5.0 ENVIRONMENTAL CONSEQUENCES

5.1 Impact Analysis Methodology

In accordance with the CEQ regulations for implementing the NEPA (40 CFR 1500 et. seq.), this section evaluates the potential environmental consequences (hereinafter referred to synonymously as effects and impacts) of the five alternatives. The analysis of each alternative considers the direct, indirect, and cumulative effects on environmental resources within the Permit Area. As defined by CEQ regulations, direct impacts are those occurring at the same time and place as the proposed action, while indirect impacts are those occurring later in time or at a greater distance from the proposed action. Cumulative impacts are those caused by the effects of the proposed action when added to other separate past, present, and reasonably foreseeable future actions regardless of the agency or person that undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. The direct and indirect impact analyses in this EIS consider only the effects of proposed non-federal actions that are subject to USACE Regulatory Program authorization under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act and/or BOEM authorization via the issuance of leases for the use of OCS sand resources. Federal USACE civil works projects, including the MCH, Bogue Inlet, and AIWW Bogue Inlet Crossing navigation projects, are not considered in the direct and indirect impact analyses. However, federal projects are considered in the analyses of cumulative impacts under each alternative.

5.1.1 Direct, Indirect, and Cumulative Impact Analysis

This EIS evaluates the direct, indirect, and cumulative effects of the alternatives on resources within the limits of the Permit Area over the next 50 years. Direct impacts are defined in this EIS as those caused by the proposed action that are expected to occur during the active processes of beach fill placement, dredging, and/or groin construction and within the active project areas associated with these activities. In contrast, indirect impacts are those caused by the proposed action that are expected to occur after the completion of project activities and/or at a location removed from the active project area. Cumulative impacts are those resulting from the incremental effects of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. For this document, the reasonably foreseeable future captures a time period of 50 years. Direct and indirect impacts were projected through quantitative and qualitative methods of analysis. Quantitative methods consisting of Geographic Information System (GIS) and numerical modeling analyses were used primarily to determine direct and indirect impacts on the physical environment. Direct impacts on physical habitats were quantified through GIS analysis by superimposing the beach fill, dredging, and groin footprints of disturbance on the baseline (existing condition) habitat map. Indirect impacts on physical coastal processes, shorelines, and habitats were quantified via numerical modeling analyses. Direct and indirect impacts on biological resources and public interest factors, which in most cases do not lend themselves to numerical measurements, were primarily assessed qualitatively based on scientific literature review, correspondence with federal and state natural resource agencies, and consideration of the quantitative impact projections. Cumulative impacts were assessed by using the results of both direct and indirect impacts and projecting the probable effects. The analysis of cumulative effects focuses on the potential for impact "crowding" at temporal and spatial scales. Temporally crowded cumulative effects can occur when the time required for resources to recover from a single impact event is greater than the time between repeated impact events. Temporally crowded effects are primarily associated with frequent repeated impacts on a specific resource in the same area; for example, repeated dredging impacts may occur at a specific borrow site where the interval between dredging events is shorter than the time required for the benthic community to recover. Spatially crowded cumulative effects can occur when the proximity of separate actions is such that their impacts overlap in space. Overlap does not necessarily mean that the physical impacts of the separate actions are contiguous. For instance, beach fill projects on separate barrier islands might affect foraging habitat for the same population of shorebirds. Additional analysis can be found in the cumulative effects assessment (Appendix H).

Numerical and Analytical Modeling

A combination of numerical and analytical modeling was used to predict the long-term effects of the alternatives on oceanfront shoreline change. Numerical modeling analyses employed the GENESIS-T model developed by Hanson and Kraus (1989) for the USACE, which simulates shoreline and beach topography changes in response to spatial and temporal differences in longshore sediment transport produced by breaking waves, boundary conditions, and beach nourishment and other coastal engineering projects. The GENESIS-T model was calibrated using shoreline data that incorporate past nourishment events on Bogue Banks (no other data were available). Consequently, in the case of Alternatives 1 and 2 (minimal or no nourishment), the model underestimates the extent of erosional shoreline change. In order to account for this factor, the GENESIS-T modeling for Alternatives 1 and 2 was supplemented with additional analytical modeling using the 2004 NCDCM long-term shoreline erosion rates. The 2004 NCDCM erosion rates are based on shoreline position changes through 1998, thus reflecting shoreline changes prior to the initiation of beach nourishment activities on Bogue Banks.

The numerical model simulations and analytical analyses constitute the primary basis for evaluating the relative effects of the alternatives on the oceanfront shoreline, dry beach habitat, the recreational beach, and oceanfront property. The model-predicted shoreline changes under Alternative 2 (Abandon and Retreat) were used as the standard of comparison or "control" for purposes of evaluating the model-predicted changes under the three action alternatives. The modeling results for Alternative 2 represent the predicted shoreline response to waves and boundary conditions alone, whereas the modeling results for Alternatives 3, 4, and 5 reflect the influence of various shoreline management activities. By comparing the projected changes under action alternatives to those of Alternative 2, the effects of beach management practices can be distinguished from the effects of natural coastal processes. Accordingly, the impact analysis sections refer to the model-predicted changes under Alternatives 3, 4, and 5 as "changes relative to Alternative 2" or simply as "relative changes." For modeling purposes, the shoreline was defined as the area landward of the MHW line. Projected changes in the MHW line over the course of 12-year numerical modeling simulations were used to quantify oceanfront shoreline, beach width, and dry beach habitat changes under the alternatives. Projected MHW line changes based on numerical and analytical modeling were also used to evaluate the potential effects of shoreline changes on oceanfront property. Properties were considered to be "at risk" of erosional damage when the seaward parcel boundary fell within 25 ft of the MHW line.

The principal intent of the numerical and analytical modeling analyses is to provide a relative comparison of shoreline responses under the various alternatives. Although the modeling results are presented as quantitative numerical projections, these estimates must be considered within the context of the model limitations. It is not possible to accurately predict all of the complex environmental variables that influence changes in beach morphology; and consequently, the model-projected changes should not be interpreted as a precise estimate of future conditions in the Permit Area.

5.2 General Effects of Dredging and Sand Placement

This section addresses impact producing factors and environmental effects that are common to basic dredging and sand placement activities under the various alternatives. This section emphasizes analyses of potentially significant effects, in particular those that are supported by extensive background discussion and literature review, and is not intended to be an exhaustive discussion of all common effects.

Dredging

Dredging Methods

Dredging operations under the various alternatives would employ either a trailing suction hopper dredge or a cutterhead dredge. Hopper dredges are self-propelled ocean-going vessels that use pumps and long trailing suction pipes to extract seafloor sediments. The lower ends of the suction pipes are equipped with excavating "draghead" mechanisms that are drawn across the seafloor as the dredge vessel moves back and forth above the borrow site. The dragheads are equipped with cutting teeth and high pressure water nozzles that dislodge thin layers of sediment (~2 to 5 ft thick). Loosened sediment is combined with water at the draghead, and the resulting slurry is pumped through the suction pipes into a containment basin (i.e., hopper) onboard the dredge. The dredged sediment settles in the hopper, and excess water is discharged via an overflow system. Once the hopper is full, the dredged material is transported onboard the dredge to a nearshore pump-out station along the recipient beach. At the pump-out station, the dredged material is remixed with water and pumped through a submerged pipeline onto the beach. In comparison with cutterhead dredges (described below), hopper dredges employ a less productive thin layer sediment removal process that involves long shallow cuts over a relatively large seafloor area. Sediment removal is typically incomplete, resulting in a series of shallow excavated furrows separated by intervening ridges of undisturbed material.

In contrast to the mobility of self-propelled hopper dredges, hydraulic cutterhead dredges operate from barges that are towed to the dredging site and secured in place by two stern anchor pilings (spuds). Once in place, the dredge can be stepped forward into the cut or dredging area by alternately pivoting on the spuds, but otherwise is restricted to a relatively small dredging footprint. Given their lack of mobility, cutterhead dredges are most productive in deep sediment deposits where deep cuts can be used to extract large volumes of sand from a relatively small area. Sediment removal is accomplished by a pipeline with a rotating "cutterhead" mechanism at the suction end. The cutterhead is swung through the sediment in an arc-shaped motion as the two spuds are alternately lifted and returned to the seafloor. In making relatively deep cuts, the cutterhead mechanism generally remains buried in the sediment below the seafloor surface. Dislodged sediments are combined with water at the cutterhead, and the resulting slurry is pumped through a submerged pipeline that leads directly from the borrow site to the beach. Cutterhead dredges are not designed for operations in the open ocean due to their lack of mobility and sediment storage capabilities. Consequently, their use in beach nourishment is generally limited to projects involving estuarine and inlet borrow sites that are relatively close to the nourishment beach.

Sediment Removal

The potential impacts of dredging on marine soft bottom communities 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. (1999b) attributed rapid benthic community recovery (six to nine months) in relatively shallow (~3 ft) 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.

In the case of dredged navigation channels and other relatively shallow soft bottom habitats, soft bottom communities are adapted to high-frequency disturbance from waves and currents; and consequently, generally recover more rapidly than benthic communities at deeper offshore borrow sites (Wilber and Clarke 2007). Studies of benthic community recovery in dredged navigation channels along the southeastern coast have reported rapid recovery within two to six months (Van Dolah et al. 1984 and 1979, Stickney and Perlmutter 1975, Stickney 1972). These studies indicate that recolonization via slumping of adjacent undisturbed sediments into the dredged channel is an important recovery mechanism. As in the case of offshore borrow sites described above, Van Dolah et al. (1984) also attributed relatively rapid recovery in a dredged navigation channel to rapid infilling by sediments that were similar in composition to the extracted material and avoidance of spring benthic invertebrate recruitment periods.

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 et al. (1994) observed significant declines in fish diversity and abundance following dredging at an ocean borrow site; however, recovery occurred within six months.

Sediment Suspension and Redeposition

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. In addition, fine sediments that are temporarily suspended may be dispersed and redeposited outside of the active dredging footprint, potentially impacting adjacent soft bottom benthic communities through burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic 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.

In accordance with NC technical standards for beach fill, analyses of vibracore samples indicate that all potential beach fill sediments within the ODMDS and Area Y borrow sites and navigation channels are composed of highly compatible sands with very small fine sediment fractions less than six percent. Given the composition of sediments at these sites, it is expected that relatively rapid settling would limit the extent and duration of any increases in turbidity and TSS levels. As an example, observed turbidity levels during the 2005 Bogue Inlet Channel Erosion Project remained within the pre-project ambient range (9.7 to 35.2 NTUs) throughout dredging operations (CSE, unpublished data, 2005). In another case, Cleary and Knierim (2001) reported that turbidity levels during dredging in Nixon Channel along the north end of Figure Eight Island (located ~40 miles south of Bogue Banks) did not exceed the state standard of 25 NTUs for tidal salt waters. Based on the small percentage of fine material, it is anticipated that the effects of dredging-induced sediment suspension on marine and estuarine water quality and pelagic communities would be short-term and localized.

Entrainment

Hopper and cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). The planktonic larvae of marine fishes and invertebrates lack effective swimming capabilities; and therefore, are vulnerable to entrainment by dredges operating in both offshore and inshore waters. 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. In the case of the alternatives addressed in this EIS, all dredging associated with beach placement operations would be completed by 30 April, thereby avoiding peak larval ingress periods. Based on the low projected entrainment rates and avoidance of peak ingress periods, it is anticipated that the loss of larvae due to entrainment would have negligible effects on marine and estuarine-dependent fish and invertebrate populations.

The principal project-related threat to sea turtles in the water would be the potential for entrainment during hopper dredging operations at the offshore borrow sites. Cutterhead dredges are not known to entrain sea turtles. Therefore, the use of cutterhead dredges would not be expected to present any risk of entrainment to sea turtles. Sea turtles are vulnerable to direct injury by hopper dredges as a result of being entrained in the dredge intake pipe during the sediment extraction process. The USACE Wilmington District reported 22 sea turtle takes by hopper dredges in the vicinity of Bogue Banks between 1992 and 2013; including 16 takes during navigation dredging in the MCH channels and six takes during offshore borrow site dredging in conjunction with beach nourishment projects along Bogue Banks (USACE Sea Turtle Data Warehouse). All of the borrow site takes occurred at three areas (A, B1, and B2) that were located one to three miles offshore of central Bogue Banks (i.e., Pine Knoll Shores, Indian Beach/Salter Path, and eastern Emerald Isle). Most of the reported takes in the vicinity of Bogue Banks occurred during late November through mid-December (n=8) and mid-March through April (n=8). The remaining takes occurred during late October (n=2) and early to mid-May (n=4). As a means of reducing the entrainment risk, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges and generally restricts hopper dredging projects to the colder months when most sea turtles have moved to warmer waters. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a V-shaped sand ridge in front of the draghead as it is drawn along the seafloor, thus providing for the deflection of sea turtles while avoiding direct contact with the draghead. The distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that inshore and nearshore sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April to 20 November for inshore waters and a range of 23 April to 27 November for nearshore ocean waters.

Although leatherback sea turtles may be present in nearshore ocean waters during warmer months, this species is primarily associated with deep, offshore waters. Furthermore, the pelagic feeding habit of the leatherback reduces its vulnerability to entrainment, and there are no records of incidental take during dredging operations throughout the South Atlantic Ocean or the Gulf of Mexico. Based on the low probability of occurrence in the action area during the proposed 16 November to 30 April hopper dredging window, and considering that incidental take by dredges has not been documented, dredging would not be expected to have any effect on leatherbacks. In the case of loggerhead, green, Kemp's ridley, and hawksbill sea turtles; the proposed hopper dredging window would limit dredging to periods when most individuals have moved to warmer waters, thus reducing the potential for sea turtle entrainment. However, as stated above, incidental takes of sea turtles have occurred during the dredging window. Although the specific factors contributing to the history of takes during otherwise cooler months are not fully understood, a principal factor may be the influence of warm water gyres that spin off from the gulfstream (Dickerson et al. 2007). Additional conservation measures; including relocation trawling and the use of rigid draghead deflectors would further reduce the likelihood of sea turtle entrainment during dredging operations. The implementation of endangered species observer monitoring and the USACE Dredging Quality Management system will support documentation of any incidental takes on board the dredge and evaluation of the operating conditions of the dredge when the take occurred. Based on the history of takes, the proposed conservation measures would reduce, but not eliminate, the potential for incidental takes of sea turtles.

Underwater Noise

Underwater sounds produced by dredges and other industrial sources have the potential for physiological and behavioral effects on marine mammals, sea turtles, and fishes. Although the effects of dredging sounds on fishes have not been fully assessed, limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) changes in fishes (Popper and Hastings 2009). Dredging noise may also mask biologically important signals, thereby interfering with fish communication and predator/prey interactions [Normandeau Associates, Inc. (NAI) 2012]. Although the effects of dredging noise are not fully known, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

The NMFS defines two levels of acoustic “take” under the Marine Mammal Protection Act (MMPA). Actions that may expose marine mammals to noise in excess of the values shown in Table 5.1 constitute Level A harassment with the potential to cause injury. Actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. The NMFS has used similar criteria to assess the impacts of dredging noise on sea turtles, specifically ≥180 dB re 1μPa rms for injurious effects, and based on a study by McCauley et al. (2000), ≥166 dB re 1μPa rms for behavioral disruption (NMFS 2010b). Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1μPa rms at a distance of 40m during navigation dredging in Mobile Bay, Alabama. A more recent study of the sounds produced by hopper dredges during sand mining at offshore borrow sites in Virginia reported noise levels ranging from 161 to 179 dB re 1μPa rms (Reine et al. 2014). Peak source levels did not exceed the NMFS Level A harassment threshold (≥180 dB re 1μPa rms) for injurious effects on marine mammals; however, noise levels generally exceeded the NMFS Level B harassment threshold (≥120 dB re 1μPa rms) within 1.2 km of the source and generally remained at or near 120 dB re 1μPa rms out to 2.1 km. The peak levels reported by Reine et al. (2014) indicate that hopper dredge source levels may exceed the 166 dB re 1μPa rms threshold for behavioral effects on sea turtles; however, given the attenuation of source levels to ~120 dB re 1μPa rms at a distance of ~1.2 km, levels >166 dB re 1μPa rms would likely be confined to the immediate vicinity of the dredge. According to a study by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms with rapid attenuation occurring at short distances from the dredge and sound levels becoming essentially inaudible at a distance of approximately 500 m.

Most observations of marine mammal responses to anthropogenic noise have been limited to short-term responses involving cessation of feeding, resting, or social interactions. Although shipping and industrial noise may represent a threat to large whales, the severity of this potential threat is unknown (NMFS 2010c). Observed responses of baleen whales to various types of underwater noise include avoidance of the source area, cessation of feeding, rapid swimming away from the source, altered dive patterns, vocalization changes, and changes in respiration (Fisheries and Oceans Canada 2010). North Atlantic right whales in the Bay of Fundy summer foraging area showed no response to experimental shipping noise. However, whales exposed to synthetic alert signals abandoned their foraging dives and remained at the surface for the duration of the exposure period (Nowacek et al. 2004). Responses of Hawaiian humpback whales to experimental shipping noise included changes in diving/surfacing behavior, swimming speed, and direction of travel (Hemphill et al. 2006, Green and Green 1990). Although baleen whale hearing has not been studied directly, they are assumed to have a hearing range that is similar to their vocalizations (NMFS 2010b). Based on an analysis of vocalizations and comparative anatomy, Southall et al. (2007) assigned baleen whales to a low frequency (7 Hz –

Table 5.1. Level A [permanent threshold shift (PTS) onset] harassment values for marine mammal hearing groups.

Hearing Group	PTS Onset (Received Level)	
	Impulsive	**Non-Impulsive**
Low-Frequency (LF) Cetaceans	PK: 219 dB SEL $_{cum}$: 183 dB	SEL $_{cum}$: 199 dB
Mid-Frequency (MF) Cetaceans	PK: 230 dB SEL $_{cum}$: 185 dB	SEL $_{cum}$: 198 dB
High-Frequency (HF) Cetaceans	PK: 202 dB SEL $_{cum}$: 155 dB	SEL $_{cum}$: 173 dB
Phocid Pinnipeds (PW)	PK: 218 dB SEL $_{cum}$: 185 dB	SEL $_{cum}$: 201 dB
Otariid Pinnipeds (OW)	PK: 232 dB SEL $_{cum}$: 203 dB	SEL $_{cum}$: 219 dB

Source: NMFS 2016

PK = Peak sound level
SEL_{cum} = Cumulative sound exposure level

22 kHz) functional hearing group. Since most of the noise produced by hopper and cutterhead dredges falls within the 70 Hz to 1 kHz range (Clarke et al. 2002), baleen whales may be more susceptible to dredging noise than other cetaceans (Thomsen et al. 2009).

Marine mammals that may be present along Bogue Banks during dredge and fill operations would include Atlantic spotted and bottlenose dolphins, humpback whales, and North Atlantic right whales (DoN 2008a, 2008b). The rapid swimming capabilities of dolphins would most likely limit their exposure to noise levels ≥120 dB to very brief periods. The potential effects of dredging noise on the behavior of large whales are not fully known. However, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the Permit Area and are not actively engaged in critical feeding or mating behaviors, no significant adverse behavioral effects would be expected.

Vessel Collisions with Marine Mammals and Sea Turtles

The potential for collision impacts on marine animals is primarily associated with hopper dredges during transit between dredging sites and disposal areas. Although hopper dredges travel at slow speeds (~3 knots) during the active dredging process, the maximum unloaded transit speed of a hopper dredge is ~17 knots (USACE 2008). Cutterhead dredge plants are anchored during operations; therefore, any potential risk of collisions would be limited to relatively brief periods of dredge repositioning. In the case of hopper dredges and other large, relatively slow moving vessels; the collision risk is primarily a concern for large whales. Based on the mobility and avoidance behavior of sea turtles and the relatively slow speed of dredges during transit, dredging vessels present a negligible collision risk to sea turtles (NMFS 2012c). There are no documented instances of lethal whale-dredge interactions and only one reported non-lethal interaction, which occurred in 2005 when a hopper dredge collided with an apparent right whale along the Georgia coast near the Brunswick Harbor entrance channel (NMFS 2012c). However, the NMFS has concluded that dredge traffic between offshore borrow sites and beach placement areas may present a collision risk to large whales along the South Atlantic Coast, specifically humpback and right whales that swim close to shore during winter migration periods. Dredging projects incorporate standard conservation measures to minimize the risk of marine mammal collisions; including the 24-hour presence (during active dredging and transit) of protected species observers and compliance with federal regulations [50 CFR 224.103(c)] prohibiting the approach of any vessel within 500 yards of right whales.

The principal threat to manatees under the dredge and fill alternatives would be the potential for hopper dredge vessel collisions during transit between dredging areas and disposal sites. However, dredging windows would be expected to limit municipal and federal hopper dredge operations to the colder months when manatees are unlikely to be present in NC waters. Of the 99 opportunistic manatee sightings that were reported in NC between July 1991 and September 2012, nearly all (93%) occurred between June and October when water temperatures were above 20ºC (Cummings et al. 2014). Although occurrences during the dredging window would be unlikely, dredging contracts would require adherence to USFWS Guidelines for Avoiding Impacts to the West Indian Manatee: Precautionary Measures for Construction Activities in North Carolina Waters (Appendix I. Based on adherence to these guidelines and the low probability of manatee occurrences in the Permit Area during dredge and fill operations; direct, indirect, and cumulative dredging-related effects on manatees would not be expected under any of the alternatives.

Sand Placement

Construction Methods

Sand delivery by both hopper and cutterhead dredges is accomplished by pumping a mixture of sand and water (slurry) through a submerged pipeline onto the recipient beach. Sand delivery operations typically employ a spreader that is attached to the discharge end of the pipeline. Spreaders are designed to slow the velocity of the discharge to prevent erosion and facilitate sediment settling. Temporary shore-parallel containment dikes are constructed in front of the onshore beach discharge points to facilitate sediment settling and reduce turbidity in the nearshore environment. As placement activities progress, the onshore pipeline is extended along the beach by adding new sections of pipe. Pipeline placement is typically on the upper beach, but seaward of the dunes and any upper beach vegetation. Booster pumps may be required along the pipelines as they are extended along the beach. The location where the submerged pipeline emerges onto to the beach may also shift incrementally as construction progresses along the beach. Front-end loaders or other heavy equipment are used to transport and position the onshore pipeline sections throughout the construction process.

Bulldozers and other heavy equipment such as backhoes, front-end loaders, and tractors are used to redistribute and grade the discharged sediment as it falls out of suspension. A variety of supporting vehicles such as pick-up trucks and all-terrain vehicles are typically used to transport equipment and personnel along the beach throughout the construction process. Grade stakes are placed throughout the beach fill template to facilitate the construction of berms and dunes to design specifications. Constructed dunes are typically stabilized by planting native vegetation from the landward toe of the dune to the seaward intersection of the dune with the constructed berm. In order to maintain separation between the public and potentially hazardous operations, the active construction area, consisting of an ~500-ft zone on either side of the beach fill discharge point, is typically fenced. Sand placement operations are generally conducted around-the-clock, thus requiring appropriate nighttime lighting in accordance with USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones. Regulations also require front and back lighting on all transport vehicles and heavy equipment during nighttime operations. Post-construction tilling and/or escarpment leveling may be conducted as needed based on post-project monitoring results. Tilling and leveling are accomplished by heavy equipment similar to that employed in redistribution and grading operations. Compacted beach fill areas between the toe of the dune and the MHW line are typically tilled to a depth of 24 inches using a series of overlapping passes to ensure thorough decompaction. Chain-linked fencing or a similar apparatus may be dragged over the tilled areas as necessary to eliminate any ruts and furrows created by the tilling process. Escarpments are regraded according to the original berm design specifications.

Effects on Marine and Estuarine Benthic Communities

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. As previously described in Section 3, sediment analyses have demonstrated the compatibility of all proposed beach fill material in accordance with state technical standards. Furthermore, adherence to a 16 November - 30 April environmental nourishment window would avoid peak benthic invertebrate recruitment periods in NC [May through September (Hackney et al. 1996, Diaz 1980, Reilly and Bellis 1978)]. It is expected that the use of compatible sediments and avoidance of peak recruitment periods would facilitate relatively rapid benthic community recovery. Therefore, it is expected that the impacts of sand placement on intertidal benthic communities would be short term and localized under all of the nourishment alternatives.

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. 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).

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. However, it is anticipated that relatively rapid benthic infaunal recruitment would provide substantial prey resources along the disturbed reaches within a relatively short period of time, and substantial undisturbed intertidal beach foraging habitat would be available within the Permit Area during benthic recovery periods. Therefore, it is anticipated that the effects of benthic prey loss on shorebirds and surf zone fishes would be short term and localized.

Effects on Dry Beach and Dune Communities

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. In the case of the alternatives evaluated in this EIS, it is anticipated that the use of beach compatible sediments and avoidance of recruitment periods would facilitate relatively rapid recovery of ghost crab populations. Therefore, it is expected that the impacts of sand placement would be short-term and localized under all of the nourishment alternatives.

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.

Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. The five year study (2002-2007) included monitoring of nesting activity, hatching success, substrate compaction, and nest temperature. No significant beach nourishment effects on nesting success (i.e., nest/false crawl ratios) were detected, and there was no indication that nourishment adversely affected egg development or hatching success, with the exception of one nest on that apparently failed due to poor gas exchange. Nourishment had no significant effect on compaction; however, nests in nourished areas were on average 1.9°C warmer than nests laid at the same time on undisturbed beaches.

Although sex ratios were not determined, Holloman and Godfrey concluded that the increase in nest temperature on nourished beaches probably increased the number of females produced.
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. The initial effects of sand placement events 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 shorebirds; potentially resulting in reduced survivability and productivity. 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).

5.3 Projected Effects of the Alternatives

The following sections describe the environmental consequences of each alternative in detail. A matrix summarizing the impacts of all alternatives on all resource categories is provided in Appendix J.

5.3.1 Alternative 1: No Action

Alternative 1 (No-Action) represents the continuation of shore protection management efforts over the next 50 years in the same manner as in the past. Continuing management activities would include: 1) limited erosional hotspot response nourishment projects implemented by the individual municipalities, 2) Bogue Inlet ebb channel relocation projects implemented by the Town of Emerald Isle and/or County, 3) USACE placements of navigation dredged material on Atlantic Beach and Fort Macon via maintenance of the MCH outer harbor channel (Beaufort Inlet), and 4) USACE placements of navigation dredged material on the west end of Emerald Isle via maintenance of the AIWW Bogue Inlet Crossing. Additional activities that would be expected to continue under Alternative 1 include beach bulldozing above MHW and temporary sandbagging by local municipalities and/or individual property owners. It is anticipated that hotspot reaches along Pine Knoll Shores and eastern Emerald Isle would be nourished with ~1.0 MCY of sand approximately every 11 years. Based on the relatively large volumetric requirements for hotspot projects, it is assumed that beach fill would principally be acquired from the old and/or current ODMDS via hopper dredging. However, beach fill could also be acquired from the Area Y offshore borrow site via hopper or cutterhead dredging.

It is anticipated that ebb channel realignments would follow the design and methods employed during the 2005 Bogue Inlet Channel Erosion Project. Accordingly, realignments would entail the construction of a ~6,000-foot-long channel with variable bottom widths ranging from 150 to 500 ft. Channel excavation is anticipated to yield just over 1.0 MCY of beach compatible dredged material. It is anticipated that ~0.2 MCY of the dredged material from the new channel would be used to construct a closure dike across the old channel, with the remaining ~0.80 MCY of material being pumped directly onto the beaches of western Emerald Isle. For impact analysis purposes, it is assumed that at least two channel realignment events would occur over the next 50 years. Pursuant to the DMMP recommended plan, continuing USACE beach disposal on Atlantic Beach/Fort Macon would involve placements of up to 1,200,000 cy of compatible dredged material on approximately 6.1 miles of beach (Stations 77 to 107) every three years. AIWW inlet crossing beach disposal projects would be assumed to continue every two to three years, with placement volumes approximating the recent average of ~60,000 cy per event. The analyses of potential direct and indirect effects under Alternative 1 consider only those activities that would be undertaken by local entities; however, USACE activities are considered in the analyses of cumulative effects.

