) the mobility of surf zone fishes, and 4) the expansive distribution of alternative subtidal soft bottom habitat.

Tidal inlets are a critical conduit for the larvae of ocean-spawning/estuarine-dependent fishes and invertebrates that spawn offshore on the continental shelf and use estuarine habitats for juvenile development. Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by along-shore currents and transported to the inlet (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that larval densities within the inlet are highest from late May to early June and lowest in November (Hettler and Chester 1990). Based on the concentration of larvae in the inlets during ingress periods, the potential impacts of larval entrainment during inlet dredging projects are a particular concern. However, model-projected larval entrainment studies at Beaufort Inlet indicate that entrainment rates are very low regardless of larval concentrations and the distribution of larvae within the water column (Settle 2003). Even under worst case conditions when the dredge is operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the model-projected entrainment rate barely exceeds 0.1% of the daily (24-hour) larval flux through the inlet. Given the relatively diffuse distribution of larvae in offshore waters, entrainment rates at offshore borrow sites are likely to be much lower.

<u>Offshore Borrow Areas</u>

The potential for temporally crowded cumulative effects on marine soft bottom communities would depend on the frequency of repeated dredging and sand placement impacts on soft bottom communities within the offshore borrow site dredging areas and the beach fill footprints. Specifically, cumulative effects would be considered likely if the intervals between repeated dredging or sand placement events were insufficient to allow for full recovery of benthic communities. Offshore borrow site dredging events are projected to occur every three years; however, based on the large volume and wide distribution of compatible material at the ODMDS, it is expected that the intervals between repeated dredging in the same excavation footprint would be longer than three years. Therefore, benthic communities would be expected to fully recover during the interim periods between repeated dredging impact events. Additional activities at the current ODMDS would include USACE disposals of fine grained dredged material; however, the designated disposal area for fine-grained material is removed from the proposed beach fill deposits (USACE 2016a).

The potential for spatially crowded cumulative impacts would depend on the proximity of separate dredge and fill actions and the potential for overlapping effects on soft bottom communities. Separate federal dredging and disposal activities that may impact marine soft bottom communities would include maintenance dredging of the MCH entrance channel and associated disposal operations at the ODMDS. These additional activities may coincide with dredging operations at the offshore borrow sites, in which case the combined losses of benthic invertebrates could potentially have cumulative effects on predatory demersal fishes. However, the combined area of temporary habitat and prey loss would constitute a small fraction of the available marine soft bottom habitat, and any cumulative effects would be limited to periods of benthic community recovery. Therefore, it is anticipated that any spatially crowded cumulative effects on soft bottom communities and demersal fishes would be minor and localized.

<u>Human Resources</u>

For some coastal stakeholders (residences, businesses), a response to the loss of coastal frontage (beach system) is demonstrated by instituting protection measures ranging from placement of engineered walls made of riprap, groins, revetments, beach nourishment projects, beach scraping, and inlet channel management. Very few have demonstrated a willingness to abandon or relocate dwellings or businesses. In some cases, parts of North Topsail Beach, Holden Beach, the Outer Banks, and Ocean Isle Beach, structures have been condemned and demolished and have been prohibited from rebuilding. Currently, approximately 160 miles, or 50% of the North Carolina oceanfront coastline remains undeveloped while the other 50% is developed with residential homes and other associated infrastructure. Coastal visitors/customers will seek out alternative coastal communities having beaches suitable for recreational activity when coastal amenities are preserved.

4.0 STRESSES IN RELATION TO REGULATORY THRESHOLDS

In 1972, Congress passed the Coastal Zone Management Act, which encouraged states to keep the coasts healthy by establishing programs to manage, protect, and promote the country's fragile coastal resources. Two years later, the North Carolina General Assembly passed the landmark Coastal Area Management Act (CAMA). CAMA established the Coastal Resources Commission, required local land use planning in 20 coastal counties, and provided for a program for regulating development. The North Carolina Coastal Management Program was federally approved in 1978 by NOAA. Demands placed on lands and waters of the coastal zone from economic development and population growth require that new projects or actions be carefully planned in order to avoid stress on the coastal zone. This planning involves a review of state enforceable policies, which are designed to provide effective protection and use of land and water resources of the coastal zone. Under CAMA, the proposed work cannot cause significant damage to one or more of the historic, cultural, scientific, environmental or scenic values or natural systems identified in Areas of Environmental Concern (AECs). In addition, significant cumulative effects cannot result from a development project.

There are no known thresholds relating to the extent of ocean bottom that can be disturbed without significant population level impacts to fisheries and benthic species. Therefore, a comparison of cumulative impacts to established thresholds is not made. However, the potential impact area of the proposed project at any given time or event is small relative to the area of available, similar, undisturbed habitat on a local, regional, and statewide basis. As noted above, many species that would be affected have high recovery rates, particularly for colonizing, opportunistic species. It is expected that there is a low probability that the direct and cumulative impacts of the proposed action and other known similar activities would reach a threshold with potential for population level impacts on important commercial fish stocks. With regard to physical habitat alterations, it is expected that alterations in depths and bottom sediment would occur and may be persistent for some borrow areas. However, site modifications would be within the range of tolerance by these species and, although human-altered, consistent with natural variations in depth and sediment within the geographic range of essential fish habitat (EFH) for local commercial fish species. Byrnes et al. (2003, as cited in

USACE 2014) provided the following assessment of potential impacts to benthic organisms from dredging:

> *Because the sedimentary regime of North Carolina sand source areas is vertically uniform, recolonization of surficial sediments by later successional stages likely will proceed even if dredged shoals are not completely reestablished. Furthermore, dredging of only a small portion of the area within each of the resource areas will ensure that a supply of non-transitional, motile taxa will be available for rapid migration into dredged sites. While community composition may differ for a period of time after the last dredging, the infaunal assemblage type that exists in mined areas will be similar to naturally occurring assemblages in the study area, particularly those assemblages inhabiting inter-ridge troughs. Based on previous observations of infaunal reestablishment in dredged sites, the infaunal community in dredged sites most likely will become reestablished within 2 years, and will exhibit levels of infaunal abundance, diversity, and composition comparable to nearby non-dredged sites.*

The DOI (1999, as cited in USACE 2014) provided the following assessment of potential impacts to beach fauna from beach disposal:

> *Because benthic organisms living in beach habitats are adapted to living in high energy environments, they are able to quickly recover to original levels following beach nourishment events; sometimes in as little as three months (Van Dolah et al. 1994; Levison and Van Dolah 1996). This is again attributed to the fact that intertidal organisms are living in high energy habitats where disturbances are common. Because of a lower diversity of species compared to other intertidal and shallow subtidal habitats (Hackney et al. 1996), the vast majority of beach habitats are recolonized by the same species that existed before nourishment (Van Dolah et al. 1992; Nelson 1985; Levison and Van Dolah 1996; Hackney et al. 1996).*

While the proposed beach disposal may adversely impact benthic macrofauna, these organisms are highly resilient and any effects will be localized, short-term, and reversible (USACE 2014).

5.0 RESOURCE BASELINE CONDITION

Beaches and Dunes

NC's coastal barrier system encompasses a series of linear shore-parallel barrier islands, intervening tidal inlets, and back-barrier estuaries. The coast is divided at Cape Lookout into distinct northern and southern coastal regions that have markedly dissimilar barrier island systems. The approximately (~) 172-mile northern Outer Banks region between Cape Lookout and the Virginia border is characterized by long, low barrier islands with few tidal inlets and wide open-water back-barrier estuaries. In contrast, the ~154-mile southern region between Cape Lookout and the South Carolina border is characterized by short barrier islands, numerous tidal inlets, and narrow, primarily marsh-filled estuaries. The dissimilar northern and southern regions reflect variability in the underlying geological framework along the NC coast. As described by Riggs et al. (1995), NC's modern barrier island system is maintained by a very limited supply of new sediment, resulting in characteristically thin subaerial barriers that are perched on top of older geologic units. The underlying geologic strata constitute the subtidal shoreface and dominate the associated shoreface processes that in large part control the dynamics and physical characteristics of the barriers, inlets, and back-barrier estuaries. The underlying geology of the northern region is dominated by deep, unconsolidated sediments that are easily eroded; resulting in relatively low topography and a gently sloping land surface. The interaction of the relatively gentle slope with the ocean surface has produced the long, low barriers and wide open-water estuaries of the northern region. The southern region is underlain by older, erosion-resistant rock units that form a high platform, resulting in relatively high topography and a relatively steep land surface slope. The interaction of the relatively steep slope with the ocean surface has produced the short barriers and narrow marsh-filled estuaries of the southern region.

