SECTION 1. INTRODUCTION

Authority

This report is provided under authority of Section 2(b) of the Fish and Wildlife Coordination Act (FWCA) of 1958 (48 Stat. 401, as amended; 16 U.S.C. 661-667d). This Act established two important federal policies which are: (1) fish and wildlife resources are valuable to the nation; and, (2) the development of water resources is potentially damaging to these resources. In light of these principles, the FWCA mandates that:

> ". . . wildlife conservation shall receive equal consideration and be coordinated with other factors of water-resource development programs through effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation."

The FWCA essentially established fish and wildlife conservation as a coequal purpose or objective of federally funded or permitted water resources development projects.

In order to fully incorporate the conservation of fish and wildlife resources in the planning of water resources development, the FWCA mandates that federal agencies consult with the U. S. Fish and Wildlife Service (Service) and the state agency with the responsibility for fish and wildlife resources in the project area. The state agency with this responsibility is the North Carolina Wildlife Resources Commission (NCWRC).

Consultation during project planning is intended to allow state and federal resource agencies to determine the potential adverse impacts on fish and wildlife resources and develop recommendations to avoid, minimize, and/or compensate for detrimental impacts. Therefore, this report will:

1. Describe the fish and wildlife resources at risk in the project area;

2. Evaluate the potential adverse impacts, both direct and indirect, on these resources;

3. Develop recommendations to avoid, minimize, or compensate for any unavoidable, adverse environmental impacts; and,

4. Present an overall summary of findings and the position of the Service on the project.

This draft report will be submitted to the NCWRC for their review and comments. The report, when finalized, will include a letter of concurrence from the NCWRC and will constitute the formal report of the Service under Section 2(b) of the FWCA.

Subject of This Report

The current project is part of the larger Brunswick County Beaches Project authorized by Public Law 89-789 (House Document 511; 89th Congress) dated November 6, 1966 (Flood Control Act of 1966). The area considered in the Congressional authorization extended from the Cape Fear River westward to the North Carolina/South Carolina state line (Figure 1). The bill called for dune and beach restoration fills covering a coastline reach of 25.2 miles. Improvements were authorized for the developed portions of the coastline that included the towns of Yaupon Beach, Long Beach, Holden Beach, Ocean Isle Beach, and Sunset Beach.

In August 1999 the Wilmington District, U. S. Army Corps of Engineers (Corps), initiated coordination with the Service for their General Reevaluation Report (GRR) for the Brunswick County Beaches project. At that time the project was focused on the areas (from east to west) of Caswell Beach, Yaupon Beach, and Long Beach. In December 1999 the project was extended westward to include 37,600 linear feet (7.1 miles) of Holden Beach (Figure 2).

Scope

The geographic scope of this report includes all areas that would be directly or indirectly impacted by the proposed project. The project area includes not only the beaches seaward of the communities requiring storm damage protection, but those areas into which sand could be transported by natural forces, the offshore areas which are the most likely sand sources, and all areas likely to be impacted by the secondary development resulting from storm damage reduction measures. In all cases these areas represent habitat for fish and wildlife resources, and these resources will be considered.

The temporal scope of this report extends from direct, immediate impacts of potential storm damage measures to long-term, indirect impacts that may occur as a result of these measures. The report also considers the cumulative impacts of major structural alternatives.

Prior Studies and Reports

General Design Memorandum - Phase 1 and Environmental Analysis of 1973

Basic designs for storm protection structures were considered in a 1973 General Design Memorandum (GDM) for five of the six coastal political entities of Brunswick County (U. S. Army Corps of Engineers [hereafter USACOE] 1973). Only Caswell Beach was excluded. While the document discussed a general design for all the beaches in the 1966 authorizing legislation, engineering and economic data were presented for only Yaupon and Long Beaches. This document discussed the authorized plan to construct ". . . a levee-type fill having the general geometric configuration of an integrated dune and beach profile." The comprehensive report contained material on the hurricane history of the area (Appendix A); shoreline history (Appendix B); winds, wave climate and shore processes (Appendix C); and an environmental

analysis (Appendix H). The county-wide project was designated as "inactive" in 1974 due to lack of local support.

Ocean Isle Beach - Erosion Control and Storm Damage Reduction Project

Following the landfall of Hurricane Hugo near Charleston, South Carolina in 1989, the Town of Ocean Isle Beach requested a reevaluation of the portion of the project in that town. In November 1989, the Brunswick County Beaches - Ocean Isle Beach, Beach Erosion Control and Hurricane Wave Protection Project, Brunswick County, North Carolina (hereafter referred to as the Ocean Isle Beach Project) was separated from the larger Brunswick County project. The purpose of the project was the protection of the Town of Ocean Isle Beach from damage caused by oceanic storms. The Town of Ocean Isle Beach was the local sponsor. The Service released a Draft FWCA Report (U. S. Fish and Wildlife Service [hereafter USFWS] 1995) which was included in the Corps' Draft General Reevaluation Report (GRR) and Environmental Assessment (USACOE 1997a). Four months later the Corps released a Final GRR along with a Finding of No Significant Impact (FONSI) (USACOE 1997b). The Corps did not request a Final FWCA Report and none was included in the October 1997 project document. In November 1997 the Service informed the Corps that we did not concur with a FONSI. At the request of the Corps in July 1999, the Service provided a letter on September 7, 1999, to serve as the Final FWCA Report. This letter reiterated our opinion that certain environmental impacts had been either totally ignored or inadequately assessed and that the project was not consistent with a FONSI.

Wilmington Harbor - 96 Act

Wilmington Harbor is a Federal navigation project which extends from the Atlantic Ocean up the Cape Fear River to points above the City of Wilmington on both the Cape Fear and Northeast Cape Fear Rivers. Three environmental impact statements (EIS) have been prepared for improvements to the Wilmington navigation channel. The first was the Final Supplement to the Final EIS Wilmington Harbor-Northeast Cape Fear River (USACOE 1990). This project involved widening the Fourth East Jetty Channel to the West 100 feet and deepening the ship channel to 38 feet from the Cape Fear Memorial (CFM) Bridge to 750 feet above the Hilton Railroad Bridge. The second was the Final Supplement I to the Final EIS Wilmington Harbor Channel Widening (USACOE 1996a). This project involved the widening of five turns and bends by 75 to 200 feet, and widening by 200 feet the navigation channel in the lower harbor over a 6.2 mile distance to provide a passing lane. The third was the Final EIS Cape Fear-Northeast Cape Fear Rivers Comprehensive Study (USACOE 1996b).

The expansion of the Wilmington Harbor navigation Channel has been the subject of prior reports by the Service. The overall changes to the Wilmington Harbor Navigation Channel were originally considered as separate project for review under the FWCA. These reports include:

Planning Aid Report - Wilmington Harbor Passing Lane. (USFWS 1988a)

Planning Aid Report - Wilmington Bends and Turns. (USFWS 1988b).

Final Fish and Wildlife Coordination Act Report. Wilmington Harbor - Northeast Cape Fear River. (USFWS 1988c).

Planning Aid Report. Wilmington Harbor Bends and Turns Feasibility Level Study. (USFWS 1989).

Planning Aid Report - Wilmington Harbor Passing Lane, Feasibility Level Study. (USFWS 1990a).

Draft Fish and Wildlife Coordination Act Report. Wilmington Harbor Passing Lane. (USFWS 1990b).

Draft Fish and Wildlife Coordination Act Report. Wilmington Harbor Turns and Bends. (USFWS 1991).

Draft Fish and Wildlife Coordination Act Report. Wilmington Harbor Ocean Bar Channel Deepening. (USFWS 1993a).

Draft Fish and Wildlife Coordination Act Report. Wilmington Channel Widening Project. (USFWS 1993b).

Final Fish and Wildlife Coordination Act Report. Wilmington Harbor Ocean Bar Channel Deepening. (USFWS 1993c).

Final Fish and Wildlife Coordination Act Report. Wilmington Channel Widening Project. (USFWS 1993d).

In 1996 the various aspects of work on the Wilmington Harbor channel were consolidated into a single project. This project included proposed work on the ocean bar channel, the passing lane, channel wideners, and the overall deepening of the channel. The enlarged project was the subject of a FWCA Report (USFWS 1996a). In 1999 the Corps proposed several significant modifications to the project. In 1999 the Corps announced that major changes would be made in project design and construction. The Service released a Final FWCA Report (USFWS 2000) on these modifications. The Corps issued an Environmental Assessment for the revised project (USACOE 2000).

Sea Turtle Habitat Restoration Project, Long Beach North Carolina

This project targeted ". . . a degraded beachfront to restore nesting conditions for federally listed endangered and threatened sea turtles" (USACOE 1998). The project was originally proposed in conjunction with the removal of material from a confined disposal facility known as Yellow

Banks (USACOE 1995). The project area is within the Town of Long Beach, and plans call for moving sand from a disposal area along the Atlantic Intracoastal Waterway (AIWW) to create a main beach fill section of 8,900 feet (1.7 miles) in length. The project would create a berm 70 feet wide to an elevation of 8 feet above the National Geodetic Vertical Datum (NGVD). The project was developed under Section 1135 of the Water Resources Development Act of 1986. This section authorizes project that result from modification of an existing federal project. In this case, material dredged from the AIWW would be moved from an existing upland disposal area to the beaches. The project report (USACOE 1998, p. B-1) notes that "Plans that include relocation of structures landward to create suitable habitat are not evaluated because they do not fall under Section 1135 authority."

Acronyms used in this report will be defined when first used. A list of all acronyms used is given in Appendix A.

SECTION 2. STUDY AREA DESCRIPTION

The project is located in the southern coastal area of Brunswick County which consists of a chain of sandy, barrier islands. The islands have an east-west orientation. The islands are separated from the mainland by elongated lagoons containing expansive marshes, tidal streams, and the Atlantic Intracoastal Waterway (AIWW). The average topographic elevation of the area is eight feet above mean sea level (USACOE 1973, p. 5).

General Physical Environment and Important Coastal Processes

The project area consists of a diversity of land forms. The communities of Caswell Beach, Yaupon Beach, and Long Beach have two distinct geological settings (Pilkey et al. 1998, p. 192). In the late 1990s the Town of Yaupon Beach and Town of Long Beach merged to form the Town of Oak Island. The back side of the island is heavily forested, high-elevation, relict mainland. Marshes border this former piece of mainland. Seaward of this high former mainland is a low, narrow, modern barrier island. Caswell Beach is mostly a low, narrow strip of sand that forms the eastern third of Oak Island. Within Yaupon Beach the central part of the island is relict mainland. From this high central area the land slopes to the beach without an intervening marsh. Long Beach also has a high, forested landward section from the AIWW to Big Davis Canal. The seaward part of Long Beach is extremely low with poor to moderate vegetation cover. The island of Holden Beach is low and narrow.

Origin of Coastal Islands

The coastal islands of southeastern North Carolina were created approximately 5,000-8,000 years ago (Inman and Dolan 1989) at a time when world sea level was much lower (Figure 3). Some geologists believe that the coastal islands were born at the edge of continental shelf, where it drops off toward the oceanic abyss (Kaufman and Pilkey 1983, p. 98). As the sea gradually covered the gentle slope which is now the continental shelf, ridges of sand formed at the land-sea junction. These ridges were formed, as they are now, by wind blowing sand landward from the beach. As sea level continued to rise, the sandy ridges were breached and the area landward was flooded. This flooding created the large sounds that exist today. Storms washed sediment over the islands and built up their landward margins. As sea level continued to rise, it pushed the islands up the continental shelf. If the original masses of sand which were to become the coastal islands of Brunswick County had been held in place upon their initial formation, the sand ridges would now be miles seaward of their present location and completely underwater.

Rise in Sea Level

Sea level has risen approximately 3.9-7.8 inches during the past century (Michener et al. 1997). The rise is related to a general increase in temperature, but the extent to which global climate change is a natural phenomenon or influenced by human activities is uncertain. Warmer temperatures affect sea level by increasing the melting of large bodies of ice, but also cause

thermal expansion since the density of seawater decreases as temperature increases. The rate of sea level change during the recent past may not be the same that will occur in the future. The rate of sea level rise is likely to increase in the future. Pilkey and Dixon (1996, p. 19) state that sea level has remained "more or less the same" over the last 4,000 years (Figure 4). During this period many islands, such as Bogue Banks in North Carolina, grew seaward rather than retreating toward land. However, over the last century or two some islands along the Atlantic and Gulf Coasts began to narrow on all sides due to erosion. This erosion is probably a response to sea level rise (Pilkey and Dixon 1996, p. 20). Dean (1999, p. 34) writes that the Intergovernment Panel on Climate Change, a United Nations organization, anticipates sea level to rise by one to three feet by the middle of the 21st century.

Coastal Storms

Hurricanes are the dominant type of storm affecting Brunswick County beaches due to their southward facing orientation. Cape Fear effectively protects these beaches from devastating nor'easters, so hurricanes and southwesters are more significant agents of change to the project area's coastal systems.

While the Brunswick County beaches have some protection from winter storms, their southfacing orientation places the coast directly across the path of hurricanes that come from the south. Hurricanes form over tropical water and move northward. The official hurricane season begins on June 1 and lasts for five or six months. The east coast of the United States experienced a relatively hurricane-free period from the 1960s until 1989 when Hurricane Hugo struck South Carolina.

The project area is situated in a hazardous geographic zone with respect to the movement of Atlantic coast hurricanes. The area experienced 71 hurricanes during the period form 1804 to 1971, an average of one storm every 2.4 years (USACOE 1973, p. 5). The Corps provides an excellent summary of hurricanes that impacted Brunswick County between 1752 and September 1971 (Appendix A in USACOE 1973).

The most devastating storm to hit the Brunswick County coast in the 20th century was Hurricane Hazel which struck on October 15, 1954. This category four storm made landfall near the North Carolina/South Carolina boundary. The Brunswick County shore was approximately centered on Hazel's radius of maximum winds, and the still-water level of the ocean surge in the area reached a maximum elevation of 15 feet above mean sea level (m.s.l.), or approximately 7 feet above the average topographic elevation of the barrier island masses. (USACOE 1973, pp. 4-5). The Corps noted (USACOE 1973, p. 4) that ". . . the most striking aspect of the storm's effects on the Brunswick County shores was the absolute totality of the damage and its implications with respect to the potential for storm damage under conditions of dense development." The Corps concluded that it is reasonably certain that, had development been complete in the area, it would have been totally destroyed.

Beach Recession (Erosion) is Actually Landward Transgression

In the face of a rising sea over the past several thousand years, the low relief barrier islands would not exist today unless there were natural geologic mechanisms that allow them to move landward up the continental shelf. Kaufman and Pilkey (1983, p. 220) write that "As sea level rises, islands and beaches do not stand still and allow water to pass over them . . . they move back through a series of complex maneuvers."

This movement, in a landward direction, is called island onshore migration or transgression. Island migration is a simple function of the slope of the mainland. The more gentle the slope of the coastal plain, the more rapid the island migrates. Accordingly, the horizontal island migration rate in North Carolina has been estimated to be 100 to 1,000 times the rate of sea level rise (Pilkey et al, 1980 p. 21; Leatherman 1988, p. 42; Figure 5). That is, for every foot of sea level rise, the islands retreat 100 to 1,000 feet. Based on estimates that sea level may be rising at 1-3 feet per century, Brunswick County shoreline may move 100-3,000 feet landward over the next 100 years. Even during the official 50 year life of this storm damage reduction project, the beaches could be predicted to move 50 to 1,500 feet landward as a natural adjustment to an increase in sea level. A more recent estimate (Pilkey et al. 1998, p. 42) put the shoreline recession rate in North Carolina at 2,000 horizontal feet for every foot of sea level rise. At this greater rate, even a one foot per century rate of sea level rise would naturally produce a 1,000 foot retreat of the shoreline during the 50 year life of the project.

Island migration occurs as the island rolls over itself like the tread on a bulldozer (Pilkey and Dixon 1996, p. 16). The red sand exposed on some of the small bluffs of Caswell Beach indicate old soils and are signs that a forested barrier island occupied the site about 1,000 years ago (Pilkey et al. 1998, p. 194). Tree stumps that may occur on Caswell Beach are the remains of a forest that grew well inland from the beach (Pilkey et al. 1998, p. 43). This forest was replaced by a salt marsh on the site that is now the beach. The shoreline adjustment to a rising sea pushed sand over the older communities which are now emerging on the ocean side of the island which has passed over them.

The major processes which produce island migration are: (1) island overwashes from the ocean; and, (2) the incorporation of flood tide shoals, primarily the flood tide delta. Wind blown sediment carried from the ocean beaches and dunes may also contribute to the process. Overwash and inlet deposits are the predominant material in all Mid-Atlantic barrier islands (Inman and Dolan 1989). Therefore, sediment in both inlet shoals and overwash deposits remain in the barrier island complex.

During storms, high energy waves can carry sand landward over the entire island. The ocean side retreats as sediment is removed from the beaches and primary dunes. Sediment is carried across the island to form sandy overwash fans. Overwash fans, which often extend into estuarine areas behind the island, may cause the island to widen in a landward direction. As the waves recede, large quantities of sand may be deposited in overwash fans. The sediment carried by overwashes

help create new salt marshes and replaces sediment lost to wave erosion on the estuarine shoreline. Newly formed marshes are excellent buffers of sound side waves.

Shoreline Change

The Phase 1 GDM gives an excellent summary of shoreline change in the project area (Appendix B in USACOE 1973). Different section of the shoreline changed at different rates. Data from the period 1859-1970 indicate that Yaupon and Long Beaches had an annual average shoreline regression of 3.6 feet (USACOE 1973, p. 16). For the period of 1933-1970 Yaupon Beach had an annual shoreline regression rate of 5.7 feet. The rate for Yaupon Beach was also observed for the eastern 1,700 feet of Long Beach and the western 5,500 feet of Caswell Beach. This rate had been a "persistent phenomenon" in the area for 39 years and there were no apparent signs that the rate was decreasing. To the west of this area, the remaining 41,900 feet of Long Beach, a long-term, annual rate of 3.6 feet was used for project planning.

Pilkey et al. (1998, pp. 191-1997) have provided new data on the annual rate of shoreline recession. In the eastern part of the project area, the eastern part of Caswell Beach, the western part of Yaupon Beach, and the eastern part of Long Beach are receding at about two feet per year (Figure 6). The western part of Caswell Beach and the eastern part of Yaupon Beach have an annual recession rate of three to six feet. The western portion of Long Beach has an annual recession rate of about two feet (Figure 7). Holden Beach is characterized by two rates of recession. Near the inlets the sea is pushing back the shoreline at an annual rate of about 10 feet per year, but the rate in central part of the island is 2-3 feet per year, similar to that of Long Beach (Figure 8). Available data on rates of shoreline adjustment in the project area are given in Table 1.