5.3.1.1 Marine Benthic Communities

5.3.1.1.1 <u>Soft Bottom</u>

Direct and Indirect Impacts

Under Alternative 1, the hotspot nourishment reaches along Emerald Isle and Pine Knoll Shores would each require ~1 MCY of beach fill every 11 years. As previously described, it is expected that most of the beach fill would be acquired from the ODMDS using a hopper dredge. Additional beach fill could be acquired from Area Y using a hopper or cutterhead dredge; however, the total volumetric availability at Area Y is limited to ~1.5 MCY. At an average dredge cut depth of ~3.5 ft, the removal of ~2 MCY of material by a hopper dredge would disturb ~400 acres of marine soft bottom habitat. Compatible sand deposits at the ODMDS consist of dredged material mounds that are superimposed on the native seafloor. A two-ft vertical buffer of compatible material would be retained within the ODMDS, and dredging of the mounded ODMDS deposits would not extend to or below the original seafloor. Thus, dredging would not directly alter sediment composition within the ODMDS, and it is unlikely that fine sediment deposition would alter sediment composition in the post-extraction dredging footprints. A two-ft vertical buffer would also be retained within Area Y, thus dredging would not directly alter sediment composition. Excavation at Area Y would extend below the original seafloor elevation, resulting in a higher potential for fine sediment deposition; however, the relatively shallow excavation depths (5-10 ft) and small areas of the two proposed dredging footprints (each <50 acres) would limit the likelihood of significant fine sediment accumulation. Dredging would remove the majority of the associated benthic infaunal and epifaunal invertebrates;

resulting in an initial sharp decline in community abundance, diversity, and biomass within the dredging footprints. However, benthic recovery would begin immediately upon the cessation of dredging operations; and it is anticipated that relatively shallow dredge cuts, the mounded nature of the sand deposits at the ODMDS, and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid dredge cut infilling and benthic community recovery. As described in the General Effects section, most offshore borrow site recovery studies have reported rapid recovery of community abundance and diversity when relatively shallow dredge cuts were employed and peak infaunal recruitment periods were avoided. In the specific case of hopper dredging at the offshore borrow sites, the relatively shallow (~3.5 ft) cut depths and the retention of intervening ridges with infaunal recruits would be expected to facilitate rapid dredge cut infilling and infaunal recolonization. Therefore, it is anticipated that the direct impacts of offshore dredging on benthic communities would be short-term and localized to the excavation footprints.

Dredging-induced sediment suspension and redeposition may impact soft bottom communities within and adjacent to the excavation footprints through burial, adverse effects on the gill-breathing and filter-feeding abilities of benthic organisms, and/or adverse effects on the foraging and/or predator avoidance behaviors of visually-oriented demersal fishes (Michel et al. 2013). However, as described in the General Effects section, dredging-induced sediment suspension is typically localized and short-term when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As described in Section 3.3, sediments associated with the offshore borrow areas are composed of beach compatible sand with a very small fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension and redeposition would be short-term and localized. Losses of benthic invertebrates within the borrow site dredging footprints may negatively affect the foraging activities of predatory demersal fishes (e.g., flounders, rays, spots, and croakers), potentially inducing demersal fishes to seek out alternative soft bottom foraging habitats (Byrnes et al. 2003). However, it is anticipated that the effects of prey loss on demersal fishes would be localized and short-term based on the following considerations: 1) early recruitment of opportunistic benthic taxa to the disturbed areas would provide substantial prey resources within a relatively short period of time, 2) demersal fishes are highly mobile and capable of seeking out alternative habitats, and 3) the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. The delivery of dredged sand to the beach would involve the placement of pipelines on the subtidal seafloor, resulting in additional direct impacts on soft bottom communities; however, it is anticipated that pipeline impacts would be negligible since the impacts would be confined primarily to a narrow strip of substrate underlying the pipelines, and the extent of physical habitat disturbance would be minimal once the pipelines are removed.

Beach placement would directly impact additional areas of subtidal soft bottom habitat within the surf zone. Sand placement within the subtidal portions of the beach fill footprints would result in the burial and loss of the associated soft bottom benthic invertebrate infauna. However, benthic recovery would begin immediately upon the cessation of placement operations; and it is anticipated that the use of beach compatible material and avoidance of peak invertebrate recruitment periods would facilitate relatively rapid benthic community recovery. As described in the General Effects section, benthic soft bottom communities in shallow high-energy environments are adapted to frequent natural perturbations and generally recover rapidly from disturbance. Therefore, it is anticipated that the direct effects of sand placement on soft bottom benthic communities would be short-term and localized. Increases in suspended sediment concentrations and turbidity would be expected within the surf zone in the immediate vicinity of the active sand slurry discharge point. Sediment suspension and redeposition may have effects on soft bottom communities and surf zone fishes similar to those described above for borrow site dredging operations. However, based on the use of beach compatible sand with minimal fines and the employment of temporary dikes and spreaders to contain the discharged sand slurry, it is anticipated that sediment suspension effects would be short-term and localized.

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 within the Permit Area.

Cumulative Impacts

The potential for temporally crowded cumulative effects (i.e., recurring impacts on a site-specific resource that overlap in time) on marine soft bottom communities under Alternative 1 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 and/or sand placement events were insufficient to allow for full recovery of benthic communities. Although benthic recovery studies at offshore borrow sites have generally reported rapid recovery of community abundance and diversity; some community characteristics; including community composition and the biomass of some longer-lived species; may require longer periods of two to three years to reach pre-impact levels. Based on the anticipated need for hotspot nourishment projects approximately every 11 years, sand placement and associated dredging operations at the offshore borrow sites would not be expected to have any temporally crowded cumulative effects on benthic communities. The potential for spatially crowded cumulative impacts under Alternative 1 would depend on the proximity of additional separate dredge and fill actions and the potential for overlapping effects on soft bottom communities. Additional separate dredging and disposal activities that may impact marine soft bottom communities within the Permit Area would include federal maintenance dredging of the MCH entrance channel and associated disposal operations at the ODMDS, as well as USACE beach disposal operations on Atlantic Beach/Fort Macon. These additional activities may coincide with hotspot nourishment and associated offshore borrow site dredging operations, 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 in the Permit Area, 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.

5.3.1.1.2 Hardbottom

Direct, Indirect, and Cumulative Impacts

State coastal management regulations prohibit borrow sites within 500m of hardbottom areas (15A NCAC 07H.0208). The 500-m rule is designed to prevent both direct physical impacts from dredging, as well as indirect impacts related to the dispersal and redeposition of suspended sediments. Exposed hardbottom features are primarily associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf, which are located well seaward of the beach fill placement areas. Hall (2011) conducted a remote sensing survey for hardbottom sites at the likely offshore borrow sites; including the current ODMDS, former ODMDS, and Area Y. No potential hardbottom sites were identified within 500m of the proposed ODMDS borrow areas. A single hardbottom feature covering an area of approximately 112 sq ft was identified within the Area Y assessment area; however, the specific borrow sites (Y-80/75 and Y-120/90) that would potentially be dredged under Alternative 1 are separated from the identified hardbottom feature by a distance of more than 500 m. Additional dredging operations in Bogue Inlet would not be expected to have any effect on hardbottom communities, as exposed hardbottom features are associated with areas well seaward of the inlet on the lower shoreface and adjacent inner continental shelf. Potential sand delivery pipeline routes for hotspot nourishment projects have yet to be identified; however, approvals of proposed projects and the issuance of USACE Section 404/10 permits would be contingent on pre-project surveys demonstrating avoidance of hardbottom features. Based on the absence of hardbottom features within 500m of the proposed borrow sites; and the commitment to avoid hardbottom sites during pipeline placement; Alternative 1 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.3.1.2 Marine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Compatible sand deposits at the former and current ODMDS borrow sites are contained in a series of dredged material disposal mounds that have maximum elevations ranging from approximately -31 to -40 ft NAVD88. Extraction of the ODMDS deposits for hotspot nourishment projects would require the retention of a buffer of compatible disposal mound material above the underlying incompatible sediments. Depending on the extent of extraction, multiple dredging events over the next 50 years could reduce the elevations of the mounds by approximately ten to 20 ft; however, excavation would not extend to or below the original underlying seafloor. Although the hydrodynamic effects of ODMDS dredging have not been evaluated through modeling; considering that excavation would not extend to or below the prevailing elevation of the seafloor, it is assumed that any effects on ocean currents and wave conditions would be minor and localized. The Area Y offshore borrow sites consist of two small isolated deposits (Y-80/75 and Y-120/90) with a combined total volume of ~1.5 MCY. The two Area Y borrow sites encompass a total seafloor area of less than 100 acres, and excavation would be limited to maximum depths of 5-10 ft below the original seafloor elevation. Based on the limited areal extent of dredging and the relatively shallow maximum dredge cut depths at Area Y, it is assumed that any effects on ocean currents and wave conditions would be minor and localized.

Water Quality

Direct, Indirect, and Cumulative Impacts

Under Alternative 1, dredging-induced sediment suspension and associated turbidity increases at the offshore borrow sites may affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of marine organisms. However, as described in the General Effects section, dredging-induced sediment suspension is typically short-term and localized when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As discussed in Section 3.3, all potential beach fill deposits at the borrow sites are composed of highly compatible sands with very small fine sediment fractions. Therefore, it is anticipated that the effects of dredging-induced sediment suspension on marine water quality and pelagic communities would be short-term and localized under Alternative 1.

In addition to potential effects at the borrow sites, sand placement operations would produce temporary increases in suspended sediment concentrations and turbidity that may have similar effects on marine organisms in the surf zone along the recipient beaches. However, as described in the General Effects section, the results of water quality monitoring during nourishment operations along Bogue Banks and other southeastern NC beaches indicate that turbidity increases are typically confined to the surf zone in the immediate vicinity of the slurry discharge point. Furthermore, it is anticipated that the use of compatible beach fill with minimal fines and the use of temporary dikes and spreaders to contain the discharged sand slurry would reduce the extent of sediment suspension. Therefore, it is anticipated that sediment suspension effects attributable to sand placement would be short-term and localized. Based on the short-term and localized nature of the anticipated sediment suspension effects, cumulative impacts would not be expected under Alternative 1.

Entrainment

Direct, Indirect, and Cumulative Impacts

Hopper and cutterhead dredges both have the potential to entrain fishes and invertebrates during all life cycle phases (adults, juveniles, larvae, and eggs). Based on the entrainment studies discussed in the General Effects section, it is anticipated that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment in the dredge intake pipe. Municipal hotspot-related dredging operations at the offshore borrow sites would entrain the planktonic eggs and larvae of marine fishes and invertebrates that occur in the vicinity of the dredge pipe suction field. However, considering the diffuse distribution of larvae in offshore waters and the anticipated limited extent of sand extraction over the 50-year planning period, it is anticipated that the effects of larval entrainment on marine fish and invertebrate populations would be negligible.

Sea turtles are vulnerable to entrainment by hopper dredges and could occur in the vicinity of the offshore borrow sites during hotspot hopper dredging operations. As in the case of prior County/municipal offshore dredging projects, it is assumed that hotspot hopper dredging operations under Alternative 1 would employ conservation measures to reduce the risk of sea turtle entrainment; including adherence to a 16 November - 30 April hopper dredging window, mandatory use of rigid draghead deflectors and associated operational parameters, and sea turtle relocation trawling. Adherence to a 16 November – 30 April environmental window would limit hopper dredging operations to the colder months when most sea turtles have moved to warmer waters well seaward of the borrow sites. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a sand ridge in front of the draghead as it is drawn along the seafloor, thus pushing sea turtles away from direct contact with and outside the suction field of the draghead. Relocation trawling in front of the dredge has been shown to reduce the risk of entrainment by capturing and relocating any turtles that may be present near the bottom (Dickerson et al. 2007). However, as described in the General Effects section, six sea turtles have been entrained by hopper dredges during offshore borrow site operations along Bogue Banks that employed all of these measures. It is expected that the use of these measures under Alternative 1 would minimize, but not eliminate the risk of sea turtle entrainment. Cutterhead dredges are not known to take sea turtles; and therefore, any use of cutterhead dredges at the offshore borrow sites (specifically Area Y) would not be expected to present any risk of entrainment to sea turtles.

The federally listed Atlantic sturgeon could also occur in the vicinity of the offshore borrow sites during hopper dredging operations for hotspot nourishment projects; however, occurrences in the open ocean would likely consist of subadults and adults that would be able to avoid the dredge. As described in the General Effects section, analysis of historical take along the South Atlantic Coast indicates that the risk of hopper dredge entrainment is primarily confined to dredging within riverine channels (USACE 2014c). The potential risk of entrainment to adult sturgeon is presumed to be low, and the use of rigid deflecting dragheads and associated operating requirements likely reduces the risk of entrainment (Dickerson et al. 2004). Cutterhead dredges have not been implicated in sturgeon takes along the South Atlantic Coast, and would not be expected to present any risk of entrainment to sturgeon. Relocation trawling may present a minor risk of injury to Atlantic sturgeon; however, the extensive use of relocation trawling for sea turtles and sturgeon along the US Atlantic Coast has resulted in very few reported injuries. Out of more than 1,300 reported captures of Atlantic and shortnose sturgeon during long-term trawl surveys and relocation trawling efforts along the mid-Atlantic and northeast Atlantic states, only two sturgeon injuries were reported (NMFS 2015). Both injuries were related to debris in the trawl net; and NMFS has since adopted modified net requirements that are expected to reduce the risks associated with the capture of debris during relocation trawling. According to NMFS, it is unlikely that significant injuries to any Atlantic or shortnose sturgeon would occur during trawling operations that employ the new nets in combination with short tow durations and careful sturgeon handling (NMFS 2015). Relocation trawling under Alternative 1 would follow all NMFS requirements to minimize potential adverse effects on Atlantic sturgeon. Based on these considerations, it is anticipated that the risk of sturgeon entrainment by hopper dredges and/or injury due to trawling at the offshore borrow sites would be negligible under Alternative 1.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Based on the noise studies described in the General Effects section, the sound levels produced by cutterhead dredges under Alternative 1 would not be expected to exceed the NMFS thresholds for behavioral or injurious effects on marine mammals or sea turtles. In the case of hopper dredging, the previously described studies indicate that sound levels would not be expected to exceed the NMFS thresholds for injurious effects on marine mammals or sea turtles, but may exceed the thresholds for behavioral effects on marine mammals and sea turtles within 2.1 and 1.2 km of the dredge, respectively. As previously discussed, behavioral effects may include avoidance responses, such as diving or an increase in swimming speed; however, considering the transient nature of large whale occurrences in the Permit Area and the mobility and avoidance behavior of dolphins and sea turtles, it is expected that any behavioral effects would be short-term and localized.

As described in the General Effects section, limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) responses in fishes (Popper and Hastings 2009). However, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

Vessel Collisions

Direct, Indirect, and Cumulative Impacts

Municipal hotspot-related dredging operations at offshore borrow sites would coincide with right and humpback whale migration periods along the NC coast. Although instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent right whale along the Georgia coast near the Brunswick Harbor entrance channel (NMFS 2012c). The risk of collisions between dredges and whales during sand extraction would be very low, as hopper dredges travel at slow speeds (approximately three knots) during the active dredging process. The potential for vessel strikes would exist primarily during transit between the offshore dredging areas and disposal sites along the beach (unloaded hopper dredges are capable of speeds up to ~17 knots during transit). As in the case of prior offshore sand extraction projects, it is assumed that municipal hopper dredging operations at the offshore borrow sites under Alternative 1 would employ conservation measures to reduce the risk of vessel collisions; including 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience and compliance with federal regulations prohibiting the approach of any vessel within 500 yards of a right whale [50 CFR 224.103(c)]. It is expected that these conservation measures would reduce the risk of collisions to negligible levels. As described in the General Effects section, based on water temperature, the occurrence of a manatee in Permit Area waters during the dredging window would be unlikely. Furthermore, manatees are generally restricted to estuarine waters and would not be expected to occur in the vicinity of the offshore borrow sites or the hopper dredge ocean transit routes between the borrow sites and nearshore pump-out stations. Based on these considerations, it is expected that the risk of interactions between hopper dredges and manatees would be negligible under Alternative 1.

5.3.1.3 Oceanfront Beach and Dune Communities

Intertidal Beach

Direct and Indirect Impacts

Under Alternative 1, hotspot nourishment projects along Pine Knoll Shores and eastern Emerald Isle would directly impact ~4.5 miles and ~2.5 miles of intertidal beach habitat, respectively. Both hotspot reaches are expected to require nourishment approximately every 11 years.

Additional placements of dredged material derived from Bogue Inlet ebb channel relocations would impact approximately 5.5 miles of beach habitat along western Emerald Isle. Sand placement events would eliminate the majority of the intertidal benthic invertebrate infauna along the affected reaches through direct burial. However, benthic infaunal recovery would begin immediately upon the cessation of sand placement operations, and it is anticipated that the use of compatible beach fill and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid benthic community recovery. As described in the General Effects section, most intertidal benthic recovery studies have reported recovery within one year when highly compatible beach fill sediments were used and peak infaunal larval recruitment periods were avoided. Therefore, it is anticipated that the direct impacts of sand placement on intertidal benthic communities would be short-term and localized to the beach fill areas.

Beach construction activities; including heavy equipment operations, generator use, night-time lighting, and other related activities; may disrupt shorebird foraging activities and/or prevent shorebirds from using otherwise suitable intertidal beach foraging habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone. Direct impacts on the benthic infaunal prey base may reduce 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 and foraging habitat loss 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. However, it is anticipated that relatively rapid benthic infaunal recruitment would provide substantial prey resources along the disturbed reaches within a relatively short period of time, and substantial undisturbed intertidal beach foraging habitat would be available within the Permit Area during benthic recovery periods. Therefore, it is anticipated that the effects of benthic prey loss on shorebirds and surf zone fishes would be short-term and localized.

Cumulative Impacts

Under Alternative 1, the projected Emerald Isle East and Pine Knoll Shores hotspot nourishment intervals of 11 years would provide ample time for full recovery. Separate beach fill placement actions affecting the hotspot reaches could potentially include USACE disposals of navigation dredged material from the MCH channels on Pine Knoll Shores, dependent on the availability of material and the availability of Town monies to offset additional costs in excess of the federal least cost disposal option. However, given the projected 11-year maintenance nourishment interval for the Pine Knoll Shores hotspot reach, additional USACE placements would be unlikely to affect the ability of benthic communities to fully recover during the interim periods between nourishment events. United States Army Corps of Engineers federal placements of dredged material from the AIWW Bogue Inlet Crossing on the west end of Emerald Isle (~0.5 mile) are primarily confined to the inlet shoreline, but may overlap a short segment of the adjoining oceanfront beach placement area associated with inlet channel relocation events. However, considering the minimal extent of overlap, additional USACE placements would be unlikely to affect the ability of benthic communities to fully recover during the interim periods between nourishment events. Therefore, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 1. Continuing USACE beach disposal events along Atlantic Beach/Fort Macon could coincide with hotspot nourishment projects or Bogue Inlet channel relocation beach disposal events on western Emerald Isle. The maximum combined linear extent of oceanfront beach impact during any given year would be ~12.5 miles (~50% of the entire ocean beach) in the event of concurrent nourishment of both hotspot reaches (~7 miles) and the Atlantic Beach/Fort Macon reach (~5.5 miles). Combined losses of intertidal benthic infauna along the USACE and municipal nourishment reaches may have cumulative prey loss effects on surf zone fishes and shorebirds. However, cumulative effects would be limited to periods of benthic community recovery, and substantial undisturbed intertidal beach foraging habitat would be available within the Permit Area during recovery periods. Therefore, it is expected that any spatially crowded cumulative effects under Alternative 1 would be short term and localized.

Other separate actions affecting the oceanfront beaches along Bogue Banks could include temporary sandbag placement and beach bulldozing activities. Although generally occurring on a much smaller scale, these activities would have the potential for impacts on intertidal beach habitats and communities that are comparable to those associated with sand placement. Depending on the timing and location of specific projects, the combined impacts of sand placement under Alternative 1 and separate sandbagging/bulldozing actions could have cumulative effects on intertidal beach habitats and communities. Cumulative effects may occur if the combined actions increase the frequency of disturbance along a specific beach segment or if the combined actions result in simultaneous impacts on separate beach segments. However, considering the small scale of sandbagging and bulldozing activities, it is expected that any cumulative effects would be minor and localized.

<u>Dry Beach and Dune</u>

Direct Impacts

Dry beach (berm) and dune construction under Alternative 1 would involve the use of bulldozers and other heavy machinery to redistribute and grade the placed material according to design profile specifications. Construction activities would directly impact ghost crabs and dune vegetation through burial and/or mechanical disturbance. However, it is anticipated that the replanting of constructed dunes with native species would facilitate dune stabilization and plant community recovery. Furthermore, it is anticipated that the use of compatible beach fill and avoidance of peak recruitment periods would facilitate relatively rapid ghost crab recovery. As described in the General Effects section, post-nourishment monitoring studies have reported relatively minor and short-term effects on ghost crab populations when highly compatible beach fill sediments were used and peak recruitment periods were avoided. Therefore, it is expected that the direct impacts of sand placement on dune vegetation and macroinvertebrate infaunal communities would be short-term and localized to the beach fill areas. Sand placement projects would avoid the sea turtle nesting and hatching season through adherence to the 16 Nov - 30 April sea turtle nesting and hatching environmental window. Therefore, direct impacts on nesting females, nests, or hatchlings would not be expected under Alternative 1. Beach construction activities; including heavy equipment operations, generator use, night-time lighting, and other related activities; may disrupt shorebird activities and/or prevent shorebirds from using otherwise suitable dry beach roosting and loafing habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone.

Although the full effects of beach fill placement are not known, the USFWS generally believes that nourishment projects completed during the winter are not detrimental to seabeach amaranth (USFWS 2005). Hotspot projects would adhere to a 16 November - 30 April nourishment window, thereby avoiding the majority of the seabeach amaranth growing season; however, nourishment towards the end of the disposal window in April could result in the burial and mortality of some early seedlings. In addition, sand placement and grading operations may redistribute some seeds to unsuitable habitats, thereby preventing successful germination and/or growth. Nourishment may also have beneficial effects on habitat and seed distribution. The restoration of a wider vegetation-free dry beach can improve the quality of potential habitat along severely eroded beaches; and seeds that are banked in borrow site sediments may be transferred to suitable beach habitats (USFWS 2005). Although the relationship between nourishment, seed burial, and germination is poorly understood; increases in seabeach amaranth numbers have been observed following nourishment projects on Bogue Banks, possibly due to the creation of new habitat and/or the redistribution of seeds along with the beach fill (Personal communication, D. Suitor, USFWS Raleigh Ecological Services Field Office, 2011). Based on these considerations, it is expected that any adverse effects on seabeach amaranth under Alternative 1 would be localized and minor.

Indirect Impacts

Beach nourishment may indirectly affect sea turtles through physical modification of dry beach nesting habitat. As described in the General Effects section, observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, substrate compaction, and escarpment formation. Loggerheads prefer steeply sloped beaches and selectively choose nest sites along a given beach that correspond to the steepest slopes. 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 proportion of false crawls on the affected beaches. 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 successively excavate nests. Studies that have documented declines in nesting on nourished beaches have generally reported a return to normal nesting activity by the second or third post-project nesting season. Conversely, in the case of severely eroded beaches, the restoration of a wider and higher dry beach may enhance the quality of sea turtle nesting habitat. Studies have reported immediate increases in nesting success following sand placement on chronically eroded beaches.

As previously described, substrate modifications may have additional negative effects on the nest incubation environment and/or the ability of hatchlings to emerge from their nests. Compaction and the modification of substrate characteristics can alter the nest incubation environment; leading to adverse effects on embryonic development and hatching success. Nourished beaches often retain more water than natural beaches, thereby impeding gas exchange within the nest environment. Warmer nest temperatures attributable to the placement of relatively dark sediments may impede embryonic development or increase the incidence of late-stage embryonic mortality. Sex determination in hatchlings is controlled by nest temperature, with warmer temperatures producing more females and cooler temperatures producing more males. Thus, warmer nest temperatures attributable to sand placement may alter hatchling sex ratios. Measures employed to minimize adverse effects on nesting habitat would include the use of compatible sediments, escarpment monitoring, and sediment compaction monitoring. It is expected that these measures would facilitate relatively rapid physical habitat recovery, thereby minimizing the duration of any adverse habitat-modification effects on sea turtles; however, it is expected that sea turtle nesting could be reduced along the affected reaches for the first post-construction year.

Changes in sediment composition can also potentially affect the suitability of dry beach habitats for nesting shorebirds and waterbirds. However, as described in the General Effects section, traditional oceanfront dry beach and dune breeding sites on NC's stabilized developed barrier islands have essentially been abandoned in favor of more isolated inlet spit/shoal habitats and estuarine spoil islands. It is expected that any potential beneficial effects of nourishment on oceanfront beach nesting habitat would be negligible in comparison to the long-term exclusionary effects of development, stabilization, and chronic human disturbance. Therefore, Alternative 1 would not be expected to have any indirect effects on the suitability of oceanfront beach shorebird/waterbird nesting habitats. Hotspot nourishment projects may have short-term beneficial effects on dry beach shorebird roosting habitat; however, it is expected that any beneficial effects would be limited by considerable unmitigated erosion during the lengthy interim periods between nourishment events.

Cumulative Impacts

Based on the projected hotspot nourishment intervals of 11 years, dry beach habitats and communities would be expected to fully recover during the interim periods between nourishment events. Separate beach fill placement actions affecting the hotspot reaches could potentially include USACE disposals of navigation dredged material from the MCH channels on Pine Knoll Shores, dependent on the availability of material and the availability of town monies to offset additional costs in excess of the federal least cost disposal option. However, given the projected 11-year maintenance nourishment interval for the Pine Knoll Shores hotspot reach, additional USACE placements would be unlikely to affect the ability of dry beach and dune communities to fully recover during the interim periods between nourishment events. USACE federal placements of dredged material from the AIWW Bogue Inlet Crossing on the west end of Emerald Isle (~0.5 mile) are primarily confined to the inlet shoreline, but may overlap a short segment of the adjoining oceanfront beach placement area associated with inlet channel relocation events. However, considering the minimal extent of overlap, additional USACE placements would be unlikely to affect the ability of benthic communities to fully recover during the interim periods between nourishment events. Therefore, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 1. Continuing USACE beach disposal events along Atlantic Beach/Fort Macon could coincide with hotspot nourishment projects or Bogue Inlet channel relocation beach disposal events on western Emerald Isle. The maximum combined linear extent of oceanfront beach impact during any given year would be ~12.5 miles (~50% of the entire ocean beach) in the event of concurrent nourishment of both hotspot reaches (~7 miles) and the Atlantic Beach/Fort Macon reach (~5.5 miles). Simultaneous USACE and County sand placement projects could increase the linear extent of habitat modification effects on sea turtle nesting and shorebird roosting. However, given the short term nature of these impacts, it is expected that any cumulative effects would be relatively minor. Therefore, it is expected that any spatially crowded cumulative effects under Alternative 1 would be short term and localized.

Other separate actions affecting the oceanfront beaches along Bogue Banks could include temporary sandbag placement and beach bulldozing activities, which may have impacts on dry beach and dune communities that are comparable to those of sand placement. However, considering the small scale of sandbagging and bulldozing activities, it is expected that any cumulative effects would be minor and localized.