The northern and southern regions are also dissimilar in regard to land use and shoreline management. Approximately 60 percent (%) (103 miles) of the northern region oceanfront shoreline is undeveloped and in permanent conservation under the jurisdiction of the National Park Service (NPS), USFWS, or State of NC (Table 2). In contrast, approximately 63% (97 miles) of the southern region shoreline is currently developed, with an additional ten percent (16 miles) of the shoreline considered to be developable. Approximately 27 miles of shoreline in the northern region are currently managed under a sand placement initiative, compared with 85 miles of shoreline in the southern region.

Table 2. Shoreline development status1.

Shoreline Status	Northern Region (Miles)	Southern Region (Miles)	Total (Miles)
Developed	66	97	163
Undeveloped	3	16	19
Conservation	103	41	144
Total	**172**	**154**	**326**

[1]Data originally cited in the NC BIMP Source: DENR 2011

Barrier island dynamics and associated shoreline changes are influenced by many factors; including the geological framework, sediment supply, wave energy, tidal inlet dynamics, storm activity, and sea level rise. Variable wave energy regimes along the NC coast reflect differences in the configuration of the coastline (Heron et al. 1984; Moslow and Heron 1994). The coastline north of Cape Hatteras has a north-south orientation, resulting in east-facing barriers that are fully exposed to the dominant high energy northeast wind and wave regime. The coastline south of Cape Hatteras is characterized by a series of seaward-protruding capes (Cape Hatteras, Cape Lookout, and Cape Fear) and cuspate embayments (Raleigh Bay, Onslow Bay, and Long Bay). Barrier islands along the three arc-shaped coastline segments trend from north-south to east-west, resulting in a range of east to south-facing barriers. The individual barriers are exposed to varying levels of wave energy depending on their orientation and proximity to the seaward-protruding cape-shoal features. The capes and their shoal complexes have a sheltering effect on the associated barrier islands, providing some protection from the high energy northeast wind and wave regime. The south to southeast-facing barriers, which are positioned along the low energy western flanks of the capes, are the most protected; however, they are highly exposed to tropical storms and hurricanes approaching from the south.

In response to sea level rise and a limited sand supply, NC's barrier islands have generally entered a recessional phase and are experiencing active erosion along both the ocean and estuarine shorelines. NCDCM's long-term (50-year) shoreline erosion rates along the majority (58%) of the NC coast are ≤2 feet per year (ft/yr); however, a significant proportion (26%) of the coast is subject to relatively severe long-term erosion rates of >4 ft/yr (NCDCM 2015). Many of the highly erosional shoreline reaches are associated with tidal inlets. In other cases, relatively high erosion rates are associated with a significant shift in shoreline orientation, such as that occurring along Hatteras Island at Rodanthe (DENR 2011).

<u>Nearshore Zone</u>

Nearshore subtidal softbottom (subtidal shoreface out to depth of closure, subject to sand placement effects)

<u>Marine Water Column</u>

The ocean water column provides important habitat for pelagic fish species such as alewife (*Alosa pseudoharengus*), shad (*A. sapidissima*), blueback herring (*A. aestivalis*), bay anchovy (*Anchoa mitchilli*), silversides, Atlantic menhaden, striped mullet, bluefish (*Pomatomus saltatrix*), cobia (*Rachycentron canadum)*, Spanish mackerel (*Scomberomorus maculates*), and king mackerel (*S. cavalla*). Coastal pelagics, highly migratory species, and anadromous fish species are dependent on the water column for adequate foraging (Manooch and Hogarth 1983). The boundaries of water masses (coastal fronts) in the nearshore ocean are important foraging areas for mackerel and mahi mahi (*Coryphaena hippurus*) (SAFMC 1998). King and Spanish mackerel feed on baitfish that congregate seasonally over shoals, hardbottoms, and artificial reefs. Anadromous species such as shad, river herring, and striped bass (*Morone saxatilis*) utilize cape shoals as a staging area for migration along the coast. Some pelagic species, such as anchovies and king mackerel, rely on the nearshore boundaries of ocean water masses as nursery habitats (SAFMC 1998). Juveniles of other pelagic species, such as Spanish mackerel and bluefish, use the surf zone and nearshore waters seasonally while migrating between estuarine and ocean waters (Godcharles and Murphy 1986, Hackney et al. 1996, and NCDMF 2000).

Ichthyoplankton (larval fish) are an important component of the zooplankton community in the ocean water column. Ichthyoplankton studies indicate that abundance and diversity are lowest on the inner shelf and highest on the mid-to-outer shelf (Powell and Robbins 1994, 1998). During late fall and winter, the larvae of estuarine-dependent ocean-spawning species such as Atlantic menhaden, spot, and Atlantic croaker are an important component of the zooplankton community. Ichthyoplankton from estuarine-dependent species that spawn in the sounds and inlets [e.g., pigfish, silver perch, and weakfish) are found in the ocean water column shortly after the spring/early summer spawning period; and reef fish larvae are most abundant during spring, summer, and early fall.

Offshore Borrow Sites

Marine soft bottom habitats support a diverse assemblage of benthic invertebrate infauna and epifauna. Soft bottom benthic invertebrate assemblages at nearshore (1 to 5 miles) ocean sites in Onslow Bay were strongly dominated by polychaetes, which accounted for 65 to 75 percent of the total abundance (Peterson and Wells 2000). Other dominant taxa in order of decreasing abundance included bivalve mollusks, nematodes, amphipod crustaceans, echinoderms (sand dollars), and gastropods. Soft bottom sites also provide important habitat for large mobile decapod crustaceans (i.e., crabs and shrimp). Annual trawl surveys in Onslow Bay indicate that the large decapod assemblage is dominated by white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), and the iridescent swimming crab (*Portunus gibbesii*). Offshore soft bottom habitats and their associated benthic invertebrate communities provide important habitat and food resources for many species of demersal (bottom-dwelling) fishes. Trawl survey catches in Onslow Bay have been consistently dominated by sciaenid fish, many of which utilize estuaries during part of their life cycle (SEAMAP-SA 2000). Overall patterns of abundance are strongly influenced by the abundance of spot and Atlantic croaker (*Micropogonias undulatus*). These two species have been consistently dominant, accounting for more than 36 percent of the total catch between 1990 and 1999. Other numerically important demersal fishes include Atlantic bumper (*Chloroscombrus chrysurus*), scup (*Stenotomus* sp.), pinfish (*Lagodon rhomboides*), star drum (*Stellifer lanceolatus*), banded drum (*Larimus fasciatus*), gray trout (*Cynoscion regalis*), silver seatrout (*C. nothus*), southern kingfish (*Menticirrhus americanus*), and inshore lizardfish (*Synodus foetens*).

Intertidal Flats and Shoals

Tidal inlets and their associated ebb and flood tidal delta shoals are critical elements of the coastal sediment budget that influence barrier island dynamics (Riggs et al. 2009). Changes in the ebb and flood tidal channels and deltas control patterns of erosion and accretion along portions of the adjoining barrier island shorelines. The inlets and the adjoining shoreline reaches that they influence are highly dynamic and subject to rapid changes in patterns of accretion and erosion. In NC, the relatively short barriers of the southern region are separated by a total of 15 inlets, while the relatively long barrier islands of the northern region are separated by just four tidal inlets. According to Rice (2012b), dredging has occurred in 16 of NC's ~19 inlets. In the southern region, eight inlets are currently maintained under federal navigation projects; including two deep draft navigation projects at Beaufort Inlet and Cape Fear Inlet and six shallow draft projects at Lockwoods Folly Inlet, Carolina Beach Inlet, Masonboro Inlet, New River Inlet, New Topsail Inlet, and Bogue Inlet. Numerous beach disposal of navigation dredged material projects have been implemented in conjunction with all of the inlet navigation projects. In the northern region, only Oregon Inlet is currently maintained under a federal navigation project. Oregon Inlet has a long history of southward migration that has resulted in extensive efforts to stabilize the ebb channel and adjoining shorelines for purposes of protecting NC 12 and the Bonner Bridge (Jarrett 2011). The inlet has been maintained by dredging under a federal navigation project since 1962, with beach and/or nearshore disposal along the adjoining ocean shoreline of PINWR. In NC, four inlets are currently stabilized by jetties or groins; including Oregon Inlet, Beaufort Inlet, Masonboro Inlet, and Cape Fear Inlet.