The 1973 GDM discusses (USACOE 1973, p. B-9) the effects of sea level rise on shoreline recession. The document gives the contention of P. Bruun that as sea level rises the beach profile reestablishes itself. In this natural process the beach profile, or slope of the beach, adjusts to establish the same bottom depths relative to the surface of the ocean that existed at an earlier time of lower sea level. Bruun's ideas state that assuming the longshore littoral transport into and out of a given shoreline is equal, the quantity of material required to reestablish the equilibrium bottom profile must be derived from erosion of the shoreline.

The Corps' use of the term erosion does not differentiate between shoreline recession at the coast and inland erosion. Inland erosion is produced by the natural hydrologic cycle and does transport sediment completely out of the area where water first picks up material. Sediment picked up in inland mountains can in theory be carried to the sea and land area is permanently lost. The situation on Atlantic barrier islands is completely different. The barrier islands are surrounded by water that has been rising for thousands of years (Pilkey et al. 1998, p. 40-41; Frankenberg 1997, pp. 2-12). If barrier islands could be destroyed by the type of erosion suggested by the Corps, they would have disappeared thousands of years ago. The reason that the islands still exist is that they move landward in response to rising seas.

The major factor in worldwide shoreline recession, or beach erosion, is rising sea level (Pilkey et al. 1998, p. 45). Kaufman and Pilkey (1983, p. 25) wrote that Dr. Peter Rosen of the Virginia Institute of Marine Science used statistics to prove that the rate of shoreline erosion is everywhere controlled by the rise of sea level. Rosen's study stripped away the many masks that have led scientists and laymen to blame erosion on forces that seemed more susceptible to human control. Inman and Dolan (1989) state that ". . . extensive geological literature makes it clear that the Outer Banks have migrated landward with rising sea level. . ."

When the process of island migration is considered, the Corps is wrong in assuming that long-term ocean processes are destroying the barrier islands. However, the natural mechanisms of moving sand from the ocean beach to landward side of coastal islands have been ignored in project planning. The artificial dune prevent island overwash and sand moved inland by smaller storms is pushed back to the beach. Some sand that is prevented from moving to the back side of the island eventually goes back out to sea, and may ultimately be lost to the barrier islands. This is the real threat to the long-term survival of the barrier islands.

Biological Communities

The project envisioned in the 1973 GDM would directly impact a number of biological communities (Table 2). Furthermore, the storm damage reduction provided by the proposed work would facilitate additional development that would impact many estuarine and upland biological communities either directly or indirectly. This section will consider the basic physical characteristics, major plants, and important invertebrates of each community. These community attributes are important in supporting vertebrate populations that will be discussed later. The habitats of a typical Atlantic coast barrier island are shown in Figure 9. The communities will be described from seaward to landward. A typical arrangement of the most landward communities in the project area is given in Figure 10 which shows the major communities in the vicinity of Lockwoods Folly inlet (USACOE 1973, Plate H-8).

Offshore Pelagic

The division between offshore and nearshore waters is somewhat arbitrary, but the offshore zone is generally considered to extend seaward from the point where waves first influence, or scour, bottom sediment (Leatherman 1988, p. 20). Stated somewhat differently, the offshore zone is seaward of the breaker line, the point at which wave energy is influenced by bottom sediment.

Offshore pelagic areas have a role in primary production. Primary production may be defined as the rate at which radiant energy is converted by photosynthetic and chemosynthetic activity of producers organisms (chiefly green plants) to organic substances (Odum 1983, pp 98-99). Total primary production on the continental shelf of North Carolina is supported by three sources (Cahoon 1993). These are phytoplankton, benthic macroalgae, and benthic microalgae. The pelagic community is composed of organisms which remain in the water column. This community is dominated by microscopic plants known as phytoplankton which are tiny

unicellular or colonial marine algae. Phytoplankton in the waters of the southeastern United States continental shelf is dominated by centric diatoms, coccolithophores, and dinoflagellates (Marshall 1969, 1971). These small plants form the basis for the marine food chain (Figure 11). The species composition of the plankton community changes seasonally. Herbaceous zooplankton, small animals of several phyla, feed on phytoplankton and are, in turn, eaten by larger organisms. The most important groups are copepod crustaceans, arrowworms, hydromedusae, krill, tunicates, and the larvae of many benthic species (Ruppert and Fox 1988, p. 344). Zooplankton are usually most abundant and varied during the summer.

Offshore Benthic - Soft Substrate

This community consists of the organisms that live on or within the unconsolidated sediments of the ocean floor. Offshore sandy bottoms are often considered to be relatively lifeless and unproductive. While there is limited specific information on the plants and invertebrates of this community, recent work points to an important role for such areas. The area of unconsolidated sediment may be designated as the pelecypod-annelid biome (Gosner 1978, p. 22). These terms refer to the bivalve mollusks (pelecypod) and polychaete worms (annelids) which may be found in offshore benthic sediment.

Onslow Bay, less than 100 miles northeast of the project area, has a distinct, productive benthic microflora (Cahoon et al. 1990). This conclusion is based on the finding of at least three times as much chlorophyll *a* in the sediment as in the entire overlying water column, data which suggest that Onslow Bay is not generally a depositional environment. The frequently observed near-bottom chlorophyll *a* maxima in Onslow Bay are likely to be created by suspension of benthic microalgae rather than the sinking of phytoplankton, i.e., organic detritus (Figure 11). The positive correlation of sediment chlorophyll *a* with sediment adenosine triphosphate (ATP), an energy-carrying molecule, was considered a good argument for the existence of a viable, productive benthic microflora.

The concentration of microalgal biomass at the top of sand ridges rather than the troughs, suggests that these microalgae are firmly attached to the sediment (Cahoon et al 1990). Observations of pennate diatoms in sediment samples indicate that benthic microalgae are distinct from the phytoplankton, which is dominated by centric diatoms, coccolithophores, and dinoflagellates.

Chlorophyll data strongly suggest that benthic microalgae are likely to be major primary producers across the continental shelf in Onslow Bay (Cahoon et al. 1990). Benthic microalgal biomass averaged 36.4 mg of chlorophyll *a* per square meter (Cahoon and Cooke 1992). This biomass consistently equals or exceeds that of the integrated phytoplankton which averaged 8.2 mg of chlorophyll *a* per square meter (Cahoon and Cooke 1992). Gross benthic microalgal production in Onslow Bay averaged 24.9 mg of carbon per square meter per hour (mg $C/m^{-2}/h^{-1}$) (Cahoon and Cooke 1992). This figure compares to an average primary production of 27.4 mg $C/m^{-2}/h^{-1}$ in the integrated water column.

Microalgae are a previously unmeasured source of primary production and may contribute significantly to continental shelf food webs, particularly the meiobenthos and macrobenthos. Microalgae at the sediment surface may also play an important role in nutrient cycling at the sediment-water interface.

Cahoon and Tronzo (1992) reported that the concentrations of holozooplankton (plankton that remain continuously in the water column) and demersal zooplankton (plankton living in or on the bottom) in Onslow Bay, North Carolina, are each in the general range of 1 to 6 x 10^4 per square meter. The high numbers of demersal zooplankton associated with soft substrates in Onslow Bay suggest that these organisms are an important component of the continental shelf ecosystem. Currents may carry these soft sediment organisms into hardbottom habitats, making them available to resident planktivores.

Offshore bottoms contain an entire category of animals known as the meiofauna (Thurman 1994, p. 434). These organisms live in the spaces between sediment particles and have lengths ranging from 0.004 to 0.08 inches (0.1 to 2 mm). The meiofauna feed primarily on bacteria removed from the surface of sediment particles. The group consists mostly of nematodes, arthropods (primarily copepods), mollusks, and polychaete worms.

Frying Pan Shoals and Jay Bird Shoals are both extensive sand bodies associated with Cape Fear and the Cape Fear River mouth. The shoals form bathymetric highs that rise above the seafloor and influence the wave energy and patterns reaching the adjacent beaches. Jay Bird Shoals may become more dynamic in its sediment transport pathways and rates following construction of the new Wilmington Harbor navigational channel, which will remove millions of cubic yards of sediment from the area. The origin of cape-associated shoals is still a much debated mystery but is likely a combination of sedimentary processes and promontory-related residual flows (McNinch 2000).

Geotechnical data gathered during investigations of the Wilmington Harbor deepening project indicate that these sandy shoals are underlain by a highly geologic framework that includes rock, mud, clay and organic material. There is an estimated 30 million cubic yards of sandy sediment within Jay Bird and Bald Head Shoals, but much of it is muddy (Cleary 2000a; McLeod et al. 2000).

Offshore soft benthic areas may contain historic artifacts. The Corps tentatively identified a 19th century wood-hulled sailing vessel on Jay Bird Shoal during development of the Wilmington Harbor 96 Act modifications (USACOE 2000a).

Offshore Benthic - Hard Substrate (Hardbottoms)

Localized areas not covered by unconsolidated sediments, where the ocean floor consists of hard rock, are known as hardbottoms. Hardbottoms are found along the continental shelf off the

North Carolina coasts. Hardbottoms are also called "live-bottoms" because they support a rich diversity of invertebrates such as corals, anemones, and sponges which are refuges for fish and other marine life. Hardbottoms are most abundant in southern portions of North Carolina, and they are located along the entire coast (U. S. Mineral Management Service [hereafter USMMS] 1990).

The seafloor in the targeted borrow and fill areas for the proposed project varies from sandy shoals such as Frying Pan and Jay Bird Shoals to extensive hardbottoms with exposed rocky substrates. The ocean and nearshore waters off Cape Fear contain a high number of hardbottom habitats (USMMS 1990; Zullo and Harris 1993; Harris and Laws 1994; Riggs et al. 1996; Southeast Monitoring and Assessment Program [hereafter SEAMAP] 1998; Riggs et al. 1998; Cleary 1999; Cleary 2000b).

Frying Pan Shoals is adjacent to abundant hardbottom exposures of limestone, sandstone, mudstone and dolomite with up to 10 meters of relief (Riggs et al. 1996). Onslow Bay to the north is underlain by geologic rock outcrops ranging in age from Oligocene to Pleistocene. Long Bay to the south is underlain by older Eocene, Paleocene and Cretaceous rocks (Zullo and Harris 1993; Harris and Laws 1994; Cleary 1999). Riggs et al. (1996) and Riggs et al. (1998) describe the distinctive morphology of various hardbottom outcrop types, and document the incredible biological resources and values associated with them.

Riggs et al. (1998) identified storms as playing a major role in the distribution of hardbottom benthic communities as they remove sediments accumulated from bioerosion and redistribute the ephemeral bottom sediments, exposing or burying hardbottom surfaces. Riggs et al. (1996, p. 844) state that “[t]he surficial sand sheet on the upper flat hardbottoms is generally very thin, has an irregular distribution, and is highly mobile.”

Scarped hardbottoms can exhibit up to 10 meters of relief that varies with the rock type and can be associated with overhangs, ramps and rubble mounds (Riggs et al. 1996). Species diversity and density of infauna and epibenthos increases with the relief of these types of livebottoms. High relief scarped hardbottoms support flourishing reef-fish communities (Riggs et al. 1996).

“New” sediment can be created by bioerosion of hardbottoms, contributing to the existing sediment supply found on the continental shelf. Boring infauna are the dominant bioeroders of hardbottom scarps (Riggs et al. 1996, Riggs et al. 1998). “Morphologically prominent hardbottoms are actively being degraded and retreating in response to intense bioerosion by endolithic bivalves, crustaceans, and worms” (Riggs et al. 1996, p. 844). This bioerosion may develop seafloor relief of millimeters to meters to tens of meters depending on the lithology and bioerosional processes involved (Riggs et al. 1998).

Hardbottoms represent one of the most valuable biological communities in the project area. They provide very important habitat for fish and invertebrate species. Riggs et al. (1998) note that “Exposed hardbottom habitats free of sand are dominated by highly diverse communities of endolithic fauna and epilithic fauna and flora, those habitats with 2-6 cm of sand are generally dominated by scattered epilithic fauna with small growths of epilithic flora irregularly distributed on topographic highs, and those habitats with > 6 cm of sand are generally dominated by softbottom benthic communities." Endolithic refers to organisms living within rocks or other stony substances; e.g., mollusk shells or corals. Epilithic refers to organisms living on, or attached to, stone or stone-like material. Burgess (1993) states that "[s]ome of these rocky hardbottoms are veritable oases covered with algal meadows, sponges, soft whip corals, tropical fishes and territorial and predatory animals. These habitats provide shelter and food to sustain valuable commercial and recreational fish such as groupers and snappers, worth millions of dollars to the state's economy. More than 300 species of fish and hundreds of thousands of invertebrates call these reefs home." Frankenberg (1997, pp. 191-192) states that these "hardground" habitats ". . . support a community of algae, soft and encrusted coral, sea anemones, sea whips, and recreational important finfish. These rocky outcrops are oases of sea floor life that support a northern extension of the snapper-grouper complex of fish as well as habitat for predators like mackerel and bluefish."

"The availability of specific hardbottoms for development of a benthic community, as well as the structure of that community, are greatly influenced by specific habitat controls including composition, geometry, and morphology of the hardbottom and the distribution and thickness of the Holocene surface sand sheet" (Riggs et al. 1996, p. 844). "[S]urficial sediment patterns...control the composition and spatial distribution of benthic communities" (Riggs et al. 1998). Thus any project that could remove or add to the surface sediments via dredging and filling will influence the availability of the hardbottom habitats, their benthic communities and the structure of those communities.

Flat hardbottoms can be buried temporarily or permanently by thin layers of modern sediment, "either modifying the benthic community structure or removing the hardbottom from the sediment-water interface and eliminating hardbottom bioproduction" (Riggs et al. 1996, p.835). These types of hardbottoms can support vast macroalgal meadows or no visible biota at all, and are the most abundant type of hardbottom in Onslow Bay (Riggs et al. 1996).

In addition to simple, flat, rocky bottoms, areas with high relief such as underwater channels and cliffs, also provide valuable habitat. Areas of "high-relief scarps" create the most productive of hardbottom habitats (Burgess 1993). Rocks which break off these scarps collect as underwater rubble mounds that provide many nooks and crannies that serve as important hiding places for reef fishes and invertebrates such as the arrow crab (*Stenorhynchus seticornis*) and spiny lobster (*Panulirus argus*). Seaweeds such as brown sargassum (*Saragassum* spp.) and green calcareous algae attach to the rock surfaces.

Van Dolah and Knott (1984) sampled the benthos offshore the South Carolina coast, including some hardbottoms. They found 167 species representing nine major taxa. McCrary and Taylor (1986) studied benthic macrofauna assemblages offshore from Fort Fisher, North Carolina. Their grab samples were taken from between approximately 0.5 to 2 miles offshore. They found many polychaete species, isopods, amphipods, decapods, molluscs, echinoderms, many nematodes, and a few amphioxus (*Brachiostoma caribaeum*) in the benthic samples. In reference to one of their sampling locations located approximately 0.5 mile offshore, they state that it was obvious that a hardbottom was in the vicinity, although hard substrate was not found in the sediment samples of the site. They found 33 individuals of Chrysopetidae, a family which is predominately associated with coral or other hard substrates.

The benthos inhabiting potential offshore borrow areas serve as food for commercially important species and are essential in marine food chains. For example, adult spot (*Leiostomus zanthurus*) are benthic feeders (Benthivores in Figure 11), primarily eating polychaetes and benthic copepods. Atlantic croaker (*Micropogonias undulatus*) are also bottom feeders, preying on polychaetes and bivalves. Pink shrimp (*Penaeus duorarum*) and white shrimp (*P. setiferus*) also prefer benthos.

Artificial reefs have been created offshore of Brunswick County in many places in order to take advantage of these diverse aquatic resources. These reefs have been created out of everything from old vessels to concrete "reef balls". As a result the project area has not only natural hardbottom communities but artificial ones as well.

Nearshore Pelagic

The nearshore zone may be defined as the area between the low tide breaker line and the low tide shoreline (Thurman 1994, p. 284). It is generally considered to extend out as far as the point where waves do not scour the ocean bottom. The width of the nearshore area varies, but typically it is described as extending out to a water depth of 30 feet (Leatherman 1988, p. 20). There is considerable sediment transport within the nearshore zone. The nearshore area is strongly influenced by freshwater inflows from the Cape Fear and Lockwoods Folly Rivers (USACOE 1973, p. H-12). Freshwater inflows have a high nutrient load and are rich in organic detritus. The inshore waters are important commercial shrimping areas.

Nearshore Benthic

Substrate in the nearshore benthic community (Figure 9) is characterized by rippling on the surface due to wave action. The nearshore marine communities have been described in association with both completed and proposed beach nourishment projects. Cleary (1999) characterizes the nearshore marine environment offshore of Oak Island as containing undulating hardbottoms, low relief scarps, ripple scour depressions and sandy and muddy surficial deposits of various thicknesses.

Because Long Beach is not backed by a wide sound but is relatively close to the mainland, the flood tidal delta at Lockwood's Folly Inlet is not well developed (Cleary 2000b). The ebb tidal deltas at Lockwood's Folly Inlet and the Cape Fear River, on the other hand, contain an estimated 8.0 to 100 million cubic meters of sandy material (Cleary 2000b). The ebb tidal shoal of Lockwood's Folly Inlet is estimated to contain 7 to 8 million cubic yards of material and the flood tidal shoal contains 1 to 1.5 million cubic yards. Cleary (2000b, p.66) states that the volume of material within the targeted borrow area within Lockwood's Folly Inlet would provide "only a short-term solution." Lockwood's Folly Inlet is underlain by sandstone outcrops of the Cretaceous Rocky Point Member (McLeod et al. 2000). The nearshore area off of Yaupon Beach is underlain by Eocene limestones of the Yaupon Beach Member (McLeod et al. 2000). Shallotte Inlet influences at least 1.5 miles of shoreline on both Holden Beach and Ocean Isle, and using the tidal deltas of this inlet is predicted to destabilize Holden Beach, increasing its erosion rates and the likelihood of an inlet breach at the site where Hurricane Hazel broke through (Cleary 2000a).