5.3.1.4 Inlet and Estuarine Resources

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Based on the offshore locations of the ODMDS and Area Y borrow sites and the mid-island locations of the hotspot reaches, municipal hotspot dredging and sand placement operations would not be expected to have any direct or indirect effects on intertidal flats and shoals. Realignments of the Bogue Inlet ebb channel under Alternative 1 would involve the excavation of a new mid-inlet channel by a cutterhead dredge. Any intertidal shoals that are present within the new channel footprint at the time of realignment events would be excavated and converted to subtidal soft bottom habitat. Associated intertidal benthic infaunal and epifaunal communities within the new channel footprint would be removed and replaced by subtidal soft bottom benthic communities. Any direct losses of intertidal benthic invertebrates may reduce foraging opportunities for shorebirds and demersal fishes. Associated beach placement operations would not be expected to have any direct impacts on intertidal flats and shoals, as these habitats would be lacking along the eroded Bogue Banks inlet shoreline and the excavated material would be placed primarily along the oceanfront beach of Emerald Isle. Delivery pipelines leading to the oceanfront beach would be routed to avoid intertidal flats and shoals and other high value inlet habitats for shorebirds. Ebb channel realignment dredging operations may disrupt the foraging activities of shorebirds, potentially inducing shorebirds to expend additional energy seeking out alternative intertidal foraging habitats. However, during-construction monitoring for the 2012/2013 New River Inlet relocation project showed continued use of inlet complex habitats by a diverse assemblage of coastal waterbirds (USACE unpublished data). Furthermore, considering that USACE maintenance dredging of the Bogue Inlet navigation channel has occurred twice a year for decades, shorebirds are likely to exhibit some degree of habituation to inlet dredging activities under Alternative 1. Therefore, it is expected that any dredging-related shorebird disturbance under Alternative 1 would be short term and localized to the immediate vicinity of the active construction zone.

Indirect Impacts

The Bogue Inlet ebb channel is currently exhibiting an eastward migration pattern that is similar to its rapid eastward migration leading up to the 2005 ebb channel relocation project. If the current migration pattern continues, it is anticipated that most of the intertidal and supratidal habitat associated with the Bogue Banks inlet shoreline would eventually be lost to erosion. Prior to the initiation of an ebb channel relocation project, sandbags would likely be placed along the inlet shoreline to protect infrastructure, resulting in shoreline conditions similar to those leading up to the 2005 Bogue Inlet Channel Erosion Project. Some of the habitat loss would likely be offset by concurrent expansion of the Bear Island sand spit and/or new habitat formation elsewhere within the inlet complex in response to shifting patterns of flow and sediment transport. However, analysis of historical ebb channel alignments indicates that an extreme eastward alignment is unfavorable for spit development on both Bear Island and Bogue Banks in relation to a centralized channel alignment (Cleary 2008). Thus, an eastward alignment similar to that of the pre-project 2005 channel may have net adverse effects on the quantity of intertidal flat and shoal habitats for an extended period leading up to ebb channel relocation events.

Realignments of the ebb channel would modify patterns of flow and initiate a period of sediment redistribution and habitat reconfiguration within the inlet complex. During the post-construction adjustment process; the areal extent of intertidal flats and shoals within the inlet complex would be expected to fluctuate in response to sediment redistribution and related conversions between supratidal, intertidal, and subtidal habitats. Over the three-year post construction monitoring period following the 2005 realignment project, the extent of intertidal habitat within the Bogue Inlet complex increased by ~90 acres relative to pre-project conditions, despite the prolonged period of former channel infilling that is discussed below (Rosov and York 2009). In contrast, intertidal habitat declined substantially in the northern estuarine channels that connect the inlet complex to the AIWW, resulting in a net loss of ~229 acres within the more expansive overall study area. However, the post-project monitoring study was unable to distinguish between project-related habitat changes and those attributable to the fundamental dynamic nature of the inlet and the influence of Hurricane Ophelia (September 2005), which removed an estimated 1.5 MCY of sand from Bogue Banks and substantially altered the dynamics of Bogue Inlet. Arriving just months after completion of the 2005 project, Ophelia breached the closure dike across the old channel, thereby reestablishing a connection with the new channel that effectively delayed infilling and abandonment of the old channel, as well as accretion and sand spit development along the Bogue Banks inlet shoreline (Cleary 2008). The storm also breached the northwestern tip of Emerald Isle, establishing a second hydrological connection between the old ebb channel and the Coast Guard channel that leads north to the AIWW. The breach of Emerald Isle resulted in direct losses of intertidal habitat, and it appears likely that the reestablishment of tidal flow between the Coast Guard channel and the Atlantic Ocean was responsible for some of the subsequent intertidal habitat reductions in the northeastern estuarine channel (Rosov and York 2009). Despite the catastrophic effects of a major hurricane within months of completion, the project was resilient and ultimately functioned as intended. By 2009, infilling of the former channel was nearly complete and the eastern segment of the ebb delta had been reconfigured in accordance with the new ebb channel alignment. Spit development on the east end of Bogue Banks occurred concurrently with reorganization of the inlet shoal system, and by October 2010 the developing spit had prograded ~1,830 ft westward into the inlet.

The post-realignment habitat reconfiguration process would produce corresponding changes in the distribution and composition of intertidal benthic communities. Following the 2005 realignment project, two years of post-project benthic monitoring was conducted at intertidal sampling stations along the Bogue Banks inlet shoreline and on the shoals adjacent to the new inlet channel. At the inlet shoreline stations, post-project diversity indices remained similar to pre-project conditions, indicating that intertidal benthic communities were not impacted by the realignment project (Carter et al. 2008). Conversely, year-one post-project diversity indices at the intertidal shoal stations were significantly reduced, and a shift in community structure was observed from pre-project dominance by malacostracans to year-one post-project dominance by a less diverse group of polychaetes. However, data from the year-two post-project intertidal shoal sampling event indicated that the initial project-related disturbance had abated and that the community was returning to pre-project conditions.

Project-related habitat fluctuations may temporarily reduce the availability or quality of intertidal flat and shoal foraging habitats for shorebirds, including the federally listed piping plover and red knot. Following the 2005 project, the results of post-project surveys indicated substantial declines in the numbers of shorebirds and waterbirds that were using habitats within the Bogue Inlet complex. Shorebird numbers were substantially reduced during post-project years one and two, but generally rebounded during the following years (Rice and Cameron 2008). However, colonial waterbird numbers were reduced throughout the five-year (2005-2008) post-project monitoring period. Although the specific project-related effects that may have contributed to the declines were not identified, the final monitoring report noted a number of potential contributing factors; including the loss of high value intertidal flat and tidal pool foraging habitats along the northwestern tip of Emerald Isle, an apparent general decline in the availability of high tide roosting sites, and the failure of the Bogue Banks sand spit to develop as projected during the post-project monitoring period. Positive habitat changes were also indicated, notably the development of expansive high quality intertidal foraging habitat along the Bear Island sand spit. Substantial numbers of piping plovers and red knots, both federally-listed threatened species, continued to use inlet complex habitats throughout the post-project monitoring period. Total piping plover observations initially declined during 2005 (n=149) and 2006 (n=106); however, totals for 2007 (n=181) and 2008 (n=275) surpassed the pre-project annual total of 179 observations. Annual red knot totals from 2005-2008 (range of 138-409 observations) were substantially higher than the pre-project annual total of 41 observations.

Some of the negative habitat changes noted in the final monitoring report were related to Hurricane Ophelia, which impacted Bogue Inlet shortly after the 2005 realignment was completed. The indicated area of intertidal foraging habitat loss was greatly affected by the storm and the resulting breach that severed the northwestern tip of Emerald Isle and reopened the Coast Guard Channel. As described above, the breach of Emerald Isle resulted in direct losses of intertidal habitat, and it appears likely that the reestablishment of tidal flow between the Coast Guard channel and the Atlantic Ocean was responsible for some of the subsequent intertidal habitat reductions in the northeastern estuarine channel. Furthermore, Ophelia breached the sand dike across the former channel, effectively delaying sand spit and associated habitat development along the Bogue Banks inlet shoreline. Although delayed, sand spit development occurred shortly after the end of the shorebird monitoring project, prograding ~1,830 ft into the inlet by late 2010. By the end of 2011, the developing sand spit had reconnected with the severed portion of Emerald Isle, forming a large intertidal flat/dry beach habitat complex on the west end of Bogue Banks. A cursory analysis of aerial imagery indicates that the newly formed habitat on Bogue Banks, as well as the high quality habitat that developed on Bear Island, have been maintained to date.

Beach placement of the excavated material would occur on Emerald Isle, thus retaining the sediment within the inlet littoral system and minimizing the potential for any negative effects on the inlet sediment budget. Following the 2005 relocation project, measured annual sediment volumes indicate that the inlet accreted sediment at an average rate of 374,000 cy/yr over the course of the initial five-year (2005-2009) post-project period (M&N 2015). The calculated average accretion rate is consistent with the original estimated gross longshore sediment transport rate for the inlet area and the projected rates of post-project shoaling in the new and former ebb channels (CPE 2004). The results of the sediment volume change analysis indicate that the constructed channel performed largely as anticipated with minimal negative effects on hydrodynamics and associated sediment transport processes (M&N 2015).

Cumulative Impacts

Under Alternative 1, it is expected that two inlet realignment events would occur over the next 50 years. Separate actions potentially affecting intertidal flats and shoals within Bogue Inlet would include continuing USACE placements of navigation dredged material from the AIWW Bogue Inlet Crossing on the Bogue Banks inlet shoreline every two to three years. Inlet realignment dredging under Alternative 1 may directly impact mid-inlet intertidal shoals within the new channel excavation footprint, depending on the configuration of shoals at the time of realignment events. However, considering the limited number and wide temporal spacing of realignment events and the temporary nature of the effects, it is expected that any cumulative effects on intertidal flat and shoal habitats and communities would be minor and short term.

Inlet Dry Beach, Overwash, and Dune Communities

Direct Impacts

Based on the offshore locations of the ODMDS and Area Y borrow sites and the mid-island locations of the hotspot reaches, municipal hotspot dredging and sand placement operations would not be expected to have any direct or indirect effects on inlet dry beach, overwash, or dune communities. Based on the mid-inlet alignment of the proposed channel, channel excavation under Alternative 1 would not be expected to have any direct impacts on inlet dry beach, overwash, or dune habitats. Associated beach placement operations would not be expected to have any direct impacts on inlet dry beach, overwash, or dune habitats; as the excavated material would be placed along the oceanfront beach of Emerald Isle. Delivery pipelines would be routed to avoid potential shorebird nesting sites and other high value inlet habitats. Ebb channel realignment dredging operations could potentially disturb breeding and roosting shorebirds and colonial nesting waterbirds on the Bogue Banks and Bear Island sides of the inlet. A few shorebird/waterbird breeding pairs are typically recorded each year along the Bogue Banks sand spit/inlet shoreline. An annual average of 2.7 shorebird/waterbird breeding pairs were recorded on Bogue Banks during the six-year (2003-2008) pre-project/post-project monitoring period for the 2005 realignment project; including oystercatchers, least terns, and Wilson's plovers. Piping plover breeding activity has not been recorded on the west end of Bogue Banks, and future nesting attempts are unlikely due to high levels of human disturbance (Personal communication, Sara Schweitzer, NCWRC Coastal Waterbird Biologist, 2011). The first piping plover nesting attempt at Bogue Inlet was documented in 2006 on the east end of Bear Island (Rice and Cameron 2008). Since 2006, one to two breeding pairs have been recorded on Bear Island during most years, the only exceptions being 2013 and 2014 when no breeding pairs were observed. In total, ten breeding pairs were reported on Bear Island from 2006 through 2015. Considering that USACE maintenance dredging of the inlet channel has occurred twice a year for decades, it is expected that any dredging-related shorebird/waterbird disturbance would be minor and short term under Alternative 1.

Indirect Impacts

If the current Bogue Inlet ebb channel eastward migration pattern continues, it is anticipated that most of the supratidal habitat associated with the Bogue Banks inlet shoreline would eventually be lost to erosion. As in the case of intertidal flats and shoals, an eastward alignment similar to that of the pre-project 2005 channel may have net adverse effects on the quantity of dry inlet beach, overwash, and dune habitats for an extended period leading up to ebb channel relocation events. As previously described, ebb channel realignments would modify the inlet hydrodynamic regime and initiate a period of sediment redistribution and habitat reconfiguration within the inlet complex. During the post-construction inlet adjustment process; the areal extent of inlet dry beach, overwash, and dune habitats would be expected to fluctuate in response to sediment redistribution and related conversions between supratidal, intertidal, and subtidal habitats. Over the three-year post-construction monitoring period following the 2005 realignment project, the extent of inlet dry beach, overwash, and dune habitat within the Bogue Inlet complex increased by ~54 acres relative to pre-project conditions, while changes within the more expansive overall study area resulted in a net increase of ~60 acres. Expansive growth of the Bear Island sand spit led to substantial increases in potential shorebird nesting habitat; however, Rice and Cameron (2008) indicated that beneficial effects on nesting were likely somewhat negated by an increase in predator activity (unrelated to the project). Most of the nests that were established on Bear Island during the monitoring period were apparently lost to raccoons and other mammalian predators. Gradual infilling of the former channel over a period of several years and associated expansion of the Bogue Banks sand spit would eventually be expected to offset any supratidal habitat reductions attributable to channel excavation and the subsequent inlet adjustment process.

The material placed on Emerald Isle would be retained within the inlet littoral system, thus minimizing the potential for any negative effects on the inlet sediment budget. Measured annual sediment volume changes (2005-2009) indicate that the inlet accreted sediment at an average rate of 374,000 cy/yr over the course of the initial five-year post-project period (M&N 2015). The calculated average accretion rate is consistent with the original estimated gross longshore sediment transport rate for the inlet area and the projected rates of post-project shoaling in the new and former ebb channels (CPE 2004). The results of the sediment volume change analysis indicate that the constructed channel performed largely as anticipated with minimal negative effects on hydrodynamics and associated sediment transport processes (M&N 2015).

Cumulative Impacts

Under Alternative 1, it is expected that two inlet realignment events would occur over the next 50 years. Separate actions potentially affecting inlet dry beach, overwash, and dune habitats within Bogue Inlet would include continuing USACE placements of navigation dredged material from the AIWW Bogue Inlet Crossing on the Bogue Banks inlet shoreline every two to three years. Direct impacts on inlet dry beach, overwash, and dune habitats would not be expected under Alternative 1; and post-realignment fluctuations in the distribution and potentially the areal extent of these habitats would be consistent with the highly dynamic nature of the inlet. Considering the limited number and wide temporal spacing of realignment events, it is expected that any cumulative effects on inlet dry beach, overwash, and dune communities would be minimal.

Upland Dredged Material Disposal Islands

Direct, Indirect, and Cumulative Impacts

Based on the availability of offshore borrow site sand resources well in excess of the anticipated hotspot needs, the extraction of beach fill from AIWW disposal islands would not be expected under Alternative 1. Therefore, Alternative 1 would not be expected to affect shorebird breeding activity or potential nesting habitat on the disposal islands.

Estuarine Soft bottom

Direct and Indirect Impacts

Under Alternative 1, dredging operations associated with Bogue Inlet ebb channel relocations would directly impact approximately 35 acres of estuarine soft bottom habitat within the new channel excavation footprint. Dredging would remove the majority of the associated benthic infaunal and epifaunal invertebrates; resulting in an initial sharp decline in community abundance, diversity, and biomass within the new channel footprint. However, as described in the General Effects section, studies of benthic community recovery in dredged navigation channels along the southeastern coast have reported rapid recovery within six months. Rapid recovery has been attributed to recolonization via slumping of adjacent undisturbed sediments into the dredged channel and avoidance of spring benthic invertebrate recruitment periods. The project construction window (16 November – 30 April) would avoid peak benthic invertebrate recruitment periods; and therefore, it is anticipated that impacts on estuarine soft bottom communities would be short term and localized under Alternative 1. The construction of a sand dike across the old channel would directly impact an additional ~12 acres of estuarine soft bottom habitat, resulting in the burial and loss of the associated benthic infaunal and epifaunal invertebrates. However, based on avoidance of peak benthic recruitment periods and the rapid recovery capabilities of soft bottom communities that occur in shallow, frequently disturbed habitats; it is anticipated that the effects of dike construction would be short term and localized.

Based on the composition of the inlet dredged material (sand with minimal fines), it is expected that the effects of dredging-induced sediment suspension and redeposition on benthic communities and demersal fishes would be relatively minor. The removal of benthic invertebrate prey may affect the foraging activities of predatory demersal fishes; however, recruitment of opportunistic benthic taxa to the dredged channel would provide substantial prey resources within a relatively short period of time, and the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. Based on all of these considerations, it is anticipated that the effects of Alternative 1 on estuarine soft bottom communities would be short term and localized.

Cumulative Impacts

Continuing twice-yearly USACE side-cast maintenance dredging of the Bogue Inlet ebb channel would be expected to maintain benthic invertebrate communities in a relatively early successional stage. The effects of two inlet ebb channel relocation events over a 50-year period on soft bottom communities would not be expected to add measurably to the effects of continuing federal USACE dredging. Therefore, cumulative impacts on estuarine soft bottom communities would not be expected under Alternative 1.

Estuarine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Bogue Inlet ebb channel relocations would realign the channel to the previously constructed 2005 channel location. The post-realignment hydrodynamic performance of the ebb channel would be expected to approximate that of the 2005 realignment channel. An initial post-realignment flow study conducted in June 2005 found that the new channel was clearly dominant and was capturing most (~74%) of the combined ebb tidal discharge of the new and old channels; and a somewhat lesser majority (59%) of the combined flood discharge of the two channels, with some persistent westerly flow occurring across the closure dike during the flood cycle. The performance of the new channel was subsequently affected by Hurricane Ophelia (September 2005), which breached the closure dike across the old channel and reopened a connection between the old channel and Coast Guard channel leading to the AIWW. Although Hurricane Ophelia delayed infilling and abandonment of the former channel (Cleary 2008), infilling of the former channel was nearly complete by 2009 and the eastern segment of the ebb delta had been reconfigured in accordance with the new ebb channel alignment. Reorganization of the inlet shoal system was accompanied by spit development on the east end of Bogue Banks, and by October 2010 the developing Bogue Banks spit had prograded 1,830 ft westward into the inlet.

Post-project sediment volume changes from 2005-2009 indicate that the inlet accreted sediment at an average rate of 374,000 cy/yr (M&N 2015). The calculated average accretion rate is consistent with the estimated gross longshore sediment transport rate in the vicinity of the inlet and the projected post-project shoaling rates in the new and former ebb channels (CPE 2004). The results of the sediment volume change analysis indicate that the constructed channel performed largely as anticipated with minimal negative effects on hydrodynamics and associated sediment transport processes. Based on the performance of the 2005 project, it is expected that any adverse direct and indirect effects on inlet hydrodynamics would be minor under Alternative 1.

It is expected that the USACE would continue to maintain the Bogue Inlet navigation channel during the interim periods between realignment events. Maintenance of the Bogue Inlet channel is typically conducted twice-yearly by sidecast dredges, following the thalweg or deepest portion of the channel, with open water disposal of the dredged material. Dredging follows the deepwater ebb channel that exists at the time of maintenance events, with the channel being allowed to migrate freely during interim periods. Hydrodynamic conditions would continue to fluctuate in response to natural channel migration and alternating cycles of shoaling and maintenance dredging; however, USACE maintenance of the authorized cross-sectional area would be expected to maintain the general flow regime and tidal prism.

Water Quality

Direct, Indirect, and Cumulative Impacts

Dredging-induced sediment suspension and associated turbidity increases may affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of estuarine organisms. However, as described in the General Effects section, sediment suspension by cutterhead dredges is typically confined to the near bottom water column and is typically short term and localized when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As previously discussed, analyses of vibracore samples from the proposed ebb channel realignment footprint have characterized the sediments as highly compatible sand with a very small fine sediment fraction of less than two percent. Furthermore, during the 2005 Bogue Inlet ebb channel realignment project, observed turbidity levels remained within the ambient range of 9.7 to 35.2 NTUs throughout dredging operations. Therefore, it is anticipated that the effects of dredging-induced sediment suspension on estuarine water quality and estuarine communities would be short-term and localized under Alternative 1.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Based on the noise studies described in the General Effects section, the sound levels produced by cutterhead dredges would not be expected to exceed the NMFS thresholds for behavioral or injurious effects on marine mammals or sea turtles. Limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) responses in fishes (Popper and Hastings 2009). However, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

Entrainment

Direct, Indirect, and Cumulative Impacts

Based on the entrainment studies discussed in the General Effects section, it is anticipated that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment in the dredge intake pipe. Cutterhead dredging in Bogue Inlet would entrain the planktonic eggs and larvae of estuarine dependent fishes and invertebrates that occur in the vicinity of the dredge pipe suction field. However, as described in the General Effects section, modeling studies of larval entrainment during simulated dredging in Beaufort Inlet indicate that dredge entrainment rates are extremely low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2003). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1% of the daily (24-hour) larval flux through the inlet. Furthermore, it is expected that the larval, juvenile, and adult forms of other demersal and pelagic fishes would continue to follow the existing ebb tide channel during the period of construction leading up to the redirection of flow through new channel. Therefore, dredging would not be expected to have any measurable effect on estuarine-dependent fish and invertebrate populations. Cutterhead pipeline dredges have not been implicated in sea turtle takes; and therefore, inlet dredging operations would not be expected to present any risk of entrainment to sea turtles. Atlantic sturgeon could potentially occur in Bogue Inlet during relocation dredging operations; however, cutterhead dredges have not been implicated in Atlantic sturgeon takes along the South Atlantic Coast; and any individuals that may be present in Permit Area waters would likely consist of subadults and adults that would be able to avoid the dredge. Therefore, inlet dredging operations under Alternative 1 would not be expected to present any risk of entrainment to Atlantic sturgeon.

Shellfish

Direct, Indirect, and Cumulative Impacts

Shellfish beds are generally restricted to waters inland of the Bogue Inlet ebb channel realignment footprint. As previously described, NCDMF benthic habitat maps do not show any shell bottom habitats within the proposed channel or the main inlet throat complex. Therefore, direct impacts on shellfish would not be expected under Alternative 1. Fine sediments suspended by the dredging process may be transported inland and redeposited in areas containing shellfish beds; however, based on the composition of the dredged material (sand with minimal fines), it is expected that any sediment suspension and redeposition effects on shellfish would be minor under Alternative 1. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of shellfish beds and other benthic habitats and communities within the estuarine complex surrounding the inlet; however, this process and any associated reductions in shellfish habitat would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. Additionally, the post-project monitoring results for the 2005 realignment showed no change in the quantity of shellfish habitat within the study area over the three-year monitoring period (Rosov and York 2009). Therefore, it is expected that any dredging-related effects on shellfish would be minor and localized under Alternative 1.

<u>SAV</u>

Direct, Indirect, and Cumulative Impacts

SAV beds are generally restricted to waters inland of the Bogue Inlet ebb channel realignment footprint. As previously described in the Affected Environment section (see Figure 4.6), SAV maps developed by the NOAA and NCDMF do not show any SAV habitats within the proposed channel or the main inlet throat complex. Therefore, direct impacts on SAV would not be expected under Alternative 1. Fine sediments suspended by the dredging process may be transported inland, potentially affecting SAV through increases in turbidity and/or sediment redeposition. However, based on the composition of the dredged material, it is expected that any sediment suspension and redeposition effects on SAV would be minor under Alternative 1. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of benthic habitats within the estuarine complex surrounding the inlet; however, this process and any associated reductions in SAV would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. Additionally, the post-project monitoring results for the 2005 realignment showed an increase in SAV of ~17 acres within the study area over the three-year monitoring period (Rosov and York 2009). Therefore, it is expected that any dredging-related effects on SAV would be minor and localized under Alternative 1.

<u>Tidal Marsh</u>

Direct, Indirect, and Cumulative Impacts

Tidal marshes are generally associated with estuarine islands and back-barrier shorelines along the lateral and inland margins of the main inlet throat area, and coastal wetland maps developed by NCDCM do not show any tidal marshes within the proposed channel footprint. Therefore, ebb channel realignments under Alternative 1 would not be expected to have any direct impacts on tidal marshes. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of estuarine habitats surrounding the inlet; however, this process and any associated reductions in tidal marsh would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. The post-project monitoring results for the 2005 realignment showed a decrease in tidal marsh of ~18 acres within the inlet complex and an increase of ~77 acres within the more expansive overall study area over the three-year monitoring period (Rosov and York 2009).

Losses within the inlet complex were primarily associated with the reopening of the Coast Guard channel by Hurricane Ophelia and resulting erosional effects on the breached western tip of Emerald Isle. Therefore, it is expected that any project-related effects on tidal marshes would be minor and localized under Alternative 1.

5.3.1.5 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Remote sensing surveys did not identify any potential archaeological resources in the vicinity of the ODMDS or Area Y offshore borrow sites (Hall 2011). Ebb channel relocations would realign the channel to the previously dredged 2005 channel footprint; which prior surveys indicate does not contain cultural resources. Therefore, Alternative 1 would not be expected to have any adverse effects on cultural resources.

5.3.1.6 Public Interest Factors

<u>Public Safety</u>

Direct, Indirect, and Cumulative Impacts

Beach construction would involve the use of bulldozers and possibly backhoes to redistribute beach fill as it is discharged onto the nourishment beach. In order to take advantage of the limited nourishment window and maximize the efficient use of manpower and machinery, beach nourishment operations would be conducted around-the-clock. As with any construction project involving the use of heavy machinery, beach construction would present a minor short-term risk to public safety. However, adherence to environmental sand placement/beach disposal windows would limit beach construction to the colder months when recreational use is at its lowest point, thus limiting public exposure to construction activities. In order to maintain separation between the public and potentially hazardous operations; the active construction area, consisting of a ~500-ft zone on either side of the beach fill discharge point, would be fenced. During nighttime operations, appropriate lighting would be provided in accordance with USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones. Regulations also require front and back lighting on all transport vehicles and bulldozers during nighttime operations. Considering these safety measures, as well as the anticipated low level of recreational activity during the period of construction and the short-term duration of potential effects; it is anticipated that any direct, indirect, and cumulative impacts on public safety under Alternative 1 would be negligible.

Dredges and associated pump and pipeline systems would present a minor short-term collision risk to recreational boaters. Most dredging operations would occur during the colder months when recreational boating activity is at its lowest point, thus limiting the potential for dredge/recreational vessel interactions. During nighttime operations, appropriate on-board lighting would be provided in accordance with the USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of 30 lumens per square foot on dredges. Dredges would be subject to vessel inspections and other federal safety regulations that are enforced by the USCG. As deemed necessary to ensure the safety of recreational boating activities, the USCG would establish temporary safety zones around dredging operations. Considering these safety measures and the anticipated low level of recreational boating activity during dredging operations; no direct, indirect, or cumulative impacts to public safety would be expected under Alternative 1.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

During beach nourishment events, the presence of pipelines and construction equipment on the beach and associated noise emissions and artificial nighttime lighting would temporarily diminish the aesthetic quality of the beach along the affected management reaches. Temporary construction safety zones would restrict public beach access within a ~500-ft zone on either side of the beach fill discharge point, thus potentially impacting recreational activities such as beach-combing, fishing, and surfing. Public access to beaches outside of the active safety zone would be maintained through the construction of sand ramps across the pipeline at intervals of ~500 ft. Public exposure to aesthetic and recreational impacts would be limited, as beach nourishment construction windows would limit operations to the colder months when recreational beach use is at its lowest point. During Bogue Inlet ebb channel realignment events, the existing federal Bogue Inlet channel would remain open to recreational vessels throughout construction. The closure dike across the old channel would be constructed after completion of the new channel; and therefore, ebb channel realignments would not be expected to have any direct, indirect, or cumulative impacts on recreational boating activities. Hotspot nourishment and Bogue Inlet channel realignment beach disposal events may reduce the need for emergency measures (i.e., sandbags and beach bulldozing) that would be detrimental to recreation and the aesthetic quality of the beach. Considering the low level of public exposure and the short-term nature of the adverse impacts, it is anticipated that effects on aesthetics and recreation would be minor under Alternative 1.

<u>Navigation</u>

Direct, Indirect, and Cumulative Impacts

The Morehead City ODMDS is a USEPA-designated ocean dredged material disposal site. The USEPA Morehead City ODMDS Site Monitoring and Management Plan encourages the extraction of compatible deposits for beach placement as a means of reducing potential mounding impacts on navigation (USEPA and USACE 2010). Dredging at the ODMDS would be confined to areas west of the MCH entrance channel; and therefore, would not impede commercial traffic or present a risk of collision to commercial vessels. Therefore, offshore borrow site dredging at the ODMDS would not be expected to have any adverse effect on navigation. The Area Y offshore borrow site is located east and south of the authorized Bogue Inlet navigation project; and therefore no direct, indirect, or cumulative effects on the federal project would be expected under Alternative 1. During Bogue Inlet ebb channel realignment events, the navigability of the existing federal Bogue Inlet channel would be maintained throughout the period of construction. The closure dike across the old channel would be constructed after completion of the new channel. Navigability of the ebb channel would be maintained by continuing USACE maintenance dredging during the interim periods between channel realignment events. Therefore, ebb channel realignments under Alternative 1 would not be expected to have any direct, indirect, or cumulative impacts on navigation.