Intertidal flats support a highly productive benthic microalgal community. Benthic microalgae, along with imported primary production in the form of phytoplankton and detritus, support a diverse community of infaunal and epibenthic invertebrates. Important benthic invertebrates include nematodes, copepods, polychaetes, amphipods, decapods, bivalves, and gastropods (SAMFC 1998). Large mobile invertebrates that move onto intertidal flats with the rising tide include blue crabs, horseshoe crabs, and penaeid shrimp. Mobile predatory gastropods (e.g., whelks and moon snails) occur along the lower margins of submerged tidal flats, and fiddler crabs (*Uca* spp.) are common on exposed flats during low tide (Peterson and Peterson 1979). Benthic invertebrates are an important food source for numerous predatory fishes that move onto intertidal flats with the rising tide. Common predatory fishes on intertidal flats include Atlantic croaker, flounders, inshore lizardfish, pinfish, red drum (*Sciaenops ocellatus*), southern kingfish, and spot. Planktivores [e.g., anchovies, killifish (*Fundulus* sp.), and menhaden] and detritivores [e.g., striped and white mullet (*M. curema*) and pinfish] also forage on tidal flats during high tide. Intertidal flats function as an important nursery area for numerous benthic oriented estuarine-dependent species, especially Atlantic croaker, penaeid shrimp, flounders, and spot (SAFMC 1998).

Habitats associated with coastal inlets (e.g., intertidal flats, sand spits, shoals, and small islands) are especially important to migrating shorebirds (Harrington 2008). Most shorebirds are long distance migrants, who migrate through and winter in NC en route to find suitable breeding sites in the Arctic. To complete these flights, shorebirds must obtain a large food reserve. Intertidal flats and shoals are used by shorebirds as migration stop-over areas to replenish food reserves and accumulate fat needed for the long flights. There are few places that have the necessary combination of resources. In some areas, between 50% and 80% of the entire population of a species may visit a single site (MCCS 2003). Migratory arctic-bound shorebird species that may be found during the non-breeding season at NC inlets include the piping plover, red knot (*Calidris canutus rufa*), dunlin (*Calidris alpine*), western sandpiper (*Calidris mauri*), and sanderlings (*Calidris alba*).

6.0 CAUSE AND EFFECT RELATIONSHIPS

Beaches and Dunes

Sand placement on top of the existing intertidal beach substrate generally eliminates the majority of the intertidal benthic invertebrate infauna through direct burial. The subsequent process of benthic community recovery is generally rapid. However, recovery rates vary according to a number of operational and environmental variables. The principal project-related factors that influence benthic community recovery rates are the compatibility of the beach fill sediments with those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009, Peterson et al. 2006, and Hackney et al. 1996). Most benthic recovery studies have reported rapid recovery within one year of the initial impact when highly compatible beach fill sediments were used and larval recruitment periods were avoided (Jutte et al. 1999a, Burlas et al. 2001, Van Dolah et al. 1994, Van Dolah et al. 1992, Gorzelany and Nelson 1987, Salomon and Naughton 1984, Parr et al. 1978, and Hayden and Dolan 1974). Conversely, longer recovery periods ranging from 15 months (Rakocinski et al. 1996) to four years (Peterson et al. 2014) have been associated with the use of highly incompatible beach fill sediments containing excessively large quantities of fine silt and clay or shell hash material. In an effort to minimize the biological impacts of beach nourishment projects, NC has enacted regulatory technical standards for the compatibility of beach fill sediments with those of the native beach (15A NCAC 07H .0312). The Technical Standards (aka State Sediment Criteria) require the characterization of sediments from the recipient beach and the proposed borrow sites; including analyses of percent weight of fine-grained sediment, percent weight of granular sediment, percent weight of gravel, and percent weight of calcium carbonate.

Sand placement can impact shorebirds through disturbance, habitat modification, and reductions in the intertidal benthic invertebrate prey base. During the active beach construction process; heavy equipment operations, generator use, pipeline placement, night-time lighting, and related construction activities can affect shorebirds through disturbance and behavioral modification. Disturbance may cause shorebirds to spend less time forging and conserving energy; thereby potentially affecting survivability and productivity. Disturbance may prevent shorebirds from using otherwise suitable breeding, foraging, and roosting sites; requiring birds to expend additional energy seeking out alternative habitats. Sand placement may eliminate important microhabitat elements such as wrack lines, tidal pools, and isolated clumps of vegetation; thereby reducing the quality or availability of breeding, foraging, and/or roosting habitats. In the case of severely eroded beaches, the restoration of a wider and higher dry beach can improve the quality of potential loafing, roosting, and nesting habitats for shorebirds and waterbirds (Melvin et al. 1991).

Direct impacts on the benthic infaunal prey base may indirectly affect fish and birds by reducing foraging opportunities for shorebirds and surf zone fishes, potentially inducing both to expend additional energy seeking out alternative habitats. The specific effects of temporary prey loss on shorebirds and surf zone fishes are difficult to predict, but potentially include a reduction in energy reserves resulting in reduced survivability or productivity, particularly in the case of migratory shorebirds that use beaches as stopover refueling sites. Peterson et al. (2006) reported a 70 to 90% decline in shorebird feeding activity on a nourished beach at Bogue Banks. The decline in shorebird activity was attributed primarily to depressed infaunal communities. However, it was noted that the use of fill containing large quantities of shell hash during nourishment events in 2001-2003 may have contributed to the decline by impeding shorebird foraging. Following the winter nourishment event, feeding activity remained depressed through July, but increased substantially between July and September and returned to normal between September and November. A two-year investigation of the effects of beach nourishment on shorebird and waterbird communities at Holden Beach and Oak Island detected no significant effects on shorebird or waterbird abundances (Grippo et al. 2007). However, the authors noted the possibility that abundances on nourished beaches could have been maintained by a continuous flux of arriving and departing migratory birds as opposed to extended residency by the same individuals. In terms of behavioral effects, Grippo et al. (2007) detected a significant reduction in waterbird feeding activity on nourished beaches; however, the feeding activities of shorebirds that are heavily dependent on intertidal beach foraging habitats (e.g., willet and sanderling) were not affected.

According to Wilber et al. (2003), the effects of a beach nourishment project in New Jersey on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. According to Stull et al. (2016), beach nourishment projects along Wrightsville Beach, Carolina Beach, and Kure Beach had no significant effects on zooplankton abundance in the surf zone. Total zooplankton abundances remained high throughout pre- and post-project sampling periods and were essentially constant across all nourishment sites, suggesting an abundant and consistent surf zone food source for planktivorous fishes (Stull et al. 2016).

Sand placement on the upper dry beach may impact ghost crabs and other burrowing invertebrate macrofauna through direct burial. The reported effects of beach nourishment and beach scraping on ghost crabs range from no significant response (Bergquist et al. 2008) to significant long-term effects lasting approximately one year (Dixon 2007). The results of ghost crab recovery studies indicate that influential project-related factors are similar to those associated with intertidal benthic infaunal recovery rates; including sediment compatibility, the timing of operations relative to recruitment periods, and the frequency of repeated impacts. Bergquist et al. (2008) attributed the absence of any clear response to a nourishment project at Folly Beach, South Carolina, to the use of highly compatible beach fill. However, Lindquist and

Manning (2001) and Peterson et al. (2000) attributed significant reductions in ghost crab abundances lasting six to eight months to changes in sediment composition on newly constructed dune faces at Bogue Banks. Peterson et al. (2006) reported that ghost crab recruitment on filled beaches appeared to be inhibited following a winter 2001/2002 nourishment project on Bogue Banks, although sampling detected no statistically significant effects. The apparent effects on ghost crabs were attributed to the placement of incompatible beach fill containing a high percentage of coarse shell material. During the following summer, shell hash cover on filled beaches averaged 25 to 50% compared with six to eight percent cover on control beaches. In contrast to the minimal effects of a winter nourishment project on Folly Beach reported by Bergquist et al. (2008); a separate summer nourishment project at Folly Beach resulted in significant long-term (approximately one year) effects on local ghost crab population structure, including the loss of entire cohorts (Dixon 2007). Lindquist and Manning (2001) detected no response to an initial beach nourishment project at Topsail Beach; however, repeated annual nourishment projects resulted in significant reductions in ghost crab abundances.