In nearshore benthic habitats deposit feeders are dominant with a few filter feeders and carnivores present. Invertebrates, such as crustaceans, polychaetes and molluscs, comprise the benthic community of the nearshore waters. Van Dolah and Knot (1984) conducted benthic surveys off of Myrtle Beach, South Carolina, and found that infaunal assemblages in nearshore subtidal areas were more complex than those in intertidal areas. They found 243 species representing 24 major taxa. The most dominant species were polychaetes (*Spiophanes bombyx*, *Caulleriella killariensis*, *Clymenella torquata*, *Mediomastus californiensis*), amphipods (*Batea catherinensis*, *Erichthonius brasiliensis*, *Ampelisca vadorum*), and *Unicola serrata*. Oligochaetes, pelecypods, and decapods were also highly represented. These invertebrates serve as food for fish and larger invertebrates and are an important part of the nearshore marine community.

The Corps reports (USACOE 1973, p. H-12) that Hobbie (1971) studied the benthos of the ocean discharge site of the Brunswick Nuclear Power Plant, located on the southern shore of Oak Island. Sediments varied from clayey-sand to sand. Mud was found west of the discharge site and sand to south and east. This work found 56 species of benthos with eight species considered to be dominant.

Shoreface and Intertidal (Wet) Beach

There is no single, technical definition of a beach. Coastal geologists and the typical tourist clearly have different meanings for the term. To the geologist, the recreational beach is only the landward part of a larger zone of active (moving) sand/sediment that extends seaward to the innermost continental shelf. This area of active sediment, the shoreface, plays a major role in the behavior of the barrier islands. The shoreface in North Carolina is a relatively steep surface extending out to depths of 30-40 feet. The Outer Banks do not rest on an infinitely thick substrate of sand, but are in fact ". . . thin accumulations of sand perched on a preexisting and highly dissected surface previously eroded by rivers, channels, and old inlet" (Pilkey et al. 1998, p. 51). It is the complexity of the underlying geologic framework, in association with the physical dynamics of the specific barrier island, that ultimately determines the island's three-dimensional shoreface shape, the composition of beach sediment, and the shoreline erosion rate (Pilkey et al. 1998, p. 51).

Technical beach definitions are sometimes given in terms of sand mobility. For example, the beach may extend from the maximum shoreward movement of water during a severe storm to a seaward limit where ". . . substantial shore-perpendicular motion of sand ceases" (National Research Council [hereafter NRC] 1995, p. 20). Leatherman (1988, p. 21) considered a beach to be ". . . an accumulation of wave-washed, loose sediment that extends between the outermost breakers and the landward limit of wave and swash action." Much of the area given in these definitions cannot be used for what is commonly considered as beach recreation. A more traditional definition would include the area extending from the low tide line landward across unvegetated sediment to the beginning of permanent vegetation or the seaward edge of the next geomorphic feature (Davis 1994, p. 154). The feature limiting the landward extension of a beach is usually a natural dune, but may include artificial structures, such as a seawall or a constructed dune. The latter definition, unless otherwise specified, will be used in this report.

The entire beach will be divided into two parts, a wet and dry section. The intertidal zone, or wet beach, is the area between the line of low and high tide and may be called the foreshore or littoral zone (Thurman 1994, p. 284; Figure 9). This part of the beach contains two of the four beach zones given by Reilly and Bellis (1978) who designated a wet zone and a swash zone. The wet zone consists of the unvegetated area below the high tide drift line and above the saturated zone. The swash zone is the area alternately covered and exposed by waves.

Cleary (2000b, p. 66) reports that "[t]he shoreface characterized by outcropping silica cemented sandstones and limestones of Paleoecene [sic] and Eocene age is an unlikely source of significant sand resources. The overlying sediment cover is thin, mobile and consists of 10-300 cm units of muddy sands and gravely muddy sands. The distribution of hardbottoms and the mud content of the sediments precludes the use of the shoreface as a long-term borrow source." McLeod et al. (2000) also notes that "[t]he distribution of hardbottoms and the muddy nature of the sediments preclude the use of the shoreface as a long-term source of [beach nourishment] material."

Sandy or silty sand beaches support many species of fat, soft-bodied, white, burrowing amphipods in many genera of the family Haustoriidae (Phylum Arthropoda) (Ruppert and Fox 1988, p. 346). High energy, intertidal beaches in the southeastern United States may have 20-30 invertebrate species (Ruppert and Fox 1988, p. 346). Invertebrates found here include the beach digger (*Haustorius canadensis*), a polychaete worm (*Scolelepis squamata*), and, in late summer, the mole crab (*Emerita talpoida*) and coquina clam (*Donax* sp.). The swash zone is dominated by the mole crab and coquina clam.

Beach - Subaerial (Dry)

The dry, or subaerial, beach, is the sandy area which is literally under air. The dry beach extends from the high tide line to the line of primary dunes. This area appears to coincide with the backshore designated in Figure 9. Two of the four beach areas given by Reilly and Bellis (1978), the upper beach and high tide drift line, may be considered subaerial. The upper beach is the area between the high tide line and the primary dune. Vegetation consists primarily of a few annual, succulent species, including sea rocket (*Cakile edentula*), and seabeach amaranth (*Amaranthus pumilis*). Invertebrates inhabiting this zone include the ghost crab (*Ocypode quadrata*), beach flea (*Talorchestra megalophalma*), and various insects. . The second subdivision is the high tide drift line, a small unvegetated area consisting of the line of detritus that marks the highest point to which the preceding high tide advanced. Ghost crabs and small invertebrates, such as amphipods and insects, use this area.

The subaerial beach may be called a berm. While the seaward part of the berm may slope down toward the ocean, there is usually a wider, flat part of the subaerial beach which is more characteristic of a berm. The berm is the active, unvegetated portion of the dry beach and is the direct product of waves and currents (NRC 1995, p. 72). The berm is a primary factor in dissipating wave energy.

While the beaches of Brunswick Counties share some attributes, each beach in the project area has a unique history. The beaches of Brunswick County have been described in great detail (USACOE 1973). More recent descriptions are provided by Pilkey et al. (1998, pp. 191-202). The beaches of New Hanover County have also been described in association with previous beach nourishment projects (USFWS 1993e). The general shoreline of Brunswick County has been described in Frankenberg (1997, pp. 207-218) and Pilkey et al. (1998, pp. 191-202).

Oak Island consists of a 2.2-mile (3.5 kilometer (km)) long segment of Pleistocene subaerial headland that is flanked by transgressive barrier spits. Caswell Beach is situated on a 2.5-mile (4 km) long spit to the east of this headland, and the 8.7-mile (14 km) western spit consists of Long Beach (Cleary 2000b). Oak Island is not a natural barrier island, but was created during the construction of the Atlantic Intracoastal Waterway (McLeod et al. 2000).

The subaerial headland centered around Yaupon Beach forms a hinge point for Oak Island and is composed of an iron-stained and cemented Pleistocene sandstone (McLeod et al. 2000). The headland is fronted by a thin beach that frequently has tree stumps exposed on it, indicating the relatively high erosion rates that have rolled the island over the historic forest (McLeod et al. 2000).

Dunes

Dunes are an important component of the barrier island ecosystem. They deflect salt spray and allow the development of shrub thickets and maritime forests which increase barrier island resistance to wind erosion. Dunes are major storage centers for beach sediments, and they absorb and dissipate storm waves. The dunes are part of the sand sharing system which allows a barrier island to survive rising sea levels and the tremendous energies of the ocean (Godfrey and Godfrey 1976; Leatherman 1979). In this sand sharing system, an equilibrium is reached as sand grains move back and forth between offshore areas, such as sandy bars, and onshore areas, such as beaches and dunes, in response to wind, waves, currents, and tidal effects.

Dune vegetative cover ranges from sparse to fairly dense. The dunes are dominated by species which can withstand the continuous salt spray, shifting sand and excessive drainage found in this dynamic and stressful environment. The most characteristic dune plant is sea oats (*Uniola paniculata*). Sea oats are important in building dunes due to their ability to grow upward through the sand which collects around them, as well as their resistance to salt spray and drought conditions. Sea rocket (*Cakile harperi*) and dune [beach] spurge (*Euphorbia polygonifolia*) may occur nearer to the beach. Dune [silver] panic grass (*Panicum amarum*), salt meadow cordgrass (*Spartina patens*), and bluestem (*Andropogon scoparius*) may occur behind the primary dune. American beach grass (*Ammophila breviligulata*) normally occurs only north of Hatteras, but has been planted farther south to help stabilize dunes (Frankenberg 1997, p. 50).

Overwash Flats

Overwash, or washover, fans (Figure 9) are created by the flow of water through the primary dune line. The fan is basically part of the beach and dunes that has been pushed landward over the island. The ocean water that creates an overwash flat is referred to as an island overwash, and the process covers only part of the island or extends all the way to estuarine waters. These overwash events usually occur during storms, but smaller events can occur in low areas in the barrier dune line when large breaking waves coincide with a high spring tide. Young overwash fans are essentially unvegetated. However, the areas are capable of normal plant succession and, depending on their location, early successional stages will progress to more stable plant communities.

This community is usually absent or temporary in developed areas such as the project area. However, the importance of overwash areas in the natural geology of barrier islands and the impacts of artificial dunes on the overwash process merit consideration in this report. Frankenberg (1997, pp 51, 56) writes that aperiodic overwashes bring sand and seawater into interdune areas and often bury the grassland communities beneath several inches of new sand. Maritime grassland plants tolerate these sand additions, and simply grow up through the new sand layer. Overwash fans can raise the elevation of central areas of a barrier island. Such increases in elevation add protection against future storms. However, this protective feature of overwash fans is greatly reduced if the sand is pushed back to the beach.

Low Shrub/Grasslands

Coastal low shrub/grasslands occur within dunefields and on overwash terraces behind the primary dune. Sea oats, beach grass, and other dune plants create a prairie that covers the sand with low vegetation (Frankenberg 1997, p. 51, 56; grasslands in Figure 9). This community may occur in areas known as barrier flats (Leatherman 1988, p. 31), areas of low relief formed by island overwashes that destroy dune ridge topography. This community is often a transitional area between the diverse high marsh community and the more stable maritime shrub thicket (CZR 1992). The plants are well adapted to direct sunlight, high soil temperatures, and the porous soil that occurs in the dunes. Low shrub/grasslands are commonly found behind the protection of taller shrub thickets and low dunes. Low, stable dunes and overwash fans behind or between low dunes support grasslands. These grasslands may occasionally be overwashed or buried by sand. Vegetation may be moderate or dense except in recently overwashed areas.

Grasslands may extend from the front or backslope of a dune to the sound. Vegetation consists primarily of grasses, sedges, and a few forbs, with sea oats being dominant. Common plants include pennywort (*Hydrocotyle ranunculoides*), seaside goldenrod (*Solidago semipervirens*), broomsedge (*Andropogon* spp.), salt meadow cordgrass, and panic grass.

Where human and natural disturbances are minimized, the grasslands and high marsh often support scattered wax myrtle (*Myrica cerifera*), groundsel tree (*Baccharis halimifolia*), and marsh elder (*Iva frutescens*). As plant succession continues, a maritime shrub thicket and/or a maritime forest may develop in well protected areas.

Maritime Shrub Thicket

Maritime shrub thickets (Thicket in Figure 9) typically occur landward of the low shrub/grassland community where they are protected from salt spray and harsh winds (Frankenberg 1997, pp. 57, 60). The construction of artificial dunes may have allowed this community to develop. This community is usually found between the dunes and a maritime forest (USACOE 1973, p. III-H-3). Shrubs are strongly influenced by salt spray and they have a close-cut, hedge-like appearance due to the destruction of young branches on the windward side by wind-blown salt. Shrub thickets are often scattered and wind sheared in areas of intense salt spray, but become taller and denser in less exposed areas. The community is characterized by dense shrubs that are usually entangled with vines. Characteristic species include wax myrtle, groundsel tree, yaupon (*Ilex vomitoria*), red cedar (*Juniperus virginiana*), and stunted live oak (*Quercrus virginiana*) (Bellis 1995, p. 4). Other shrubs that dominate the higher elevations include bayberry (*Myrica pennsylvanica*), black cherry (*Prunus serotina*), and loblolly pine (*Pinus taeda*). Plant species common in lower areas are marsh elder, wax myrtle, yaupon, and groundsel tree. Common vines include poison ivy (*Toxicodendron radicans*), catbrier (*Smilax bona-nox*), pepper vine (*Ampelopsis arborea*), and muscadine (*Vitis rotundifolia*).

Herbaceous Swale and Other Freshwater Wetlands

This community occurs in interdune areas with elevations near the water table which are protected from salt spray. Herbaceous swales also occur in sandflats where the water table is normally just below the surface, old overwash terraces, and in sand-filled marshes. Broad swales are found between dune ridges within maritime forests. These swales may contain standing water year round and some larger swales have open water. These freshwater wetlands are marsh communities with cattail and saw grass in some areas and swamp forest in others.

The heterogeneous vegetation includes both shrubs and herbs, and is characterized by one or two dominants within any single area (Nifong, 1981, p. 10). Typical species include salt meadow cordgrass, marsh elder, groundsel-shrub, and wax myrtle.

Interdune ponds and other freshwater wetlands are seasonally to permanently saturated. They are densely vegetated with a high diversity of both wetland and mesic species. Interdunal, or swale ponds, are created by a rising sea level that raises the freshwater lens beneath the island until it intercepts the topographic lows between dune ridges (Bellis 1995, p. 69). These ponds are generally dominated by salt meadow cordgrass, fimbry (*Fimbristylis* sp.), or Gulf muhly (*Muhlenbergia filipes*). Freshwater ponds provide habitat for many species that might otherwise be severely limited by lack of a dependable freshwater supply (Bellis 1995, p. 69) .

Maritime Forest and Other Upland Communities

In areas where protection from salt spray and wind forces is substantial, the shrub thicket community gradually becomes maritime forest as one moves landward. Many of the shrubs found within the shrub thicket are full grown trees in the maritime forest. Maritime forest are considered the "climax communities" on stabilized dunes subject to predominantly maritime influences such as wind and salt stress (Nifong 1981, p. 10). The maritime forest is the most stable community of the beach area (USACOE 1973, p. H-11). The forests between Davis Canal and the AIWW are dominated by live oak (*Quercus virginiana*), laurel oak (*Q. laurifolia*), and loblolly pine (*Pinus taeda*).

The floristic makeup of maritime forests varies depending on many factors including elevation, hydrology, soils, protection from salt spray, and level of succession. Typical maritime forest vegetation includes live oak, red cedar, yaupon, wax myrtle, red maple (*Acer rubrum*), red [swamp] bay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), and loblolly pine. Extensive maritime forests include such canopy species as black walnut (*Juglans nigra*), sweet pignut hickory (*Carya glabra*), American beech (*Fagus grandifolia*), white oak (*Quercus alba*), laural oak (*Quercus laurifolia*), water oak (*Quercus nigra*), bald cypress (*Taxodium distichum*), and black gum (*Nyssa sylvatica*). A maritime forest may contain a large variety of herbaceous plants such as various ferns, orchids, such as pink lady slipper (*Cypripedium acaule*), Southern twayblade (*Listera australis*) and water-spider orchid (*Habenaria repens*); and various grasses and sedges.

The invertebrate fauna of maritime forests has been described (Bellis 1995, pp. 48-50). Insect and spiders are conspicuous components of maritime forests, and as such perform important ecological functions in mineral cycling and energy flow.

High Marsh

The high marsh occupies a zone between the upland communities and the shore of estuarine water behind the island. These areas are generally flooded on an irregular basis as a result of storms and wind (USACOE 1973, p. III-H-4). High marsh is generally found on sandy flats of old overwash fan or old tidal deltas that are no longer in the intertidal zone. The water table is close to the surface, and irregular flooding from strong winds and/or seasonally high tides create conditions that allow the dominance of several plant species. The vegetation of the high marsh is usually diverse as it contains species from other grassland and dune communities, as well as some intertidal marsh species. Where flooding is more regular, co-dominant species include smooth [saltwater] cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), sea ox-eye (*Borrichia frutescens*) , and sea lavender [marsh rosemary] (*Limonium nashii*).

Some sections of high marsh appear as meadows dominated largely by salt meadow cordgrass and rushes (*Juncus* spp.). Other species found in this community include rush (*Juncus polycephalus* [= *J. biflorus*]), toad rush (*Juncus bufonius*), marsh pink (*Sabatia stellaris*), and seaside goldenrod. Where human and natural disturbances are minimized, the high marsh often supports scattered wax myrtle, groundsel tree, and marsh elder. When provided with continued protection, high marsh may eventually succeed into a low shrub-grassland community.

Within the intertidal zone, this emergent wetland community is composed of homogenous stands of black needlerush. Irregular flooding controls the distribution of this common marsh species. Smooth cordgrass is often found along the lower fringes of this community. At higher elevations, salt meadow cordgrass, and rushes become co-dominant. These tidal marshes have high primary productivity and provide inorganic and organic nutrients to adjacent aquatic communities. They also protect the sound side of the barrier island from wind and wave action. Many aquatic invertebrates, such as the saltmarsh snail (*Melampus bidentatus*), depend on tidal marshes. The high marsh may serve as an important nutrient sink and thus may be of significance in the dynamics of estuaries (USACOE 1973, p. III-H-5).

Low Marsh

Low marshes in the project area are regularly flood and dominated by smooth cordgrass (*Spartina alterniflora*). This emergent wetland community is within the intertidal zone. Along the fringe of tidal creeks, the community receives regular tidal inundation and marsh plants provide stability for the shoreline margins.

The low marsh community typically provides nursery areas for various species of shrimp, crabs, and marine and estuarine fish. In the Chesapeake region, low marsh provides habitat for the marsh periwinkle (*Littorina irrorate*), Atlantic ribbed mussel (*Geukensia demissa*), and fiddler crabs (*Uca* spp.) (Lippson and Lippson 1997).

Intertidal marshes have high primary productivity. Tidal marshes are among the most productive ecosystems in the world, producing up to 80 metric tons per hectare (71,400 pounds/acre) of plant material annually, or 8,000 grams/m^2/year, in the southern coastal plain of North America (Mitch and Gosselink 1993, p. 249). Gross primary productivity in a Georgia salt marsh was calculated to convert 6.1% of incident sunlight energy, verifying that the community is one of the most productive ecosystems in the world (Mitch and Gosselink 1993, p. 256 based on Teal (1962). Nixon and Oviatt (1973 as given in Mitch and Gosselink (1993, p. 256-257)) report that energy flows during summer and winter in a salt marsh-estuary complex in New England revealed that an estimated 23% of the net productivity of the salt marsh was exported to the embayment. These findings led to the conclusion that the aquatic embayment is actually a heterotrophic ecosystem that depends on the import of organic matter from the autotrophic salt marsh. It is very likely that the high primary productivity of salt marshes in the project area is the foundation for the food chain of many primary (herbivores) and secondary (carnivores) consumers of the area.