Hazardous, Toxic, and Radioactive Waste (HTRW)

Direct, Indirect, and Cumulative Impacts

Potential beach fill sediments in the offshore borrow areas and the federal Bogue Inlet channel are derived from sediment transport and deposition by ocean currents. The probability of the areas being contaminated by pollutants is low, and it would not be expected that any hazardous and toxic waste sites would be encountered during dredging operations (USACE 2014a). Magnetometer and side-scan sonar surveys of the ODMDS and Area Y borrow sites did not identify any anomalies, thus indicating that any unexploded ordnance would be small and unlikely to present a safety hazard to workers on the dredge or persons on the beach (USACE 2014a). However, any hazardous and toxic waste sites that are identified would be addressed through response plans and remedial actions. Any unexploded ordnance that is encountered would be handled in accordance with the Military Munitions Rule (40 CFR 260-270). Therefore, no direct, indirect, or cumulative effects related to HTRW would be expected under Alternative 1.

Air Quality

Direct, Indirect, and Cumulative Impacts

Carteret County is designated as an attainment area for all criteria pollutants (USEPA 2016); and therefore, General Conformity regulations are not applicable to the proposed action. Mobile source emissions generated by dredges and onshore construction equipment would result in temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM; however, it is expected that emissions would be rapidly dispersed, thereby precluding any significant effects on air quality. Furthermore, an emissions analysis conducted by the USACE for the proposed Bogue Banks CSDR project determined that the combined emissions of dredging and sand placement activities that are comparable to those of the no action alternative would fall below de minimis levels and would not have any adverse effect on air quality (USACE 2014a). Therefore, Alternative 1 would not be expected to have any direct, indirect, or cumulative impacts on air quality.

Infrastructure

Direct, Indirect, and Cumulative Impacts

In the absence of a comprehensive nourishment project, unmitigated background and storm erosion would eventually threaten many of the oceanfront structures along Pine Knoll Shores, Indian Beach Salter Path, and Emerald Isle. Based on the 2004 NCDCM long-term shoreline erosion rates, 226 oceanfront structures are projected to be at risk over the next 50 years (Table 5.2). Properties are considered to be at risk of erosional impacts when the seaward parcel boundary is within 25 ft of the MHW line. It should be noted that the older 2004 NCDCM rates provide the best indication of erosional conditions under Alternative 1, as the newer rates incorporate the offsetting effects of nourishment under the Bogue Banks Restoration Project and subsequent FEMA-funded storm projects. It is expected that the individual municipalities and individual property owners would initiate separate mitigative measures such as beach scraping and sandbagging. This would provide short-term and in some cases long-term protection to structures.

Table 5.2. Alternative 1 properties at risk.

Management Reach	**Year**				
	10	**20**	**30**	**40**	**50**
Bogue Inlet	0	0	0	0	0
Emerald Isle - West	0	0	0	0	0
Emerald Isle - Central	21	22	22	23	24
Emerald Isle - East	1	17	26	40	61
Indian Beach/ Salter Path	9	21	31	40	47
Pine Knoll Shores	50	73	80	88	94
Total	**81**	**133**	**159**	**191**	**226**

Economics

Direct, Indirect, and Cumulative Impacts

The anticipated hotspot nourishment and Bogue Inlet ebb channel realignment projects would cost approximately $85.2M over the next 50 years. Continuing USACE sand placement activities; including the disposal of navigation dredged material from the MCH outer harbor channel on Atlantic Beach and beach disposal on the west end of Emerald Isle via maintenance of the Bogue Inlet AIWW Crossing; would cost approximately $245.2M over the next 50 years. As indicated above, 226 oceanfront properties are projected to be at risk over the next 50 years. Based on the average oceanfront property value on Bogue Banks (~$1.7M), lost property value could total $392.8M over the next 50 years. Based on the municipal property tax rates, an additional $96.6M in tax revenue could be lost over 50 years. The total cumulative cost of nourishment and lost property value/tax revenue under Alternative 1 would be $819.8M over the next 50 years.

5.3.2 Alternative 2: Abandon and Retreat

Under Alternative 2, the County and municipalities would not pursue a long-term beach management project, nor would they undertake any federally permitted actions to mitigate oceanfront shoreline erosion along Bogue Banks. Actions requiring a federal permit, and thus excluded under Alternative 2, would include beach nourishment, dredging, inlet management, and any other activities below MHW that require a federal Section 404/Section 10 permit. In the absence of a beach management plan, oceanfront structures that become threatened by erosion would either be relocated to vacant lots or demolished. Relocation would involve the detachment and transport of the structure to a new lot, and the removal and transport of the existing foundation, driveway pavement, patio concrete, and any other remaining exterior features to an appropriate landfill. In the case of demolition, heavy equipment would be used to take down the structures, and all material would be hauled to an appropriate landfill. It is expected that most demolition projects would require no more than two weeks to complete; however, longer completion periods would be expected in the case of larger multi-family complexes. Prior to demolition or relocation, individual property owners may choose to protect structures by installing temporary sandbags or conducting beach bulldozing above the MHW line. The use of sandbags and bulldozing would be expected to delay structure relocations and demolitions, with the extent of the delay being contingent on site-specific erosion rates at the time. It is assumed that ongoing USACE navigation dredging and beach disposal practices, which are not subject to Section 10 or 404 permit authorizations, would continue over the next 50 years in the same manner as described under Alternative 1; including USACE placements of navigation dredged material on Fort Macon and Atlantic Beach via maintenance of the MCH outer harbor channel (Beaufort Inlet) and USACE placements of navigation dredged material on the west end of Emerald Isle via maintenance of the AIWW Bogue Inlet Crossing. Continuing

USACE placements would be expected to preclude the need for structure relocations or demolitions along Atlantic Beach over the next 50 years.

5.3.1.7 Marine Benthic Communities

5.3.1.7.1 <u>Soft Bottom Communities</u>

Direct and Indirect Impacts

Demolition and relocation activities under Alternative 2 would occur above the MLW line; and therefore, would not be expected to have any direct or indirect impacts on subtidal marine soft bottom communities.

Cumulative Impacts

Separate dredging and disposal activities that may impact marine soft bottom communities within the Permit Area would include federal maintenance dredging of the MCH entrance channel and associated disposal operations at the ODMDS, as well as USACE beach disposal operations on Atlantic Beach/Fort Macon. However, since demolition and relocation activities would not produce any direct or indirect impacts that would add to those of the federal actions, Alternative 2 would not have any cumulative impacts on marine soft bottom communities.

5.3.1.7.2 <u>Hardbottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities would occur above the MLW line, and no hardbottom habitats are located in the intertidal zone where demolition and relocation activities would potentially take place. Therefore, no direct, indirect, or cumulative impacts on hardbottom communities would be expected under Alternative 2.

5.3.1.8 Marine Water Column

<u>Hydrodynamics</u>

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities under Alternative 2 would occur above the MLW line; and therefore, would not be expected to have any direct, indirect, or cumulative impacts on hydrodynamics.

Water Quality

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities under Alternative 2 would occur above the MLW line; and therefore, would not be expected to have any direct, indirect, or cumulative impacts related to sediment suspension and turbidity.

Underwater Noise and Entrainment

Direct, Indirect, and Cumulative Impacts

Alternative 2 would not involve any dredging; and therefore, would not have any effects on the marine water column related to underwater noise or entrainment.

5.3.1.9 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 2, the demolition and relocation of structures would potentially include operations by heavy machinery on the beach; potentially resulting in minor direct impacts on intertidal beach communities through mechanical substrate disturbance. However, demolition and relocation projects would occur incrementally as structures become threatened; and therefore, it is anticipated that the extent of direct impacts at any given time would be negligible.

Indirect Impacts

Under Alternative 2, unmitigated shoreline erosion would be expected to reduce the quantity of intertidal beach habitat along the ~18 miles of oceanfront shoreline comprising Pine Knoll shores, Indian Beach/Salter Path, and Emerald Isle. The extensive system of forested beach ridges on Bogue Banks would be expected to prevent overwash and island migration over the next 50 years and beyond (Bush et al. 1999). In the absence of overwash and migration, it is expected that continuing beach erosion and shoreface steepening would result in gradual oceanfront beach narrowing. The rate of these processes would depend largely on the rate of sea level rise and the extent of storm-related sand losses. Sea level rise predictions for the Bogue Banks area over the next 30 years range from approximately three feet when the observed 20th century trend is extrapolated through 2045 to approximately eight feet under a high greenhouse gas emissions scenario (NC Science Panel 2015). Regardless of the specific sea level rise rate, the general effect would be the gradual conversion of intertidal beach habitat to subtidal habitat over the next 50 years. The loss and degradation of intertidal beach habitat would be expected to have adverse effects on benthic infaunal communities and shorebirds.

Declines in benthic infaunal invertebrate populations and shorebird intertidal foraging habitat use would be expected, particularly along the hotspot reaches.

Cumulative Impacts

In contrast to the effects of unmitigated erosion under Alternative 2, the continuing MCH and AIWW Bogue Inlet Crossing beach disposal projects would be expected to maintain wider beaches and higher quality intertidal beach habitat along Atlantic Beach/Fort Macon and the Bogue Inlet reaches. The federal beach disposal projects would be expected to reduce the overall cumulative extent of intertidal habitat degradation along Bogue Banks; and therefore, adverse cumulative effects on intertidal beach communities would not be expected under Alternative 2.

<u>Dry Beach and Dune Communities</u>

Direct Impacts

As indicated above, the demolition and/or relocation of structures under Alternative 2 would potentially include operations by heavy machinery on the beach; potentially resulting in minor direct impacts on dry beach and dune communities through mechanical substrate disturbance. It is expected that the condition of the shoreline at the time of relocations or demolitions would be such that dry beach habitat would be absent or greatly reduced in the vicinity of the structures. Dune communities may be impacted during the removal process; however, it is anticipated that any disturbed dune habitats would be replanted with native vegetation upon completion of the removal process. Demolition and relocation projects would occur incrementally as structures become threatened; and therefore, it is anticipated that the extent of direct impacts at any given time would be negligible.

Indirect Impacts

Under Alternative 2, unmitigated shoreline erosion would be expected to reduce the quality and quantity of dry beach and dune habitat along the ~18 miles of oceanfront shoreline comprising Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle. In the absence of shore protection efforts, the GENESIS model-projected shoreline changes primarily reflect the influence of natural background processes of erosion and accretion. The majority of the ~18-mile shoreline is erosional over the 12-year model simulation period, resulting in an overall net loss of ~78 acres of dry beach habitat (Table 5.3) and an overall net reduction in average beach width of ~14 ft (Table 5.4). Losses are concentrated along the known hotspot reaches (Pine Knoll Shores and Emerald Isle East) and the Emerald Isle West reach, which experience dry beach habitat reductions ranging from 16 to 34 acres. Projected dry beach loss is relatively minor along Emerald Isle Central, while net accretion along the Indian Beach/Salter Path and Bogue Inlet reaches results in relatively minor gains of dry beach habitat at the end of the 12-year simulation.

Table 5.3. Alternative 2 model-predicted YR-0 to YR-12 dry beach area change.

Management Reach	YR-0 to YR-12 Dry Beach Change (acres)
Bogue Inlet	+7.1
Emerald Isle West	-25.2
Emerald Isle Central	-3.4
Emerald Isle East	-15.6
Indian Beach/Salter Path	+6.5
Pine Knoll Shores	-34.0
Total	**-78.2**

Table 5.4. Alternative 2 model-predicted YR-12 average beach width[1] and YR-0 to YR-12 change in average beach width.

Management Reach (Transects)	YR-12 Average Beach Width (ft)	Change in Average Width YR-0 to YR-12 (ft)
Bogue Inlet (1-11)	301	+78
Emerald Isle West (12-25)	127	-58
Emerald Isle Central (26-36)	118	-9
Emerald Isle East (37-48)	62	-48
Indian Beach/Salter Path (49-58)	181	+35
Pine Knoll Shores (59-76)	100	-48
All reaches	**143**	**-14**

[1] Beach width = distance from toe of foredune to MHW line

As described above, in the absence of island overwash and migration, the expected oceanfront shoreline response to continuing erosion over the next 50 years would involve shoreface steepening and gradual oceanfront beach narrowing. The rate of these processes would depend largely on the rate of sea level rise and the extent of storm-related sand losses. As described above, sea level rise predictions for the Bogue Banks area over the next 30 years range from approximately three to eight feet. Regardless of the specific sea level rise rate, the general effect would be the gradual conversion of dry beach and dune habitat to intertidal and subtidal habitat. As the high sand volume dune ridges on Bogue Banks begin to erode, some of the eroded material would be reworked on the shoreface and incorporated into the subaerial oceanfront beach (Bush et al. 1999), potentially slowing the rate of habitat loss. However, the overall trend over the next 50 years would involve progressive subaerial beach narrowing and dry beach/dune habitat loss. The loss and degradation of dry beach and dune habitat would be expected to have adverse effects on ghost crabs, shorebirds, sea turtles, and seabeach amaranth. Significant declines in ghost crab populations, shorebird habitat use, sea turtle nesting, and seabeach amaranth populations would be expected, particularly along the hotspot reaches.

It is expected that the indirect effects of demolition and relocation activities on dry beach and dune communities would be minimal. As previously described, it is expected that shoreline conditions would be such that dry beach habitat would be absent or greatly reduced in the vicinity of the structures. It is anticipated that any disturbed dune habitats would be replanted with native vegetation; however, prior to replanting, dune systems in the immediate vicinity of active work sites may be more vulnerable to erosion during storm events.

Cumulative Impacts

In the absence of shore protection efforts, unmitigated dry beach erosion along the hotspot reaches and other portions of the island would expose dunes to an increased risk of erosion, especially during storm events. As previously described, the 12-year modeling simulation shows the dune systems along the hotspot reaches of Emerald Isle West and Pine Knoll Shores to be highly susceptible to erosion, with predicted dry beach losses of 25.2 and 34 acres occurring along the two reaches, respectively. Dry beach losses along the hotspot reaches would reduce the extent of nesting habit for sea turtles. Conversely, model-predicted accretional gains of dry beach habitat along other reaches (i.e., Bogue Inlet and Indian Beach/Salter Path) would be beneficial for sea turtle nesting. The continuing MCH and AIWW inlet crossing beach disposal projects would provide nesting habitat along Atlantic Beach/Fort Macon and the Bogue Inlet reach. The federal beach disposal projects would be expected to reduce the overall cumulative extent of habitat loss along Bogue Banks; and therefore, adverse cumulative effects on dry beach and dune communities would not be expected under Alternative 2.

5.3.1.10 Inlet and Estuarine Resources

<u>Intertidal Flats and Shoals/Inlet Dry Beach, Overwash, and Dune Communities</u>

Direct, Indirect, and Cumulative Impacts

The Bogue Inlet ebb channel is currently exhibiting an eastward migration pattern that is similar to that leading up to the 2005 ebb channel relocation project. If the current migration pattern continues, the ebb channel alignment could approximate that of the 2005 pre-relocation channel in approximately 8 to 12 years. Thus, under Alternative 2, it is anticipated that most of the intertidal flats and supratidal (dry, beach, overwash, and dune) habitats along the eastern (Bogue Banks) inlet shoreline would be converted to subtidal soft bottom within the next eight to 12 years. It is likely that some of the habitat loss would be offset by concurrent expansion of the Bear Island sand spit and/or new habitat formation elsewhere within the inlet complex in response to shifting patterns of flow and sediment transport. However, analysis of historical ebb channel alignments indicates that an extreme eastward alignment, relative to a centralized position, is less conducive for inlet spit development on both Bear Island and Bogue Banks (Cleary 2008). Thus, an eastward alignment similar to that of the pre-project 2005 channel may result in a net loss of intertidal flat, dry beach, and overwash habitat within the inlet complex.

Upland Dredged Material Disposal Islands

Direct, Indirect, and Cumulative Impacts

Alternative 2 would not involve any activities that would affect AIWW disposal islands. Therefore, Alternative 2 would have no effect on potential disposal island shorebird nesting habitat.

Estuarine Soft bottom

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, estuarine soft bottom communities would be affected primarily by natural background inlet processes (e.g., tidal currents, waves, and channel migration) and storm-driven inlet changes. The distribution and composition of soft bottom benthic and demersal fish communities would continue to fluctuate in response to shifting patterns of tidal flow and sediment transport. As previously described, benthic invertebrate communities and demersal fishes are adapted to frequent natural perturbations and typically recover rapidly from disturbance events.

Estuarine Water Column

Hydrodynamics and Water Quality

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, hydrodynamic conditions would continue to fluctuate in response to natural inlet processes of shoaling, erosion, and channel migration; however, continuing USACE maintenance dredging of the Bogue Inlet navigation channel would be expected to maintain the general flow regime and tidal prism. Suspended sediment concentrations would generally be expected to remain within the ambient range; however, short-term increases would be expected in response to storm events and periodic USACE maintenance dredging projects.

Underwater Noise and Entrainment

Direct and Indirect Impacts

Demolition and relocation activities under Alternative 2 would not involve any in-water activities that would expose estuarine organisms to elevated noise levels or a risk of entrainment.

Cumulative Impacts

Separate dredging activities that may expose estuarine organisms to elevated noise levels or a risk of entrainment would include federal maintenance dredging of the MCH, Bogue Inlet, and AIWW Bogue Inlet Crossing navigation channels. However, since demolition and relocation activities would not produce any direct or indirect impacts that would add to those of the federal actions, Alternative 2 would not have any cumulative noise or entrainment impacts on estuarine communities.

Shellfish, SAV, and Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities under Alternative 2 would occur above the MLW line along the Bogue Banks inlet shoulder. The inlet shoulder is a high energy zone where high velocity currents and shifting sediments typically preclude the occurrence of shellfish, SAV, and tidal marshes. This would especially be the case at the time of relocations or demolitions, as the inlet shoulder would be in a highly eroded condition. Therefore, Alternative 2 would not be expected to have any direct, indirect, or cumulative impacts on these estuarine communities.

5.3.1.10 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities under Alternative 2 would be confined to the inlet shoulder shoreline above the MLW line; and therefore, would not be expected to have any direct, indirect, or cumulative impacts on underwater archaeological resources.

5.3.1.11 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

As with any construction activity involving the use of heavy machinery, the relocation or demolition of threatened structures would present a minor short-term risk to public safety.

However, operations would be confined to the winter months to the extent possible, thus limiting public exposure to potential risk. Therefore, the relocation and demolition of structures would not be expected to have any direct, indirect, or cumulative impacts on public safety.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

During relocation and demolition activities, the presence of construction equipment and demolition debris on or adjacent to the beach, as well as the associated emissions of noise, would temporarily diminish the aesthetic quality of the beach. However, operations would be confined to the winter months to the extent possible, thus limiting the extent of public exposure to adverse effects. Demolition and relocation projects would occur incrementally as structures become threatened; and therefore, the extent and duration of direct impacts at any given time would be negligible. Unmitigated erosion would result in narrow chronically-eroded oceanfront beaches, thus diminishing the aesthetic quality of the beach and reducing recreational opportunities. As previously described, it is expected that long-term shoreface steepening and subaerial beach narrowing would eventually eliminate most of the recreational dry beach. Unmitigated erosion may also threaten parking facilities and other infrastructure that facilitate public beach access. Thus, Alternative 2 would be expected to have long-term adverse effects on aesthetics and recreation via loss of the recreational beach.

<u>Hazardous, Toxic, and Radioactive Waste</u>

Demolished structures may contain hazardous and toxic materials such as asbestos and lead paint; however, it is assumed that these materials would be removed and disposed of in accordance with applicable state and federal regulations.

<u>Air Quality</u>

Direct, Indirect, and Cumulative Impacts

Carteret County is designated as an attainment area for all criteria pollutants (USEPA 2016); and therefore, General Conformity regulations are not applicable to proposed relocation and demolition activities. Mobile source emissions generated by onshore construction equipment would result in very minor and temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM; however, it is expected that emissions would be rapidly dispersed, thereby precluding any significant effects on air quality. Therefore, Alternative 2 would not be expected to have any direct, indirect, or cumulative impacts on air quality.

Navigation

Direct, Indirect, and Cumulative Impacts

Demolition and relocation activities under Alternative 2 would be confined to the oceanfront and inlet shoulder shorelines above the MLW line; and therefore, would not be expected to have any direct, indirect, or cumulative impacts on navigation.

Infrastructure

In the absence of shore protection efforts, unmitigated background and storm erosion would eventually threaten many of the oceanfront structures along Pine Knoll Shores, Indian Beach Salter Path, and Emerald Isle. Based on the 2004 NCDCM long-term shoreline erosion rates, 451 oceanfront structures are projected to be at risk over the next 50 years (Table 5.5). Properties are considered to be at risk of erosional impacts when the seaward parcel boundary is within 25 ft of the MHW line. It should be noted that the older 2004 NCDCM rates provide the best indication of erosional conditions under Alternative 2, as the newer rates incorporate the offsetting effects of nourishment under the Bogue Banks Restoration Project and subsequent FEMA-funded storm projects.

Table 5.5. Alternative 2 – projected properties at risk over the next 50 years.

Management Reach	**Year**				
	10	**20**	**30**	**40**	**50**
Bogue Inlet	0	5	34	62	82
Emerald Isle - West	0	0	0	16	33
Emerald Isle - Central	21	22	22	23	24
Emerald Isle - East	1	22	34	53	81
Indian Beach/Salter Path	9	21	31	40	47
Pine Knoll Shores	97	143	156	172	184
Total	**128**	**213**	**277**	**366**	**451**

Economics

Direct, Indirect, and Cumulative Impacts

In the absence of shore protection efforts, there would be losses of property value and tax revenue attributable to unmitigated background and storm erosion. As indicated above, 451 oceanfront structures are projected to be at risk over the next 50 years. The relocation of each structure would cost approximately $75,000, resulting in a total cost of $33.8M for all 451 structures. As described in Section 3.3.2, 114 threatened oceanfront structures could potentially be relocated to other oceanfront lots, thereby maintaining property values. However, based on the average non-oceanfront property value on Bogue Banks (~$287,000), losses of property value associated with the relocation of 337 oceanfront structures to interior lots could total $489.0M. Based on municipal property tax rates, $118.6M in tax revenue could be lost over 50 years. The cost of continuing USACE sand placement activities; including the disposal of dredged material from MCH on Atlantic Beach and the disposal of dredged material from the AIWW Bogue Inlet Crossing channel on the west end of Emerald Isle; would be approximately $245.2M over the next 50 years. The total cumulative cost of USACE nourishment, relocations, and property value and tax revenue losses under Alternative 2 could total $886.5M over the next 50 years.

5.3.2 Alternative 3: Beach Nourishment Only

Under Alternative 3, the County, through an interlocal agreement with the island municipalities, would manage the approximately ten miles of beaches along Pine Knoll Shores (~4.5 miles), Indian Beach/Salter Path (~2.4 miles), and eastern Emerald Isle (~2.5 miles) through the implementation of a comprehensive 50-year beach nourishment project. Atlantic Beach is also a party to the interlocal agreement; however, continuing USACE placements of navigation dredged material from the MCH channels are expected to meet its maintenance nourishment requirements. Therefore, the County is not anticipating any maintenance sand placement on Atlantic Beach under its 50-year management plan. However, the County's 50-year plan would provide for interim maintenance nourishment events along Atlantic Beach should USACE MCH placements cease. Furthermore, the County's 50-year plan would provide storm-response nourishment for Atlantic Beach to address any storm-related needs that exceed the volumes placed by the USACE MCH project. The 50-year project would employ a recurring cycle of nourishment events to continuously maintain beach profile sand volumes along the managed reaches at a 25-year Level of Protection (LOP). The three management reaches are projected to require recurring maintenance nourishment to offset background erosion at approximate intervals of three (Emerald Isle East) and six (Pine Knoll Shores and Indian Beach/Salter Path) years. Additional sand placement would be conducted to address storm-related losses, resulting in some accelerated nourishment cycles for the managed reaches over the 50-year project. As described in Section 3, based on sand volume availability constraints, Alternative 3 would not provide any management of the approximately eight miles of beaches along central and western Emerald Isle and Bogue Inlet.

Beach fill would be acquired from a combination of offshore borrow sites (old ODMDS, current ODMDS, and Area Y), AIWW disposal islands, and upland sand mines. Based on the projected nourishment needs over the next 50 years, full utilization of all identified sand resources at each of the borrow sources is anticipated under Alternative 3. Based on the sediment analyses described in Section 3, it is assumed that all material placed on the beach under Alternative 3 would be beach compatible in accordance with NC Technical Standards for Beach Fill Projects (15A NCAC 07H .0312). Dredging operations at the ODMDS and Area Y borrow sites would most likely involve thin layer sediment removal by hopper dredges, but could also include the use of hydraulic cutterhead pipeline dredges in the case of Area Y. It is expected that beach fill extraction from the AIWW disposal sites would involve pump-outs by a cutterhead dredge, with direct pipeline delivery to the beach. The use of beach fill from upland sites would involve delivery via dump trucks, with beach access via public access points. Should the need arise for interim maintenance nourishment of Atlantic Beach, the County would use these same borrow sources for interim maintenance nourishment events while seeking supplemental authorization to add Beaufort Inlet as a borrow source under its 50-year plan.

5.3.2.1 Marine Benthic Resources

5.3.2.1.1 <u>Soft Bottom</u>

Direct and Indirect Impacts

On average, the projected maintenance nourishment regime under Alternative 3 would require the extraction of approximately 0.2 to 1.2 MCY of sand from the ODMDS and/or Area Y offshore borrow sites every three years. As previously described, borrow site dredging operations under Alternative 3 would primarily involve the acquisition of beach fill from the old and current ODMDS borrow sites using a hopper dredge. Additional beach fill would be acquired from Area Y using a hopper or cutterhead dredge; however, operations at Area Y would be minimal based on the limited total volumetric availability of ~1.5 MCY. At an average dredge cut depth of ~3.5 ft, the removal of 0.2 to 1.2 MCY of material by a hopper dredge would disturb approximately 35 to 240 acres of soft bottom habitat. A two-ft vertical buffer of compatible material would be retained within the ODMDS and Area Y borrow site dredging footprints. Thus, dredging would not directly alter sediment composition within the dredging footprints. Dredging of the mounded ODMDS deposits would not extend to or below the original seafloor; and therefore, it is unlikely that fine sediment deposition would alter sediment composition in the post-extraction dredging footprints. Excavation at Area Y would extend below the original seafloor elevation, resulting in a higher potential for fine sediment deposition; however, the relatively shallow excavation depths (5-10 ft) and small areas of the two proposed dredging footprints (each <50 acres) would limit the likelihood of significant fine sediment accumulation. Dredging would remove the majority of the associated benthic infaunal and epifaunal invertebrates; resulting in an initial sharp decline in community abundance, diversity, and biomass within the dredging footprints. However, benthic recovery would begin immediately upon the cessation of dredging operations; and it is anticipated that relatively shallow dredge cuts, the mounded nature of the sand deposits at the ODMDS, and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid dredge cut infilling and benthic community recovery. As described in the General Effects section, most offshore borrow site recovery studies have reported rapid recovery of community abundance and diversity when relatively shallow dredge cuts were employed and peak infaunal recruitment periods were avoided. In the specific case of hopper dredging at the offshore borrow sites, the relatively shallow (~3.5 ft) cut depths and the retention of intervening ridges with infaunal recruits would be expected to facilitate rapid dredge cut infilling and infaunal recolonization. Therefore, it is anticipated that the direct impacts of offshore dredging on benthic communities would be short-term and localized to the excavation footprints.