Sand placement can indirectly impact sea turtle nesting by altering dry beach nesting habitat in ways that deter nesting or reduce nesting and/or hatching success. Observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, substrate compaction, and escarpment formation (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). Loggerheads prefer steeply sloped beaches (Provancha and Ehrhart 1987) and typically select nest sites that correspond to the steepest slopes along a given beach (Wood and Bjorndal 2000). By design, sand placement projects construct a flat berm that gradually steepens to the natural equilibrium profile over time as the placed sediments are redistributed by natural transport processes. The initial post-construction reduction in slope may deter nesting females from emerging onto the beach or increase the likelihood of false crawls. The post-construction beach profile equilibration process may induce the formation of escarpments that prevent adult females from accessing upper dry beach nesting habitats. Furthermore, the compaction of sediments by construction activities may impede the ability of adult females to excavate nests. Studies that have documented declines in nesting success on nourished beaches have generally reported a return to normal nesting activity by the second or third post-project nesting season (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). In the case of severely eroded beaches, the restoration of a wider and higher dry beach may enhance the quality of sea turtle nesting habitats. Studies have reported immediate increases in nesting success following sand placement projects on chronically eroded beaches (Davis et al. 1999 and Byrd 2004).

Substrate modifications may have additional negative effects on the nest incubation environment and the ability of sea turtle hatchlings to emerge from the nest (Nelson and Dickerson 1988, and Crain et al. 1995). Compaction and the modification of substrate characteristics such as grain size, density, organic content, and color can alter the nest incubation environment; leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995, Ehrhart 1995, and Ackerman 1996). Nourished beaches often retain more water than natural beaches, thereby impeding gas exchange within the nest environment (Mrosovsky 1995, and Ackerman 1996). Warmer nest temperatures attributable to the placement of relatively dark sediments (Hays et al. 2001) may impede embryonic development (Matsuzawa et al. 2002) or increase the incidence of late-stage embryonic mortality (Ernest 2001). Sex determination in hatchlings is controlled by nest temperature, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2003). Thus, warmer nest temperatures attributable to sand placement may alter hatchling sex ratios.

Nearshore Zone

Sand placement may impact nearshore soft bottom habitat within the subtidal portions of the beach fill footprints, resulting in the burial and loss of the associated soft bottom benthic invertebrate infauna. Subsequent to the initial placement of sand, the beach profile equilibration process results in some of the material being transported seaward and deposited on nearshore soft bottom habitats located seaward of the beach fill footprints. However, benthic soft bottom communities in shallow high-energy environments are adapted to frequent natural perturbations and generally recover rapidly from disturbance. Increases in suspended sediment concentrations and turbidity can occur within the surf zone in the vicinity of the active sand slurry discharge point. Sediment suspension and redeposition may have additional effects on nearshore soft bottom communities and surf zone fishes that are similar to those described above for borrow site dredging operations. Losses of benthic invertebrates may negatively affect the foraging activities of demersal surf zone fishes (e.g., flounders, rays, spots, and croakers), potentially inducing demersal fishes to seek out alternative soft bottom foraging habitats.

Marine Water Column

Dredging activities may indirectly impact marine organisms via temporary sediment suspension and associated increases in turbidity. Increased sedimentation and turbidity during the dredging process can potentially affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of marine organisms (Michel et al. 2013). The extent and duration of these impacts are influenced by sediment composition at the borrow site, the type of dredge employed, and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities, whereas the sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge (Schroeder 2009).

Hopper dredges are generally associated with higher rates of suspension and dispersal (relative to hydraulic cutterhead dredges), primarily due to the surface discharge associated with overflow dredging. However, if the dredged material is primarily composed of clean sand, settling in the hoppers is more efficient and the percentage of sediments in the hopper dredge overflow is generally small (Palermo and Randall 1990). Miller et al. (2002) described the turbidity plume associated with overflow hopper dredging in coarse-grained (97% sand) sediments as being confined to the dredged channel footprint, with suspended sediment concentrations returning to ambient levels within one hour of the passing of the dredge. Miller et al. (2002) also noted that observed turbidity levels remained within the range of pre-project ambient turbidities throughout the period of dredging in coarse-grained sediments. Sediment suspension by cutterhead dredges is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Based on sediment resuspension data collected during navigation dredging projects, Hayes et al. (2000) and Hayes and Wu (2001) reported average cutterhead dredge sediment resuspension rates ranging from 0.003 to 0.135% of the fine silt/clay fraction.

Offshore Borrow Sites

The potential impacts of dredging on marine soft bottom communities at ocean borrow sites are related to the direct removal of benthic organisms, sediment suspension and redeposition, and seafloor habitat modification. The removal of seafloor sediments by both hopper and cutterhead dredges also removes the majority of the associated benthic infaunal and epifaunal invertebrates; resulting in an initial sharp decline in community abundance, diversity, and biomass within the active dredging area. Soft bottom communities are generally dominated by opportunistic taxa that recover relatively rapidly from dredging-induced seafloor disturbance (Posey and Alphin 2002). However, recovery rates vary according to a number of operational and environmental variables; including the extent of dredging-induced habitat modification, the timing of dredging operations relative to benthic infaunal recruitment periods, existing substrate composition, and the natural disturbance regime of the borrow site (Wilber and Clarke 2007).

Reported rates of recovery at ocean borrow sites along the Atlantic Coast range from a few months to three years (Wilber and Clarke 2007). Generally, reports of relatively long recovery periods (>1 year) have been associated with relatively deep borrow pits that accumulate fine silt/clay sediments; whereas relatively short recovery periods (<1 year) have generally been associated with shallow borrow pits that were rapidly infilled by sandy sediments of similar composition to the extracted material (Burlas et al. 2001). Posey and Alphin (2002) attributed relatively rapid (<9 months) recovery at ocean borrow sites along Kure Beach to rapid infilling of relatively shallow dredge cuts and avoidance of spring benthic invertebrate larval recruitment periods. Jutte et al. (1999) attributed rapid benthic community recovery (six to nine months) in relatively shallow (~3 feet) hopper dredge furrows to the retention of benthic invertebrates on undisturbed intervening ridges, which provided an immediate source of potential recruits that likely contributed to rapid recolonization. Burlas et al. (2001) reported full recovery of the benthic community in terms of abundance, diversity, and composition within one year at ocean borrow sites in New Jersey. However, full recovery of biomass composition required longer periods ranging from 1.5 to 2.5 years. Dredging-related impacts on benthic invertebrates may temporarily reduce the availability of prey for predatory demersal fishes that live on or near the seafloor (e.g., flounders, rays, spots, and croakers). Losses of invertebrate prey may induce migrations of demersal fishes to alternative undisturbed soft bottom foraging habitats (Byrnes et al. 2003). Van Dolah (1994) observed significant declines in fish diversity and abundance following dredging at an ocean borrow site; however, recovery occurred within six months.

Intertidal Flats and Shoals

Inlet dredging projects can potentially affect shorebirds by altering the hydrodynamic and sediment transport processes that create and maintain emergent shoals, sand spits, and other important inlet complex habitats. Additionally, the extraction of sand from inlets for placement on adjacent shorelines may directly impact emergent shoal habitats and/or modify inlet sediment budgets in ways that limit the formation of new emergent shoal or sand spit habitats. The potential effects of inlet dredging on shorebirds may include the loss or modification of habitats that are used for nesting, foraging, and roosting; including piping plover critical wintering habitat PCEs. Groins and jetties that are constructed for purposes of inlet stabilization can potentially affect shorebirds by altering the hydrodynamic and sediment transport processes that create and maintain emergent shoals, sand spits, and other important inlet complex habitats. Additionally, improperly designed groins and jetties can potentially alter longshore hydrodynamics and associated sediment transport processes in ways that increase erosion and habitat loss or limit new shorebird habitat formation along adjacent oceanfront shorelines.