Areas of low marsh are characterized by the movement of organisms migrating seasonally out of the estuary (USACOE 1973, p. H-7). Some species migrate from freshwater or offshore as young, and use the marshes for growth and development, i.e., as a nursery area. Organisms may migrate into the marshes as zooplankton or as juveniles (USACOE 1973, p. H-7)

Estuarine Waters and Tidal Creeks

Tidal creek and sloughs divide the marshes of the project area into numerous islands and peninsulas. Estuarine waters in the project area, especially tidal creeks, are generally classified as nursery areas by the State (USACOE 1973, p. H-5). Tidal creeks support a large biomass of nekton (organisms capable of movement) which contributes to the value of these areas as nursery for immature fish and shellfish (Copeland and Birkhead 1972).

Estuarine Benthic

There are little data on the specific organisms inhabiting estuarine benthic areas. The Phase 1 GDM notes (USACOE 1973, p. H-16) that "[d]redging operations in the shoaled area in Eastern Channel will destroy benthic organisms presently growing on these sand flats; however, after dredging operations, the area should be rapidly colonized and result in a more desirable assemblage of organisms because of the more stable conditions which will occur with deeper water."

Unvegetated, Intertidal, Estuarine Flats (Mudflat and Sandflats)

The estuary is characterized by broad expanses of mud flats covered by intertidal oysters that are exposed at low tide and broad expanses of regularly flooded low salt marsh. This tidally influenced community is found on the landward side of the islands in the project area. It is characterized by saltwort (*Salsola kali*) (McCrain 1988). Rooted aquatic plants are not characteristic of intertidal flats (Lippson and Lippson 1997, p. 51). However, other forms of plant life, such as microscopic algae, thrive on flats. Bacteria and algae are highly productive on flats and form thin sheets covering shells and sediment particles. The ecology of intertidal flats in North Carolina is given by Peterson and Peterson (1979).

The mobile, epifaunal animals in this community are primarily crustaceans and snails that prey on the rich supply of buried infauna (Lippson and Lippson 1997, p. 53). Many foragers, such as blue crab, small fish, and shrimp, come in with the tide to feed on surface detritus or to prey on intertidal burrowers. However, these species leave the flats on the receding tide and are more properly at home in the shallow, estuarine waters.

Artificial and Disturbed Communities

The project area has several communities created or maintained by the activities of man. These include pine stands, canals, ditches, dredge sites, old fields, dredge material disposal sites, and roadsides. These areas are in various stages of plant succession and are usually in a sub-climax stage. These areas are characterized by a large amount of "edge" habitat in relation to their area (USACOE 1973, p. II-H-21).

The most prominent artificial communities in the project area are dredge disposal sites. These sites may exist as either islands or upland areas. Dredge material disposal islands support cordgrass (*Spartina* spp.) marshes and intertidal oysters (USACOE 1973, p. H-9). Yellow Banks, an upland disposal site for dredging of the Atlantic Intracoastal Waterway, is estimated to contain over 5 million cubic yards of beach fill material (McLeod et al. 2000). Approximately 1.8 million cubic yards of this material will be removed for the Sea Turtle Restoration Project on Long Beach (USACOE 1998, p. EA-7). The removal of this material will limit the ability of this site to be a long-term supply for the proposed Brunswick County Beaches nourishment project. In the Phase 1 GDM the Corps acknowledged this fact by stating ". . . dependence on the mainland mass [of sediment] for an unlimited source of beach fill is neither realistic nor desirable" (USACOE 1973, p. H-21).

SECTION 3. FISH AND WILDLIFE CONCERNS AND PLANNING OBJECTIVES

The involvement of the Service in this planning process is in response to a Congressional mandate through the FWCA which directs that the conservation of fish and wildlife resources shall receive full and equal consideration and be coordinated with other features of federal projects. Fish, wildlife, and their habitats are valuable public resources which are conserved and managed for the people by state and federal governments. If proposed land or water developments may reduce or eliminate the public benefits that are provided by such natural resources, then state and federal resources agencies have a responsibility to recommend means and measures to mitigate such losses. In the interest of serving the public, it is the policy of the Service to seek to mitigate losses of fish, wildlife, and their habitats and to provide information and recommendations that fully support the Nation's needs for fish and wildlife resource conservation as well as sound economic and social development through balanced, multiple use of the Nation's natural resources.

Fish and Wildlife Concerns

The proposed project seeks to reduce storm damage which is a worthwhile goal. The key issue is the alternatives that will be considered and the extent to which all short- and long-term adverse environmental impacts of each alternative will be weighed in the selection of the preferred alternative. Within the project area, well understood geologic processes driven by a rising sea level are creating hazardous conditions for man-made structures. As the distance between structures and the sea decreases over time, these structures are at greater risk of storm damage. Efforts to protect these structures by putting an artificial sand barrier in the path of the sea may provide some temporary protection, but when viewed from a perspective of several decades such measures have little chance of provide long-term protection.

The Service recognizes that estuarine waters, barrier island uplands, beaches, and the nearshore ocean represent unique and valuable habitats for fish and wildlife resources. Our first concern is that these habitat values not be eliminated or degraded. Therefore, the selection of a method for reducing storm damage should look beyond the short-term advantages or disadvantage of any particular technology and fully evaluate and compare the long-term consequences of each alternative. Any manipulation of sensitive natural areas will be harmful, to some degree, to certain organisms within those habitats. In the past, these manipulations were smaller and impacted a smaller geographical area. Many organisms could simply move to other, less disturbed areas. At present, the efforts to delay the removal of structures built on shifting sand have come to encompass a larger area usurping vast areas of habitat. In some cases, the species that depend on the ocean-beach interface are running out of undisturbed options. Therefore, a complete consideration of the cumulative impacts of any construction alternative must be made.

Specific Fish and Wildlife Service Concerns for Direct Impacts

While the Service hopes that alternatives to an artificial beach-dune system will be thoroughly evaluated, such a system is now considered the most likely alternative. Therefore, our concerns will focus on that alternative. Direct impacts associated with creating an artificial beach-dune system are primarily related to the removal of offshore sand, its transportation to beach areas, and its placement on beaches. The Service is concerned that offshore borrow areas may be used at a time and dredged in a manner that would adversely affect fisheries resources and primary productivity in both soft- and hardbottom areas.

The Service is concerned that sediment disposal may adversely affect fish and wildlife resources on the beach and nearshore zone. The scheduling of sediment disposal would influence the extent of impact on beach invertebrates, nesting sea turtles, foraging shorebirds, and nearshore fisheries.

Specific Fish and Wildlife Service Concerns for Indirect Impacts

Indirect impacts are likely to emerge slowly during the years and decades after initial offshore sand mining and periodic sand placements on the beach. The most significant indirect impact involves the development that would be fostered by the artificial beach-dune system. The initial construction of artificial beach-dune system and an assumption that the system would be maintained in perpetuity will create a sense of security that could lead to greater and more expensive development. Increased development is likely to put greater pressure on fragile and limited freshwater resources, increase the amount of wastewater requiring disposal, and foster the construction of more transportation infrastructure such as roads and bridges. The combined effects of these factors pose a significant threat to existing fish and wildlife habitat values in the project area.

Potential Positive Consequences of the Project

In addition to the potential problems associated with the project, there may be opportunities for fish and wildlife resource conservation and enhancement. Benefits to fish and wildlife include the creation of sea turtle and shorebird nesting habitat and possibly even the creation of reef habitat as sand is removed from hard bottoms offshore. The potential for reef creation in association with offshore sand mining is unknown and should be studied.

Planning Objectives

Careful planning and a conscientious balancing of economic considerations with environmental concerns can produce a project with minimal, short- and long-term environmental impacts. The Service proposes the following planning objectives:

1. Planning should include a thorough evaluation of all available technologies to reduce storm damage. While creation of an artificial beach-dune system may offer short-term advantages, the planning effort should consider that an artificial beach and dune is temporary, the system would encourage additional development, and that a continuing rise in sea level may renders the system untenable. Therefore, non-structural alternatives should be thoroughly developed and evaluated.

2. If a program of artificial beach and dune creation is selected as the preferred alternative, the complete long-term ramifications of initiating this alternative should be fully explored. Both the Corps and local sponsors should look beyond the standard 50-year life of the project. A project objective should be the full consideration of the environmental impacts associated with development that would be engendered by the sense of security provided, on a short-term basis, by the artificial beach and dune. Furthermore, project plans should consider whether the benefits of postponing the movement or destruction of fixed structures in the project area, by implementing the preferred alternative, outweigh the loss of natural aesthetics that will result from ever-increasing sand placements at greater frequencies.

3. If the artificial beach-dune system is selected, offshore sand mining should be done in a manner and at a time of year so as to avoid negative impacts to primary productivity, hardbottoms, important offshore fish habitat, and other marine resources, including marine mammals. The utilization of offshore sand resources may be the most environmentally acceptable method of obtaining borrow material; however, prior to a commitment to offshore sand mining, a thorough study of the biological impacts associated with the offshore mining of sand must be conducted.

4. If the artificial beach-dune system is selected, the transportation of sand to and placement on the beaches should be done in a manner and at a time of year so as to avoid significant adverse impacts to beach organisms, nearshore aquatic ecosystems, nesting sea turtles, and migratory shorebirds.

In accordance with the FWCA, as amended, these planning objectives should be given full and equal consideration with the economic benefits expected from the project.

SECTION 4. EVALUATION METHODS

Descriptions of natural resources present within the study area and the preliminary assessment of the environmental impacts of the proposed project are based on previous studies for similar projects, published literature, and personal communications with knowledgeable individuals. Published reports and studies were examined to determine their relevance to the proposed project. Material which describes potential environmental impacts of similar projects and methods of reducing these impacts are incorporated by reference in this report.

The Service is familiar with the coastal processes in the project area and ongoing efforts to protect fixed structures in southeastern North Carolina. The Service has worked with the Corps on beach projects at Wrightsville Beach, Carolina Beach, Fort Fisher, Bald Head Island, Ocean Isle Beach, and, most recently, the effort to place sand from the Wilmington Harbor enlargement project on the beaches of New Hanover and Brunswick Counties.

A valuable source of information was a report on the availability of sand for beachfill offshore of Oak Island in Brunswick County (Cleary 1999). This report focused on the location of deposits of beachfill quality sand resources in excess of five million cubic yards and the distributions of hardbottoms. The database for this study consisted of geological and geophysical information collected over the past three decades.

Nomenclature in this report follows Tiner (1993) for coastal plants; Rohde et al. (1994) for freshwater fish; Robins and Ray (1986) for marine fish; Martof et al. (1980) for amphibians and reptiles; Potter et al. (1980) for birds; and Webster et al. (1985) for mammals. Both common and scientific names from cited literature follow the original publication. If the Service is aware of a widely accepted synonym for the common name, that synonym is given in brackets. If the Service is aware of a change in the scientific name of a given species, the revised nomenclature is included in brackets following the published name.

SECTION 5. EXISTING FISH AND WILDLIFE RESOURCES

The discussion of fish and wildlife resources which occur in the project area is divided into three sections. The resources are first considered by taxonomic class. The next topic will be the resources protected by the Endangered Species Act. The final section will consider these resources by major biological communities (Table 2) presented in Section 2.

Fish and Wildlife Resources by Vertebrate Classes

The Corps' 1973 General Design Memorandum provides a good list of the vertebrates that have been reported in the project area (Appendix H in USACOE 1973). This attachment forms the basis for this section of the report, but additional material will be provided where available.

Fish

The diverse range of habitats in the project area as well as its geographical location near the convergence of major biogeographic zones result in a large number of fish species that have been reported. The Corps reported 65 species of fish from 38 families in the southern North Carolina estuarine zone (Table 3). Fish occurrence was based on the work of Tagatz and Dudley (1961) in areas near Beaufort, North Carolina. The Phase 1 GDM states that, in most cases, the Brunswick marshes are protected from the ocean by the barrier beach, and backed by extensive tidal creeks entering from a general input of upland drainage. Approximately 70 to 90 percent of the commercially important fishery species are estuarine-dependent during some part of their life cycle.

Amphibians

Amphibians which require freshwater for reproduction are not numerous in the project area. The Phase 1 GDM lists only six species (Table 4) based on the work of Parnell and Adams (1971).

Terrestrial Reptiles

All marine reptiles in the project area, the sea turtles, are federally protected, and will be discussed later. The Phase 1 GDM gives (USACOE 1973, p. I-H-4) 12 terrestrial reptiles for the project Area (Table 5).

Birds

Birds of the project are listed in Table 6 (USACOE 1973, pp I-H-5 to I-H-8; Parnell and Adams (1971). The list includes 147 species. The Phase 1 GDM commented (USACOE 1973, p. H-5 based on (Quay and Adams 1961)) noted that "[n]umerous bird species are found in the project area and their populations change seasonally. The general region is especially valuable for migrating waterfowl and shore birds. Funderburg and Quay(1959) reported on the nesting habitats of summer maritime birds, which were :

> '. . . bare sand and shell areas, partially vegetated sand and shell areas, salt marsh, shrub thicket, thicket woodland on small islands surrounded by salt marsh, tall pines at mainland edge of salt marsh, and man-made structures.'

Mammals

The mammalian fauna of the project area is limited. This may be due to the limited supplies of permanent freshwater sources and the dynamic nature of the barrier islands which may join together or split apart periodically. The mammals that have been reported in the area are listed in Table 7 (USACOE 1973, p. I-H-8; Parnell and Adams 1971).

<u>Federally Protected Species</u>

Cetaceans

Marine mammals occur in offshore and inshore waters of North Carolina. Twenty-nine species of cetaceans have been recorded along the coast of the Carolinas, Virginia, and Maryland (Webster et al. 1985, p. 206). Some species occur only in deeper offshore waters beyond the project limits, but other species that occasionally appear in waters close to shore could occur within the project area.

Whales - The humpback whale (*Megaptera novaeangliae*) and the federally-endangered [northern] right whale (*Eubalaena* [*Balaena*] *glacialis*) are spring and fall migrants off North Carolina's coast. Both species may be found in nearshore waters. During spring migration, right whales migrate immediately adjacent to the coast, and probably utilize deeper waters during fall migration. Since 1991, humpbacks have been spotted off the North Carolina coast in every month, with a peak of abundance occurring in January through March (McLellan 1997). Humpback whales have been observed from dredges in the Wilmington Harbor ship channel (National Marine fisheries Service [hereafter NMFS] 1995). The right whale may migrate through areas that are potential borrow areas for the project (McLellan 1997). The long-finned pilot whale (*Globicephala melaena*) and short-finned pilot whale (*G. macrorhynchus*) are primarily oceanic, but frequently move inshore when food resources are more plentiful there (Webster et al. 1985, p. 217). The sei whale (*Balaenoptera borealis*) and blue whale

(*Balaenoptera musculus*) occur in North Carolina offshore waters on an irregular basis.

The August 1995 Biological Opinion of NMFS under the Endangered Species Act Section 7 consultation for hopper dredging of channels and beach nourishment activities in the southeastern United States describes three days of dredging in the Wilmington Channel that encountered humpback whales:

> On January 12, 1995, a humpback whale was observed within a quarter of a mile of the dredge at Wilmington channel and resurfaced near the dredge. An approaching humpback on January 13, 1995 was observed ahead of the dredge initially, but resurfaced near the stern after the vessel slowed. Dredging was stopped while the whale, and two other humpbacks nearby, approached within 100 yards, including one passing under the bow. On January 18, still within the Wilmington Harbor channel dredging area, one of a few humpbacks observed feeding surfaced and quickly dove again within 10 meters of the dredge. (NMFS 1995, p. 17)

The sperm whale (*Physeter macrocephalus*), dwarf sperm whale (*Kogia simus*), and pygmy sperm whale (*K. breviceps*) inhabit the offshore waters of North Carolina (Webster et al. 1985, p. 220). While the sperm whale favors the deeper waters off the continental shelf, the species may use shallow waters to calve or in times of sickness (Webster et al. 1985, p. 222). The sperm whale is a year-round resident of the continental shelf edge and pelagic waters. This species probably moves farther offshore during the winter.

Dolphins and Porpoises - Bottle-nosed dolphins (*Tursiops truncatus*) and harbor porpoises (*Phocoena phocoena*) utilize nearshore waters including bays, estuarine creeks, and sounds. Bottle-nosed dolphins are common in this area. This species (also known as the Atlantic bottle-nosed dolphin) is the most abundant cetacean along the Atlantic coast (Webster et al. 1985, p. 213). It inhabits inshore waters and frequently enters sounds, rivers, and tidal creeks of North Carolina (Webster et al. 1985, p. 213). Lippson and Lippson (1997, p. 251) report these dolphins as summer inhabitants of the lower Chesapeake Bay where they are often seen feeding in the swift currents near the Elizabeth and James Rivers. Coastal migratory bottle-nosed dolphins are regularly seen in the waters off the project area from April to November (McLellan 1997).

The harbor porpoise is the only member of the Family Phocoenidae that enters the coastal waters of the mid-Atlantic region. The species spends summer and fall farther north in cold, subarctic water, but migrates southward to the mid-Atlantic region during the winter and spring (Webster et al. 1985, p. 218). Yearlings are relatively common from January through May. Inshore waters and shallow coastal bays are used by the species. Since the early 1990s stranded harbor porpoises have been collected on mid-Atlantic beaches from November to May as far south as Ocracoke Island, north of the project area (McLellan 1997).

Seabeach Amaranth

Seabeach amaranth was listed as threatened in the Federal Register on April 7, 1993, and this listing became effective on May 7, 1993. Seabeach amaranth (*Amaranthus pumilus*) is an annual plant which grows on barrier islands primarily in disturbed areas, such as overwash flats on accreting spits. However, it can sometimes be found on middle portions of islands on upper strands of non-eroding beaches. Seabeach amaranth is a dune building pioneer species and is usually found high on the beach in front of the foredune.