Dredging-induced sediment suspension and redeposition may impact soft bottom communities within and adjacent to the excavation footprints through burial, adverse effects on the gill-breathing and filter-feeding abilities of benthic organisms, and/or adverse effects on the foraging and/or predator avoidance behaviors of visually-oriented demersal fishes (Michel et al. 2013). However, as described in the General Effects section, dredging-induced sediment suspension is typically localized and short-term when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As described in Section 3.3, sediments associated with the offshore borrow areas are composed of beach compatible sand with a very small fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension and redeposition would be short-term and localized. Losses of benthic invertebrates within the borrow site dredging footprints may negatively affect the foraging activities of predatory demersal fishes (e.g., flounders, rays, spots, and croakers), potentially inducing demersal fishes to seek out alternative soft bottom foraging habitats (Byrnes et al. 2003). However, it is anticipated that the effects of prey loss on demersal fishes would be localized and short-term based on the following considerations: 1) early recruitment of opportunistic benthic taxa to the disturbed areas would provide substantial prey resources within a relatively short period of time, 2) demersal fishes are highly mobile and capable of seeking out alternative habitats, and 3) the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. The delivery of dredged sand to the beach would involve the placement of pipelines on the subtidal seafloor, resulting in additional direct impacts on soft bottom communities; however, it is anticipated that pipeline impacts would be negligible since the impacts would be confined primarily to a narrow strip of substrate underlying the pipelines, and the extent of physical habitat disturbance would be minimal once the pipelines are removed.

Beach placement would directly impact additional areas of subtidal soft bottom habitat within the surf zone. Sand placement within the subtidal portions of the beach fill footprints would result in the burial and loss of the associated soft bottom benthic invertebrate infauna. However, benthic recovery would begin immediately upon the cessation of placement operations; and it is anticipated that the use of beach compatible material and avoidance of peak invertebrate recruitment periods would facilitate relatively rapid benthic community recovery. As described in the General Effects section, benthic soft bottom communities in shallow high-energy environments are adapted to frequent natural perturbations and generally recover rapidly from disturbance. Therefore, it is anticipated that the direct effects of sand placement on soft bottom benthic communities would be short-term and localized. Increases in suspended sediment concentrations and turbidity would be expected within the surf zone in the immediate vicinity of the active sand slurry discharge point. Sediment suspension and redeposition may have effects on soft bottom communities and surf zone fishes similar to those described above for borrow site dredging operations. However, based on the use of beach compatible sand with minimal fines and the employment of temporary dikes and spreaders to contain the discharged sand slurry, it is anticipated that sediment suspension effects would be short-term and localized. 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 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 within the Permit Area.

Cumulative Impacts

The potential for temporally crowded cumulative effects on marine soft bottom communities under Alternative 3 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). Therefore, temporally crowded cumulative effects on soft bottom communities at the offshore borrow sites would not be expected under Alternative 3. Based on the average projected maintenance nourishment intervals of three to six years, benthic communities would be expected to recover during the interim periods between successive nourishment events. Storm events and/or periods of accelerated background erosion may temporarily increase the frequency of nourishment events along specific reaches. In the case of a maintenance event that is followed in the same year by a major storm, a storm response project could be implemented as early as the second post-storm winter season, resulting in a shortened two-year nourishment interval. However, full recovery would still be expected during the two year interval. Therefore, temporally crowded cumulative effects on soft bottom communities within the beach fill footprints would not be expected under Alternative 3.

The potential for spatially crowded cumulative impacts under Alternative 3 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 within the Permit Area 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 in the Permit Area, 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. Separate sand placement actions affecting subtidal soft bottom communities within the management reach beach fill templates would potentially include (if available) the disposal of excess dredged material from the MCH channels on Pine Knoll Shores. However, based on the projected six-year maintenance nourishment interval for Pine Knoll Shores under Alternative 3, additional USACE placement would be unlikely to affect the ability of benthic communities to fully recover during interim periods. Therefore, temporally-crowded cumulative effects on marine soft bottom communities would not be expected under Alternative 3. Some of the federal nourishment events along Atlantic Beach/Fort Macon and the Bogue Inlet reach may coincide with sand placement events along the County management reaches. Simultaneous losses of soft bottom benthic invertebrates along the affected reaches may have cumulative prey loss effects on surf zone fishes. However, the combined area of temporary habitat and prey loss would still constitute a small fraction of the available marine soft bottom habitat in the Permit Area, and any cumulative effects would be limited to periods of benthic community recovery.

5.3.2.1.2 Hardbottom

Direct, Indirect, and Cumulative Impacts

State coastal management regulations prohibit borrow sites within 500m of hardbottom areas (15A NCAC 07H.0208). The 500-m rule is designed to prevent both direct physical impacts from dredging, as well as indirect impacts related to the dispersal and redeposition of suspended sediments. Hall (2011) conducted a remote sensing survey for hardbottom sites at the proposed offshore borrow sites; including the current ODMDS, former ODMDS, and Area Y. No potential hardbottom sites were identified within 500m of the proposed ODMDS borrow areas. A single hardbottom feature covering an area of approximately 112 square ft was identified within the Area Y borrow site; however, the specific sand deposits that are proposed for extraction under Alternative 3 are more than 500m away from the identified hardbottom feature. Potential sand delivery pipeline routes for nourishment projects have yet to be identified; however, approvals of proposed projects would be contingent on pre-project surveys demonstrating avoidance of hardbottom features. Based on the demonstrated absence of hardbottom features within 500m of the proposed borrow sites; and the commitment to avoid hardbottom sites during pipeline placement; Alternative 3 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.3.2.2 Marine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Compatible sand deposits at the former and current ODMDS borrow sites are contained in a series of dredged material disposal mounds that have maximum elevations ranging from approximately -31 to -40 ft NAVD88. The proposed cut depths of -50 to -52 ft NAVD88 under Alternative 3 account for the retention of a two-foot buffer of compatible disposal mound material above the underlying incompatible sediments. Over the 50-year project, dredging would reduce the elevations of the mounds by approximately 29 to 38 ft; however, excavation would not extend to or below the original underlying seafloor. Although the hydrodynamic effects of ODMDS dredging have not been evaluated through modeling; considering that excavation would not extend to or below the prevailing elevation of the seafloor, it is assumed that any effects on ocean currents and wave conditions would be minor and localized. Compatible sand at the Area Y offshore borrow site is limited to two small isolated deposits with a combined total volume of ~1.5 MCY. Based on the limited extent of dredging at Area Y, it is assumed that any effects on ocean currents and wave conditions would be minor and localized.

Water Quality

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, dredging-induced sediment suspension and associated turbidity increases at the offshore borrow sites may affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms. However, as described in the General Effects section, dredging-induced sediment suspension is typically short-term and localized when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As discussed in Section 3.3, all potential beach fill deposits at the borrow sites are composed of highly compatible sand with a very small fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension on marine water quality and pelagic communities would be short-term and localized under Alternative 3. Increases in suspended sediment concentrations and turbidity attributable to sand placement would also be expected in the surf zone along the management reaches. However, as described in the General Effects section, the results of water quality monitoring during nourishment operations along Bogue Banks and other southeastern NC beaches indicate that turbidity increases are typically confined to the surf zone in the immediate vicinity of the slurry discharge point. Furthermore, it is anticipated that the beach compatible composition of the fill and the use of temporary dikes and spreaders to contain the discharged sand slurry would reduce the extent of sediment suspension. Therefore, it is anticipated that sediment suspension effects attributable to sand placement would be short-term and localized. Based on the short-term and localized nature of the anticipated sediment suspension effects, cumulative impacts on marine water quality would not be expected under Alternative 3.

Entrainment

Direct, Indirect, and Cumulative Impacts

Hopper and cutterhead dredges both have the potential to entrain fishes and invertebrates during all life cycle phases (adults, juveniles, larvae, and eggs). Based on the entrainment studies discussed in the General Effects section, it is anticipated that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment in the dredge intake pipe. Dredging at the offshore borrow sites would entrain the planktonic eggs and larvae of marine fishes and invertebrates that occur in the vicinity of the dredge pipe suction field. However, considering the diffuse distribution of larvae in offshore waters, it is anticipated that the effects of larval entrainment on marine fish and invertebrate populations would be negligible.

Sea turtles are vulnerable to entrainment by hopper dredges and could occur in the vicinity of the offshore borrow sites during hopper dredging operations. Cutterhead dredges are not known to take sea turtles; and therefore, any use of cutterhead dredges at the offshore borrow sites would not be expected to present any risk of entrainment to sea turtles. The temporal distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April - 20 November for inshore waters and a range of 23 April - 27 November for nearshore ocean waters. Hopper dredging operations under Alternative 3 would employ conservation measures to reduce the risk of sea turtle entrainment; including adherence to a 16 November - 30 April hopper dredging window, mandatory use of rigid draghead deflectors and associated operational parameters, and sea turtle relocation trawling.

Adherence to a 16 November – 30 April environmental window would limit hopper dredging operations to the colder months when most sea turtles have moved to warmer waters well seaward of the borrow sites. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a sand ridge in front of the draghead as it is drawn along the seafloor, thus pushing sea turtles away from direct contact with and outside the suction field of the draghead. Relocation trawling in front of the dredge has been shown to reduce the risk of entrainment by capturing and relocating any turtles that may be present near the bottom (Dickerson et al. 2007). Under Alternative 3, relocation trawling would be initiated at the onset of hopper dredging projects and conducted continuously throughout the duration of the operations. A recent study by Dickerson et al. (2007) found that trawling was most effective at reducing entrainment when it was initiated at the onset of dredging operations and continued throughout the duration of the project. Effectiveness also increased with the intensity of trawling, with the lowest number of entrainments per unit of dredging effort occurring when tows were conducted at a rate of >1.7 per hour.

As described in the General Effects section, a total of six sea turtles have been entrained by hopper dredges during offshore borrow site operations along Bogue Banks, despite adherence to environmental windows and the use of rigid dragheads and relocation trawling. Of the six takes associated with offshore borrow site dredging, four occurred in December 2002 during dredging operations for Phase I of the Bogue Banks Restoration project. The concentration of four takes during December 2002 was thought to be related to the unanticipated presence of artificial reef-like structure composed of derelict tires, which supported a sea turtle food source consisting of crustaceans, octopi, and other marine invertebrates (USACE 2016b). The two remaining takes occurred in April 2003 and March 2004 during offshore borrow site operations for Phases I and II of the Bogue Banks Restoration project, respectively. Thus, all of the sea turtle takes occurred during the two dredging events associated with Phases I and II of the restoration project in 2002/2003 and 2004, and four were thought to be related to the unanticipated presence of an artificial reef-like structure.. Furthermore, although relocation trawling was active when the takes occurred, trawling was limited to periods of warmer water temperatures and was not conducted throughout the dredging events. As indicated above, based on the work by Dickerson et al. (2007), relocation trawling would be initiated at the onset of hopper dredging projects and would occur continuously throughout the duration of dredging events. It is expected that these measures would further minimize but not entirely eliminate the risk of sea turtle entrainment during hopper dredging within the proposed 16 November - 30 April environmental hopper dredging window.

The federally listed Atlantic sturgeon could also occur in the vicinity of the offshore borrow sites during hopper dredging operations; however, occurrences in the open ocean would likely consist of subadults and adults that would be able to avoid the dredge. As described in the General Effects section, analysis of historical take along the South Atlantic Coast indicates that the risk of hopper dredge entrainment is primarily confined to dredging within riverine channels (USACE 2014c). The potential risk of entrainment to adult sturgeons is presumed to be low, and the use of rigid deflecting dragheads and associated operating requirements likely reduces the risk of entrainment (Dickerson et al. 2004). Cutterhead dredges have not been implicated in sturgeon takes along the South Atlantic Coast, and would not be expected to present any risk of entrainment to sturgeon. Relocation trawling may present a minor risk of injury to Atlantic sturgeon; however, the extensive use of relocation trawling for sea turtles and sturgeon along the US Atlantic Coast has resulted in very few reported injuries. Out of more than 1,300 reported captures of Atlantic and shortnose sturgeon during long-term trawl surveys and relocation trawling efforts along the mid-Atlantic and northeast Atlantic states, only two sturgeon injuries were reported (NMFS 2015). Both injuries were related to debris in the trawl net; and NMFS has since adopted modified net requirements that are expected to reduce the risks associated with the capture of debris during relocation trawling. According to NMFS, it is unlikely that significant injuries to any Atlantic or shortnose sturgeon would occur during trawling operations that employ the new nets in combination with short tow durations and careful sturgeon handling (NMFS 2015). Relocation trawling under Alternative 3 would follow all NMFS requirements to minimize potential adverse effects on Atlantic sturgeon. Based on these considerations, it is anticipated that the risk of sturgeon entrainment by hopper dredges and/or injury due to trawling at the offshore borrow sites would be negligible under Alternative 3.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Based on the noise studies described in the General Effects section, the sound levels produced by hopper dredges under Alternative 3 would not be expected to exceed the NMFS thresholds for injurious effects on marine mammals or sea turtles, but may exceed the thresholds for behavioral effects on marine mammals and sea turtles within 2.1 and 1.2 km of the dredge, respectively. As previously discussed, behavioral effects may include avoidance responses such as diving or an increase in swimming speed; however, considering the transient nature of large whale occurrences in the Permit Area and the mobility and avoidance behavior of dolphins and sea turtles, it is expected that any behavioral effects would be short-term and localized. The previously described noise studies indicate that the sound levels produced by cutterhead dredges would not be expected to exceed the NMFS thresholds for behavioral or injurious effects on marine mammals or sea turtles. As described in the General Effects section, limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) responses in fishes (Popper and Hastings 2009). However, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

Vessel Collisions

Direct, Indirect, and Cumulative Impacts

Dredging operations at offshore borrow sites under Alternative 3 would coincide with right and humpback whale migration periods along the NC coast. Although instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent right whale along the Georgia coast near the Brunswick Harbor entrance channel (NMFS 2012c). The risk of collisions between dredges and whales during sand extraction would be very low, as hopper dredges travel at slow speeds (approximately three knots) during the active dredging process. The potential for vessel strikes would exist primarily during transit between the offshore dredging areas and disposal sites along the beach (unloaded hopper dredges are capable of speeds up to ~17 knots during transit). Under Alternative 3, hopper dredging operations at the offshore borrow sites would employ conservation measures to reduce the risk of vessel collisions; including 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience and compliance with federal regulations prohibiting the approach of any vessel within 500 yards of a right whale [50 CFR 224.103(c)]. It is expected that these conservation measures would reduce the risk of collisions to negligible levels. As described in the General Effects section, based on water temperature, the occurrence of a manatee in Permit Area waters during the proposed dredging window would be unlikely. Furthermore, manatees are generally restricted to estuarine waters and would not be expected to occur in the vicinity of the offshore borrow sites or the hopper dredge ocean transit routes between the borrow sites and nearshore pump-out stations. Based on these considerations, it is expected that the risk of interactions between hopper dredges and manatees would be negligible under Alternative 3.

5.3.2.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct and Indirect Impacts

Under Alternative 3, three management reaches encompassing a total of approximately ten beach miles would receive regular maintenance nourishment at approximate intervals of three (Emerald Isle East) and six (Indian Beach-Salter Path/Pine Knoll Shores) years. Should the need arise for interim maintenance nourishment of Atlantic Beach, an additional ~5.0 beach miles would be nourished every three years under Alternative 3. The direct and indirect effects of sand placement events on intertidal beach communities would be of the same nature as those described under Alternative 1. Sand placement would eliminate the majority of the intertidal benthic invertebrate infauna along the affected reaches through direct burial. However, benthic infaunal recovery would begin immediately upon the cessation of sand placement operations, and it is anticipated that the use of compatible beach fill and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid benthic community recovery. As described in the General Effects section, most intertidal benthic recovery studies have reported recovery within one year when highly compatible beach fill sediments were used and peak infaunal larval recruitment periods were avoided. Therefore, it is anticipated that the direct impacts of sand placement on intertidal benthic communities would be short-term and localized to the beach fill areas.

Beach construction activities; including heavy equipment operations, generator use, nighttime lighting, and other related activities; may disrupt shorebird foraging activities and/or prevent shorebirds from using otherwise suitable intertidal beach foraging habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone. Direct impacts on the benthic infaunal prey base may reduce 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 and foraging habitat loss are not fully known, but potentially include a reduction in energy reserves resulting in reduced survivability or productivity, particularly in the case of migratory shorebirds that use intertidal beaches as stopover refueling sites. However, it is anticipated that relatively rapid benthic infaunal recruitment would provide substantial prey resources along the disturbed reaches within a relatively short period of time, and substantial undisturbed intertidal beach foraging habitat would be available within the Permit Area during benthic recovery periods. Therefore, it is anticipated that the effects of benthic prey loss on shorebirds and surf zone fishes would be short-term and localized under Alternative 3.

Cumulative Impacts

Under Alternative 3, the projected maintenance nourishment intervals of three and six years would provide ample time for full recovery. In response to major storm events, one or more of the three management reaches, as well as Atlantic Beach, may experience an accelerated nourishment cycle. In the case of a maintenance event that is followed in the same year by a major storm, a storm response project could be implemented as early as the second post-storm winter season, resulting in a shortened two-year nourishment interval. However, full recovery would still be expected during the two year interval. Separate beach fill placement actions affecting the management reaches could potentially include USACE disposals of navigation dredged material from the MCH channels on Pine Knoll Shores, dependent on the availability of material and the availability of town monies to offset additional costs in excess of the federal least cost disposal option. However, given the projected six-year maintenance nourishment interval for the Pine Knoll Shores reach, additional USACE placements would be unlikely to affect the ability of benthic communities to fully recover during the interim periods between nourishment events. Based on these considerations, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 3.

Some of the continuing USACE beach disposal events along Atlantic Beach/Fort Macon and the Bogue Inlet reach may coincide with County nourishment events, potentially increasing the total linear extent of beach impact during a given year by approximately six miles. Simultaneous USACE disposal and County nourishment events would reduce the pool of potential infaunal invertebrate recruits for recolonization of the impacted reaches, thus potentially extending infaunal community recovery periods. However, full recovery would still be expected during the three- to six-year intervals between nourishment events; and therefore, any cumulative effects on intertidal benthic infaunal communities under Alternative 3 would be short-term. Simultaneous losses of intertidal benthic infauna may have short-term and localized cumulative prey loss effects on surf zone fishes and shorebirds.

Dry Beach and Dune Communities

Direct Impacts

Dry beach (berm) and dune construction under Alternative 3 would involve the use of bulldozers and other heavy machinery to redistribute and grade the placed material according to design profile specifications. Construction activities would directly impact ghost crabs and dune vegetation through burial and/or mechanical disturbance. However, it is anticipated that the replanting of constructed dunes with native species would facilitate dune stabilization and plant community recovery. Furthermore, it is anticipated that, the use of compatible beach fill and avoidance of peak recruitment periods would facilitate relatively rapid ghost crab recovery. As described in the General Effects section, post-nourishment monitoring studies have reported relatively minor and short-term effects on ghost crab populations when highly compatible beach fill sediments were used and peak recruitment periods were avoided. Therefore, it is expected that the direct impacts of sand placement on dune vegetation and macroinvertebrate infaunal communities would be short-term and localized to the beach fill areas. Nourishment projects would avoid the sea turtle nesting and hatching season through adherence to the 16 November - 30 April sea turtle sand placement environmental window. Therefore, direct impacts on nesting females, nests, or hatchlings would not be expected under Alternative 3. Beach construction activities; including heavy equipment operations, generator use, nighttime lighting, and other related activities; may disrupt shorebird activities and/or prevent shorebirds from using otherwise suitable dry beach roosting and loafing habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone.

Indirect Impacts

Beach nourishment may indirectly affect sea turtles through physical modification of dry beach nesting habitat. As described in the General Effects section, observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, substrate compaction, and escarpment formation. Additionally, substrate modifications may have negative effects on the nest incubation environment and/or the ability of hatchlings to emerge from their nests. As previously described, sediment compaction and the modification of substrate characteristics such as water retention, gas exchange, and sediment color can alter the nest incubation environment; potentially affecting embryonic development, hatching success, and hatchling sex ratios. As described in the General Effects section, the five-year post-nourishment nesting study on Bogue Banks did not show any effects on nesting or hatching success (Holloman and Godfrey 2008). A slight increase in nest temperature was observed along nourished reaches; however, potential effects on hatchling sex ratios were not evaluated. In the case of studies that have documented declines in nesting on nourished beaches, a return to normal nesting activity has generally been reported by the second or third post-project nesting season. Under Alternative 3, measures employed to minimize adverse effects on nesting habitat would include the use of compatible sediments, escarpment monitoring, and sediment compaction monitoring. It is expected that these measures would minimize the extent and duration of any habitat-modification effects on sea turtles. Based on the results of the prior Bogue Banks study and the use of these conservation measures, it is expected that any adverse effects on sea turtle nesting would be short-term and localized. Changes in beach morphology and sediment characteristics can also potentially affect the suitability of dry beach nesting habitat for coastal waterbirds. However, as previously described, sand placement on the oceanfront dry beaches of Bogue Banks is not expected to have any habitat-related effects on breeding or nesting activity, as traditional oceanfront beach breeding sites on NC's stabilized and developed barrier islands have essentially been abandoned in favor of more isolated inlet and estuarine sites.

Under Alternative 3, the maintenance of wider and higher oceanfront dry beaches along the managed reaches would be expected to increase the quantity and quality of potential sea turtle nesting habitat and high tide roosting habitat for coastal waterbirds. As previously described, studies have reported immediate increases in sea turtle nesting success following sand placement on severely eroded beaches. Based on the GENESIS model-projected MHW line changes, average dry beach widths along the Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle East management reaches at the end of the 12-year simulation period are 67 to 98 ft wider than the projected widths under Alternative 2 (Table 5.6). The relative increases in beach width under Alternative 3 equate to relative increases in dry beach area of approximately 20 to 40 acres along the three management reaches (Table 5.7). Conversely, in the absence of shore protection efforts along the Emerald Isle Central, Emerald Isle West, and Bogue Inlet reaches, Alternative 3 has essentially no relative effect on beach widths or areas. Thus, adverse effects on dry beach communities comparable to those described under Alternative 2 would be expected along these unmanaged reaches.

Table 5.6. Alternative 3 model-predicted average YR-12 dry beach width relative to Alternative 2.

Management Reach	Year-12 Average Beach Width (ft)		Alt 3 Year-12 Relative Average Beach Width (ft)
	Alt 2	Alt 3	
Bogue Inlet	301	301	0
Emerald Isle West	127	128	+1
Emerald Isle Central	118	121	+3
Emerald Isle East	62	129	+67
Indian Beach/Salter Path	181	279	+98
Pine Knoll Shores	100	174	+74
All Reaches	**143**	**183**	**+40**

Table 5.7. Alternative 3 model-predicted YR-12 dry beach area change relative to Alternative 2.

Management Reach	YR-0 to YR-12 Relative Dry Beach Change (acres)
Bogue Inlet	0.0
Emerald Isle West	+0.5
Emerald Isle Central	+1.1
Emerald Isle East	+20
Indian Beach/Salter Path	+28.2
Pine Knoll Shores	+39.9
Total	**+89.7**

Cumulative Impacts

Based on the projected average maintenance nourishment intervals of three to six years, dry beach habitats and communities would be expected to fully recover during the interim periods between recurring nourishment events. In response to storm events and/or periods of accelerated background erosion, one or more of the management reaches may experience an accelerated nourishment cycle. In the case of a maintenance event that is followed in the same year by a major storm, a storm response project could be implemented as early as the second post-storm winter season, resulting in a shortened two-year nourishment interval. However, full recovery would still be expected during the two year interval. Some of the USACE beach disposal events along Atlantic Beach/Fort Macon and/or the Bogue Inlet reach may coincide with County nourishment events, potentially increasing the total linear extent of beach impact during a given year by approximately six miles. Simultaneous sand placement on the USACE disposal and County management reaches would reduce the pool of potential ghost crab and other macrofaunal invertebrate recruits for recolonization of the impacted reaches, thus potentially extending macrofaunal invertebrate community recovery periods. However, full recovery would still be expected during the three- to six-year intervals between nourishment events; and therefore, any cumulative effects on invertebrate communities under Alternative 3 would be short-term. Simultaneous USACE and County sand placement projects could increase the linear extent of habitat modification effects on sea turtle nesting and shorebird roosting. However, given the short-term nature of these impacts, it is expected that any cumulative effects would be relatively minor.

5.3.2.4 Inlet and Estuarine Resources

<u>Intertidal Flats and Shoals</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, dredging at the offshore borrow sites and sand placement along the oceanfront beach would not have any direct impacts on intertidal flats and shoals in Bogue or Beaufort Inlets. The extraction of sand from AIWW disposal islands would involve the placement of a pipeline leading through Bogue Inlet to the Emerald Isle East oceanfront beach. Although the pipeline route has yet to be identified, approvals of proposed projects would be contingent on pre-project surveys demonstrating efforts to avoid or minimize impacts on intertidal habitats to the maximum extent practicable.

The Bogue Inlet ebb channel is currently exhibiting an eastward migration pattern similar to that leading up to the 2005 ebb channel relocation project. Under Alternative 3, in the absence of inlet management, the ebb channel alignment would be expected to approximate that of the 2005 pre-relocation channel in approximately eight to 12 years. Thus, it is expected that most of the intertidal flats and supratidal (dry, beach, overwash, and dune) habitat along the eastern (Bogue Banks) inlet shoreline would be converted to subtidal soft bottom within the next eight to 12 years. Sandbags would likely be placed along the inlet shoreline to protect infrastructure, resulting in shoreline conditions similar to those leading up to the 2005 relocation project. It is likely that some of the habitat loss would be offset by concurrent expansion of the Bear Island sand spit and/or new habitat formation elsewhere within the inlet complex in response to shifting patterns of flow and sediment transport. However, analysis of historical ebb channel alignments indicates that an extreme eastward alignment is unfavorable for spit development on both Bear Island and Bogue Banks in relation to a centralized channel alignment (Cleary 2008). Thus, an eastward alignment similar to that of the pre-project 2005 channel may result in a net loss of intertidal flats within the inlet complex.

Inlet Dry Beach, Overwash, and Dune Communities

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, dredging at the offshore borrow sites and sand placement along the oceanfront beach would not be expected to have any direct impacts on inlet dry beach, overwash, and dune communities. As indicated above, if the current Bogue Inlet ebb channel eastward migration pattern continues, most of the supratidal habitat associated with the Bogue Banks inlet shoreline would be converted to subtidal soft bottom within the next eight to 12 years. An eastward alignment similar to that preceding the 2005 channel relocation project may result in a net loss of dry beach, overwash, and dune habitat within the inlet complex.

Upland Dredged Material Disposal Islands

Under Alternative 3, beach fill would also be excavated from a number of active USACE AIWW dredged material disposal islands within the Bogue Inlet complex. Although man-made and subject to periodic dredged material placement impacts, these disposal sites provide important nesting habitat for shorebirds and waterbirds. Several of the disposal sites that are proposed as borrow sources under Alternative 3 are included in the NCNHP list of state natural areas as a component of the Bogue Inlet/Bogue Sound Bird Nesting Islands complex (NCNHP 2015). Beach fill extraction from the disposal sites would likely involve pump-outs by a cutterhead dredge, with direct pipeline delivery to the beach or delivery via scows/barges and nearshore pump-out stations. Excavation below MHW is not proposed as a component of sand extraction at these sites; and therefore, Alternative 3 would not reduce the area of potential supratidal nesting habitat. Sand extraction would likely increase the area of sparsely vegetated supratidal habitat, thereby potentially enhancing the quality of nesting habitat for some species. The NCWRC indicates that disposal island elevations above ten feet may expose birds and their nests to high winds and sand movement (USACE 2016a), thus sand extraction may also have beneficial effects on nesting habitat through reductions in elevation. Furthermore, in the specific case of these disposal islands, sand extraction would be completed between 16 November and 31 March, thus avoiding the shorebird/waterbird breeding season. Therefore, adverse effects on shorebird/waterbird breeding or nesting attributable to the extraction of sand from AIWW disposal sites would not be expected under Alternative 3.