Human Resources

The proposed project as well as past and future nourishment/renourishment facilitates continuing human occupation (dwelling, recreation, and development) of coastal areas. With local, county, and State governments understanding the need, sometimes collectively, to protect properties, infrastructure, and the commerce value along the oceanfront beaches, dredging and beach nourishment activities have dramatically increased over the last decade. This understanding is also expected to result in an increased rate of these type projects in the foreseeable future. Beach shoreline protection and navigational improvement projects have occurred recently, and are being planned, all along the developed sections of North Carolina oceanfront; from Duck to Ocean Isle. Even during times where government budgets have had shortfalls and/or have reduced spending, government entities in North Carolina have continued to finance and implement these types of projects to protect oceanfront shoreline beaches and to maintain navigational channels.

With the local, county, and State's overall awareness and recognized need for shoreline and inlet projects, the human community is expected to be maintained, and in some circumstances, improved as it pertains to protection of property, recreational beaches, local and State commerce, and recreational and commercial boat use. Other human resource use, such as bird watching, aesthetics, and undisturbed vistas, may temporarily be interrupted by dredging and beach nourishment projects, but this interruption will tend to be localized and short-term.

Even with their continuation, dredging, inlet, and beach nourishment activities are generally not conducted on an annual basis for each beach or barrier island and/or inlet. Nor are these activities occurring along the North Carolina coastline simultaneously. Project cost and essential planning tend to keep the number of implemented actions low and on an as-needed basis, pending storm activities and beach conditions. Also, due to cost and funding constraints, it is generally expected that only projects with crucial needs will likely be constructed. As discussed earlier, most of North Carolina barrier islands, under a local or county municipalities' jurisdiction, have been developed for residential and/or commercial use, especially oceanfront properties. Outside of the municipality controlled islands, approximately 57 miles, or 18% of North Carolina's oceanfront shoreline is protected from development within the foreseeable future due to its ownership by Federal, state, and non-profit organizations. Most of these oceanfront shorelines are expected to remain or be managed in their natural state.

The number of past, present, and future projects overall have and are expected to greatly enhance and maintain human resource uses along the oceanfront shoreline and within inlets. These benefits will significantly impact individual, local, county, and State entities. Other human resource uses that may be temporarily affected are expected to be maintained for future generations due to the amount of undeveloped and long-term protected North Carolina oceanfront shoreline.

7.0 DETERMINE THE MAGNITUDE AND SIGNIFICANCE OF CUMULATIVE EFFECTS

The following is a qualitative assessment of the potentially beneficial, adverse, or neutral cumulative effects of the proposed action and similar past, present, or reasonably foreseeable future actions on identified resources.

7.1 Actions Affecting Benthic Resources

7.1.1 Dredging

Table 3 (adapted from USACE 2014) summarizes federal and known non-federal projects indicating placement of sediment on beaches as well as the currently identified borrow sources. Table 4 lists navigation project that have incorporated sand placement for dredged materials. For North Carolina projects, borrow areas have been identified predominantly within inlets and associated channels as well as offshore borrow areas located between approximately 1-5 miles offshore. Additionally, portions of ebb shoals and cuspate forelands have been dredged or identified to be dredged. Upland borrow sources as well as Confined Disposal Facilities (CDFs) have also been utilized. However, this assessment will focus on only dredging impacts that affect marine benthic resources.

Literature and monitoring reports have documented that dredging activities may result in impacts to benthic faunal resources. The significance of impacts is dependent on various planning considerations relative to the borrow area design, location, dredge type, etc. However, re-colonization by opportunistic species is expected to begin soon after the dredging activity ceases, primarily due to re-colonization from the migration of benthic organisms from adjacent areas and also due to larval transport and recruitment.

Monitoring studies of post-dredging infauna status and recovery rates of borrow areas indicate that most borrow areas usually show significant recovery by benthic organisms approximately 1 to 2 years after dredging (Naqvi and Pullen 1982, Bowen and Marsh 1988, Johnson and Nelson 1985, Saloman et al. 1984, Van Dolah et al. 1984, and Van Dolah et al. 1992; as cited in USACE 2014). According to Posey and Alphin (2000), benthic fauna associated with sediment removal from borrow areas off of Carolina Beach recovered quickly. Of course, a change in species composition, population, and community structure may occur from the initial sediment removal impact as well as the change in surficial sediment characteristics and depth. This could result in longer recovery times (i.e., 2-3 years) (Johnson and Nelson 1985, Van Dolah et al. 1984; as cited in USACE 2014). Such differences may last 2-3 years after initial density and diversity levels recover (Wilber and Stern 1992). Specifically, large, deeper-burrowing infauna can require as many as three years to reach pre-disturbance abundance. It may be interesting to note that Turbeville and Marsh (1982) indicated that long-term effects of a borrow site at Hillsboro Beach (Florida) included species diversity being higher at the borrow site than at the control site. Jutte et al. (1999 and 2001) evaluated recovery rates of hopper-dredged borrow areas and found that such dredging creates a series of ridges and furrows, with the ridges representing areas missed by the hopper dredge. Rapid recolonization rates were documented due to the dredge's inability to completely remove all of the sediment to a consistent grade. Furthermore, Jutte et al. (2002) documented that dredging to shallower depths is less likely to

Table 3. Summary of federal and non-federal beach renourishment projects in North Carolina.

Federal / Non-Federal	Project	Source of Sand for Nourishment	Beachfront Nourished	Approximate Length of Shoreline (miles)	Approximate Distance From the Project Area (miles)
Federal	*Dare County Beaches, NC Bodie Island (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Kitty Hawk and Nags Head Beaches	14	250
	Dare County Beaches, NC Hatteras to Ocracoke Portion	NA	Hatteras and Ocracoke Island (Hot Spots)	10	150
	Cape Lookout National Seashore -East Side of Cape Lookout Lighthouse	Channel	East Side of Cape Lookout Lighthouse	1	100
	*Beaufort Inlet Dredging - Section 933 Project (Outer Harbor)	Beaufort Inlet Outer Harbor	Indian Beach, Salter Path, and Portions of Pine Knoll Shores	7	100
	*Beaufort Inlet and Brandt Island Pumpout - Section 933 (Dredge Disposal to Eastern Bogue Banks)	Beaufort Inlet Inner Harbor and Brandt Island Pumpout	Fort Macon and Atlantic Beach	4	100
	*Bogue Banks, NC (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Communities of Bogue Banks	24	100
	Surf City and North Topsail Beach - (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Surf City and North Topsail Beach	10	50
	*West Onslow Beach New River Inlet (Topsail Beach) (Coastal Storm Damage Reduction)	Offshore Borrow Areas	Topsail Beach	6	50
	Wrightsville Beach (Coastal Storm Damage Reduction)	Masonboro Inlet and Banks Channel	Wrightsville Beach	3	30
	Carolina Beach and Vicinity, NC Carolina Beach Portion(Coastal Storm Damage Reduction)	Carolina Beach Inlet	Carolina Beach	2	20
	Carolina Beach and Vicinity, NC Kure Beach Portion (Coastal Storm Damage Reduction)	Wilmington Harbor Confined Disposal Area 4 and an Offshore Borrow Area	Kure Beach	2	20
	*Brunswick County Beaches, NC - Oak Island, Caswell, and Holden Beaches (Coastal Storm Damage Reduction)	Offshore Borrow Areas - Frying Pan Shoals	Caswell Beach, Oak Island, Holden Beach	30	0
	*Wilmington Harbor Deepening (Section 933 Project) – Sand Management Plan	Wilmington Harbor Ocean Entrance Channels	Bald Head Island, Caswell Beach, Oak Island	4	0
	*Holden Beach (Section 933 Project)	Wilmington Harbor Ocean Entrance Channels	Holden Beach	2	0
	*Oak Island Section 1135 - Sea Turtle Habitat Restoration	Upland Borrow Area - Yellow Banks	Oak Island	2	0
	Ocean Isle Beach, NC (Coastal Storm Damage Reduction)	Shallotte Inlet	Ocean Isle Beach	2	20
Non-Federal	*Town of Kill Devil Hills - Beach Nourishment Project	Offshore Borrow Areas	Kill Devil Hills	4	250
	*Town of Nags Head - Beach Nourishment Project	Offshore Borrow Areas	Nags Head	10	250
	*Emerald Isle FEMA Project	USACE ODMDS – Morehead City Port Shipping Channel	Emerald Isle	4	100
	*Emerald Isle "Hotspots" FEMA Project	USACE ODMDS – Morehead City Port Shipping Channel	Emerald Isle	7	100