Seabeach amaranth plants germinate between April and July and mortality of seedlings can be very high. Flowering begins as soon as the plant is large enough, possibly as early as June. Seed production begins in July or August and usually reaches a peak in September, but continues until the death of the plant. Seed dispersal occurs primarily by wind but tides may also play a role in spread of the seeds. Sand placement on beaches can bury these annual plants, resulting in their mortality, and the depth of the disposal material will be such that germination of the seeds the following season may not occur. On the other hand, beach disposal/nourishment projects may benefit the species by providing additional suitable habitat. Sand placement may be compatible with seabeach amaranth provided the timing of placement is appropriate, the material placed is compatible with the natural sand, and special precautions are adopted to protect seabeach amaranth. Further studies are needed to determine the best methods of beach disposal in seabeach amaranth habitat (Weakley and Bucher 1992).

This plant has been extirpated from 75 percent of its historical range and North Carolina is considered seabeach amaranth's present stronghold (Weakley and Bucher 1992). Brunswick County was considered a stronghold of the species during the 1980s. This was probably due to the south facing beaches that had experienced relatively little erosion. However, beginning with Hurricane Hugo in 1989 and the series of hurricanes in 1996 (Bertha and Fran), 1998 (Bonnie), and 1999 (Dennis and Floyd) the beaches of the area receded. Corps survey data from 1992 to 1996 indicate varying numbers of seabeach amaranth plants on two project beaches (Table 8).

Table 8. Number of seabeach amaranth plants recorded on two areas within the Brunswick County Beaches Project, 1992-1999. Source: Wilmington District, U. S. Army Corps of Engineers.

	Number of Plants Observed								
Area	1992	1993	1994	1995	1996	1997	1998	1999	
Holden Beach	21	52	239	59	99				
Long Beach	3,148	6,103	4,409	4,628	1,983	599	5,367	15	

Beach disposal activities will bury these annual plants, resulting in their mortality, and the depth of the disposal material will be such that germination of the seeds the following season may not occur. On the other hand, beach disposal/nourishment projects may benefit the species by providing additional suitable habitat. Beach disposal/nourishment may be compatible with seabeach amaranth provided the timing of beach disposal is appropriate, the material placed on the beach is compatible with the natural sand, and special precautions are adopted to protect seabeach amaranth. Further studies are needed to determine the best methods of beach disposal in seabeach amaranth habitat (Weakley and Bucher 1992).

Sea Turtles

All five Atlantic sea turtles may occur in the coastal waters of North Carolina (Epperly et al. 1995). These species are the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*), Kemp's ridley sea turtle (*Lepidochelys kempi*), the hawksbill sea turtle (*Eretmochelys imbricata*), and the leatherback sea turtle (*Dermochelys coriacea*).

The hawksbill sea turtle is rare in North Carolina waters. Leatherbacks are seen regularly in low numbers in the nearshore waters of the state during northern migrations in May and June. Both species are Federally-listed as endangered. Survey data (Table 3 in USFWS 1996a) in the Cape Fear River from 1980 to 1991 included 7 leatherbacks among 157 total sea turtles (David Webster, University of North Carolina, Wilmington, personal communication, June 1994). Epperly et al. (1995) report the capture of a single leatherback in Pamlico Sound during the 1989-1992 period. A hawksbill was found within the Cape Fear River at the Carolina Power and Light plant near Southport (Sherry Epperly, NMFS, personal communication, April 1993). Epperly et al. (1995) reference State data for the capture of a single hawksbill in Pamlico Sound during the 1989-1992 period.

The Federally-endangered Kemp's ridley sea turtle, the Federally-threatened loggerhead, and Federally-threatened green sea turtle occur within the Cape Fear River estuary, primarily during the warmer months. Among 157 sea turtles reported in the Cape Fear River from 1980 to 1991, there were 135 loggerheads, 11 Kemp's ridleys, and 3 greens (N. L. Grogan and W. D. Webster, University of North Carolina, Wilmington, personal communication, June 1994).

Preliminary analysis of sea turtle sightings and strandings within North Carolina indicate that the Cape Fear River may provide important developmental habitat for green sea turtles (Crouse 1985). From 1989 through 1992, 9 sea turtles were observed in the Cape Fear River by recreational fisherman as reported by the Marine Recreational Fisherman Statistics Survey (Epperly et al. 1995). The NMFS also provided the Service with data which indicate that between 1980 and 1991 approximately 43 loggerheads, 2 greens, 2 leatherbacks, and 2 Kemp's ridleys were reported as stranded within the Cape Fear River area. Although NMFS states that these data are preliminary, they give an indication of the relative abundance of the various species of sea turtles found in the Cape Fear River (NMFS 1993). The North Carolina Wildlife Resources Commission (NCWRC) reports that 888 sea turtle strandings were found in

Brunswick and New Hanover Counties from 1980-1999 (Table 9). NCWRC also reports that 137 sea turtles were found within or near the CP&L Brunswick County Nuclear Power Plant intake canal between 1995 and 1999 (Table 10) (Ruth Boettcher, Sea Turtle Coordinator, N.C. Wildlife Resources Commission, personal communication, February 6, 2000).

The presence of sea turtles in nearshore and estuarine waters of North Carolina appears to be seasonal. Epperly et al. (1995) reported that sea turtles were present in the offshore water of North Carolina throughout the year and were present in inshore waters from April through December. Seasonal data on sea turtles in the Cape Fear River and from Bald Head and Oak Islands which flank the mouth of the Cape Fear River were collected by Grogan and Webster (David Webster, University of North Carolina, Wilmington, personal communication, June 1994) (Table 3 in USFWS 1996a). These data show that sea turtles were found in the Cape Fear River during every month except February. The months with the highest occurrences were April through September. These six months account for 144 (91.7%) of the 157 reports.

As the most southern beaches in North Carolina, the beaches of Brunswick County have the highest occurrence of sea turtle nesting in the state. Available data indicate that three species of sea turtles nest on beaches that are targeted for sand placement. Table 11 gives data on recorded nests for the loggerhead sea turtle and green sea turtle. Among the three beaches considered, four green sea turtle nests and 1,868 loggerhead sea turtle were recorded from 1988 through 1999. Green sea turtles normally nests in Florida and the Caribbean.

On June 17, 1992 a Kemp's ridley sea turtle (*Lepidochelys kempi*), a federally endangered species, nested on Long Beach. This positive identification is the first record of the species nesting in North Carolina. However, two other descriptions of sea turtles nesting in North Carolina during the 1992 season fit the description of the Kemp's ridley turtles (Therese Conant, Sea Turtle Coordinator, N.C. Wildlife Resources Commission, personal communication, August, 1992). This species nests primarily at a single site (Rancho Nuevo) on the Gulf coast of Mexico.

Piping Plover

The piping plover is a small, nearctic shorebird which breeds in three geographic regions: the Northern Great Plains, the Great Lakes, and the Atlantic Coast. Piping plovers within the project area are part of the Atlantic Coast population, and are federally listed as threatened.

The piping plover (*Charadrius melodus*) is federally-listed as threatened. The species generally breeds north of the project area. However, there are limited data indicating nesting in southeastern North Carolina. Data collected by the NCWRC during 1993 found that 4 pairs of piping plovers nested on Holden Beach near Shallotte Inlet, just west of the project area (Tom Henson, NCWRC, 1993, personal communication to Janice Nicholls; USFWS 1996a). The Service’s 1996 recovery plan includes both Holden Beach and Long Beach near Lockwood Folly Inlet as actual or potential nesting sites (USFWS 1996b). Johannsen and Allen (1999) report one piping plover nest at the west end of Holden Beach in 1997 and another in 1998. Birds were also

observed in the early 1998 breeding season along Long Beach (Johannsen and Allen 1999). Piping plovers are regularly seen resting and foraging on the beaches during migration and in the winter. In the winter, the birds prefer expansive sandflats or mudflats for feeding and areas near sandy beaches for roosting. Table 12 lists the known winter sightings of piping plovers in the project area.

Table 12. Sightings of wintering piping plovers on three beaches within the area of the Brunswick County Beaches Project.

	Number of Wintering Piping Plovers[a]						
Area	1987	1989	1990	1991	1996	1997	1998
Fort Caswell	--[b]	--	--	0	0	--	--
Long Beach	3	1	1	0	0	--	--
East Holden Beach	0	--	0	0	0	0	0

[a] Source: North Carolina Wildlife Resources Commission (NCWRC)
[b] Dashed line indicates data are not available to the NCWRC

The Endangered Species Act requires the designation of critical habitat and its constituent elements by the Service, which would include the federally-listed coastal species found in North Carolina. Due to a court order, the designation of critical habitat for overwintering piping plovers is imminent, and available data indicate that such overwintering usage occurs within the project area.

The species' decline is attributed to increased development and recreational activities on beaches. Vehicular and foot traffic on beaches can directly crush eggs and chicks or indirectly lower productivity by disrupting territory establishment and breeding behavior. Increased development of beach areas has also resulted in an increase in the number of predators, such as gulls and raccoons, on piping plover chicks and eggs.

North Carolina represents the southern limit for regular breeding and the northern limit for regular wintering by the species. The Atlantic Coast population nests on barrier islands and beaches from Newfoundland to North Carolina. Piping plovers nest above the high tide line on coastal beaches; on sandflats at the ends of sandspits and barrier islands; on gently sloping foredunes; in blowout areas behind primary dunes (overwashes); in sparsely vegetated dunes; and in overwash areas cut into or between dunes. The species requires broad, open, sand flats for feeding, and undisturbed flats with low dunes and sparse dune grasses for nesting.

The breeding cycle of the species has been documented (USFWS 1996b, pp 4-8). Territorial establishment, courtship, and copulation may occur as early as the March-April period and extend into July. Incubation, which averages 27-30 days, ranges from April through August, and brood-rearing occurs during the May-late August period. In the project area nesting activities can begin as early as March (CZR, Inc. 1992).

Feeding areas include intertidal portions of ocean beaches, overwash areas, mudflats, sandflats, wrack lines and shorelines of coastal ponds, and lagoons or salt marshes (Coutu et al. 1990, USFWS 1996a).

The Atlantic Coast piping plover population is believed to overwinter primarily along the Atlantic Coast from North Carolina south to Florida, and in the Caribbean. Wintering plovers on the Atlantic Coast are generally found at the accreting ends of barrier islands, along sandy peninsulas, and near coastal inlets. Wintering piping plovers appear to prefer sandflats adjacent to inlets or passes, sandy mudflats along prograding spits, and overwash areas as foraging habitats. These substrate types may have a richer infauna than the foreshore of high energy beaches and often attract large numbers of shorebirds. Roosting plovers are generally found along inlets and adjacent ocean, estuarine shorelines and their associated berms, and on nearby exposed tidal flats (Fussell 1990, Nicholls and Baldassarre 1990b). Diverse, coastal systems may be especially attractive to plovers, and may concentrate wintering piping plovers when there is a juxtaposition of roosting and feeding areas (Nicholls and Baldassarre 1990a).

Along coastal North Carolina, piping plovers are most widespread during migration. These periods include mid-March to mid-April and August to October (Fussell 1994, p. 426). During these periods they are frequently seen on the ocean beaches.

The areas east of both Shallotte Inlet (approximately 1.3 miles on Holden Beach) and Lockwoods Folly Inlet (approximately 1.1 miles on Long Beach) are proposed as critical habitat for overwintering piping plovers. When the Corps establishes the precise limits for sand placement, the extent of impacts on these areas must be coordinated with the Service. In accordance with Section 7 of the ESA, the Corps must determine whether the project will destroy or adversely modify the primary constituent elements of piping plover critical habitat. The primary constituent elements essential for the conservation of wintering piping plovers are those habitat components that support foraging, roosting, and sheltering and the physical features necessary for maintaining the natural processes that support these habitat components. The primary constituent elements are found in geologically dynamic coastal areas that support or have the potential to support intertidal beaches and flats (between annual low tide and annual high tide) and associated dune systems and flats above high tide.

Roseate Tern

The federally endangered roseate tern generally breeds along the Atlantic coast from Long Island, New York, northward. They spend the winter from the West Indies to Brazil. The species is considered a rare coastal transient in North Carolina (Potter et al. 1980, p. 178). It may be present from late March to mid-May and from late July to October. The species feeds in salt bays, estuaries, and the ocean.

This coastal bird has a distinct preference for sandy, open beaches and interdune areas. Fussell (1994, p. 41) notes that many records of this species have been at common tern colonies at capes and inlets, immediately adjacent to the ocean. The species may also be found on mudflats and in open water. There is one recorded nesting by the species on Core Banks, northwest of the project area, in 1973 (Potter et al. 1980, p. 178). There are no records that the species nests in the project area.

West Indian Manatee

This species, also known as the Florida manatee, is a federally-listed endangered mammal. Although the manatee's principle stronghold in the United States is Florida, it occasionally makes its way into the coastal waters of North Carolina (Webster et al. 1985). Generally, manatees remain in the coastal waters of the Florida peninsula during the winter and disperse during the summer months, some moving north along the Atlantic Coast to North Carolina. Observations of manatees from within the Cape Fear River and surrounding waters are generally reported every year during the summer months. The number of sightings is usually low, but they do occur within the Cape Fear River on a regular basis during the warmer months of the year (David Webster, University of North Carolina at Wilmington, personal communication, May, 1993, and Mary Clark, North Carolina Museum of Natural History, personal communication, May, 1993).

Schwartz (1995) summarized manatee sightings in North Carolina from 1919 through 1994. This report provides information on the occurrence of 68 manatees from 59 sites and notes that the species is known to frequent nearly all North Carolina ocean and inland waters. Recorded sightings in the vicinity of the project area include one individual near Southport in 1952; one near the Carolina Power and Light Plant on the Cape Fear River; one in the lower Cape Fear River during 1976; one in the Cape Fear River near Marker 50 in March 1986; and one at the south end of the State Port at Wilmington in July 1994.

Shortnose Sturgeon

This Federally-endangered fish may occur in the project area. Current data indicate that the species is found within the Cape Fear River estuary, immediately east of the project area. The species also occurs south of the area in the Waccamaw River, Pee Dee River, and Winyah Bay ecosystems. Dr. Mary Moser and Dr. Steve Ross of the Center for Marine Science Research at the University of North Carolina at Wilmington, studied the shortnose sturgeon in the Cape Fear River from May 1990 until September 1992 (Moser and Ross 1993). During this period, they caught over 100 Atlantic sturgeons and 9 shortnose sturgeons. Thus, the number of shortnose sturgeons within the estuary appears to be very low. The species' distribution within the Cape Fear River has been documented to extend as far up the river as Lock and Dam #1. Whether shortnose sturgeons occur beyond that point is unknown (Dr. Mary Moser, University of North Carolina at Wilmington, personal communication, April 1993).

Both sturgeons are bottom dwellers and prefer deep waters and a soft substrate (Rohde et al. 1994). During spawning these species require freshwater areas with a fast flow and a rough bottom (Rohde et al. 1994). Moser indicated that sturgeon seemed to use the main channel of the river and tend to associate with deep holes. Atlantic sturgeon associate with the deepest parts of the river during the warmest times of the year, and they show a considerable amount of fidelity to deep holes (Dr. Mary Moser, personal communication, April 1993).

Fish and Wildlife Resources by Major Biological Community

The distribution of vertebrates among the major biological communities are given below. Scientific names provided in the tables of the preceding section will not be repeated.

Offshore Pelagic

In offshore waters, certain estuarine dependent species spawn and their larvae make their way through inlets into the estuaries for growth and development. Examples include spot, croaker, weakfish, red drum, southern flounder, summer flounder, penaeid shrimp, and Atlantic menhaden. Offshore shoals provide very good fishing grounds for bluefish, flounder, seatrout (*Cynoscion* spp.), and drum (Appendix H in USACOE 1973, p. H-12). Other pelagic species include blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), sailfish (*Istiophorus platypterus*), swordfish (*Xiphias gladius*), dolphin (Coryphaena hippurus), yellowfin tuna (*Thunnus albacares*), bluefin tuna (*Thunnus thynnus*), and bigeye tuna (*Thunnus obesus*) (Huntsman 1994). There are about 20 species of large, coastal sharks (Huntsman 1994). Reptiles which use this habitat are the five species of sea turtles (Epperly et al. 1995). This area is used by a variety of pelagic bird species, such as the loons, grebes, shearwaters, cormorants, scoters, mergansers, gulls, terns, and skuas. Cetaceans such as, such as whales and dolphins, are found in offshore waters.

Offshore Benthic - Soft Substrate

Huntsman (1994) discusses coastal demersal fishes, species that live on the bottom. This group includes Atlantic croaker (*Micropogonias undulatus*), spot, southern flounder, summer flounder, and weakfish.

Offshore Benthic - Hard Substrate

Huntsman (1994) states that there are more than 300 species of reef fish along the South Atlantic. These are species that might be expected at hardbottoms off North Carolina. Some species within this group are gray triggerfish (*Balistes capriscus*), scamp (*Mycteroperca phenax*), speckled hind (*Epinephelus drummondhayi*), vermilion snapper (*Rhomboplites aurorubens*), white grunt (*Haemulon plumieri*), snowy grouper (*Epinephelus niveatus*), red porgy (*Pagrus pagrus*), red snapper, and warsaw grouper (*Epinephelus nigritus*). Some of these are extremely overfished (Huntsman 1994)

Nearshore Pelagic

Many fish species are found within the surf zone and some species occur in both offshore and nearshore waters. Nearshore areas around the mouth of the Cape Fear River and Lockwoods Folly Rivers support "sizable populations" of anadromous fish. Huntsman (1994) writes that coastal pelagic species, those living in the nearshore water column, include Atlantic menhaden, Spanish mackerel, King mackerel (*Scomberomorus cavalla*), bluefish, and little tunny (*Euthynnus alletteratus*). Other fishes that may occur in this area are the summer flounder, Atlantic croaker, spot, weakfish, red drum, cobia (*Rachycentron canadum*), black sea bass, spiny dogfish, northern sea robin, and pompano. The Corps adds such species as American shad and river herring, and juveniles of marine fish, such as menhaden (USACOE 1973, p. H-12). These waters support estuarine dependent species, permanent residents, and seasonal migrants. Attachment I-H of the Phase 1 GDM (USACOE 1973) provides a list of species collected from southern North Carolina inlets by various workers. This list includes, weakfish, striped bass, black sea bass (*Centropristis striata*), spiny dogfish, red snapper, northern sea robin, and pompano.