Estuarine Soft bottom

Direct, Indirect, and Cumulative Impacts

The proposed in-water borrow sites are located between one and five miles offshore of Bogue Banks; and therefore, dredging would not be expected to have any effect on estuarine soft bottom communities. Similarly, sand placement along the mid-island oceanfront beaches would not be expected to have any impacts on estuarine soft bottom communities. In the case of AIWW disposal island pump-outs, extraction would be confined to upland deposits within the dike walls of the facilities; and therefore, would not affect soft bottom communities. Submerged pipelines leading from the disposal islands to the oceanfront beach would have minor short term impacts on estuarine soft bottom communities. Under Alternative 3, estuarine soft bottom communities would be affected primarily by natural background inlet processes (e.g., tidal currents, waves, and channel migration) and storm-driven inlet changes. The distribution and composition of soft bottom benthic and demersal fish communities would continue to fluctuate in response to shifting patterns of tidal flow and sediment transport. As previously described, benthic invertebrate communities and demersal fishes are adapted to frequent natural perturbations and typically recover rapidly from disturbance events.

Estuarine Water Column

Hydrodynamics and Water Quality

Direct, Indirect, and Cumulative Impacts

The proposed in-water borrow sites are located between one and five miles offshore of Bogue Banks; and therefore, dredging would not be expected to have any effect on inlet or estuarine hydrodynamics. Similarly, sand placement along the mid-island oceanfront beaches would not be expected to have any impacts on inlet or estuarine hydrodynamics. In the case of AIWW disposal island pump-outs, extraction would be confined to upland deposits within the dike walls of the facilities; and therefore, would not affect hydrodynamics. Under Alternative 3, hydrodynamic conditions would continue to fluctuate in response to natural inlet processes of shoaling, erosion, and channel migration; however, continuing USACE maintenance dredging of the Bogue Inlet navigation channel would be expected to maintain the general flow regime and tidal prism. Suspended sediment concentrations would generally be expected to remain within the ambient range; however, short-term increases would be expected in response to storm events and periodic USACE maintenance dredging projects.

Underwater Noise and Entrainment

Direct, Indirect, and Cumulative Impacts

Alternative 3 would not involve any inlet or estuarine dredging activities that would expose estuarine organisms to elevated noise levels or a risk of entrainment. In the case of AIWW disposal island pump-outs, extraction would be confined to upland deposits within the dike walls of the facilities; and therefore, no effects related to entrainment or underwater noise would be expected.

Shellfish, SAV, and Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

The proposed in-water borrow sites are located between one and five miles offshore of Bogue Banks; and therefore, dredging would not be expected to have any effect on estuarine communities. Similarly, sand placement along the oceanfront beach would not be expected to have any impacts on estuarine communities. Fringing shellfish beds, SAV, and/or tidal marshes may occur along the outer margins of the containment dikes that surround the AIWW disposal island borrow sites; however, pump-outs would be conducted by a cutterhead dredge operating in the adjoining AIWW channel, and sediment disturbance would be confined to the active upland disposal areas within the dike walls. Thus no impacts attributable to dredge access or sediment excavation and rewatering would be expected. The pipeline route leading to recipient beach has yet to be identified; however, approvals of proposed projects would be contingent on pre-project surveys demonstrating avoidance of shellfish, SAV, and tidal marsh habitats. Therefore, Alternative 3 would not be expected to have any direct, indirect, or cumulative impacts on these communities.

5.3.2.5 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Remote sensing surveys did not identify any potential archaeological resources in the vicinity of the ODMDS or Area Y offshore borrow sites (Hall 2011). Therefore, borrow site dredging operations under Alternative 3 would not be expected to have any effect on cultural resources. Pump-out station anchor point locations and sand delivery pipeline routes have yet to be identified; however, pre-project surveys demonstrating avoidance of cultural resources would be a mandatory condition of the required USACE Section 404/10 permit for each nourishment event.

5.3.2.6 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Under Alternative 3; the potential impacts of beach nourishment and associated dredging operations on public safety would be the same as those described under Alternative 1.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

Under Alternative 3; the potential direct, indirect, and cumulative impacts of sand placement and dredging on aesthetics and recreation would be of the same nature to those described under Alternative 1. However, the proposed maintenance nourishment regime under Alternative 3 would increase the extent and frequency of recurring placement and dredging events, thereby increasing the overall temporal and spatial extent of construction activities and associated adverse effects on aesthetics and recreation. Maintenance nourishment events under Alternative 3 would maintain consistently wider beaches along the Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle East management reaches; thus resulting in long-term beneficial effects on recreation and the aesthetic quality of the beach.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 3; the potential direct, indirect, and cumulative impacts of offshore borrow site dredging operations on navigation would be the same as those described for municipal offshore dredging under Alternative 1. Beach fill extraction from the AIWW disposal islands may temporarily affect navigation, depending on the pipeline route; however, it is expected that any infringement on navigable waters would be localized and minor based on the availability of surrounding unaffected navigable waters. General use of the AIWW, Bogue Inlet Channel, and the adjacent creeks and channels by boaters, kayakers, and other vessels would be expected to continue during construction, which would take place during the colder months when boating activity is at its lowest point.

Hazardous, Toxic, and Radioactive Waste (HTRW)

Direct, Indirect, and Cumulative Impacts

Under Alternative 3; potential direct, indirect, and cumulative impacts related to HTRW would be the same as those described for municipal offshore dredging under Alternative 1. Potential beach fill sediments in the AIWW disposal islands are derived from natural sediment transport and deposition in the federal AIWW channel. The probability of these sediments being contaminated by pollutants is low, and it would not be expected that any hazardous and toxic substances would be encountered during the extraction of the material (USACE 2014a). However, any identified hazardous or toxic waste would be addressed through response plans and remedial actions. Therefore, no direct, indirect, or cumulative effects related to HTRW would be expected under Alternative 3.

Air Quality

Direct, Indirect, and Cumulative Impacts

Carteret County is designated as an attainment area for all criteria pollutants (USEPA 2016); and therefore, General Conformity regulations are not applicable to the proposed action. Mobile source emissions generated by dredges and onshore construction equipment would result in temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM; however, it is expected that emissions would be rapidly dispersed, thereby precluding any significant effects on air quality. Furthermore, an emissions analysis conducted by the USACE for the proposed Bogue Banks CSDR project determined that the combined emissions of dredging and sand placement activities that are comparable to those of the proposed action would fall below de minimis levels and would not have any adverse effect on air quality (USACE 2014a). Therefore, Alternative 3 would not be expected to have any direct, indirect, or cumulative impacts on air quality.

Infrastructure

In the absence of shore protection efforts along central and western Emerald Isle, unmitigated background and storm erosion would eventually threaten many of the associated oceanfront structures. Based on the GENESIS modeled MHW line changes, 122 oceanfront structures are projected to be at risk over the next 50 years under Alternative 3 (Table 5.8). Properties are considered to be at risk of erosional impacts when the seaward parcel boundary is within 25 ft of the MHW line. It is expected that the individual municipalities and individual property owners would initiate separate mitigative measures such as beach scraping and sandbagging. This would provide short-term and in some cases long-term protection to structures.

Table 5.8. Alternative 3 projected properties at risk over the next 50 years.

Management Reach	**Year**				
	10	**20**	**30**	**40**	**50**
Bogue Inlet	0	4	28	50	66
Emerald Isle - West	0	0	0	16	33
Emerald Isle - Central	9	14	18	21	23
Emerald Isle - East	0	0	0	0	0
Indian Beach/Salter Path	0	0	0	0	0
Pine Knoll Shores	0	0	0	0	0
Total	**9**	**18**	**46**	**87**	**122**

Economics

Under Alternative 3, projected County/municipal maintenance nourishment events would cost approximately $140.4M over the 50-year life of the project. Storm losses are estimated to require additional placements totaling ~27.2 MCY over the next 50 years at a cost of $360.4M. Continuing USACE sand placement activities; including the disposal of navigation dredged material from the MCH channels on Atlantic Beach and beach disposal on the Pointe adjacent to Bogue Inlet via maintenance of the Bogue Inlet AIWW Crossing channel; would cost approximately $245.2M over the next 50 years. The total cumulative cost of all nourishment would be approximately $746.0M over the next 50 years. In addition to the cost of nourishment, there would be a number of properties at risk due to the lack of nourishment to offset background erosion along central and western Emerald Isle and Bogue Inlet. As indicated above, 122 oceanfront structures are projected to be at risk over the next 50 years. Based on current property values, lost property value could total $212.1M over the next 50 years. Based on the municipal property tax rates, an additional $48.2M in tax revenue could be lost over 50 years. The total cumulative cost of all nourishment and lost property value/tax revenue under Alternative 3 would be $1.006 billion over the next 50 years.

5.3.3 Alternative 4: Beach Nourishment and Non-Structural Inlet Management (Applicant's Preferred Alternative)

Under Alternative 4, 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. As in the case of Alternative 3, it is expected that continuing USACE placements of navigation dredged material from the MCH channels will be sufficient to meet the maintenance nourishment requirements of the ~5.0-mile Atlantic Beach management reach. Therefore, the County is not anticipating any maintenance sand placement on Atlantic Beach under its 50-year management plan. However, the County's 50-year plan would provide for interim maintenance nourishment events along Atlantic Beach should USACE MCH placements cease. Furthermore, the County's 50-year plan would provide storm-response nourishment for Atlantic Beach to address any storm-related needs that exceed the volumes placed by the USACE MCH project. The approximately ten miles of beaches encompassing the Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle East management reaches would be maintained in exactly the same manner as described under Alternative 3. Management of the additional approximately eight miles of beaches encompassing the Emerald Isle Central (~3.0 miles), Emerald Isle West (~4.2 miles), and Bogue Inlet (~1.4 miles) management reaches would involve similar recurring nourishment events to maintain a 25-year LOP. The three additional reaches are projected to require recurring maintenance nourishment to offset background erosion at approximate intervals of six (Bogue Inlet) and nine (Emerald Isle Central and West) years. Additional sand placement would be conducted to address storm-related losses, resulting in some accelerated nourishment cycles for the managed reaches over the 50-year project.

Sources of beach fill and associated extraction methods would include all of those previously described under Alternative 3 (i.e., Old and Current ODMDS, Area Y, AIWW disposal islands, and upland borrow sites). As in the case of Alternative 3, based on the projected nourishment needs over the next 50 years, full utilization of all identified sand resources at each of these borrow sources is anticipated under Alternative 4. An additional source of beach fill under Alternative 4 would include compatible dredged material derived from realignments of the Bogue Inlet ebb channel. Over the 50-year project life, it is anticipated that ebb channel realignments would provide up to 4.3 MCY of compatible material for beach placement, thus providing the additional sand volume required to maintain a 25-year LOP along the entire 18-mile project shoreline; including the Emerald Isle Central, Emerald Isle West, and Bogue Inlet management reaches. Should the need arise for interim maintenance nourishment of Atlantic Beach, the County would use these same borrow sources for interim nourishment events while seeking supplemental authorization to add Beaufort Inlet as a borrow source under its 50-year plan.

Bogue Inlet management would encompass periodic realignments of the ebb channel (via cutterhead dredging) to a mid-inlet position approximately every ten to 15 years, with corresponding placement of dredged material from the newly excavated channel on the beaches of Emerald Isle. In contrast to Alternative 1, decisions to undertake realignment projects under Alternative 4 would be based on the position of the ebb channel relative to the boundaries of an established “safe box” within the inlet throat. The ebb channel would be allowed to migrate freely so long as it remains within the boundaries of the safe box; however, migration beyond the eastern boundary of the safe box would trigger realignment events. The mid-inlet channel design and associated construction methods would be the same as those employed during the 2005 ebb channel relocation project. Realignments under Alternative 4 would entail the construction of a ~6,000-foot-long channel with variable bottom widths ranging from 150 to 500 ft and a project depth of -16.5 ft NAVD (includes overdredge). Channel excavation is anticipated to yield just over 1.0 MCY of beach compatible dredged material, which would be pumped directly onto the Emerald Isle central and west management reaches. Due to the preemptive nature of realignment events under Alternative 4, the need for a closure dike is generally not anticipated. Contrary to Alternative 1, there would be sufficient time for the old channel to fill in before it presents a threat to Emerald Isle. However, in the event of extreme rapid ebb channel repositioning events (e.g., due to shoal breaching or hurricanes), the ebb channel could present an immediate threat to structures that would warrant the construction of a dike across the old channel to facilitate infilling. In such cases, it is anticipated that ~0.2 MCY of the dredged material from the new channel would be used to construct a closure dike across the old channel, with the remaining ~0.80 MCY of material being pumped directly onto the beaches of Emerald Isle.

5.3.3.1 Marine Benthic Resources

5.3.3.1.1 Soft Bottom Communities

Direct and Indirect Impacts

Under Alternative 4, offshore borrow site dredging operations and associated direct and indirect impacts on marine soft bottom communities would be the same as those described under Alternative 3. Dredging events involving the extraction of approximately 0.2 to 1.2 MCY of sand from the ODMDS and/or Area Y offshore borrow sites would disturb approximately 35 to 240 acres of soft bottom habitat every three years. A two-ft vertical buffer of compatible material would be retained within the ODMDS and Area Y borrow site dredging footprints. Thus, dredging would not directly alter sediment composition within the dredging footprints. Dredging of the mounded ODMDS deposits would not extend to or below the original seafloor; and therefore, it is unlikely that fine sediment deposition would alter sediment composition in the post-extraction dredging footprints. Excavation at Area Y would extend below the original seafloor elevation, resulting in a higher potential for fine sediment deposition; however, the relatively shallow excavation depths (5-10 ft) and small areas of the two proposed dredging footprints (each <50 acres) would limit the likelihood of significant fine sediment accumulation. Dredging would remove the majority of the associated benthic infaunal and epifaunal invertebrates; resulting in an initial sharp decline in community abundance, diversity, and biomass within the dredging footprints. However, benthic recovery would begin immediately upon the cessation of dredging operations; and it is anticipated that relatively shallow dredge cuts, the mounded nature of the sand deposits at the ODMDS, and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid dredge cut infilling and benthic community recovery. Based on the composition of the dredged material (sand with minimal fines), it is expected that the effects of dredging-induced sediment suspension and redeposition on benthic communities and demersal fishes would be relatively minor. The removal of benthic invertebrate prey may affect the foraging activities of predatory demersal fishes; however, recruitment of opportunistic benthic taxa to the disturbed areas would provide substantial prey resources within a relatively short period of time, and the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. Based on all of these considerations, it is anticipated that the effects of dredging on soft bottom communities at the offshore borrow sites would be short-term and localized.

Under Alternative 4, the effects of beach placement on subtidal soft bottom communities within the surf zone would be of the same nature as those described under Alternative 3. Sand placement within the subtidal portions of the beach fill footprints would result in the burial and loss of the associated soft bottom benthic invertebrate infauna and epifauna; however, benthic recovery would begin immediately upon the cessation of placement operations; and it is anticipated that the use of beach compatible material and avoidance of peak invertebrate recruitment periods would facilitate relatively rapid benthic community recovery. Increases in suspended sediment concentrations and turbidity would be expected within the surf zone in the immediate vicinity of the active sand slurry discharge point. However, based on the use of beach compatible sand with minimal fines and the employment of temporary dikes and spreaders to contain the discharged sand slurry, it is anticipated that the effects of sediment suspension and redeposition on soft bottom communities would be relatively minor. Losses of benthic invertebrate prey may affect the foraging activities of demersal surf zone fishes; however, recruitment of opportunistic benthic taxa to the disturbed areas would provide substantial prey resources within a relatively short period of time, and the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. 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 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.

Cumulative Effects

Under Alternative 4, offshore borrow site dredging operations and associated cumulative impacts on marine soft bottom communities would be the same as those described under Alternative 3.

5.3.3.1.2 Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

State coastal management regulations prohibit borrow sites within 500m of hardbottom areas (15A NCAC 07H.0208). The 500-m rule is designed to prevent both direct physical impacts from dredging, as well as indirect impacts related to the dispersal and redeposition of suspended sediments. Remote sensing surveys by Hall (2011) did not identify any hardbottom sites within 500m of the proposed dredging areas at the current ODMDS, former ODMDS, or Area Y. Additional dredging operations in Bogue Inlet under Alternative 4 would not be expected to have any effect on hardbottom communities, as exposed hardbottom features are associated with areas well seaward of the inlet on the lower shoreface and adjacent inner continental shelf. Potential sand delivery pipeline routes for nourishment projects have yet to be identified; however, approvals of proposed projects would be contingent on pre-project surveys demonstrating avoidance of hardbottom features. Based on the absence of hardbottom features within 500m of the proposed borrow sites; and the commitment to avoid hardbottom sites during pipeline placement; Alternative 4 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.3.3.2 Marine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, offshore borrow site dredging operations and associated effects on hydrodynamics would be the same as those described under Alternative 3. As previously described, compatible sand deposits at the former and current ODMDS borrow sites are contained in a series of dredged material disposal mounds that have maximum elevations ranging from approximately -31 to -40 ft NAVD88. The proposed cut depths of -50 to -52 ft NAVD88 under Alternative 4 account for the retention of a two-foot buffer of compatible disposal mound material above the underlying incompatible sediments. Over the 50-year project, dredging would reduce the elevations of the mounds by approximately 29 to 38 ft; however, excavation would not extend to or below the original underlying seafloor. Although the hydrodynamic effects of ODMDS dredging have not been evaluated through modeling; considering that excavation would not extend to or below the prevailing elevation of the seafloor, it is assumed that any effects on ocean currents and wave conditions would be minor and localized. The Area Y offshore borrow sites consist of two small isolated deposits (Y-80/75 and Y-120/90) with a combined total volume of ~1.5 MCY. The two Area Y borrow sites encompass a total seafloor area of less than 100 acres, and excavation would be limited to maximum depths of 5-10 ft below the original seafloor elevation. Based on the limited areal extent of dredging and the relatively shallow maximum dredge cut depths at Area Y, it is assumed that any effects on ocean currents and wave conditions would be minor and localized.

Water Quality

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, offshore borrow site dredging operations and associated sediment suspension effects would be the same as those described under Alternative 3. As previously described, dredging-induced sediment suspension is typically short-term and localized when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. All potential beach fill deposits at the borrow sites are composed of highly compatible sand with a very small fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension on marine water quality and pelagic communities would be short-term and localized under Alternative 4. Increases in suspended sediment concentrations and turbidity attributable to sand placement would also be expected in the surf zone along the management reaches. However, as previously described, the results of water quality monitoring during nourishment operations along Bogue Banks and other southeastern NC beaches indicate that turbidity increases are typically confined to the surf zone in the immediate vicinity of the slurry discharge point. Furthermore, it is anticipated that the beach compatible composition of the fill and the use of temporary dikes and spreaders to contain the discharged sand slurry would reduce the extent of sediment suspension. Therefore, it is anticipated that sediment suspension effects attributable to sand placement would be short-term and localized.

<u>Entrainment</u>

Direct, Indirect, and Cumulative Impacts

Hopper and cutterhead dredges both have the potential to entrain fishes and invertebrates during all life cycle phases (adults, juveniles, larvae, and eggs). Based on the entrainment studies discussed in the General Effects section, it is anticipated that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment in the dredge intake pipe. Offshore borrow site dredging would entrain the planktonic eggs and larvae of marine fishes and invertebrates that occur in the vicinity of the dredge pipe suction field. However, considering the diffuse distribution of larvae in offshore waters, it is anticipated that the effects of larval entrainment on marine fish and invertebrate populations would be negligible.

Sea turtles are vulnerable to entrainment by hopper dredges and could occur in the vicinity of the offshore borrow sites during hopper dredging operations. Cutterhead dredges are not known to take sea turtles; and therefore, any use of cutterhead dredges at the offshore borrow sites would not be expected to present any risk of entrainment to sea turtles. The temporal distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April - 20 November for inshore waters and a range of 23 April - 27 November for nearshore ocean waters. Hopper dredging operations under Alternative 4 would employ conservation measures to reduce the risk of sea turtle entrainment; including adherence to a 16 November - 30 April hopper dredging window, mandatory use of rigid draghead deflectors and associated operational parameters, and sea turtle relocation trawling.

Adherence to a 16 November - 30 April environmental window would reduce the risk of entrainment by limiting hopper dredging to the colder months when most sea turtles have moved to warmer waters well seaward of the borrow sites. Rigid deflector dragheads create a sand ridge in front of the draghead as they are drawn along the seafloor, thus pushing sea turtles away from direct contact with and outside the suction field of the draghead. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). Relocation trawling in front of the dredge has been shown to reduce the risk of entrainment by capturing and relocating any turtles that may be present near the bottom (Dickerson et al. 2007). Under Alternative 4, relocation trawling would be initiated at the onset of hopper dredging projects and conducted continuously throughout the duration of the operations. A recent study by Dickerson et al. (2007) found that trawling was most effective at reducing entrainment when it was initiated at the onset of dredging operations and continued throughout the duration of the project. Effectiveness also increased with the intensity of trawling, with the lowest number of entrainments per unit of dredging effort occurring when tows were conducted at a rate of >1.7 per hour.

As described in the General Effects section, a total of six sea turtles have been entrained by hopper dredges during offshore borrow site operations along Bogue Banks, despite adherence to environmental windows and the use of rigid dragheads and relocation trawling. Of the six takes associated with offshore borrow site dredging, four occurred in December 2002 during dredging operations for Phase I of the Bogue Banks Restoration project. The concentration of four takes during December 2002 was thought to be related to the unanticipated presence of derelict tires, which supported a sea turtle food source consisting of crustaceans, octopi, and other marine invertebrates (USACE 2016b). The two remaining takes occurred in April 2003 and March 2004 during offshore borrow site operations for Phases I and II of the Bogue Banks Restoration project, respectively. Thus, all of the sea turtle takes occurred during the two dredging events associated with Phases I and II of the restoration project in 2002/2003 and 2004, and four were thought to be related to the unanticipated presence of an artificial reef-like structure. Furthermore, although relocation trawling was active when the takes occurred, trawling was limited to periods of warmer water temperatures and was not conducted throughout the dredging events. As indicated above, based on the work by Dickerson et al. (2007), relocation trawling under Alternative 4 would be initiated at the onset of hopper dredging projects and would occur continuously throughout the duration of dredging events. Additionally, specific efforts would be made to ensure that no sea turtle attractants are located in the vicinity of the dredging areas. It is expected that these measures would further minimize, but not entirely eliminate the risk of sea turtle entrainment during hopper dredging.

The federally listed Atlantic sturgeon could also occur in the vicinity of the offshore borrow sites during hopper dredging operations; however, occurrences the open ocean would likely consist of subadults and adults that would be able to avoid the dredge. As described in the General Effects section, analysis of historical take along the South Atlantic Coast indicates that the risk of hopper dredge entrainment is primarily confined to dredging within riverine channels (USACE 2014c). The potential risk of entrainment to adult sturgeons is presumed to be low, and the use of rigid deflecting dragheads and associated operating requirements likely reduces the risk of entrainment (Dickerson et al. 2004). Cutterhead dredges have not been implicated in sturgeon takes along the South Atlantic Coast, and would not be expected to present any risk of entrainment to sturgeon. Relocation trawling may present a minor risk of injury to Atlantic sturgeon; however, the extensive use of relocation trawling for sea turtles and sturgeon along the US Atlantic Coast has resulted in very few reported injuries. Out of more than 1,300 reported captures of Atlantic and shortnose sturgeon during long-term trawl surveys and relocation trawling efforts along the mid-Atlantic and northeast Atlantic states, only two sturgeon injuries were reported (NMFS 2015). Both injuries were related to debris in the trawl net; and NMFS has since adopted modified net requirements that are expected to reduce the risks associated with the capture of debris during relocation trawling. According to NMFS, it is unlikely that significant injuries to any Atlantic or shortnose sturgeon would occur during trawling operations that employ the new nets in combination with short tow durations and careful sturgeon handling (NMFS 2015). Relocation trawling under Alternative 4 would follow all NMFS requirements to minimize potential adverse effects on Atlantic sturgeon. Based on these considerations, it is anticipated that the risk of sturgeon entrainment by hopper dredges and/or injury due to trawling at the offshore borrow sites would be negligible under Alternative 4.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Based on the noise studies described in the General Effects section, the sound levels produced by hopper dredges at the offshore borrow sites would not be expected to exceed the NMFS thresholds for injurious effects on marine mammals or sea turtles, but may exceed the thresholds for behavioral effects on marine mammals and sea turtles within 2.1 and 1.2 km of the dredge, respectively. As previously discussed, behavioral effects may include avoidance responses such as diving or an increase in swimming speed; however, considering the transient nature of large whale occurrences in the Permit Area and the mobility and avoidance behavior of dolphins and sea turtles, it is expected that any behavioral effects would be short-term and localized. The previously described noise studies indicate that the sound levels produced by cutterhead dredges would not be expected to exceed the NMFS thresholds for behavioral or injurious effects on marine mammals or sea turtles. As described in the General Effects section, limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) responses in fishes (Popper and Hastings 2009). However, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

5.3.3.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct and Indirect Impacts

Under Alternative 4, six management reaches encompassing a total of ~18 beach miles would receive regular maintenance nourishment at approximate intervals of three (Emerald Isle East), six (Indian Beach-Salter Path/Pine Knoll Shores/Bogue Inlet), and nine (Emerald Isle Central/West) years. Should the need arise for interim maintenance nourishment of Atlantic Beach, an additional ~5.0 beach miles would be nourished every three years under Alternative 4. The direct and indirect effects of sand placement events on intertidal beach communities would be of the same nature as those described under Alternative 3. Sand placement would eliminate the majority of the intertidal benthic invertebrate infauna along the affected reaches through direct burial. However, benthic infaunal recovery would begin immediately upon the cessation of sand placement operations, and it is anticipated that the use of compatible beach fill and avoidance of peak benthic infaunal recruitment periods would facilitate relatively rapid benthic community recovery. As described in the General Effects section, most intertidal benthic recovery studies have reported recovery within one year when highly compatible beach fill sediments were used and peak infaunal larval recruitment periods were avoided. Therefore, it is anticipated that the direct impacts of sand placement on intertidal benthic communities would be short-term and localized to the beach fill areas.

Beach construction activities; including heavy equipment operations, generator use, nighttime lighting, and other related activities; may disrupt shorebird foraging activities and/or prevent shorebirds from using otherwise suitable intertidal beach foraging habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone. Direct impacts on the benthic infaunal prey base may reduce 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 and foraging habitat loss 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 intertidal beaches as stopover refueling sites. However, it is anticipated that relatively rapid benthic infaunal recruitment would provide substantial prey resources along the disturbed reaches within a relatively short period of time, and substantial undisturbed intertidal beach foraging habitat would be available within the Permit Area during benthic recovery periods. Therefore, it is anticipated that the effects of benthic prey loss on shorebirds and surf zone fishes would be short-term and localized under Alternative 4.

Cumulative Impacts

Under Alternative 4, the projected maintenance nourishment intervals of three, six, and nine years would provide ample time for full recovery of benthic infaunal communities. In response to major storm events, one or more of the six management reaches, as well as Atlantic Beach, may experience an accelerated nourishment cycle. In the case of a maintenance event that is followed in the same year by a major storm, a storm response project could be implemented as early as the second post-storm winter season, resulting in a shortened two-year nourishment interval. However, full recovery would still be expected during the two year interval. Separate beach fill placement actions affecting the management reaches could potentially include USACE disposals of navigation dredged material from the MCH outer harbor channel on Pine Knoll Shores, dependent on the availability of material and the availability of town monies to offset additional costs in excess of the federal least cost disposal option. However, given the projected six-year maintenance nourishment interval for the Pine Knoll Shores reach, additional USACE placements would be unlikely to affect the ability of benthic communities to fully recover during the interim periods between nourishment events. Based on these considerations, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 4.

Some of the continuing USACE beach disposal events along Atlantic Beach/Fort Macon and the Bogue Inlet reach may coincide with County nourishment events, potentially increasing the total linear extent of beach impact during a given year by approximately six miles. Simultaneous USACE disposal and County nourishment events would reduce the pool of potential infaunal invertebrate recruits for recolonization of the impacted reaches, thus potentially extending infaunal community recovery periods. However, full recovery would still be expected during the three- to nine-year intervals between nourishment events. Therefore, any cumulative effects on intertidal benthic infaunal communities under Alternative 4 would be short-term. Simultaneous losses of intertidal benthic infauna may have short-term and localized cumulative prey loss effects on surf zone fishes and shorebirds.