Federal / Non-Federal	Project	Source of Sand for Nourishment	Beachfront Nourished	Approximate Length of Shoreline (miles)	Approximate Distance From the Project Area (miles)
Non-Federal	*Bogue Banks FEMA Project	USACE ODMDS – Morehead City Port Shipping Channel	Emerald Isle (2 segments), Indian Beach, Salter Path, Pine Knoll Shores	13	100
	*Bogue Banks Restoration Project – Phase I – Pine Knoll Shores and Indian Beach Joint Restoration	Offshore Borrow Areas	Pine Knoll Shores and Indian Beach	7	100
	*Bogue Banks Restoration Project – Phase II – Eastern Emerald Isle	Offshore Borrow Areas	Indian Beach and Emerald Isle	6	100
	*Bogue Banks Restoration Project – Phase III– Bogue Inlet Channel Realignment Project	Bogue Inlet Channel	Western Emerald Isle	5	100
	*North Topsail Dune Restoration (Town of North Topsail Beach)	Upland borrow source near Town of Wallace, NC	North Topsail Beach	NA	60
	*North Topsail Beach Shoreline Protection Project	New River Inlet Realignment and Offshore Borrow Area	North Topsail Beach	11	60
	*Topsail Beach - Beach Nourishment Project	Disposal Island	Topsail Beach	6	50
	*Topsail Beach - Beach Nourishment Project	New Topsail Inlet	Topsail Beach	6	50
	Figure Eight Island	Banks Channel and Nixon Channel	North & South Sections of Figure Eight Island	3	30
	Rich Inlet Management Project	Relocation of Rich Inlet	Figure Eight Island	NA	30
	Mason Inlet Relocation Project	Mason Inlet (new channel) and Mason Creek	North end of Wrightsville Beach and south end of Figure Eight Island	2	30
	New Hanover County Beaches - Beach Nourishment	TBD	Wrightsville Beach, Carolina Beach, Kure Beach	TBD	20
	Bald Head Island Creek Project	Bald Head Creek	South Beach	0.34	10
	Bald Head Island - Beach Nourishment	Offshore Borrow Area (Jay Bird Shoals)	West and South Beach of Bald Head Island	4	10
	Bald Head Island - Terminal Groin and Beach Nourishment	TBD	TBD	TBD	10
	*Holden Beach - Terminal Groin and Beach Nourishment	TBD	Holden Beach w/in vicinity of Lockwood Folly Inlet	TBD	0
	*Holden Beach Interim Beach Nourishment	Offshore Borrow Area	Holden Beach	4	0
	*Holden Beach East & West	Upland Borrow Source (Truck Haul)	Extension of 933 Project	3	0
	*Ocean Isle - Terminal Groin and Beach Nourishment	TBD	Ocean Isle Beach w/in vicinity of Shallotte Inlet	TBD	15

Source: USACE 2014

Note: These are projects that have recently occurred, are currently underway, or will occur in the reasonably foreseeable future. This list is not entirely comprehensive and does not include all small scale beach fill activities (i.e. dune restoration, beach scraping, etc.).

***** - federal or non-federal projects which may utilize the same borrow sources and/or overlap beach placement locations.

Table 4. Summary of dredged material disposal activities on the ocean front beach associated with navigation dredging.

	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ESTIMATED ACTUAL DISPOSAL	ESTIMATED QUANTITY (CU)	COMMENTS
Outer Banks	**Avon**	Begins at a point 1.15 miles south of Avon Harbor and extends north 3.1 miles	3.1 miles (16,368 lf)	0.4 miles or 2,000 linear feet	<50,000 every 6 yrs	Special Use Permit Required From NPS/CHNS
	Rodanthe	Extends from rd to Rodanthe Harbor south 700' to south end of beach disposal area (straight out from existing dirt road). North end at Wildlife Refuge Boundary (PINWR)	.91 miles (4,800 lf)	0.4 miles or 2,000 linear feet	<100,000 every 6 yrs	Special Use Permit Required From NPS/CHNS
	Ocracoke Island	Begins at a point 5,000 linear feet south of Hatteras Inlet and extends southward about 3,000 linear feet.	0.6 mile (3,000 lf)	0.4 mile or 2,000 linear feet	<100,000 every 2 to 3 years	Special Use Permit Required From NPS/CHNS
	Rollinson (Hatteras)	Begins at a point 0.85 miles south of Hatteras Harbor and extends north 5.85 miles to a point north of Frisco, NC	5.85 miles (30,888 lf)	0.4 miles or 2,000 linear feet	<60,000 every 2 years	Special Use Permit Required From NPS/CHNS
	Silver Lake (Teaches Hole/Ocracoke)	From a point 2,000' NE of inlet and extending approximately 2,000 linear feet (0.4 miles) to the NE (Ocracoke Island)	0.4 miles (2,000 lf)	0.4 miles or 2,000 linear feet	<50,000 every 2 yrs	Special Use Permit Required From NPS/CHNS
	Oregon Inlet	Pea Island National Wildlife Refuge (PINWR)	3 miles(15,840 lf)	1.5 miles or 7,920 linear feet	300,000 Annually	Special Use Permit Required From USFWS/PINWR
	Drum Inlet	Core Banks. From a point 2,000 feet on either side of inlet extending for 1 mile in either direction	2 miles (10,560 lf)	1 mile or 5,280 linear feet	298,000 initial, 100,000 maint. (Assume 8 year cycle)	SUP from NPS/CLNS (Included in analysis; however, no determination of site being reused can be made at this time)
Beaufort	***Morehead City**	2,000 ft west of inlet, Fort Macon and Atlantic Beach to Coral Bay Club, Pine Knoll Shores	7.3 miles (38,300 lf)	5.2 miles or 27,800 linear feet	3.5 million every 8 yrs	Material from Ocean Bar routinely placed in nearshore berm or ODMDS on annual basis
	***AIWW Section I, Tangent B**	Pine Knoll Shores, vicinity of Coral Bay	2 miles (10,500 lf)	0.4 miles or 2,000 linear feet	<50,000 every 5 yrs	This area is included every 8 years as part of the pumpout of Brandt Island. Also included in the area under investigation for beach nourishment at Bogue Banks.
Swainsboro	***AIWW Bogue Inlet Crossing Section I, Tangent- H through F**	Approx. 2,000 feet from inlet going east to Emerald Point Villas, Emerald Isle (Bogue Banks)	1 mile (5,280 lf)	0.4 miles or 2,000 linear feet	<100,000 annually	The Town of Emerald Isle has received permits to place the material directly on the west end of Emerald Isle at Bogue Inlet.

	PROJECT	DISPOSAL LOCATION	APPROVED DISPOSAL LIMITS	ESTIMATED ACTUAL DISPOSAL	ESTIMATED QUANTITY (CU)	COMMENTS
Browns Inlet	**AIWW Section II, Tangents- F,G,H**	Camp Lejeune, 3,000 feet west of Browns Inlet extending westward	1.58 miles (6,000 lf)	1 mile or 5,280 linear feet	<200,000 every 2 yrs	
New River Inlet	***AIWW, New River Inlet Crossing Section II, Tangents I & J, Channel to Jax. Section III, tangents 1&2**	N. Topsail Beach, 3,000 feet west of inlet extending westward to Maritime Way (Galleon Bay area)	1.5 miles (8,000 lf)	0.8 miles or 4,000 linear feet	<200,000 annually	Two areas 2,000 linear feet on either side of disposal area are routinely used.
New Topsail Inlet (Hampstead)	***AIWW, Sect. III**	Topsail Island, Queens Grant	0.6 miles (2,500 lf)	0.6 miles or 2,500 lf	<50,000 every 6 yrs	
	***AIWW, Topsail Inlet Crossing & Topsail Creek**	Topsail Beach, from a point 2,000 feet north of Topsail Inlet	1 mile (5,280 lf)	0.4 mi or 2,000 ft	<75,000 annually	
Wrightsville Beach	**AIWW Sect. III,Tang 11&12 Mason Inlet Crossing**	Shell Island (north end of Wrightsville Beach from a point 2,000 feet from Mason Inlet	0.4 miles (2,000 lf)	0.4 mi. or 2,000 lf	<100,000	Not recently required since the inlet crossing closed up. If reopened will be rescheduled if needed
	***Masonboro Sand Bypassing**	At a point 9,000 feet from jetty extending southward midway of island	1.2 miles (6,000 lf)	1 mile 5,280 lf	500,000 every 4 years	Same time as Wrightsville Beach Nourishment
Carolina Beach	**AIWW, Section IV, Tangent 1**	Southern end of Masonboro Island at a point 2,000 linear feet from Carolina Beach Inlet extending northward to Johns Bay area	1.3 miles (7,000 lf)	0.4 miles (2,000 linear feet)	<50,000 annually	This site is used alternately with Carolina Beach Disposal Site on North end of Island
	AIWW, Section IV, Tangent 1	North end of Carolina Beach at Freeman Park				Limits for each disposal event are dependent on the quantity of material to be dredged
Carswell Beach	***Caswell Beach**	Beachfront on eastern end of island	4.7 miles (25,000 lf)	4.7 miles or (25,000 linear feet)	1.1 million every 6 years	Disposal Material from Wilmington Harbor Ocean Bar Project
Bald Head	***Bald Head**	Beach front on eastern and western shoreline	3.0 miles (16,000 lf)	3.0 miles or 16,000 lf	1.1 million every 2 years (except every 6th when it goes to Caswell)	Least Costly Disposal Option From Wilmington Harbor Ocean Bar Project.
Holden Beach	**AIWW**	Beach front on eastern end of the shoreline				Limits for each disposal event are dependent on the quantity of material to be dredged
Ocean Isle	**AIWW**	Beachfront on eastern end of the island within the vicinity of Shallotte Blvd				Limits for each disposal event are dependent on the quantity of material to be dredged