Hackney et al (1996. p. 52) state that "Apparently, many surf zone fishes not only exhibit ontogenetic changes in diet, but also shift diets in relation to prey availability. . . Such opportunism has great advantages in a variable environment like the surf zone. The ability to modify feeding could also mitigate impacts from beach renourishment." There are two species of small coastal sharks, the dogfish and spiny dogfish (Huntsman 1994).

The three species of sea turtles (loggerhead, Kemp's ridley, and greens, that are known to nest on the beaches of the project area would use this area on their approach to the beaches. Gulls (*Larus* sp.), terns (*Sterna* sp.), brown pelicans (*Pelecanus occidentalis*), ospreys (*Pandion haliaetus*), gannets (*Morus bassanus*) and loons (*Gavia* sp.) feed in the surf zone and nearshore waters. The bottle-nosed dolphin is common in the nearshore waters of North Carolina and other cetaceans also enter the nearshore waters occasionally. The manatee may migrate through nearshore waters.

Many birds utilize the food resources of nearshore waters. Gulls (*Larus* spp.), terns (*Sterna* spp.), brown pelicans (*Pelecanus occidentalis*), ospreys (*Pandion haliaetus*), gannets (*Sula bassanus*), and loons (*Gavia* spp.) feed in the surf zone and nearshore waters.

Nearshore Benthic

This area may be used by species which also inhabit the offshore benthic area. Birds that feed in offshore areas are likely to use the areas closer to shore.

Shoreface and Intertidal (Wet) Beach

The invertebrates of this area are an important food source for shorebirds and fishes utilizing the nearshore zone. Shorebirds use the intertidal beach for feeding and resting. Birds such as the sanderling, black-bellied plover, willet, ruddy turnstone , greater yellowleg, lesser yellowleg, marbled godwit (*Limosa fedoa*), American oystercatcher , laughing gull, herring gull, and great black-backed gull forage on the algae and invertebrates of the foreshore. Terrestrial mammals forage on the area beaches. Raccoons, opossums, foxes, and other small mammals prowl the beaches at night for prey (Lippson and Lippson 1997, p. 24)

Beach - Subaerial (Dry)

Loggerhead sea turtles nest on the upper beach and interdunal areas during the spring and summer. Lesser numbers of green sea turtles and Kemp's ridley sea turtles also nest in this area.

Shorebirds that nest along the upper beach in undisturbed areas include willets and American oystercatchers. In certain areas, colonial waterbirds such as least terns and black skimmers nest along the upper beach. Large monospecific and mixed species flocks of shorebirds often rest on the upper beach during migration and/or during the winter. Shorebirds utilizing the area during the winter and during migration include the common black-headed gull (*Larus ridibundus*), great black-backed gull, Forster's tern (*Sterna forsteri*), American oystercatcher, piping plover, killdeer (*Charadrius vociferous*), whimbrel, marbled godwit, willet, ruddy turnstone, sanderling, and red knot.

Dunes

Vertebrates are generally scare in this dry, relatively unstable environment. Amphibians are absent due to the dryness. These areas may be used by terrestrial reptiles such as the six-lined race runner, eastern glass lizard, black racer, and five-lined skink. Mammals that may occur in dune areas of the Outer Banks (CZR 1992) and are found in the project area include the opossum, eastern cottontail, gray fox, raccoon, least shrew, meadow vole, and house mouse.

The sparsely vegetated low dunes may be used by boat-tailed grackles and red-wing black birds. Arctic peregrine falcons (*Falco peregrinus tundrius*) and merlins (*Falco columbarius*) use the dunes for foraging during migration and occasionally as winter residents. The red-tailed hawk, a casual winter visitant, also forages over dunes, as does the American kestrel (*Falco sparverius*). Other avian species utilizing area dune and interdunal habitats include the northern harrier [marsh hawk] and barn owl. The bald eagle (*Haliaeetus leucocephalus*) may forage over dune areas. Species found in dune areas include the opossum, eastern cottontail, gray fox, raccoon, least shrew, eastern mole, meadow vole, house mouse, and feral house cat (CZR 1992).

Overwash Flats

This community has many similarities to the dry beach and may be used by vertebrates that use the dry beach and dunes. Overwash areas are an important nesting area for piping plovers. As a landward extension of the beach, overwash fan can provide suitable nesting areas for sea turtles.

Low Shrub/Grasslands

This area probably contains species which inhabit both the dunes and the thicker shrub habitats. As a transitional community, the area on the Outer Banks has a diverse assemblage of animals (CZR 1992). Utilization may depend partly on the wetness of the area.

Maritime Shrub Thicket

Various reptiles also inhabit the shrub thicket, as they are offered protection from the salt spray. Among the species recorded in the project area, Quay (1959) noted that shrub thickets on the Outer Banks may contain the eastern glass lizard, eastern ribbon snake, eastern hognose snake, black racer, and eastern kingsnake.

Shrub thickets provide critical habitat for many migrating birds. Species which may be found here include lark and clay-colored sparrows, western kingbird ( ), and dickcissel. Spring migrants include the scarlet tanager, rose-breasted grosbeak, blue grosbeck, northern oriole, Blackburnian and bay-breasted warblers, and gray kingbird. Some of the rarest migrants include the white-winged dove (*Zenaida asiatica*), vermilion flycatcher (*Pyrocephalus rubinus*), scissor-tailed flycatcher (*Muscivora forficata*), tropical kingbird (*Tyrannus melancholicus*), Sprague's pipit (*Anthus spragueii*), and Townsend's warbler (*Dendroica townsendii*) (Fussell 1994, p. 158).

Common residents include the Carolina wren, gray catbird, northern cardinal, and boat-tailed grackle (Parnell et al. 1989). Breeding birds include great crested flycatcher ( ), prairie warbler, yellow-breasted chat, indigo bunting, and field sparrow (Fussell 1994, p. 148). Other species which use these thickets include rufous-sided towhee, common yellowthroat, yellow-billed cuckoo, eastern wood pewee, eastern kingbird, white-eyed vireo, and pine warbler (Fussell 1994, p. 150).

Breeding birds in the wetter shrub thickets include the common yellowthroat and red-winged blackbird (Fussell 1994, p. 148). Shrub thickets may also harbor the white-crowned and clay-colored sparrows. Winter residents include the yellow-rumped warbler, yellow-bellied sapsucker, downy woodpecker, brown creeper, hermit thrush, and both the golden-crowned and ruby-crowned kinglets (Fussell 1994 p. 151). Sharp-shinned hawks, fairly common transients and winter residents, forage at the edge of shrub thickets.

Herbaceous Swale and Other Freshwater Wetlands

Swales, typically wet transition zones, supports a variety of animals species found in both the drier dune communities, as well as the wet marsh areas. Areas of standing water provide breeding sites for amphibians. Those snakes that feed on amphibians are likely to hunt near freshwater areas. These areas should support some wetland species such as the red-wing blackbird and marsh wren. Freshwater areas on the Outer Banks may provide habitat for muskrats, nutria, mink, and river otters.

Maritime Forest and Other Upland Communities

Maritime forests provide some of the best fish and wildlife habitat on the barrier islands. Frankenberg (1995, p. 29) states that Nags Head Woods contains 100 species of birds and 65 land vertebrates, including 46 species of reptiles and amphibians and six species of freshwater fish. The vertebrate fauna of Southern Atlantic coast maritime forests is discussed by Bellis (1995, pp. 50-60). Depending on the extent of wet environments, maritime forests may provide habitat for all amphibian species known to occur in the project area. Bellis (1995, p. 520) lists four turtles, two lizards, and 10 snakes that may occur in the maritime forests of North Carolina. These woodlands also provide habitat for the raccoon, gray squirrel (*Sciurus carolinensis*), gray fox, white-tailed deer and other mammals. The characteristic amphibians, reptiles, and mammals of Brunswick County maritime forest have been summarized (USACOE 1973, p. II-H-19).

Maritime forests are important resting and foraging sites for many migratory birds such as the yellow-bellied sapsucker, magnolia warbler, black-throated blue warblers, palm warblers, and ruby-crowned kinglets, as well as for resident species, such as the Carolina wren, the chuck-will's widow (*Caprimulgus carolinensis*), yellow-rumped [myrtle] warbler, and gray catbird. Birds characteristic of these forests in Brunswick County are given in the Phase 1 GDM (USACOE 1973, p. II-H-19).

High and Low Marsh

Salt and brackish marshes are considered essential habitat for many fish species. They serve as nursery grounds for numerous fish including flounder (Bothidae), herring (Clupeidae), and drum (Sciaenidae).

The diamondback terrapin inhabits coastal marshes, bays, lagoons, creeks, mudflats, and similar environments characterized by salt or brackish water (Palmer and Braswell 1995, p. 59). Terrapins are relatively common in a few places where damage to their habitats has been minimal (Palmer and Braswell 1995, p. 58). Populations in many areas have been, and continue to be, depleted by extensive coastal development and the alteration of marshes.

Several birds are characteristic of the Brunswick County salt marshes (USACOE 1973, p. II-H-20). Birds that forage on the seeds of saltmarsh cordgrass include the seaside sparrow and sharptailed sparrow. Waterfowl species that use brackish marshes as winter habitat include the black duck, mallard, and northern pintail . Many other species use the brackish marshes during spring and fall migration. Clapper rails are common summer residents of tidal marshes in the area, nesting in salt and brackish marshes. Belted kingfishers forage in and around marsh habitats during the summer. Bald eagles hunt in estuarine marshes.

Saltmeadow flats contain many of the species which also use the wetter saltmarsh. These areas are sparsely vegetated with marsh grasses and other herbaceous species. Such flats may be similar to the saltmeadow flats considered by CZR, Inc. (1992). The salt flats are used by shorebirds during spring and fall migrations. Flats are favored loafing spots for terns from April through October. Wading birds are common during the warmer months. Birds using the salt flats include the lesser golden plover, buff-breasted sandpiper, Baird's sandpiper, long-billed curlew, black-necked stilt, Wilson's phalarope, white ibis, glossy ibis, yellow-crowned night heron, whimbrel, seaside sparrow, black rail, as well as the gull-billed, black, and sandwich terns (Fussell 1994, p. 163).

Birds frequently encountered in the high marsh include the northern harrier, savannah sparrow, seaside sparrow, eastern meadowlark, red-winged blackbird, and boat-tailed grackle (CZR 1992). All marshes may be used by clapper and Virginia rails. The sora inhabits marshes during migration.

Mammals inhabiting these marshes can be divided into two groups: (1) species living there by necessity; and, (2) those which chose to venture into the area. The first group contains those species which are specially adapted to this wet environment and contains the muskrat, nutria, river otter, mink, marsh rabbit, and marsh rice rat. The second group contains species which are adapted to a wide range of upland and wetland habitats and includes the raccoon, gray fox, and white-tailed deer.

Estuarine Waters and Tidal Creeks

Fish in estuarine waters are a mix of anadromous, catadromous, migratory, and indigenous species. Estuarine dependent fish use sounds as a passageway to nursery and feeding grounds. Commercially important species include Atlantic croaker, spot, summer flounder, and southern flounder.

Sea turtles use the pelagic waters of North Carolina sounds. Leatherback sea turtles have been seen in Chesapeake Bay (Lippson and Lippson 1997, p. 252). The most common species in the project area is the loggerhead sea turtle.

The birds that use estuarine water are quite diverse (USACOE 1973, pp. II-H-14 and 18). Some species found in the Cape Fear estuary include the brown pelican, Canada goose (*Branta canadensis*), mallard, canvasback duck, lesser scaup, royal tern, and black skimmer.

The manatee may occur in estuarine waters. The bottle-nosed dolphin inhabits inshore waters and frequently enters sounds, rivers, and tidal creeks of North Carolina (Webster et al. 1985, p. 213). Lippson and Lippson (1997, p. 251) report that bottle-nosed dolphins are summer inhabitants of the lower Chesapeake Bay where they are often seen feeding in the swift currents near the Elizabeth and James Rivers.

Estuarine Benthic

Estuarine benthic habitats may be vegetated or unvegetated, and this characteristic has a great influence on the vertebrates present. There is no specific information on estuarine benthic characteristics within the project area. In describing the shallow estuarine waters of the Chesapeake Bay, Lippson and Lippson (1997, p. 10) state that "[s]chools of small fish may often be seen . . . Duck and geese dive and 'tip up' to feed on aquatic vegetation and invertebrates."

Fish populations in areas of SAV, or seagrass beds, are abundant and diverse. Some fish are permanent residents of seagrass meadows, but because of seasonal variations in plant growth, most fish are seasonal residents composed primarily by juveniles (Kenworthy et al. 1988). In temperate areas there is an increase in plant abundance during the warmer months. This period coincides with the larval, post-larval, or juvenile stages of estuarine and estuarine-dependent, marine fishes. Larvae and juveniles of bluefish, mullet, spot, croaker, herrings and others appear in *Zostera* beds in the spring and early summer (Kenworthy et al. 1988). Many of these fish reside only temporarily in the grass beds in order to forage, spawn, or escape predators. Some species remain in these areas until the fall when they return to the coastal shelf waters to spawn.

Sea turtles, such as the green and immature hawksbills feed on submerged aquatic plants. Areas of submerged aquatic vegetation provide food for wintering diving ducks, such as the canvasback, redhead, the scaups, and ring-necked duck. Manatees may also feed on submerged estuarine vegetation.

Unvegetated, Intertidal, Estuarine Flats (Mudflat and Sandflats)

The unvegetated intertidal zone is an important environment for many coastal and marine fishes (Peterson and Peterson 1979). Numerous fishes live and feed on intertidal flats during high tides while other species are dependent on those species which forage in these areas. Peterson and Peterson (1979) present extensive data on fish which utilize intertidal flats in North Carolina.

These areas provide habitat for piping plovers, Lapland longspurs and snow buntings (Fussell 1994, p. 145). Oystercatchers occur here all year. During migration these areas are used by the semipalmated plover, marbled godwit, dunlins, and short-billed dowitchers. Other species found on the flats include the red knot, western sandpiper; sandwich, common, and roseate terns; and lesser black-backed, Iceland, and glaucous gulls.

Artificial and disturbed Areas

These areas which contain a diversity of successional stages provide habitat for many vertebrates. While some areas consist of only recently deposited sand, other areas may have young pine trees. The birds, amphibians, reptiles, and mammals in these areas may be very diverse (USACOE 1973, pp. II-H-22 and 23).

SECTION 6. FUTURE FISH AND WILDLIFE RESOURCES WITHOUT PROJECT

This section presents the opinion of the Service on the condition of fish and wildlife resources in the project area which could be reasonably anticipated in the absence of the creation of the artificial beach-dune system.

General Habitat Values Within the Project Area

The coastal areas of Brunswick County will continue to be developed with limitations imposed by the availability of suitable land, soil constraints, water supplies, and local land use regulations, zoning regulations, and ordinances. Frankenberg (1997, pp. 219-235) discusses trends in human population, land, use, and economic development along the southern North Carolina coast. While local governments seek orderly development, development will continue for the foreseeable future as long as favorable economic conditions exist. More and better roads will bring more people to the project area. It is likely that all available uplands which are not protected by designation as a conservation area within local Land Use Plan (LUP) will be developed. Existing oceanfront setback regulations require the construction of buildings to be set back 30 times the established annual erosion rate, or a minimum of 60 feet, from the shoreline.

Sea level rise can be expected to increase the rate of shoreline adjustment. If current conditions prevail, the remnants of the natural beach will continue to be squeezed between the rising sea and a fixed line of beachfront development. Beach front property will continue to be lost to larger storms. If the state and local governments adopted a policy of letting nature take its course with regard to island migration, natural island movement would allow a wide, recreational beach to persist.

Without the proposed project, offshore areas which are now designated as borrow sites, would remain relatively unchanged. Although the pelagic and benthic resources of these area may be subjected to some increases in pollution from the nearby coastline, any changes by factors other than large-scale dumping or dredging would be relatively minor. In the absence of the project, the primary production that these areas provide to the marine food chain would not be significantly altered.

The biota of the nearshore (subtidal) area might be expected to remain relatively unchanged without the project. Natural changes in currents and sediment deposits can be expected to change depths for specific locations. However, over a wide area the amount of nearshore habitat will probably remain fairly stable when compared to the sudden and pronounced changes produced by dredging and the removal of sediment. Any hardbottoms near potential borrow areas would continue to be subject to normal coastal geologic processes.

The absence of an artificial beach-dune system would also increase the occurrence of island overwash from the ocean. An increase of overwashing can be expected to increase the addition of sediment to sound side marshes as oceanfront sand is naturally transported to the sound side of the island. This orderly, natural process would ensure the continued existence of both ocean beaches and sound side marshes. The periodic additions of sediment would allow these marshes to overcome the gradual erosion due to wind driven waves from the sounds and drowning by a rising water level in the sound. Overall, the habitat values of sound side marshes are likely to be enhanced without the project.

General Influences on All Fish and Wildlife Resources

Tropical hurricanes and northeasters will periodically hit the project area. Without the project, development associated with the tourist industry may gravitate to the more protected areas of the island. The limitation of development would alleviate pressure on habitats near the beach and could allow some habitats, such as overwash fans, that have been greatly diminished to return naturally. The threat to the natural freshwater supply would be reduced and the extent of freshwater wetlands would remain stable or increase. Overall, the future of the area without the project could be less pressure on existing natural areas and the possible recovery of some natural areas which have been lost.

Outlook for Classes of Vertebrates

Marine and Estuarine Fish

The future of these fishes is likely to be a continuation of present trends. On a global scale, marine fishes face a serious threat from overfishing. The problem of overfishing has been characterized as simply too many fishermen and not enough fish (Parfit 1995). The 50-year boom in fishing technology has created an immensely powerful industrial fleet of 37,000 ships crewed by about a million people worldwide (Parfit 1995). A modern freezer trawler can catch and process a ton or more of fish per hour.

The primary factor in the future of the many marine fish will be the efficacy of regulations to allow harvests which are sustainable. The state's 1997 Fisheries Reform Act and the management plans created under it seek to maintain viable fish stocks using flexible methods of gear and area restrictions (Powell 1999). Federal legislation seeks to rebuild fisheries stocks. Fishing pressure from commercial and recreational fishermen will continue. If overfishing is allowed, some species may not survive.

In the absence of the proposed project, marine and anadromous species would not be periodically harmed by offshore dredging required to maintain the beach-dune system. A policy designed to move buildings back from the receding shoreline or simply the no action alternative would generally be beneficial to marine fishes. Estuarine fish would benefit from island overwashes that maintain the estuarine marshes as important nursery areas.