Dry Beach and Dune Communities

Direct Impacts

Dry beach (berm) and dune construction under Alternative 4 would involve the use of bulldozers and other heavy machinery to redistribute and grade the placed material according to design profile specifications. Construction activities would directly impact ghost crabs and dune vegetation through burial and/or mechanical disturbance. However, it is anticipated that the replanting of constructed dunes with native species would facilitate dune stabilization and plant community recovery. Furthermore, it is anticipated that the use of compatible beach fill and avoidance of peak recruitment periods would facilitate relatively rapid ghost crab recovery. As described in the General Effects section, post-nourishment monitoring studies have reported relatively minor and short-term effects on ghost crab populations when highly compatible beach fill sediments were used and peak recruitment periods were avoided. Therefore, it is expected that the direct impacts of sand placement on dune vegetation and macroinvertebrate infaunal communities would be short-term and localized to the beach fill areas. Nourishment projects would avoid the sea turtle nesting and hatching season through adherence to the 16 Nov - 30 April sea turtle sand placement environmental window. Therefore, direct impacts on nesting females, nests, or hatchlings would not be expected under Alternative 4. Beach construction activities; including heavy equipment operations, generator use, night-time lighting, and other related activities; may disrupt shorebird activities and/or prevent shorebirds from using otherwise suitable dry beach roosting and loafing habitats in the immediate vicinity of the active construction zone. However, the effects of disturbance would be short-term and localized to the vicinity of the active construction zone.

Indirect Impacts

Beach nourishment under Alternative 4 may indirectly affect sea turtles through physical modification of dry beach nesting habitat. As described in the General Effects section, observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, substrate compaction, and escarpment formation. Additionally, substrate modifications may have negative effects on the nest incubation environment and/or the ability of hatchlings to emerge from their nests. As previously described, sediment compaction and the modification of substrate characteristics such as water retention, gas exchange, and sediment color can alter the nest incubation environment; potentially affecting embryonic development, hatching success, and hatchling sex ratios. As described in the General Effects section, the five-year post-nourishment nesting study on Bogue Banks did not show any effects on nesting or hatching success (Holloman and Godfrey 2008). A slight increase in nest temperature was observed along nourished reaches; however, potential effects on hatchling sex ratios were not evaluated. In the case of studies that have documented declines in nesting on nourished beaches, a return to normal nesting activity has generally been reported by the second or third post-project nesting season. Under Alternative 4, measures employed to minimize adverse effects on nesting habitat would include the use of compatible sediments, escarpment monitoring, and sediment compaction monitoring. It is expected that these measures would minimize the extent and duration of any habitat-modification effects on sea turtles. Based on the results of the prior Bogue Banks study and the use of these conservation measures, it is expected that any adverse effects on sea turtle nesting would be short-term and localized. Changes in beach morphology and sediment characteristics can also potentially affect the suitability of dry beach nesting habitat for coastal waterbirds. However, as previously described, sand placement on the oceanfront dry beaches of Bogue Banks is not expected to have any habitat-related effects on breeding or nesting activity, as traditional oceanfront beach breeding sites on NC's stabilized and developed barrier islands have essentially been abandoned in favor of more isolated inlet and estuarine sites.

Under Alternative 4, the maintenance of wider and higher oceanfront dry beaches along the managed reaches would be expected to increase the quantity and quality of potential sea turtle nesting habitat and high tide roosting habitat for coastal waterbirds. As previously described, studies have reported immediate increases in sea turtle nesting success following sand placement on severely eroded beaches. Based on the GENESIS model-projected MHW line changes, the average width of the dry beach along the management reaches at the end of the 12-year simulation period is 53 ft wider than the projected average width under Alternative 2 (Table 5.9). The corresponding effect on dry beach area along the managed shoreline is a relative increase of approximately 113 acres at the end of the 12-year simulation period (Table 5.10).

Cumulative Impacts

Based on the projected average maintenance nourishment intervals of three, six, and nine years, dry beach habitats and communities would be expected to fully recover during the interim periods between recurring nourishment events. In response to storm events and/or periods of accelerated background erosion, one or more of the six management reaches, as well as Atlantic Beach, may experience an accelerated nourishment cycle. In the case of a maintenance event that is followed in the same year by a major storm, a storm response project

Table 5.9. Alternative 4 model-predicted average YR-12 dry beach width relative to Alternative 2.

Management Reach	Year-12 Average Beach Width (ft)		Alt 4 Year-12 Relative Average Beach Width (ft)
	Alt 2	Alt 4	
Bogue Inlet	301	368	+58
Emerald Isle West	127	130	+3
Emerald Isle Central	118	141	+23
Emerald Isle East	62	125	+63
Indian Beach/Salter Path	181	278	+97
Pine Knoll Shores	100	173	+73
All Reaches	**143**	**196**	**+53**

Table 5.10. Alternative 4 model-predicted YR-12 dry beach area change relative to Alternative 2.

Management Reach	YR-0 to YR-12 Relative Dry Beach Change (acres)
Bogue Inlet	+15.4
Emerald Isle West	+1.4
Emerald Isle Central	+8.5
Emerald Isle East	+20
Indian Beach/Salter Path	+28.2
Pine Knoll Shores	+39.9
Total	**+113.4**

could be implemented as early as the second post-storm winter season, resulting in a shortened two-year nourishment interval. However, full recovery would still be expected during the two year interval. Some of the USACE beach disposal events along Atlantic Beach/Fort Macon and the Bogue Inlet reach may coincide with County nourishment events, potentially increasing the total linear extent of beach impact during a given year by approximately six miles. Simultaneous sand placement on the USACE disposal and County management reaches would reduce the pool of potential ghost crab and other macrofaunal invertebrate recruits for recolonization of the impacted reaches, thereby potentially extending macrofaunal invertebrate community recovery periods. However, full recovery would still be expected during the three- to six-year intervals between nourishment events; and therefore, any cumulative effects on invertebrate communities under Alternative 4 would be short-term. Simultaneous USACE and County sand placement projects could increase the linear extent of habitat modification effects on sea turtle nesting and shorebird roosting. However, given the short-term nature of these impacts, it is expected that any cumulative effects would be relatively minor.

5.3.3.4 Inlet and Estuarine Resources

Intertidal Flats and Shoals

Direct and Indirect Impacts

Under Alternative 4, the potential direct and indirect impacts of Bogue Inlet ebb channel realignments on intertidal flats and shoals would be similar to those previously described for realignments under Alternative 1. Inlet realignment dredging under Alternative 4 may directly impact mid-inlet intertidal shoals within the new channel excavation footprint, depending on the configuration of shoals at the time of realignment events. Any intertidal shoals that are present within the new channel footprint at the time of realignment events would be excavated and converted to subtidal soft bottom habitat. The benthic infaunal communities associated with any excavated intertidal shoals would be removed and replaced by subtidal soft bottom benthic communities. It is expected that any direct impacts would be offset by new intertidal habitat formation via dredged material placement along the Bogue Banks inlet shoulder, natural shoaling of the old channel, and subsequent expansion of the Bogue Banks sand spit. Unlike Alternative 1, realignments under Alternative 4 would occur before the ebb channel reaches an extreme westward alignment, thereby preempting a recurrence of the extreme erosional conditions that eliminated essentially all intertidal habitat along the Bogue Banks inlet shoreline during the period leading up to the 2005 realignment project. Due to the preemptive nature of realignment events under Alternative 4, the need for a closure dike is generally not anticipated. In contrast to Alternative 1, there would be sufficient time for the old channel to fill in before it presents a threat to Emerald Isle. However, in the event of extreme rapid ebb channel repositioning events (e.g., due to shoal breaching or hurricanes), the ebb channel could present an immediate threat to structures that would warrant the construction of a dike across the old channel to facilitate infilling. In such cases, it is anticipated that ~0.2 MCY of the dredged material from the new channel would be used to construct a closure dike across the old channel, with the remaining ~0.80 MCY of material being pumped directly onto the beaches of Emerald Isle.

Realignments of the ebb channel would modify patterns of flow and initiate a period of sediment redistribution and habitat reconfiguration within the inlet complex. During the adjustment period, the distribution and areal extent of intertidal flats and shoals within the inlet complex would be expected to fluctuate in response to sediment redistribution and related conversions between supratidal, intertidal, and subtidal habitats. However, habitat fluctuations would be consistent with the dynamic nature of inlet habitats and the habitat changes associated with natural ebb channel repositioning events that occur periodically in Bogue Inlet. Dredged material from the new channel would be placed within the inlet littoral system on western Emerald Isle, thus minimizing the likelihood of negative effects on the inlet sediment budget. As previously described, sediment volume change analyses indicate that the constructed channel performed largely as anticipated with minimal negative effects on sediment transport processes (M&N 2015). The habitat reconfiguration process would produce corresponding changes in the distribution and composition of intertidal benthic communities; however, it is expected that the gradual pace of habitat change would allow benthic communities to adjust accordingly. As described under Alternative 1, post-construction benthic monitoring for the 2005 realignment project found no project-related effects on benthic communities at inlet shoreline stations, while data from intertidal shoal stations along the new channel showed significant project-related effects on community composition that abated by the end of the second post-construction year.

Dredging operations may disrupt the foraging activities of shorebirds, potentially inducing shorebirds to expend additional energy seeking out alternative intertidal foraging habitats. However, during-construction monitoring for the 2012/2013 New River Inlet relocation project showed continued use of inlet complex habitats by a diverse assemblage of coastal waterbirds (USACE unpublished data). Furthermore, considering that USACE maintenance dredging of the Bogue Inlet navigation channel has occurred twice a year for decades, shorebirds are likely to exhibit some degree of habituation to inlet dredging activities under Alternative 4. Therefore, it is expected that any dredging-related shorebird disturbance under Alternative 4 would be short term and localized to the immediate vicinity of the active construction zone. Any direct impacts on intertidal shoals and associated benthic infaunal communities within the channel excavation footprint may temporarily reduce foraging opportunities for shorebirds. However, it is expected that any losses would be offset by new intertidal habitat formation via dredged material placement along the Bogue Banks inlet shoulder, natural shoaling of the old channel, and subsequent expansion of the Bogue Banks sand spit.

Cumulative Impacts

Under Alternative 4, inlet realignment events would be expected to occur at intervals of ten to 15 years, resulting in a total of four to five events over the next 50 years. Separate actions potentially affecting intertidal flats and shoals within Bogue Inlet would include continuing USACE placements of navigation dredged material from the AIWW Bogue Inlet Crossing on the Bogue Banks inlet shoreline every two to three years. Inlet realignment dredging under Alternative 4 may directly impact mid-inlet intertidal shoals within the new channel excavation footprint, depending on the configuration of shoals at the time of realignment events. However, considering the limited number and wide temporal spacing of realignment events and the short term nature of the direct impacts, it is expected that any cumulative effects on intertidal flat and shoal communities would be minor and short term. Unlike Alternative 1, management of the ebb channel in accordance with the safe box under Alternative 4 would avoid extreme habitat loss on Bogue Banks and maintain a more centralized alignment that would be favorable for sand spit and associated intertidal habitat development on both inlet shoulders. Thus, under Alternative 4, the maintenance of a more expansive and diverse inlet throat spit-shoal habitat complex over the next 50 years may have beneficial cumulative effects on intertidal flat and shoal communities in relation to Alternative 1 and the non-inlet management alternatives (Alternatives 2 and 3).

Inlet Dry Beach, Overwash, and Dune

Direct and Indirect Impacts

Under Alternative 4, the potential direct and indirect impacts of Bogue Inlet ebb channel realignments on inlet dry beach, overwash, or dune communities would be similar to those previously described for realignments under Alternative 1. Based on the proposed mid-inlet channel alignment, channel excavation under Alternative 4 would not be expected to directly impact inlet dry beach, overwash, or dune habitats. Unlike Alternative 1, realignments under Alternative 4 would occur before the ebb channel reaches an extreme westward alignment, thereby preempting a recurrence of the extreme erosional conditions that eliminated essentially all inlet dry beach and overwash habitat along the Bogue Banks inlet shoreline during the period leading up to the 2005 realignment project. During the post-construction inlet adjustment process; the distribution and areal extent of inlet dry beach, overwash, and dune habitats would be expected to fluctuate in response to sediment redistribution and related conversions between supratidal, intertidal, and subtidal habitats. However, habitat fluctuations would be consistent with the dynamic nature of inlet habitats and natural ebb channel repositioning events that occur periodically in Bogue Inlet. As described above, the retention of dredged material from the new channel within the inlet littoral system and the post-construction sediment volume changes following the 2005 realignment project suggest that the likelihood of negative effects on the inlet sediment budget would be minimal. Therefore, no adverse direct and indirect effects on inlet dry beach, overwash, and dune habitats would be expected under Alternative 4. Dredging operations may disrupt the breeding and roosting activities of shorebirds, potentially inducing shorebirds to expend additional energy seeking out alternative supratidal breeding and roosting habitats. However, as described above, the during-construction shorebird monitoring results for the New River Inlet project and the long history of frequent USACE dredging in Bogue Inlet suggest that shorebirds are likely to exhibit some degree of habituation to inlet dredging activities under Alternative 4. Sand delivery pipelines would be routed to avoid potential inlet shorebird nesting and roosting sites to the maximum extent practical. Therefore, it is expected that any dredging-related shorebird disturbance under Alternative 4 would be short term and localized to the immediate vicinity of the active construction zone.

Cumulative Impacts

Under Alternative 4, inlet realignment events would be expected to occur at intervals of ten to 15 years, resulting in a total of four to five events over the next 50 years. Separate actions potentially affecting inlet dry beach, overwash, or dune communities would include continuing USACE placements of navigation dredged material from the AIWW Bogue Inlet Crossing on the Bogue Banks inlet shoreline every two to three years. However, considering the limited number and wide temporal spacing of realignment events and the short term nature of the potential direct and indirect impacts, it is expected that any cumulative effects on inlet dry beach, overwash, and dune communities would be minor and short term. Unlike Alternative 1, management of the ebb channel in accordance with the safe box under Alternative 4 would avoid extreme habitat loss on Bogue Banks and maintain a more centralized alignment that would be favorable for sand spit and associated dry beach, overwash, and dune habitat development on both inlet shoulders. Thus, under Alternative 4, the maintenance of a more expansive and diverse inlet throat spit-shoal habitat complex over the next 50 years may have beneficial cumulative effects on inlet dry beach, overwash, and dune communities in relation to Alternative 1 and the non-inlet management alternatives (Alternatives 2 and 3).

Upland Dredged Material Disposal Islands

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, beach fill would also be excavated from a number of active USACE dredged material disposal islands along the Bogue Inlet crossing and other sections of the AIWW. Although man-made and subject to periodic dredged material placement impacts, these disposal sites provide important nesting habitat for shorebirds and waterbirds. Several of the disposal sites that are proposed as borrow sources under Alternative 4 are included in the NCNHP list of state natural areas as a component of the Bogue Inlet/Bogue Sound Bird Nesting Islands complex (NCNHP 2015). Beach fill extraction from the AIWW disposal sites would likely involve pump-outs by a cutterhead dredge, with direct pipeline delivery to the beach or delivery via scows/barges and nearshore pump-out stations. Excavation below MHW is not proposed as a component of sand extraction at these sites; and therefore, Alternative 4 would not reduce the area of potential supratidal nesting habitat. Sand extraction would likely increase the area of sparsely vegetated supratidal habitat, thereby potentially enhancing the quality of nesting habitat for some species. The NCWRC indicates that disposal island elevations above ten feet may expose birds and their nests to high winds and sand movement (USACE 2016a), thus sand extraction may also have beneficial effects on nesting habitat through reductions in elevation. Furthermore, in the specific case of these disposal islands, sand extraction would be completed between 16 November and 31 March, thus avoiding the shorebird/waterbird breeding season. Therefore, adverse effects on shorebird/waterbird breeding or nesting attributable to the extraction of sand from AIWW disposal sites would not be expected under Alternative 4.

Estuarine Soft Bottom

Direct and Indirect Impacts

Under Alternative 4, the potential direct and indirect effects of Bogue Inlet ebb channel realignments on estuarine soft bottom communities would be similar to those previously described for realignments under Alternative 1. Each realignment event would directly impact ~35 acres of estuarine soft bottom habitat within the new channel excavation footprint. Dredging would remove the majority of the associated soft bottom benthic infaunal and epifaunal invertebrates; resulting in an initial sharp decline in community abundance, diversity, and biomass within the new channel footprint. However, as described in the General Effects section, studies of benthic community recovery in dredged navigation channels along the southeastern coast have reported rapid recovery within six months. Rapid recovery has been attributed to recolonization via slumping of adjacent undisturbed sediments into the dredged channel and avoidance of spring benthic invertebrate recruitment periods. The project construction window (16 Nov – 30 April) would avoid peak benthic invertebrate recruitment periods; and therefore, it is anticipated that impacts on estuarine soft bottom communities would be short term and localized under Alternative 4. Unlike Alternative 1, it is expected that the preemptive implementation of realignments under Alternative 4 would preclude the need for a closure dike across the old channel. However, in the event of an extreme rapid ebb channel repositioning event (e.g., due to a hurricane or other shoal breaching event), the ebb channel could present an immediate threat to structures that would warrant the construction of a dike across the old channel to facilitate infilling. In such a case, the placement of ~0.2 MCY of dredged material in the old channel to construct a closure dike would directly impact an additional ~12 acres of estuarine soft bottom habitat, resulting in the burial and loss of the associated benthic infaunal and epifaunal invertebrates. However, based on avoidance of peak benthic recruitment periods and the rapid recovery capabilities of soft bottom communities that occur in shallow, frequently disturbed habitats; it is anticipated that the effects of dike construction would be short term and localized.

Based on the composition of the inlet dredged material (sand with minimal fines), the sediment suspension characteristics of cutterhead dredges, and the low turbidity levels observed throughout the 2005 realignment project; it is expected that the effects of dredging-induced sediment suspension and redeposition on benthic communities and demersal fishes would be short term and minor. The removal of benthic invertebrate prey may affect the foraging activities of predatory demersal fishes; however, recruitment of opportunistic benthic taxa to the dredged channel and dike footprint would provide substantial prey resources within a relatively short period of time, and the distribution of alternative soft bottom habitats within the overall Permit Area is expansive. Based on all of these considerations, it is anticipated that the direct and indirect effects of Alternative 4 on estuarine soft bottom communities would be short term and localized to the active construction areas.

Cumulative Impacts

Continuing twice-yearly USACE side-cast maintenance dredging of the Bogue Inlet ebb (navigation) channel would be expected to maintain subtidal soft bottom benthic communities in a relatively early successional stage. The effects of 4 to 5 ebb channel realignment events over a 50-year period would not be expected to add measurably to the impacts of continuing frequent federal USACE dredging. Therefore, cumulative impacts on estuarine soft bottom communities would not be expected under Alternative 4.

<u>Estuarine Water Column</u>

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the potential direct and indirect effects of Bogue Inlet ebb channel realignments on hydrodynamics would be similar to those previously described for realignments under Alternative 1. Realignments would construct a new channel in accordance with the previously constructed 2005 channel specifications. The post-realignment hydrodynamic performance of the ebb channel would be expected to approximate that of the 2005 realignment project channel. An initial post-realignment flow study conducted in June 2005 found that the new channel was clearly dominant and was capturing most (~75%) of the combined ebb tidal discharge of the new and old channels; and a somewhat lesser majority (59%) of the combined flood discharge of the two channels, with some persistent westerly flow occurring across the closure dike during the flood cycle. As previously described, the performance of the new channel was subsequently affected by Hurricane Ophelia (September 2005), which breached the closure dike across the old channel and reopened a connection between the old channel and Coast Guard channel leading to the AIWW. Although Ophelia delayed infilling and abandonment of the former channel (Cleary 2008), infilling of the former channel was nearly complete by 2009 and the eastern segment of the ebb delta had been reconfigured in accordance with the new ebb channel alignment. Reorganization of the inlet shoal system was accompanied by spit development on the east end of Bogue Banks, and by October 2010 the developing Bogue Banks spit had prograded 1,830 ft westward into the inlet.

The results of a model-simulated inlet realignment event under current inlet conditions show relatively minor effects on the tidal prism, with a predicted six percent increase in average ebb flow and a predicted 8 percent decrease in average flood flow. The overall predicted change in the tidal prism is a small decrease in average net flow in the flood direction (into the inlet). The modeling results are consistent with the calculated annual (2005-2009) sediment volume changes following the 2005 realignment project, showing that the inlet accreted sediment at an average rate of 374,000 cy/yr (M&N 2015). The calculated average accretion rate is consistent with the estimated gross longshore sediment transport rate in the vicinity of the inlet and the projected post-project shoaling rates in the new and former ebb channels (CPE 2004). The results of the sediment volume change analysis indicate that the constructed channel performed largely as anticipated with minimal negative effects on hydrodynamics and associated sediment transport processes. Based on the performance of the 2005 project, and the model-predicted ebb channel performance, it is expected that any adverse direct and indirect effects on inlet hydrodynamics and the tidal prism would be minor under Alternative 4. Based on the relatively minor predicted tidal prism response, effects on estuarine salinity levels would be unlikely under Alternative 4.

Cumulative Impacts

It is expected that the USACE would continue to maintain the Bogue Inlet navigation channel during the interim periods between realignment events. Maintenance of the Bogue Inlet channel is typically conducted twice-yearly by sidecast dredges, following the thalweg or deepest portion of the channel, with open water disposal of the dredged material. Dredging follows the deepwater ebb channel that exists at the time of maintenance events, with the channel being allowed to migrate freely during interim periods. Hydrodynamic conditions would continue to fluctuate in response to natural channel migration and alternating cycles of shoaling and maintenance dredging; however, USACE maintenance of the authorized cross-sectional area would be expected to maintain the general flow regime and tidal prism. Therefore, inlet realignments under Alternative 4 would not be expected to have any cumulative effects on inlet hydrodynamics.

Water Quality

Direct, Indirect, and Cumulative Impacts

Dredging-induced sediment suspension and associated turbidity increases may affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of estuarine organisms. However, as described in the General Effects section, sediment suspension by cutterhead dredges is typically confined to the near bottom water column and is typically short-term and localized when the dredged material is composed of relatively clean sand with a minimal fine silt/clay fraction. As previously discussed, analyses of vibracore samples from the proposed ebb channel realignment footprint have characterized the sediments as highly compatible sand with a very small fine sediment fraction of less than two percent. Furthermore, during the 2005 Bogue Inlet ebb channel realignment project, observed turbidity levels remained within the ambient range of 9.7 to 35.2 NTUs throughout dredging operations. Therefore, it is anticipated that the effects of dredging-induced sediment suspension on estuarine water quality and estuarine communities would be short-term and localized under Alternative 4.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Based on the noise studies described in the General Effects section, the sound levels produced by cutterhead dredges would not be expected to exceed the NMFS thresholds for behavioral or injurious effects on marine mammals or sea turtles. Limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) responses in fishes (Popper and Hastings 2009). However, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013).

Entrainment

Direct, Indirect, and Cumulative Impacts

Based on the entrainment studies discussed in the General Effects section, it is anticipated that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment in the dredge intake pipe. Cutterhead dredging in Bogue Inlet would entrain the planktonic eggs and larvae of estuarine dependent fishes and invertebrates that occur in the vicinity of the dredge pipe suction field. However, as described in the General Effects section, modeling studies of larval entrainment during simulated dredging in Beaufort Inlet indicate that dredge entrainment rates are extremely low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2003). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1% of the daily (24-hour) larval flux through the inlet. Therefore, infrequent cutterhead dredging in Bogue Inlet every ten to 15 years would not be expected to have any measurable effect on estuarine-dependent fish and invertebrate populations. Cutterhead pipeline dredges have not been implicated in sea turtle takes; and therefore, ebb channel realignment dredging in Bogue Inlet would not be expected to present any risk of entrainment to sea turtles. Atlantic sturgeons could potentially occur in Bogue Inlet during dredging operations; however, cutterhead dredges have not been implicated in Atlantic sturgeon takes within the South Atlantic region. Furthermore, any individuals that might be present would likely consist of subadults and adults that would be able to avoid the dredge. Therefore ebb channel realignment would not be expected to present any risk of entrainment to Atlantic sturgeon.

Shellfish

Direct, Indirect, and Cumulative Impacts

Shellfish beds are generally restricted to waters inland of the channel realignment footprint. As previously described, NCDMF benthic habitat maps do not show any shell bottom habitats within the proposed channel or the main inlet throat complex. Therefore, direct impacts on shellfish would not be expected under Alternative 4. Fine sediments suspended by the dredging process may be transported inland and redeposited in areas containing shellfish beds; however, based on the composition of the dredged material (sand with minimal fines), it is expected that any sediment suspension and redeposition effects on shellfish would be minor under Alternative 4. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of shellfish beds and other benthic habitats within the estuarine complex surrounding the inlet; however, this process and any associated reductions in shellfish habitat would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. Additionally, the post-project monitoring results for the 2005 realignment showed no change in the quantity of shellfish habitat within the study area over the three-year monitoring period (Rosov and York 2009). Therefore, it is expected that any dredging-related effects on shellfish would be minor and localized under Alternative 4. Fringing shellfish beds may be present along the outer margins of the containment dikes that surround the AIWW disposal island borrow sites; however, pump-outs would be conducted by a cutterhead dredge operating in the adjoining AIWW channel, and the sediment excavation and rewatering process would be confined to the active disposal area within the dike walls. Pipeline routes would be coordinated with NCDMF to ensure avoidance of shellfish beds and other high value benthic resources. Therefore, the extraction and delivery of sand from AIWW disposal islands would not be expected to have any direct, indirect, or cumulative impacts on shellfish.

SAV

Direct, Indirect, and Cumulative Impacts

SAV beds are generally restricted to waters inland of the channel realignment footprint and main inlet complex. As previously described, SAV maps developed by NOAA and NCDMF do not show any SAV habitats within the proposed channel or the main inlet throat complex. Therefore, direct impacts on SAV would not be expected under Alternative 4. Fine sediments suspended by the dredging process may be transported inland, potentially affecting SAV through increases in turbidity and/or sediment redeposition. However, based on the composition of the dredged material, it is expected that any sediment suspension and redeposition effects on SAV would be minor under Alternative 4. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of benthic habitats within the estuarine complex surrounding the inlet; however, this process and any associated reductions in SAV would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. Additionally, the post-project monitoring results for the 2005 realignment showed an increase in SAV of ~17 acres within the study area over the three-year monitoring period (Rosov and York 2009). Therefore, it is expected that any dredging-related effects on SAV would be minor and localized under Alternative 4. Fringing SAV beds may be present along the outer margins of the containment dikes that surround the AIWW disposal island borrow sites; however, pump-outs would be conducted by a cutterhead dredge operating in the adjoining AIWW channel, and the sediment excavation and rewatering process would be confined to the active disposal area within the dike walls. Pipeline routes would be coordinated with NCDMF to ensure avoidance of SAV and other high value benthic resources. Therefore, the extraction and delivery of sand from AIWW disposal islands would not be expected to have any direct, indirect, or cumulative impacts on SAV.