Source: USACE 2014

Note: Projects listed and associated disposal locations and quantities may not be all encompassing and represent an estimate of navigation disposal activities for the purposes of this cumulative impacts assessment.

***** - Navigation disposal sites which may overlap with existing federal or non-federal beach nourishment projects.

modify wave energy and currents at a borrow site. Therefore, reduction of the likelihood of infilling of fine-grained sediment occurs. As a result of the significant number of borrow areas identified throughout NC for beach nourishment material, there is concern for potential cumulative impacts to benthic organisms due to statewide borrow area cumulative acreage, spatial relationship, and frequency of dredging which may impact recovery times (USACE 2014).

7.1.2 Other Activities

Many factors unrelated to dredging material from borrow areas may affect benthic resources including beach resources and fisheries. The factors can be a result of natural events such as natural population cycles or as a result of favorable or negative weather conditions including La Niña, El Niño, climate change, and major storms or hurricanes to name a few. These global events have far greater impacts on these resources at the population level than relatively local activities such as removal of sand from a given area of ocean bottom. Primary man-induced factors affecting fish stocks are over-fishing and degradation of water quality due to pollution. When examining the cumulative effect of space crowded perturbations, these other factors may outweigh the potential incremental effects of borrow dredging of sand on benthic or fish populations (USACE 2014).

7.2 Actions Affecting Beach and Nearshore Resources

7.2.1 Scope of Actions

Sources of beach impacts include material deposition for berm and dune construction, beach scraping, sand-bagging, etc. Of particular concern are effects on macroinvertebrates, fishes, shorebirds, and sea turtles that utilize or occur on, or adjacent to, ocean beaches. These resources are also impacted by natural events and anthropogenic activities that are unrelated to disposal of sand on the beach as discussed below.

7.3 Offshore Borrow Areas

7.3.1 Site-Specific Impacts

Borrow area Y and the ODMDS are the identified borrow sources for this project and extends between 1-5 miles offshore at depths between -40 and -57 feet (ft). There are many possible sequences and methods for dredging and placing available material on the beach for the proposed project; a site-specific borrow area use plan has yet to be defined, though potential sand sources are discussed above in Section 1.0. Both initial construction and each nourishment interval will utilize varying components of the borrow site with a sequence of temporary impacts to benthic resources over the life of the project. Subsequent intervals of dredging within the borrow area will likely occur in portions not previously dredged. Upon each dredging interval, recovery in adjacent areas will have already occurred; re-occurring impacts to any sub-component of a borrow area are not anticipated. Therefore, the total acreage of impact that could occur during any given dredging event is the one-time impact of the surface area required to dredge the volume of sediment for initial construction or nourishment. This cyclic use of borrow areas would result in cumulative effects from space-crowded perturbations on a local scale. Assuming that the borrow areas are not impacted by unusually high sedimentation rates or some other disturbance, a natural succession of species should occur, potentially restoring the area to its original levels of abundance and biomass within 1-5 years (Naqvi and Pullen 1982, Bowen and Marsh 1988, Johnson and Nelson 1985, Saloman et al. 1984, Van Dolah et al. 1984 and 1992, and Wilber and Stern 1992; as cited in USACE 2014). Considering that un-impacted or recovered portions of the borrow area will likely be available during any particular dredging event, more rapid recruitment from adjacent areas is expected to expedite recovery. Cumulative impacts from space-crowded perturbations could occur at the local scale resulting from the use of the borrow areas.

7.3.2 Statewide Impacts: Existing and Potential Sites

Beach compatible sediment identified for all federal and non-federal nourishment projects throughout North Carolina is most often identified from upland sites, navigation channel maintenance or deepening, and/or offshore borrow areas. For the purposes of this impact assessment, only offshore borrow areas are evaluated for cumulative marine resource impacts because upland sources are outside of the marine environment and navigation channels are repeatedly dredged already in order to maintain navigation. Of all the projects listed with offshore borrow areas in Table 3, there are currently only one federal (Carolina Beach and Vicinity, NC Kure Beach portion) and four non-federal (Bogue Banks Federal Emergency Management Agency, Bogue Banks Restoration Project – Phases 1&2, Bald Head Island Beach Nourishment, and Nags Head Beach Nourishment) offshore borrow sites that have received permits and/or authorizations and funding, and are currently in use. Other offshore borrow areas identified for projects are either under study and have not been permitted and/or authorized yet or have received permits and/or authorizations but have not been funded or constructed yet. Considering only the projects that are currently in use, significant cumulative impacts associated with time and space crowded perturbations are not expected considering that these borrow areas are spread out throughout the state and the acreage of impact for these borrow areas relative to the available un-impacted sites throughout the state is not significant (USACE 2014). However, recognizing the potential for all of the federal and non-federal projects identified in North Carolina to occur within the reasonably foreseeable future, there is a potential for cumulative impacts for time- and space-crowded perturbations associated with the cyclic use of the offshore borrow areas throughout the state.

7.4 Beaches

7.4.1 Site-Specific Impacts

The impacts of beach disposal on North Carolina beaches are evaluated in the main text of the EIS. The degree of cumulative impact would increase proportionally with the total length of beach impacted. The most likely projects to increase the cumulative length of North Carolina beaches receiving material are beach nourishment projects, although beaches may also receive material as a result of beneficial use deposition from navigation projects.

As shown in Table 5 below, North Carolina ocean beaches (320 miles) are listed based on the potential for beach nourishment. The CAMA applies to all 20 North Carolina coastal counties. Beach nourishment, navigation disposal, and/or local maintenance within these counties is generally regulated under CAMA or USACE permitting authorities alone, and for this discussion, are labeled "CAMA-regulated." Approximately 37% of North Carolina beaches are in this category. Other North Carolina ocean beach areas which are less likely to be considered for beach disposal include those identified under the Coastal Barrier Resources Act (CBRA) of 1982 (PL 9-348), the Coastal Barrier Improvement Act of 1990 (PL 101-591), and national and state park lands (USACE 2014). The CBRA restricts federal expenditures in those areas comprising the Coastal Barrier Resources System (CBRS). Thus, long-term federal beach nourishment projects will not occur in defined CBRA zones. However, though long-term federal beach nourishment projects are restricted from CBRA zones, non-federal permitted projects may still occur (e.g., North Topsail Beach) on a short-term basis. National or state park lands are the least likely to have beach nourishment projects considering that their mission is often to manage lands in their natural state and protection of infrastructure is less common. National and state parks allow highly restricted disposal under special use permits and conduct disposal only as required to protect resources, such as at Pea Island. Only about ten percent (on national/federal and state parks) of all existing or projected disposal/nourishment in North Carolina are on beaches within this category (USACE 2014).

Table 5. North Carolina beach classifications and associated potential for beach disposal/nourishment activities.