Amphibian and Terrestrial Reptiles

In general, the future of these species will also be strongly influenced by the level of development. The creation and enforcement of land use plans that favor low density development away from environmentally sensitive areas will increase the chances that current population trends will continue.

All amphibian and reptile populations will continue to experience periods of severe stress, such as droughts, island overwashes, and hurricanes. However, these are natural forces to which the species have adapted, and populations should recover. Overall, amphibian and terrestrial reptile populations in the project area are likely to remain similar to present conditions.

Birds and Mammals

As with other terrestrial wildlife, the future of these species are dependent on the level of future development. Allowing natural barrier island processes to continue will enhance the long-term viability of all mammalian and avian species. The establishment and enforcement of zoning regulations to preserve existing natural areas, especially maritime forests, will benefit these species.

<u>Federally Protected Species</u>

Without the project, the seasonal use of the project areas by the manatee, roseate tern, bald eagle, shortnose sturgeon, and peregrine falcon is likely to be unaffected.

Piping Plovers

The developed nature of the project area limits its use by the piping plover for nesting. The area may receive limited use for foraging and roosting. For such uses, the future habitat value for this species is similar to that of other shorebirds.

Sea Turtles

The future value of the project area for sea turtle nesting is uncertain. The overall impact of measures to keep existing buildings in their present location does not bode well for the future of any beach. If this commitment remains over the coming decades, the rising sea level in combination with the ever rising cost of continuously placing sand on the beach may lead to a decision to use a more permanent structure to protect buildings, such as a seawall. Such a decision would ultimately lead to the elimination of beaches in front of the wall (Pilkey et al. 1998, p. 88-91).

Without any project to stabilize the shoreline, natural beach recession will continue. The beaches would continue to exist, but would not be in exactly the same location from year to year.

However, sea turtles have adapted to shifting beaches for millions of years and this factor would not harm nesting success.

Summary of Future Fish and Wildlife Resources Without the Project

With the exception of marine fishes that are subject to commercial harvesting, populations of wildlife and other fisheries resources are likely to maintain present population trends in the near future if the artificial beach-dune system is not constructed. If natural shoreline adjustment is allowed to continue, the beach will not disappear, but simply migrate landward. To the extent that natural beach movement is allow to continue, developers may find the risks of construction near the beach to be too great. Any reduction of construction near the shore would be beneficial to sea turtles and shorebirds. The absence of artificial dunes would also facilitate the natural process of island overwash. Such overwashes would benefit early successional wildlife, such as piping plovers, and allow for natural replenishment of sound side marshes that provide valuable habitat for fish and wildlife.

Overall, any adverse impacts to fish and wildlife resources due to implementing the storm damage reduction project must be fully considered in all environmental documents. There are no justifications for excluding such impacts on the grounds that other factors would diminish these resources.

SECTION 7. ALTERNATIVES CONSIDERED

The alternatives developed for any federal project should arise directly from the stated project purpose. In the project area, coastal storms have damaged or destroyed structures near the shoreline of Brunswick County. Since such storms will continue to periodically strike the coast, the potential for storm damage is high and likely to increase if global warming increases the frequency and magnitude of coastal storms. Likewise, the rise in sea level will continue to force shoreline adjustment in the project area. Only when viewed from the perspective of a fixed structure on the shore will the natural accommodations to the rising sea be considered as erosion or a permanent loss of land. The actual geology of the situation will be that the shoreline, and hence the natural beach will have attempted to move landward. It is the pushing of the adjusted shoreline back toward the ocean that actually creates the impression that land is being lost.

The 1966 authorizing legislation for the Brunswick County project indicated two purposes: hurricane wave protection and beach erosion control. The legislation contained a specific plan to address these problems. The plan involved (USACOE 1973, p. 1-2):

> " . . . the construction of a levee-type fill having the general geometric configuration of an integrated dune and beach profile, wherein the dune has a crest at elevation 20 feet above mean sea level (m.s.l.) fronted by a storm berm and gently sloping beach face which closes on the existing nearshore bottom . . . The shoreline of the restoration fill would be stabilized against long-term erosion by a program of periodic fill replacement referred to as 'beach nourishment.'"

The 1973 planning document notes that the authorized plan was based on recommendations by the Corps. The Corps recommendations were based on investigations authorized by Congress in 1955, the year after Hurricane Hazel struck the coast. While the 1955 authorizing legislation came before the National Environmental Policy Act (NEPA) of 1970, the NEPA applies to the present reevaluation and the requirement for a complete development and evaluation of alternatives should be undertaken.

The Phase I GDM provides an unusually detailed consideration of the alternatives considered (USACOE 1973, pp. 18-31). The document does mention the "do nothing" alternative, and states that this is simply to accept the prospect of future storm damages of significant magnitudes and the persistent loss of properties through long-term erosional processes. The acceptance of such impacts was "categorically rejected by local interests and the State" (USACOE 1973, p. 18).

The Corps also considered encircling the developed portion of the Brunswick County barrier islands with a dike and/or floodwalls (USACOE 1973, p. 19). This option was based on data indicating that most storm damage was not due to the storm surge, or "tidal anomalies", but was caused by general flooding.

In regard to beach erosion control, the Corps noted that one approach was to intercept, in part or totally, wave energy prior to its onshore arrival. Such interception could be achieved by the construction of an offshore breakwater that could partially or completely shield the shoreline. The preauthorization study considered a series of detached, offshore breakwaters to reduce wave impacts on the shoreline.

The Phase I GDM noted that natural beaches and dunes provide valuable protection from storm damage and dunes act as sand reservoirs that supply sediment to offshore beach profile when short-term shoreline retreat occurs after storms (USACOE 1973, p. 19-20). Based on these ideas of natural storm protection, the GDM noted (USACOE 1973, p. 20) that it would be "highly desirable to establish land-use controls along the open coastal reaches which prevent cultural development from encroaching on and/or destroying the natural protective system of beach and dune." The GDM stated that early measures to protect these natural protective structures were adopted by Brunswick County in 1971, but indicated that their enforcement does not preclude the possibilities of significant damage by beachfront development in the future. Future damage was likely to result because many oceanfront structures were being constructed upon or immediately adjacent to the frontal dunes, and thus are located in a zone which can be expected to erode under the action of a major storm event. Furthermore, the dangers to these structures would only increase as a result of long-term erosion. The Corps' GDM indicated (USACOE 1973, p. 20):

> "Ideally, rational land-use planning for the undeveloped areas should include the establishment of buffer zones, within which construction of permanent facilities would be prohibited. the buffer zones should be of sufficient width to accommodate large-scale storm generated shore retrogressions over 25- to 50-year periods."

Finally, the Phase I GDM considered a variety of structural alternatives (USACOE 1973, p. 20). The standard structural options included: (1) groins with beach fills; (2) groins with beach fills backed by a seawall; and (3) groins with beach and dune fills.

In the early 1990s the Corps considered a beach erosion control project and hurricane wave protection project for Ocean Isle Beach, one of the islands within the larger Brunswick County Beaches Study. In evaluating a project for this single island, the Corps noted (USACOE 1997, 12) that plan formulation was based on two principal objectives: (1) a plan acceptable to the Town of Ocean Isle Beach; and, (2) a plan which is consistent with current Federal economic, environmental, and technical requirements. It would appear that while the Corps was free to consider a range of alternatives, as it did in the Phase I GDM, the Town of Ocean Isle Beach would ultimately decide the alternative to be implemented. The EA for the project (USACOE 1997a, p. 5) considered only a "no action" alternative and the construction of a berm and dune, the beachfill option. No consideration was given to the storm damage reduction potential of removing structures from the inherently dangerous shoreline.

The present planning effort seems limited to a single alternative: the construction and maintenance of a berm and dune system that will tie into the existing dunes and vegetation line. While this recent effort may claim a foundation in the preauthorization studies of the early 1960s and the Congressional authorization of 1966, the Service believes that planning to date has not presented all alternatives to meet the stated project goal and has not considered an approach that would integrate several options. The NEPA and associated regulations state that federal action agencies may consider alternatives that are outside their jurisdiction. While the construction of the artificial beach-dune system may be the only alternative that the Corps could undertake, it is not the only action alternative which could reduce storm damage. The local community may also see an artificial beach-dune system as the most desirable form of storm damage protection, but this preference should not deter a complete evaluation of alternatives. The NEPA document should go beyond the construction alternatives and consider alternatives that could be implemented by other federal agencies, e.g., Federal Emergency Management Agency, state agencies, and local governments.

A key step in developing all possible alternatives would be to clearly define three items: (1) the categories or intensity level of storms for which protection would be provided; (2) the type(s) of damage which the project is intended to reduce; and (3) the exact area that would receive protection. The forthcoming NEPA document should clearly address these issues and the Service offers the following points on these important issues.

Categories of Storms for Which Protection Would Be Provided

Both hurricanes and winter storms can vary greatly in intensity and the damage produced is related to the magnitude of winds, flooding, and storm surges produced. Table 13 gives general data on wind speeds, storm surge heights, and general level of damage associated with the five categories of hurricanes. A similar 5-level classification system has been developed for northeasters (Davis and Dolan 1993). These data should be used in established the approximate level of damage which the project would seek to mitigate. Project planning should also take into account projects designed to protect against only minor hurricanes, categories 1-2, that would leave the area vulnerable to damage by major storms which would range from extensive to catastrophic.

The Types of Damage Which the Project Is Intended to Reduce

The Brunswick County Land Use Plan (LUP) considers coastal storm hazards to include flooding, storm surge, wave action, and winds (Brunswick County 1993, pp.122-123). Bush et al. (1996, pp. 19-40) give a thorough account of natural storm processes and physical processes that affect barrier islands and may produce property damage (Figure 12). The five major storm processes are high winds, storm waves, storm surge from the ocean, storm surge ebb (water flowing overland from estuaries), and high rainfall (Bush et al. 1996, p. 19) and these major storm processes are summarized in Table 14 and Figure 13.

Storm Winds

It is doubtful that an artificial beach-dune system would be able to mitigate damage caused by wind or wind in combination with heavy rain. In 1969 Hurricane Camille hit the Gulf coast with winds of 190 miles per hour (mph) and in 1992 Hurricane Andrew hit south Florida with winds of 180 mph (Bush et al. 1996, p. 28). Bush et al. (1996, p. 28) note that the highest winds of hurricanes, what they refer to as the universal agent of destruction, are rarely recorded because wind-measuring instruments are destroyed or blown away. Even behind a low dune high winds can rip off roofs and wind-borne debris would still have the potential to strike other buildings, a process known as missiling. Much hurricane damage is caused by falling trees which may crash through walls and roofs. Buildings with damaged roofs, walls, and windows would be subject to water damage by heavy rain.

Storm Waves

Damage produced by storm waves results from water breaking directly against structures and may be considered independently from water damage or flooding (Table 14). Bush et al. (1996, pp. 28-29) discuss the formation of waves in coastal storms. Waves are actually a form of energy carried through water. A cubic yard of water weighs about three-quarters of a ton (1,500 pounds) and breaking waves moving shoreward at 30-40 miles per hour can be one of the most destructive elements of a hurricane (Pilkey et al. 1998, p. 219). Table 14 gives several examples of the ways in which waves may cause damage. Hurricanes create huge waves that batter the coast. The greater the energy, the larger the wave. Wave energy exists both above and below the water's surface. As wave energy interacts with the bottom, the energy begins to dissipate and the wave breaks. The protective functions of beaches results from absorbing wave energy and causing the waves to break before reaching land. Frontal dunes serve as a final barrier to storm waves.

Northeasters also produce damaging waves. Dolan and Davis (1993) developed a classification of Atlantic extratropical storms based on a "wave power index." By definition a storm is characterized by deep water waves of at least five feet (Dolan and Davis 1993). The "All Hallow's Eve" storm of October 1991 produced deep water waves of 35 feet, the highest recorded over the past 50 years. These waves were larger than the 30-foot waves associated with the famous Ash Wednesday storm of March 1962. At Duck, North Carolina, immediately north of the project area, waves of 17.7 feet were recorded in water 66 feet (20 meters) deep and waves in 30 feet of water were recorded at almost 15 feet (4.5 meters) (Davis and Dolan 1992). While smaller storms produce smaller waves, the alternatives for storm damage reduction should include explanations of the ways in which each alternative would mitigate wave damage, both large and small.

Storm Surge From Ocean

A storm surge is the superelevation of the still-water surface that results from the transport and circulation of water induced by wind stresses and pressure gradients in an atmospheric storm (Pilkey et al. 1998, p. 35). Pressure gradient refers to the lowered atmospheric pressure in storms which by itself can cause a rise in sea level. Within the area of low pressure the ocean water is literally sucked upward and the upward movement in combination with landward winds causes the ocean to flow over areas normally above sea level. The overland flow of the ocean causes flood damage and, by allowing waves to occur further inland, increases the area normally subject to wave attack.

Table 13 indicates that storm surges associated with hurricane categories may range from four to more than 18 feet. Pilkey et al. (1980, p. 148) state that the storm surge at the coast may reach a height of 15 to 20 feet or more about sea level. The storm still-water surge levels along the coast from the mouth of the Cape Fear River to the South Carolina state line for one-in-25, -50, and -100 year storm frequency are approximately 9.67, 11.23, and 12.45 feet above mean sea level, respectively (Pilkey et al. 1998, p. 113). These figures are the highest along the North Carolina coast, and they do not include the additional height created by waves. The storm surge of Hurricane Hazel in 1954, a category 4 storm, reached a maximum elevation of 15 feet above mean sea level, a height approximately seven feet above the average topographic elevation of the islands (USACOE 1973, p. 5). In September 1996 Hurricane Fran, a category 3 storm, created a storm surge of 12-14 feet across Topsail Island (Pilkey et al. 1998, p. 29). There was extensive overwash and flooding that destroyed dunes, overtopped seawalls, and cut swash channels.

Northeasters with their weaker wind fields and higher pressures seldom generate storm surges in excess of 6.6 feet (2 meters) (Dolan and Davis 1993). The storm surge along with waves are the most destructive forces generated by northeasters (Pilkey et al. 1998, p. 31). The 1962 Ash Wednesday northeaster flooded and overwashed the project area. The damage from this storm was exacerbated by its occurrence during spring high tides and its persistence over five, high tide cycles.

The development of alternatives should consider the protective value of each alternative against storm surges along the entire oceanfront of the project area. The 1962 Ash Wednesday storm broke through the remnant dunes of the 1930s and covered most of Kitty Hawk, Kill Devil Hills, and Nags Head with two to four feet of water (Pilkey et al. 1998, pp. 145 and 147). Therefore, protective dunes may fail in severe storms.

Storm Surge Ebb From Estuarine Waters

Storm damage may result from water flowing over the island from estuaries rather than the ocean. Flooding from the estuaries is due to the storm surge ebb. This phenomenon occurs when water that has been piled up by winds blowing landward is suddenly pushed seaward by an abrupt shift in wind direction. Storm surges from an estuary occur at the same time that sea level on the ocean side is low due to strong seaward winds. A storm surge ebb leads to flood flows across the island in a seaward direction, resulting in erosive scour around buildings, and may create new inlets as masses of water are pushed toward the sea. Hurricane Emily in August 1993 stayed completely offshore from the Outer Banks. However, strong winds blowing over Pamlico Sound created a maximum storm surge on the back side of Hatteras Island with greater wave height and water levels on the sound side than on the ocean side (Bush et al. 1996, p. 31). The back side of barrier islands need as much attention for storm damage reduction as the ocean side. (Bush et al. 1996, pp. 31-32) state that "A mighty fortress (e.g., a seawall) is worthless if the attack comes from the rear."

Heavy Rainfall

Coastal storms produce heavy rainfall that results in damage completely independent of any overwash from the ocean or the sound. Rainfall may produce flooding and erosion damage in low-lying areas of the barrier islands without the introduction of ocean or estuarine waters (Figure 14). An artificial beach-dune system would provide little, if any, protection from flooding due to heavy rainfall.

The Area for Which Storm Damage Reduction is Expected

The third major consideration in developing alternatives is the area that the project seeks to protect. Both hurricanes and northeasters are massive storm systems that may cover hundreds of square miles. As these storms develop, there is no way to predict the exact location of future damage. High winds in combination with heavy rain can cause property damage in areas set back from the coastline (Figure 14).

The National Flood Insurance Program (NFIP) has defined different zones of flood hazard. The base flood is flooding to which a community is subject at a one percent or greater chance in any given year, also referred to a 100-year flood. In the NFIP for coastal areas, flooding is divided into an A Zone, or area of special flood hazard and a V Zone, or coastal high-hazard area (Figure 15). The separation of these zones is based on the occurrence of 3-foot breaking waves which by definition may occur in the V Zone, but not in the A Zone. In general, the V Zone extends inland to the point where the stillwater depth during the 100-year base flood decreases to less than four feet (FEMA 1986 as cited in NRC 1995, p. 65). Therefore, by definition the A Zone is only subject to storm waves less than three feet high. The main point with regard to any storm damage reduction project is that only a limited area will experience flooding in combination with high waves while a much larger area will simply be flooded.

With such a large area at risk from coastal storms (Figure 16) it is important to define the geographic extent of protection that a specific project is expected to provide. The geographic area of protection would, to some extent, be an extension of the category of storm and the type of damage for which the project seeks to provide protection. For example, to protect against storm surge flooding of a category two hurricane, an unbroken barrier at least eight feet high (Table 13)

would be needed along the coastline. If one or both ends of the artificial barrier occurred at a point on the beach without an existing dune, the extent to which the storm surge would come around one or both ends of the barrier would need to established. Development near the abrupt ends of any artificial barrier would be subject to flooding by the storm surge moving around and behind the barrier. The area behind the central part of the artificial barrier would be the geographic area protected by barrier. However, the area protected from the storm surge would still be subject to wind damage, heavy rains, and any storm surge ebb washing over from the sound.

Alternatives That Should Be Considered For Storm Damage Reduction

In any shoreline management project the twin goals of protecting structures and providing a recreational beach are constantly intertwined. However, a problem arises due to the fact that the federal government feels that protecting property is a valid national concern while ensuring a sandy playground for tourists is not really an appropriate expenditure. There may be reasons to wonder whether creating an artificial beach-dune system represents a means to an end (i.e., reducing storm damage) or is actually an end itself (i.e., replacement of the recreational beach lost to shoreline recession in the face of a rising sea).