<u>Tidal Marsh</u>

Direct, Indirect, and Cumulative Impacts

Tidal marshes are generally associated with estuarine islands and back-barrier shorelines along the lateral and inland margins of the main inlet throat area, and coastal wetland maps developed by the NCDCM do not show any tidal marshes within the proposed channel footprint. Therefore, ebb channel realignments under Alternative 4 would not be expected to have any direct impacts on tidal marshes. As previously described, the post-realignment inlet adjustment and reconfiguration process may alter the distribution and relative extent of estuarine habitats surrounding the inlet; however, this process and any associated reductions in tidal marsh would be consistent with natural ebb channel repositioning events that occur periodically in Bogue Inlet. The post-project monitoring results for the 2005 realignment showed a decrease in tidal marsh of ~18 acres within the inlet complex and an increase of ~77 acres within the more expansive overall study area over the three-year monitoring period (Rosov and York 2009). Losses within the inlet complex were primarily associated with the reopening of the Coast Guard channel by Hurricane Ophelia and resulting erosional effects on the breached western tip of Emerald Isle. Therefore, it is expected that any project-related effects on tidal marshes would be minor under Alternative 4. Fringing tidal marshes may be present along the outer margins of the containment dikes that surround the AIWW disposal island borrow sites; however, pump-outs would be conducted by a cutterhead dredge operating in the adjoining AIWW channel, and the sediment excavation and rewatering process would be confined to the active disposal area within the dike walls. Pipeline routes would be coordinated with the NCDMF to ensure avoidance of tidal marshes and other high value inlet/estuarine resources. Therefore, the extraction and delivery of sand from AIWW disposal islands would not be expected to have any direct, indirect, or cumulative impacts on tidal marshes.

5.3.3.5 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Remote sensing surveys did not identify any potential archaeological resources in the vicinity of the ODMDS or Area Y offshore borrow sites (Hall 2011). Ebb channel relocations would realign the channel to the previously dredged 2005 channel footprint; which prior surveys indicate does not contain cultural resources. Therefore, Alternative 4 would not be expected to have any adverse effects on cultural resources.

5.3.3.6 Public Interest Factors

<u>Public Safety</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the potential effects of beach nourishment and offshore dredging on public safety would be similar to those described under Alternative 3. The potential effects of inlet channel realignments would be similar to those described under Alternative 1; however, Alternative 4 would involve more frequent realignment events every ten to 15 years, resulting in a total of four to five events over the next 50 years.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the potential effects of beach nourishment and dredging on aesthetics and recreation would be similar to those described under Alternative 3.

<u>Hazardous, Toxic, and Radioactive Waste (HTRW)</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 4; direct, indirect, and cumulative effects related to the potential occurrence of HTRW within the offshore borrow sites, AIWW disposal islands, and oceanfront beach placement areas would be the same as those described under Alternative 3. As described under Alternative 1, ebb channel realignments under Alternative 4 would not be expected to result in any HTRW-related impacts.

Air Quality

Direct, Indirect, and Cumulative Impacts

Carteret County is designated as an attainment area for all criteria pollutants (USEPA 2016); and therefore, General Conformity regulations are not applicable to the proposed action. Mobile source emissions generated by dredges and onshore construction equipment would result in temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM; however, it is expected that emissions would be rapidly dispersed, thereby precluding any significant effects on air quality. Furthermore, an emissions analysis conducted by the USACE for the proposed Bogue Banks CSDR project determined that the combined emissions of dredging and sand placement activities that are comparable to those of the proposed action would fall below de minimis levels and would not have any adverse effect on air quality (USACE 2014a). Therefore, Alternative 4 would not be expected to have any direct, indirect, or cumulative impacts on air quality.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the effects of dredging operations at the offshore borrow sites and AIWW disposal islands on navigation would be the same as those described under Alternative 3. In the case of Bogue Inlet ebb channel realignment events, the navigability of the existing federal Bogue Inlet channel would be maintained throughout the period of construction. The use of a closure dike across the old channel is not anticipated; however, if required by extreme circumstances, the dike would be constructed after completion of the new channel. Navigability of the ebb channel would be maintained by continuing USACE maintenance dredging during the interim periods between channel alignment events. Therefore, ebb channel realignments under Alternative 4 would not be expected to have any direct, indirect, or cumulative impacts on navigation.

Infrastructure

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the combined beach fill volume provided by the offshore borrow sites, AIWW disposal islands, upland sand mines, and Bogue Inlet ebb channel realignments is expected to provide for continuous maintenance of 25-year LOP beach profile volumes along the entire ~18-mile managed shoreline. Therefore, no properties are projected to at risk over the next 50 years.

Economics

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, projected County/municipal maintenance nourishment and inlet realignment events would cost approximately $182.4M. Storm losses are estimated to require additional placements totaling ~27.2 MCY over the next 50 years at a cost of $360.4M in federal reimbursement monies. Continuing USACE sand placement activities; including the disposal of navigation dredged material from the MCH channels on Atlantic Beach and beach disposal on the Pointe adjacent to Bogue Inlet via maintenance of the Bogue Inlet AIWW Crossing channel; would cost approximately $245.2M over the next 50 years. The total cumulative cost of all nourishment would be approximately $787.9M over the next 50 years. As indicated above, beach nourishment under Alternative 4 is expected to provide continuous protection for all properties along the ~18-mile managed shoreline over the next 50 years. Therefore, additional costs associated with losses of property value or tax revenue are not anticipated under Alternative 4.

5.3.4 Alternative 5: Beach Nourishment and Structural Inlet Management

Under Alternative 5, the County, through an interlocal agreement with all of the island municipalities, would implement the 50-year beach nourishment project described under Alternative 3, with the addition of a structural Bogue Inlet management component consisting of a terminal groin on the west end of Emerald Isle. Nourishment parameters, regimes, and volumes for the Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle East management reaches would be identical to those previously described under Alternative 3. As in the case of Alternatives 3 and 4, continuing USACE placements of navigation dredged material from the MCH channels are expected to meet the maintenance nourishment requirements of the ~5.0-mile Atlantic Beach management reach. Therefore, the County is not anticipating any maintenance sand placement on Atlantic Beach under its 50-year management plan. However, the County's 50-year plan would provide for interim maintenance nourishment events along Atlantic Beach should USACE MCH placements cease. Furthermore, the County's 50-year plan would provide storm-response nourishment for Atlantic Beach to address any storm-related needs that exceed the volumes placed by the USACE MCH project. Alternative 5 would not provide for any nourishment of the approximately eight miles of beaches along central and western Emerald Isle and Bogue Inlet; however, Alternative 5 would attempt to reduce sand losses along these reaches through the construction of an 1,250-foot-long terminal groin along the shoulder of Bogue Inlet. Under Alternative 5, sources of beach fill and associated extraction methods would include all of those previously described under Alternative 3 (i.e., Old and Current ODMDS, Area Y, AIWW disposal islands, and upland borrow sites). As in the case of Alternative 3, full utilization of all identified sand resources at these borrow sites is anticipated under Alternative 5.

The conceptual terminal groin design encompasses a 1,250-foot-long shore perpendicular stem/head segment extending seaward from the western end of Emerald Isle and a 600-foot-long "tie-back" anchor segment that extends landward along the back-barrier inlet shoreline in front of the existing homes before tying in to the Coast Guard bulkhead . The groin is designed to be a relatively low profile structure, both to maximize sand over-passing and to minimize impacts to beach recreation and aesthetics. The terminal groin would be constructed of three- to six-feet-diameter granite armor stone; and unlike traditional jetties, would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for a large void ratio, thus providing the "leaky" characteristic that allows sand to pass through the structure. To prevent settlement of the stone, and if necessary to facilitate modification or removal of the groin, a base layer of geo-textile matting (one-foot thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the groin would have a variable crest width ranging from approximately seven to 15 ft and a variable base width of ~40 to 100 ft.

Land-based heavy equipment would be used to construct the groin by excavating the dry beach, installing the geo-textile matting and rock to design specifications, and covering the structure with the original excavated sand material. For the section that extends below the MHW line, an elevated platform may be constructed depending on the depth of the water and the linear extent of the in-water groin component, as determined by the shoreline position when construction is initiated. Based on the 2015 shoreline position, approximately 550 linear ft of the groin structure would extend below the MHW line. It is anticipated that all of the stone for groin construction would be hauled in by trucks from the quarry site. Once the structure is in place, compatible beach fill material would be placed eastward of the terminal groin to form its fillet. The groin fillet would establish a gradual transitional shoreline between the oceanfront beach and the seaward terminus of the terminal groin. Material for the initial fillet construction event would either be acquired from one of the proposed borrow areas or provided by USACE placement of navigation dredged material from the AIWW Bogue Inlet Crossing channel. Material for any future fillet maintenance events would consist of navigation dredged material from the AIWW inlet crossing provided by the USACE.

5.3.4.1 Marine Benthic Resources

5.3.4.1.1 Soft Bottom Communities

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the effects of beach nourishment and associated offshore borrow site dredging operations on soft bottom communities would be the same as those described under Alternative 3. Construction of the terminal groin under Alternative 5 would directly impact ~0.75 acres of subtidal soft bottom habitat, resulting in the permanent loss of the associated benthic infauna and epifauna. However, based on the small area of direct impact, groin construction would not be expected to have any measurable effect on soft bottom benthic communities within the Permit Area. The redeposition of sediments that are temporarily suspended by the groin construction process may have additional temporary impacts on soft bottom communities adjacent to the groin footprint. However, groin construction would occur within the inlet-dominated littoral system, where sediments consist of relatively coarse-grained sands with a very small fine sediment fraction. Thus, it is anticipated that sediment suspension and redeposition effects would be minor, short-term, and localized.

5.3.4.1.2 Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential effects of beach nourishment and offshore borrow site dredging on hardbottom communities would be the same as those described under Alternatives 3 and 4. The terminal groin would be constructed on the uppermost portion of the shoreface, whereas exposed hardbottom features are principally associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf. Therefore, groin construction would not be expected to have any adverse impacts on hardbottom communities. Submerged portions of the terminal groin would provide many of the same habitat functions that are associated with natural hardbottom habitats. The fish communities that are associated with groins and jetties in NC are typically a subset of the species found on natural ocean hardbottoms and estuarine oyster reefs (Lindquist et al. 1985 and Hay and Sutherland 1988). Taxa reported from groins and jetties in NC and South Carolina include small cryptic resident fishes (e.g., blennies and gobies), numerically dominant fishes that migrate offshore in winter (e.g., pinfish, spottail pinfish, black sea bass, and pigfish), predatory pelagic fishes (e.g., bluefish, Spanish mackerel, and king mackerel), fishes attracted to jetties during their seasonal migrations [e.g., smooth dogfish (*Mustelus canis*)], and tropical fishes occurring as strays during the summer (e.g., butterflyfishes and surgeonfishes) (Hay and Sutherland 1988). Therefore, the additional habitat created by the terminal groin would be expected to have beneficial effects on hardbottom communities.

5.3.4.2 Marine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential effects of beach nourishment and offshore borrow site dredging on hydrodynamic processes would be the same as those described under Alternatives 3 and 4. The terminal groin would have localized effects on longshore currents and associated sediment transport processes along the west end Emerald Isle shoreline. The modeling results indicate accretion along the downdrift inlet side of the groin, resulting in an increase in bed elevation ranging from 0.8 to 1.1 ft over an area of ~22 acres (M&N 2013). The projected effects of the terminal groin on the updrift oceanfront shoreline to the east are limited to shoreline accretion within approximately one mile of the groin. The modeling results indicate a slight deepening of the Bogue Inlet ebb channel along its western edge. The modeling results do not indicate any effects on the east end of Bear Island, which is consistent with past studies indicating that the primary sediment source for the eastern end of Bear Island is the ebb-shoal and not sediment bypassing from Bogue Banks across Bogue Inlet.

Sediment Suspension and Turbidity

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, sediment suspension effects attributable to beach nourishment and offshore borrow site dredging would be the same as those described under Alternatives 3 and 4. Sediments that are temporarily suspended by the groin construction process may have additional temporary impacts on water quality. However, groin construction would occur within the inlet-dominated littoral system, where sediments consist of relatively coarse-grained sands with a very small fine sediment fraction. Thus, it is anticipated that sediment suspension effects would be minor, short-term, and localized.

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the effects of underwater noise produced by offshore borrow site dredging operations would be the same as those described under Alternatives 3 and 4. Any additional noise-related effects attributable to groin construction would be short-term and localized.

Entrainment

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the effects of entrainment attributable to offshore borrow site dredging would be the same as those described under Alternatives 3 and 4.

5.3.4.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential direct effects of beach nourishment on intertidal beach communities would be the same as those described under Alternative 3. Approximately 0.2 acre of intertidal beach habitat would be permanently lost within the footprint of the terminal groin structure. Given the minimal extent of permanent impact, any habitat loss effects on benthic infaunal communities, surf zone fishes, and shorebirds would be negligible. The projected indirect and cumulative effects of the terminal groin on the updrift Emerald Isle oceanfront shoreline are limited to shoreline accretion within ~1 mile of the groin (M&N 2013). The modeling results do not indicate any effects on the east end of Bear Island, which is consistent with past studies indicating that the primary sediment source for the eastern end of Bear Island is the ebb-shoal and not the sediment bypassing from Bogue Banks across Bogue Inlet.

<u>Dry Beach and Dune Communities</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the effects of beach nourishment on dry beach and dune communities would be similar to those described under Alternative 3. Approximately 0.3 acre of dry beach habitat would be permanently lost within the footprint of the terminal groin structure. Given the minimal extent of permanent impact, any habitat loss effects on ghost crabs, shorebirds, and sea turtle nesting would be negligible. Alternative 5 would maintain a wider oceanfront dry beach along Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle, thereby potentially improving the quality of shorebird/waterbird loafing and roosting habitats. Based on the GENESIS model-projected MHW line changes, average dry beach widths along the Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle East management reaches at the end of the 12-year simulation period are 61 to 97 ft wider than the projected widths under Alternative 2 (Table 5.11). The relative increases in beach width under Alternative 5 equate to relative increases in dry beach area of approximately 19 to 43 acres along the three management reaches (Table 5.12). Conversely, Alternative 5 has essentially no relative effect on beach width or area along the Emerald Isle Central and Emerald Isle West reaches, thus indicating that mitigative terminal groin effects are absent along these reaches. Therefore, adverse effects on dry beach communities comparable to those described under Alternative 2 would be expected along these reaches. In the case of the Bogue Inlet reach, the modeling results show a minor relative increase in average dry beach width of approximately ten feet at the end of the 12-year simulation period, thus indicating that the terminal groin has limited mitigative effects on shoreline erosion. The relative increase in beach width equates to a reduction in the need for nourishment along the Bogue Inlet reach of ~20,000 cy/yr; however, the projected volumetric need is ~45,000 cy/yr, thus indicating that the reach would continue to experience substantial net erosion.

Table 5.11. Alternative 5 model-predicted average YR-12 dry beach width relative to Alternative 2.

Management Reach	Year-12 Average Beach Width (ft)		Alt 5 Year-12 Relative Average Beach Width (ft)
	Alt 2	Alt 5	
Bogue Inlet	301	311	+10
Emerald Isle West	127	127	0
Emerald Isle Central	118	120	+2
Emerald Isle East	62	123	+61
Indian Beach/Salter Path	181	278	+97
Pine Knoll Shores	100	173	+73
All Reaches	**143**	**184**	**+41**

Table 5.12. Alternative 5 model-predicted YR-12 dry beach area change relative to Alternative 2.

Management Reach	YR-0 to YR-12 Relative Dry Beach Change (acres)
Bogue Inlet	+1.8
Emerald Isle West	0.0
Emerald Isle Central	+0.8
Emerald Isle East	+19.3
Indian Beach/Salter Path	+20.1
Pine Knoll Shores	+42.5
Total	**+81.8**

Groin construction would result in minimal (~0.3 acre) permanent loss of potential dry beach sea turtle nesting habitat; and the majority of the groin segment across the dry beach would be buried, thus minimizing the potential for indirect physical habitat modification effects. The groin could affect the movements of sea turtles in the water; however, based on the groin's location near the western terminus of the oceanfront beach, and its perpendicular alignment relative to the beach, effects on sea turtle access to dry beach nesting habitats would be minimal. Therefore, the groin would not be expected to have adverse indirect or cumulative effects on sea turtles via modification of potential nesting habitat. The groin in combination with the fillet would establish a gradual transitional shoreline between the seaward terminus of the terminal groin and the updrift oceanfront beach, thus minimizing the potential for effects on sea turtle movements in the water. Furthermore, the relatively short length of the in-water groin segment (~500 ft seaward of the MHW line) would be expected to minimize the potential for adverse effects on sea turtle movements in the water. Therefore, it is expected that groin-related effects on sea turtles would be minimal.

5.3.4.4 Inlet and Estuarine Resources

Intertidal Flats and Shoals

Direct, Indirect, and Cumulative Impacts

As described above, the model-projected effects of the terminal groin include accretion along the downdrift inlet side of the groin, resulting in an increase in bed elevation ranging from 0.8 to 1.1 ft over an area of ~22 acres (M&N 2013). The projected downdrift accretional response is consistent with the porous or “leaky” design of the groin that allows for sand bypassing through the structure. Additionally, the in-water portion of the groin extends only ~500 ft seaward of the existing shoreline, a relatively short distance in relation to the much broader east-to-west longshore sediment transport corridor and the existing seaward-protruding inlet ebb tidal delta. Accretion along the downdrift Bogue Banks inlet shoreline also reflects significant wave-driven sediment transport potential from the ebb shoal toward the sand spit. The modeling results indicate that any groin-related effects on east-west longshore sediment transport and wave-driven sediment transport from the ebb tidal delta into the inlet would be minimal. The modeling results do not indicate any effects on the east end of Bear Island, which is consistent with past studies indicating that the primary sediment source for the eastern end of Bear Island is the ebb-shoal and not sediment bypassing from Bogue Banks across Bogue Inlet. Therefore, adverse effects on intertidal flats and shoals would not be expected under Alternative 5.

Inlet Dry Beach, Overwash, and Dune Communities

Direct, Indirect, and Cumulative Impacts

The potential effects of the terminal groin on inlet dry beach, overwash, and dune communities would be similar to those described above for intertidal flats and shoals. The modeling results do not indicate any erosional or sediment transport effects that would adversely affect dry beach, overwash, and dune habitats along the downdrift Bogue Banks inlet shoreline or the Bear Island inlet shoreline.

Upland Dredged Material Disposal Islands

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; methods of sand extraction from the AIWW disposal islands and associated effects on coastal waterbird nesting would be the same as those described under Alternatives 3 and 4.

Estuarine Soft bottom

Direct, Indirect, and Cumulative Impacts

Sediments that are temporarily suspended by the groin and fillet construction process could potentially be transported through the inlet and re-deposited on estuarine soft bottom habitats. However, groin construction would occur within the inlet-dominated littoral system, where sediments consist of relatively coarse-grained sands with very small fine sediment fractions. As described in the General Effects section, sediment suspension is typically short term and localized when the substrate is composed of clean sand with minimal fines. Therefore, it is anticipated that sediment suspension and redeposition effects would be minor, short-term, and localized. Once the terminal groin has been completed and the fillet and inlet shorelines have equilibrated, natural sediment transport processes would control suspended sediment concentrations and turbidity levels and associated effects on soft bottom communities within the inlet complex.

Estuarine Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

The model-projected effects of the groin on inlet and estuarine hydrodynamics are limited to a slight increase in ebb channel depth along its western edge and a negligible reduction in the tidal prism of 0.4% across spring and neap tides (reduction in volume factor of 0.004). Therefore, no adverse effects on inlet hydrodynamics would be expected under Alternative 5. Given the relatively short length of the in-water groin segment (~500 ft seaward of the MHW line), it is expected that effects on longshore hydrodynamics would be minimal. Additionally, the groin fillet would establish a gradual transitional shoreline between the Emerald Isle oceanfront beach and the seaward terminus of the terminal groin, thus further minimizing effects on longshore currents. It is expected that groin-related effects on longshore current dynamics would be minimal and highly localized to the groin structure. Under flood tide conditions, the potential for any deflection of longshore currents by the groin would be overridden by the expansive tidal push of water into the inlet; and consequently, westerly longshore currents along the Bogue Banks oceanfront shoreline would be driven tightly around the groin and into the inlet where they would resume their normal pattern of flow. Similarly, the large tidal push of water out of the inlet during ebb tide conditions would drive easterly longshore currents from the inlet tightly around the groin and along the Bogue Banks oceanfront shoreline. The minimal influence of relatively short terminal groin structures on longshore currents has been demonstrated by current vector modeling analyses conducted for other proposed terminal groins in NC, including the proposed Holden Beach East End terminal groin at Lockwoods Folly Inlet (DC&A 2015). Another potential hydrodynamic effect that is generally associated with terminal groins is the potential for interference with the transport of estuarine-dependent fish and invertebrate larvae from the updrift nearshore ocean zone to the inlet. However, the minimal anticipated effects on longshore current dynamics indicate that larval transport is unlikely to be significantly impeded by the groin. Larval transport modeling for the Holden Beach terminal groin showed no effects on nearshore larval concentrations, which is consistent with the minor and highly localized nature of the modeled groin-related effects on longshore dynamics.

Water Quality

Direct, Indirect, and Cumulative Impacts

Sediments that are temporarily suspended by the groin and fillet construction process could potentially be transported through the inlet into estuarine waters. However, groin construction would occur within the inlet-dominated littoral system, where sediments consist of relatively coarse-grained sands with a very small fine sediment fraction; and the placed fillet material would consist of beach compatible material with minimal fines. Therefore, it is anticipated that sediment suspension effects would be minor, short-term, and localized.

Underwater Noise and Entrainment

Direct, Indirect, and Cumulative Impacts

Alternative 5 would not involve any dredging in the vicinity of the inlet or inshore waters. No effects related to noise or entrainment would be expected under Alternative 5.

<u>Shellfish, SAV, and Tidal Marsh Communities</u>

Direct, Indirect, and Cumulative Impacts

The proposed in-water borrow sites are located between one and five miles offshore of Bogue Banks; and therefore, dredging would not be expected to have any effect on estuarine communities. Similarly, sand placement along the oceanfront beach would not be expected to have any impacts on estuarine communities. Fringing shellfish beds, SAV, and/or tidal marshes may occur along the outer margins of the containment dikes that surround the AIWW disposal island borrow sites; however, pump-outs would be conducted by a cutterhead dredge operating in the adjoining AIWW channel, and sediment disturbance would be confined to the active upland disposal areas within the dike walls. Thus, no impacts attributable to dredge access or sediment excavation and rewatering would be expected. The pipeline route leading to recipient beach has yet to be identified; however, approvals of proposed projects would be contingent on pre-project surveys demonstrating avoidance of shellfish, SAV, and tidal marsh habitats. The modeling results indicate that groin-related effects are confined to the inlet throat and the Emerald Isle oceanfront beach. Therefore, effects on shellfish, SAV, and tidal marsh communities would not be expected under Alternative 5.

5.3.4.5 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential effects of beach nourishment and associated offshore borrow site dredging operations on cultural resources would be the same as those described under Alternatives 3 and 4. Based on the extensive shoreface erosion that has occurred along Bogue Banks, the likelihood of any cultural resource site occurrences within the groin footprint is considered very low. In response to the proposed USACE Bogue Banks CSDR project, the NC SHPO issued a determination that surveys for cultural resources within the oceanfront intertidal beach, dry beach, and dune system were not warranted due to the erosional condition of the shoreline (USACE 2014a). The groin would extend a relatively short distance (~500 ft) beyond the current MHW line, and thus would be confined to the upper shoreface where erosional conditions are equivalent to those of the beach and dune system. Thus, adverse effects on cultural resources would not be expected under Alternative 5.

5.3.4.6 Public Interest Factors

<u>Public Safety</u>

Under Alternative 5, the potential effects of beach nourishment and offshore borrow site dredging on public safety would be the same as those described under Alternatives 3 and 4. Groin-related public safety concerns would be related to the creation of a potential hazard to navigation. The terminal groin would not be located in a navigation channel, but would constitute a potential hazard to small recreational watercraft operating in close proximity to the shoreline. As a potential hazard to navigation, the terminal groin would be subject to USCG approval and marking requirements in accordance with 33 CFR 64. Marking requirements would be determined by the USCG, and once established would be maintained until the groin is removed. Therefore, the proposed terminal groin would not be expected to have any adverse effects on public safety.

Aesthetics and Recreation

Under Alternative 5, the potential effects of beach nourishment and offshore borrow site dredging on aesthetics and recreation would be the same as those described under Alternatives 3 and 4. The terminal groin would not be consistent with the natural beach aesthetic environment, and thus may detract from the aesthetic quality of the beach for some beachgoers. To the extent that the terminal groin structure itself may be viewed as aesthetically unappealing, aesthetic quality may be reduced relative to that which would exist with a natural and stable shoreline.However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline may be seen as preferable.

Hazardous, Toxic, and Radioactive Waste (HTRW)

Under Alternative 5; potential direct, indirect, and cumulative effects related to HTRW would be the same as those described under Alternatives 3 and 4.

Air Quality

Direct, Indirect, and Cumulative Impacts

Carteret County is designated as an attainment area for all criteria pollutants (USEPA 2016); and therefore, General Conformity regulations are not applicable to the proposed action. Mobile source emissions generated by dredges and onshore construction equipment would result in temporary increases in concentrations of NOx, SO_2, CO, VOC, and PM; however, it is expected that emissions would be rapidly dispersed, thereby precluding any significant effects on air quality. Furthermore, an emissions analysis conducted by the USACE for the proposed Bogue Banks CSDR project determined that the combined emissions of dredging and sand placement activities that are comparable to those of the proposed action would fall below de minimis levels and would not have any adverse effect on air quality (USACE 2014a). Therefore, Alternative 5 would not be expected to have any direct, indirect, or cumulative impacts on air quality.

Navigation

Under Alternative 5, the potential effects of beach nourishment and offshore borrow site dredging on navigation would be the same as those described under Alternatives 3 and 4. The terminal groin would not be located in a navigation channel and would extend only ~500 ft seaward of the MHW line. Furthermore, as described above, the potential structural hazard to small recreational watercraft operating in close proximity to the shoreline would be mitigated through adherence to the USCG marking requirements pursuant to 33 CFR 64. Therefore, no direct, indirect, or cumulative groin-related impacts on navigation would be expected under Alternative 5.

Infrastructure

In the absence of effective shoreline management along central and western Emerald Isle, unmitigated background and storm erosion would eventually threaten many of the associated oceanfront structures. Based on the GENESIS modeled MHW line changes, 103 oceanfront structures are projected to be at risk over the next 50 years (Table 5.13). Properties are considered to be at risk of erosional impacts when the seaward parcel boundary is within 25 ft of the MHW line. It is expected that the individual municipalities and individual property owners would initiate separate mitigative measures such as beach scraping and sandbagging. This would provide short-term and in some cases long-term protection to structures.

Table 5.13. Alternative 5 projected properties at risk over the next 50 years.

	Number of Properties at Risk				
Management Reach	**10**	**20**	**30**	**40**	**50**
Bogue Inlet	0	3	20	36	47
Emerald Isle - West	0	0	0	16	33
Emerald Isle - Central	9	14	18	21	23
Emerald Isle - East	0	0	0	0	0
Indian Beach/Salter Path	0	0	0	0	0
Pine Knoll Shores	0	0	0	0	0
Total	**9**	**17**	**38**	**73**	**103**

Economics

Under Alternative 5, projected County/municipal maintenance nourishment events would cost approximately $140.4M over the 50-year life of the project. Construction of the terminal groin is estimated to cost approximately $4.4M. Storm losses are estimated to require additional placements totaling ~27.2 MCY over the next 50 years at a cost of $360M. Continuing USACE sand placement activities; including the disposal of navigation dredged material from the MCH channels on Atlantic Beach and beach disposal on the Pointe adjacent to Bogue Inlet via maintenance of the Bogue Inlet AIWW Crossing channel; would cost approximately $245.2M over the next 50 years. The total cumulative cost of all nourishment and groin construction would be approximately $750.4M over the next 50 years. In addition to the cost of nourishment, there would be a number of properties at risk due to unmitigated background erosion along central and western Emerald Isle. Although the modeled shoreline response to the terminal groin indicates some mitigation of sand losses along the westernmost Bogue Inlet reach, the groin does not reduce sand loss along central and western Emerald Isle. Based on the Genesis-T modeled shoreline changes, 103 oceanfront structures are projected to be at risk over the next 50 years. Properties are considered to be at risk when the seaward parcel boundary is within 25 ft of the MHW line. Based on the average oceanfront property value on Bogue Banks (~$1.7M), lost property value could total $179.0M over the next 50 years. Based on the municipal property tax rates, an additional $40.7M in tax revenue could be lost over 50 years. The total cumulative estimated cost of all nourishment, groin construction, and lost property value/tax revenue under Alternative 5 would be $970.1M over the next 50 years.