Beach Classification	Percentage of NC	Potential for Beach Disposal/
Coastal Barrier Resource System	19	Medium
Developed and/or CAMA-Regulated	37	High
National Park Lands	40	Low
State Park Lands	4	Low

7.4.2 Statewide Impacts

7.4.2.1 Overview

The following analysis of statewide impacts was guided by data shown in Tables 6 and 7. These data represent an estimate of the percent of North Carolina beaches affected by sand disposal for maintenance of federal navigation channels (recall Table 4 above), and existing, proposed, or potential federal and non-federal beach nourishment projects. Table 6 represents the total project miles for all existing and proposed federal and non-federal beach nourishment projects and the full authorized limits for beach disposal of navigation dredged material. However, assuming all of these activities were constructed to the full extent (which is very unlikely considering funding constraints, dredging needs from navigation channels, etc.) these estimates would not represent the actual extent of North Carolina ocean beaches impacted because many project areas overlap (USACE 2014).

Recognizing that many of the existing or proposed federal and non-federal beach nourishment project limits overlap, and that some portions of the federal authorized beach disposal limits are within these project areas as well, Table 7 provides an estimate of total mileage of North Carolina ocean beaches that could cumulatively be impacted by beach nourishment or navigation disposal activities without double counting the overlapping projects.

Table 6. Summary of total project miles for existing and/or proposed federal and non-federal nourishment activities and federal navigation disposal.

Project Type	Total Project Miles	% of NC Beach
Federal Beach Nourishment	122	38
Non-Federal Beach Nourishment	93	29
Federal Authorized Beach Disposal	41	13
TOTAL	**256**	**80**

Table 7. Summary of cumulative mileage of North Carolina ocean beach that could be impacted by beach nourishment and/or navigation disposal activities.

Project Type	Total Miles Impacted (*accounting for overlapping projects)	% of NC Beach
Federal and Non-Federal Beach Nourishment	112	35
Federal Authorized Beach Disposal	19	6
TOTAL	**131**	**41**

Existing Beach Nourishment. Of the total 197 potential federal and non-federal beach nourishment project miles proposed for North Carolina ocean beaches (Table 3), a total of 92 (29%) have actually been constructed as of 2014 (USACE 2014). However, this estimate represents actual project miles nourished and does not reflect circumstances where the projects overlap. Therefore, the total number of actual miles of beach nourished is less.

*Proposed Beach Nourishment***.** Approximately 121 miles or 38% of the North Carolina ocean beaches are proposed for beach nourishment (federal and non-federal) (USACE 2014).

Cumulative Impacts. Considering all proposed and existing disposal and nourishment impacts throughout the ocean beaches of North Carolina, a significant portion of the shoreline will have beach placement activities in the foreseeable future, likely resulting in time- and space-crowded perturbations. However, recognizing the funding constraints to complete all authorized and/or permitted activities, the availability of dredging equipment, etc.; it is very unlikely that all of these proposed projects would be constructed at once (USACE 2014). That factor, in concert with practices that avoid and minimize site-specific impacts, result in a high likelihood that adjacent un-impacted and/or recovered portions of beach will be available to support dependent species (i.e. surf zone fish, shore birds, etc.) and facilitate recovery of individual project sites to pre-project conditions.

7.5 Project-Level Impacts for Programmatic Nourishment at Bogue Banks

7.5.1 Specifications

The proposed project consists of approximately 23 miles of beachfill, with a consistent berm profile across the entire area, and dune expansion in certain portions. The main beachfill is bordered on either side by a 1,000-foot tapered transition zone berm. Sand for the beachfill would be delivered from offshore borrow areas by dredge. A “safe box” surrounding a re-aligned channel at Bogue Inlet would also be dredged and maintained.

7.5.2 Existing Local Beach Placement

Non-Federal Projects. The Bogue Banks Restoration (BBR) Project was implemented by Carteret County as an interim measure, to go along with placement resulting from Morehead City Harbor dredging, until a full USACE CSDR project could be implemented. The BBR project was implemented in three phases and has placed approximately 4.3 million cy of material along the island since 2001 (USACE 2014).

7.5.3 Existing Federal Beach Placement

Morehead City Section 933. Since 2004, approximately 3.2 million cy of maintenance material dredged from Morehead City Harbor has been placed in various locations in Bogue Banks as part of the Section 933 project (USACE 2014).

Morehead City Harbor Maintenance. Since 1978, about 9 million cy of material dredged during harbor maintenance has been placed on the eastern end of the island as least cost disposal (USACE 2014).

7.5.4 Proposed Beach Nourishment

Proposed projects include the following:

- The local Bogue Banks CSDR project consists of an 119,670 ft (22.7 miles) long main beachfill.
- The USACE (2014) is in the feasibility phase of a CSDR project for the areas comprising the Preferred Alternative. It is not known if the next phase of the study or construction will be funded.
- The USACE is preparing the Morehead City Dredge Materials Management Plan which will place material from the maintenance of the Morehead City Harbor onto Bogue Banks and Shackelford Banks.

7.5.5 Cumulative Impacts

The proposed project beach placement activities are approximately every three years and allow for recovery between events.

8.0 MODIFY OR ADD ALTERNATIVES TO AVOID, MINIMIZE, OR MITIGATE SIGNIFICANT CUMULATIVE EFFECTS

The private shoreline protection projects (beach nourishment, ebb tide channel relocation, and/or channel dredging) that have occurred in the last decade or are planned for the foreseeable future include avoidance and minimization strategies. These actions incorporate measures to protect the natural resources through various measures including limiting the timing of construction to the winter months when biological activity is at its lowest, improved dredge and construction methods designed to avoid or minimize environmental impacts, implementation of species conservation measures, and the use of compatible beach nourishment material. These practices, along with educating dredge operators to identify piping plovers, utilizing marine mammal and sea turtle observers, daily sea turtle nest walks and modifying equipment to include sea turtle excluder devices, have improved over the past decade or so and are expected to continue to improve as technology advances. These improvements have served to further the avoidance and minimization of adverse impacts to the natural resources found along the coastline of North Carolina. Chapter 6 of the Environmental Impact Statement describes these actions and measures in greater detail and will continue to be coordinated between federal and state resource agencies through the NEPA process.

9.0 MONITOR THE CUMULATIVE EFFECTS OF THE SELECTED ALTERNATIVE AND ADAPTIVE MANAGEMENT

As stated in the above Step (10), private beach nourishment projects that have recently occurred or are planned for the foreseeable future include avoidance and minimization strategies which can include biological resource monitoring efforts, construction measures, environmental window restrictions and lighting surveys. This section identifies existing monitoring programs that include surveys of significant resources within the impact area. While several past monitoring components have been discussed in the Environmental Impact Statement along Bogue Banks, a monitoring plan continues to be developed as consultation with State and Federal agencies is initiated.

10.0 CONCLUSION

Historically, the extent of beach nourishment activities on North Carolina beaches was limited to a few authorized federal projects. However, in the past ten years, a significant number of federal and non-federal beach nourishment efforts were pursued to protect infrastructure along the increasingly developed North Carolina shoreline. Additionally, the number of non-federal permitted beach nourishment projects has increased in recent years in efforts to initiate measures in the interim of federal projects being authorized and/or funded (e.g., Nags Head, North Topsail Beach, Topsail Beach, Ocean Isle, Holden Beach and Bogue Banks).

Given the extent of coastal development and subsequent vulnerability to long- and short-term erosion throughout the North Carolina shoreline, it is likely that the proposed beach nourishment projects within the reasonably foreseeable future will be constructed. Furthermore, the frequency of beach disposal activities for protection of infrastructure will continue throughout the state resulting in cumulative time- and space-crowded perturbations. However, assuming projects continue to adhere to environmental commitments for the avoidance and reduction of environmental impacts, and un-developed beaches throughout the state continue to remain undisturbed, it is likely that adjacent un-impacted and/or recovered portions of beach will be available to support dependent species (i.e. surf zone fish, shore birds, etc.) and facilitate recovery of individual project sites to pre-project conditions. Assuming recovery of impacted beaches and the sustainability of un-developed protected beaches (i.e. national/federal and state parks and estuarine reserves) the potential impact area from the proposed and existing actions is small relative to the area of available similar habitat on a vicinity and statewide basis (USACE 2014).

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