Historically, measures to counteract the encroachment of the sea were designated as erosion control projects. Erosion in such cases was not specifically related to major storms. While major storms did eat away at the beach, it was the steady gradual loss of the beach that led to the disappearance of the land on which structures were built. At some point a decision was made that shoreline projects could not really "control" the erosion produced by the sea. Seawalls would protect structures for a while, but the sea would eventually remove the beach. The accumulated results of shoreline management led to the need for better terms to describe efforts aimed at saving man-made structures threatened by the sea and the recreational beaches which ultimately created the need for such buildings. With a tacit acknowledgment that the slow, steady advancement of the sea could not be controlled, the emphasis turned to controlling storm damage, a goal with a clearly defined economic value.

Assuming that shoreline adjustment cannot be eliminated, three broadly defined strategies are available to a community faced with the encroachment of the sea toward existing structures (NRC 1995. p. 27). These are: (1) construct a structure, such as a seawall or groin, to limit the continuing damage or threat of damage; (2) initiate a program of periodic renourishment of the beach to provide the desired level of protection, perhaps in conjunction with hard structures; or (3) abandon or move buildings or other facilities that are damaged or endangered by continuing erosion.

When the emphasis changes from restoring a lost recreational beach to the reduction of storm damage, the options are similar. However, some hard structures that are placed perpendicular to the shoreline, such as groins and jetties, are strictly for erosion control. Seawalls are not generally considered a storm damage reduction measure. Pilkey et al. (1980, p. 45) state that

“While a seawall may extend the lives of beachfront structures in normal weather, it cannot protect those on a low-lying barrier island from the havoc wrought by hurricanes; it cannot prevent overwash or storm surge flooding.” However, a major exception is the seawall in Galveston, Texas. After the hurricane of 1900 killed more than 6,000 people, the town constructed a seawall four miles long and 17 feet high (Bush et al. 1996, p. 160). The city also pumped 16 million cubic yards of sand into the city to raise the elevation of the island. Despite these efforts Bush et al. (1996, p. 160) believe Galveston remains “extremely vulnerable to hurricanes” and a storm of the same magnitude as the 1900 hurricane would still demolish much of the city.

Leaving aside hard structures such as a seawall, there are a number of options for reducing storm damage. A list of available options based on material presented by Bush et al. (1996, p. 69) is given in Table 15. Each of these is considered below.

Abandonment/Retreat/Relocation From the Shoreline

On North Carolina’s Outer Banks abandonment was the choice in some locations following the 1962 Ash Wednesday Storm (NRC 1995, p 28). The Towns of Nags Head and Kitty Hawk have used the retreat option by gradually removing individual buildings; either by their owners or through destruction in relatively small storms (NRC 1995, p. 28). Abandonment may be an economically sound option when buildings have existed beyond their design life and the cost of relocation or protection is greater than the buildings’ value (Bush et al. 1996, p. 93).

Relocation of threatened beach structures has been undertaken by the federal government. The Upton/Jones amendment (Section 544) of the Housing and Community Development Act of 1987 authorized the NFIP to pay for the relocation or demolition of structures that are subject to imminent collapse as a result of shoreline erosion. The law allowed homeowners of threatened buildings to use up to 40 percent of the federally insured value for building relocation purposes (Bush et al. 1996, p. 93). Bush et al. (1996, pp. 93-94) state that this program:

> “. . . recognized relocation as a more economical, more permanent, and more realistic way of dealing with long-term erosion problems. . . . [the government] would pay a relatively small amount to assist in relocating a threatened house rather than paying a larger amount to help rebuilt it, only to see the rebuilt house destroyed in a subsequent storm, and paying to rebuild again . . . and again.”

The Upton-Jones program was replaced in 1995 with the National Flood Mitigation Fund which provides grants to state and local governments for planning and mitigation assistance to reduce the risk to structures covered by the NFIP. Demolition and relocation activities are eligible for grant assistance under this program, but these actions must now compete with other mitigation measures such as floodproofing structures, acquisition of flood zone property for public use, and technical assistance.

Bush et al. (1996, p. 99) report that Nags Head adopted a mitigation policy that recognized shoreline retreat as inevitable. The town determined that it is better to adopt a policy of planned retreat than to wait for a disaster to force retreat. In Nags Head, deep lots running perpendicular to the shore provide room for relocation. Within the town, funds were requested for 35 demolitions, average cost $74,409, and 19 relocations, average cost $30,211 (Williams 1993 as cited in Bush et al. 1996, p. 99). Bush et al. (1996, p. 99) note that removal costs have been less than the nourishment costs for 4.5 miles of beach. Furthermore, beach nourishment would need to be repeated every three years, while if all the threatened structures are removed, it would be 20 to 25 years before the number of threatened structures returns to current levels. Overall, the retreat option would cost about $2 million every 20 to 25 years, while beach nourishment would cost about $9 million every three years.

It is only logical to conclude that storms can only damage structures placed in their path. If those buildings which are at the greatest risk are removed or relocated, the extent of storm damage would be greatly reduced. If the goal of this project is strictly to reduce storm damage, the option of a removal/relocation program should be fully considered. A relocation program may be aesthetically superior in the long run (Bush et al. 1996, p. 93).

Soft Stabilization: Beach Nourishment

Table 15 indicates that beach nourishment may have several distinct components, but it is generally considered to be the creation of an artificial beach with or without a dune. While all the other major storm damage reduction options are directed solely at storm damage reduction, beach nourishment is considered by some as primarily a method to check shoreline erosion and replace lost recreational beaches.

Longevity - An important, but often overlooked, aspect of beach nourishment for storm damage protection is the extremely temporary nature of the protection. An artificial beach may be referred to as a “sacrificial” barrier because it will certainly be washed away over time. This is logical since the natural forces that eliminated the natural beach are still at work and will in time eliminate the artificial beach.

The disappearance of the artificial subaerial beach is due, in part, to the fact that all beach creation projects are directed at only the narrowest upper part of the real beach (Figure 17). The true beach is actually the entire shoreface, a layer or wedge of sediment resting uneasily on the more permanent continental shelf, or as the colorful metaphor of (Kaufman and Pilkey 1983, p. 85) states “an insomniac on a firm mattress.” The shoreface is a broad, thin band of restless sand and gravel, whose slope is much steeper than the almost flat shelf (Kaufman and Pilkey 1983, p. 88). In cross section it has the concave curve of a shallow saucer. Kaufman and Pilkey (1983, p. 216) write that:

> "The true beach . . . is more than a bathing strand. It is a wedge of sediment three or four miles wide stretching underwater to depths of thirty or forty feet. Replenishment drops sand only on the thin visible strip of upper beach. For obvious reasons no one has yet suggested building up the entire shoreface to thirty feet below the surface of the sea.

Sufficient money is never available to replenish the entire beach out to a depth of 40 feet. Thus, only the upper beach is covered with new sand, so that, in effect, a steep beach is created. This new steepened profile often increases the rate of erosion (Pilkey et al. 1980, p. 40). Coastal geologists seem to agree that created beaches almost always disappear faster than their natural predecessors (Pilkey et al. 1998, p. 96; Bush et al. 1996, p. 81).

An interesting aspect of the beach longevity issue as it relates to the real, or perceived, purpose of the beach is that local interests often expect a wide, dry, recreational beach regardless of the purpose for which it was build. Pilkey and Dixon (1996, pp 103-125) recount the experience of Folly Beach, South Carolina, with an artificial beach and dune design to protect the community from storms. The new beach and dune were constructed in 1993 and soon begin to disappear at a rapid rate; the width of the dry beach declined from 200 feet to 75 feet within the first year. The Corps assured local interests that ". . . the sand was still all there, just offshore, still providing storm protection for the city" (Pilkey and Dixon (1996, p. 121). In theory, local officials should have been pleased that offshore sand was indeed continuing to provide storm protection, the official purpose of the project. By 1995 little of the dry beach remained and the storm berm, or dune, was largely gone. A local official noted that the Corps' post-project declarations of a protective underwater beach was inconsistent with the way the Corps sold the project to Folly Beach residents.

The story of Folly Beach highlights the degree to which the objectives of storm damage protection and restoring a wide recreational beach can become intertwined. While there is certainly no problem with using a single project to achieve two objectives, one objective must dominate and form the basis for developing alternatives. The fact that offshore sand, essentially an underwater beach, is taken as a project failure by some despite the fact that such sand does mitigate storm damage indicates that restoring a lost recreational beach may be the primary goal in some beach-dune creation projects.

Location of Borrow Areas - A major design feature of the currently preferred alternative is the source of sand for beach placement. The five designed borrow areas are relatively close to shore. In general, offshore sand sources may result in less overall environmental harm than estuarine sites that have been used for other beach construction projects in North Carolina. Estuarine areas may have higher silt and clay content than offshore areas, and thus produce less turbidity and sedimentation. Shallow estaurine areas, especially vegetated shallows, are very productive and serve as nursery areas for shellfish and finfish.

Project design should carefully consider the location of borrow areas in relation to closure depth, the water depth at which no appreciable movement of bottom sediment results from wave action (NRC 1995, p. 8). At depths less than the closure depth wave energy is reduced by friction with the bottom sediment and removal of this sand allows stronger waves to strike the beach. A comprehensive study (NRC 1995, p. 97) reports that:

> "It is essential that material obtained from the sea be located a sufficient distance offshore that the sand placed in conjunction with the nourishment will not be carried back into the borrow areas. In most cases, borrow areas need to be a minimum of 2 km [1.24 miles] from the shoreline, well seaward of the depth of closure."

In this regard sand sources farther off the coast should receive consideration.

Grain size Compatibility Between Existing Beach and Borrow Areas - The issue of grain size compatibility is critical to many aspects of the project's success, such as longevity, and the adverse environmental impacts, such as turbidity and sedimentation. This issue is summarized by the statement (NRC 1995, p. 97) that:

> "The most important borrow material characteristic is the sediment size. Borrow material grain size matching the native material is considered synonymous with quality. A candidate borrow area may be considered unacceptable if the silt and clay fractions exceed a certain percentage. . . . Fine material also adversely affects project performance. Early projects constructed without regard for grain size performed relatively poorly, and recent developments indicate that nourishment sand that is only slightly smaller than native sand can result in significantly narrower equilibrated dry beach width compared to sand the same size as (or larger than) native sand."

Project planning must collect comprehensive, grain size data on both the existing beach and all potential borrow sites. While nearshore sites would create lower transportation costs, the use of nearshore sites with fine grained material would result in more frequent renourishment and higher turbidity. Over the 50 years of official project life, the greater costs of borrow areas farther offshore, but with larger grain sediment, could increase the time between required additional sediment placements. The cost savings from longer beach life could offset the greater transportation costs involved with more distant sites.

Design and Construction Options - Several major features of design and construction have not been established. These options will influence the ultimate environmental impacts of the project.

First, there is the issue of whether there should be large sand placements spaced several years apart or smaller sand placements annually. Pilkey and Dixon (1996, p. 83) recount the beach nourishment experience of Virginia Beach, Virginia, less than 50 miles north of the project area. In 1972 a study committee, which included the Corps, concluded that the small annual renourishment technique that had been used was superior to large nourishment projects spaced several years apart. This was due, in part, to a determination that larger volumes of sand disappeared more rapidly. However, by 1995, without evidence that would contradict the 1972 report, the Corps chose to put large volumes of sand on the beach at three year intervals. This aspect of a storm damage reduction option should be evaluated. In North Carolina, a small beach nourishment project could be on the order of 100,000 to 200,000 cubic yards of material per mile of beach (Pilkey et al. 1998, p. 100).

Second, the type of dredging equipment to be used and the manner in which the sediment would be moved to the beaches needs to be established. The basic option would probably involve either a hopper dredge or an ocean-certified pipeline dredge (NRC 1995, pp. 274-280). The nature of the equipment will influence the annual work schedule, the mode of transfer to the beach, and the need for any booster pumps. These factors would influence the environmental impacts of the project.

Modification of Development and Infrastructure

Table 15 gives several examples of measures which fall into this broad, third option for storm damage reduction. This category includes the many measures that would make structures better able to withstand coastal storms. A basic part of such measures is the improvement of building codes. Pilkey et al. (1980, p. 148) state that "It is possible to design buildings for survival in crashing storm surf. Many lighthouses, for example, have survived storm surge. But in the balanced-risk equation, it usually isn't economically feasible to build ordinary cottages to resist such forces."

Pilkey et al (1998, pp. 213-257) devote an entire chapter to construction regulations and techniques that would result in less storm damage. Their discussion covers such diverse topics as the type of house, strengthening the exterior envelope, structural integrity of buildings, and retrofitting an existing house (Figure 18). These authors also write that damage to water, sewage, electrical, telephone, and cable TV utilities can often be avoided by proper installation (Pilkey et al 1998, p. 221). The chapter notes that the best and most common method of minimizing flood damage due to waves or storm surge is to raise the lowest floor above the expected highest water level (Pilkey et al 1998, p. 234).

In addition to the advantages that better building codes and enforcement would provide to building owners, such measures would benefit the entire community by reducing missiling (flying debris), rafting (floating debris), and ramrodding (floating debris). Even entire houses that are not properly anchored may float off their foundations and become waterborne. In a coastal storm it is not enough to have your own property secure, the deficiencies of other buildings miles away can come by wind or water directly to your doorstep and then through your door.

The key method of storm hazard mitigation is the enforcement of base flood elevation standards designed to allow rising waters to flow freely under elevated structures. The enforcement of the wind load requirements for hurricane zones established by the Southern Building Codes Council can also reduce storm damage. Bush et al. (1996, p. 99) write that Nags Head, North Carolina, adopted building standards more restrictive than required by either FEMA or the North Carolina Coastal Area Management Act (CAMA). Incentives may be used to encourage the location of development as far back from the ocean as possible.

Zoning and Land Use Planning

Table 15 gives several actions by which zoning and land use planning, a fourth major option, may be employed to reduce storm damage. Bush et al. (1996, pp. 137-143) discuss these measures, but the overriding message is to identify hazard areas and avoid developing them by proper planning. These authors note that the real world provides very few good examples of planned development on barrier islands, primarily because developers and communities do not stick with their plans.

However, certain measures could be employed. For example, multi-story commercial structures could be excluded from high hazard flood areas (the V-zone), lots in ocean erodible areas could have a long axis perpendicular to the ocean in order to allow for periodic pull backs, and development could be banned from potential inlet formation sites of overwash areas. The Town of Kitty Hawk, North Carolina, recognizes that some lots fronting the ocean have or may become so shallow because of erosion, that they cannot be built on and that, wherever possible, the public may acquire though dedication or purchase land vacated by relocated structures (Kitty Hawk 1994, p. 75). The Town also expects that the environmentally sensitive land in Hazard Zone Four, an area that can expect flooding in even a minor hurricane, will develop as low density residential, if it is developed at all. These measures indicate an understanding that storm damage reduction can be achieved by zoning and land use regulations.

There are government actions that could reduce coastal storm damage. A group of individuals representing such diverse fields as coastal engineering, regional planning, coastal law, and economic geology met at the Second Skidaway Institute of Oceanography Conference on America's Eroding Shoreline in mid-1985. This group produce a "National Strategy for Beach Preservation" (Skidaway Institute of Oceanography 1985). A part of this strategy was a list of actions that could be taken at the federal (Appendix D), state (Appendix E), and local (Appendix F) levels to both minimize the economic losses of coastal storms and preserve America's beaches.

Summary For the Development of Alternatives

As noted, there is no question that efforts should be made to reduce the damage of coastal storms. The major question is the proper method or methods to achieve this goal. This section has briefly discussed the framework which the Service believes should be used in deciding on a storm damage reduction program.

<u>The Role of Economics in Developing Alternatives</u>

The Environmental Impact Statement (EIS) should contain all reasonable alternatives. The Council on Environmental Quality considers an alternative to be reasonable (Eccleston 1999, p. 271) if:

> " . . . it is deemed to be 'practical or feasible' from a 'technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant.' "

The Corps letter of January 24, 2000, indicates that the only action alternative under consideration is the construction and maintenance of a berm and dune system. The Service recommends two additional approaches that could be used either singularly or in combination. First, modification of existing development and infrastructure. This approach includes retrofitting existing structures to withstand storms, elevating houses, and improved placement of roads and utility lines. Second, improved zoning and land use planning. This approach would include greater avoidance of hazard areas by development, expanded use of setbacks for structures, and overall lower development density. These alternatives would reduce storm damage.

The development of a given alternative should not be mixed with a concurrent evaluation of that alternative. All too often, the development of an alternative is intertwined with discussions of the economic cost, potential availability of funds, or social acceptability of that alternative. While economics may play a role in the selection of a preferred alternative, it should not be considered in the development of alternatives. This mixing of alternative development and evaluation often leads to a rapid declaration that a given alternative is too expensive, too difficult, not within the jurisdictional of the federal agency preparing the document, or not favored by local interests. This process can lead to the elimination of an alternative before it is fully developed. For the need to reduce storm damage on Brunswick County beaches, it may be argued that retrofitting and/or relocating houses are expensive alternatives. However, there is seldom a consideration of how the funds that are easily provided for one alternative, such as creating an artificial beach, could be used for other alternatives. The project EIS should, at least, develop the abandonment/relocation option to the same level of spending proposed for the sand mining, sand transport, and beach disposal associated with construction of the artificial beach-dune system. If funds can be spent on creating an artificial beach, they can also be spent on programs for relocating houses, retrofitting structures, or purchasing endangered structures.

The Corps should recognize that "economic feasibility" is not the same as "funding feasibility." These are two entirely different aspects of project planning. If there is knowledge that federal and local funds would only be provided for a single alternative (funding feasibility), this fact must not play a role in the development and evaluation of alternatives. While economic feasibility can play a role in deciding whether an alternative is reasonable, funding feasibility must not. Discussions of alternative development and evaluation are intended to present data to funding sources that could alter any predetermined spending plans. However, certain knowledge that only a single alternative would be funded can be used in the section discussing the selection of the preferred alternative.

In the past, some alternatives have been quickly dismissed because they are beyond the duties of the agency drafting the NEPA document. The agency may note that a given alternative has possibilities, but the action would need to be developed and implemented by other governmental entities. The action is then quickly dropped from any further discussion. The designation of the Corps, primarily involved in the design and construction of civil works projects, as the lead agency in the planning process may create the appearance that the need to reduce storm damage is most likely to be addressed by the construction of an artificial beach-dune system. However, the Service recommends that the Corps undertake this planning process as a problem solving effort rather than a prelude to a civil works construction project. Title 40 Code of Federal Regulations (40 CFR), § 1502.14[c] states that a NEPA document must consider ". . . reasonable alternatives not within the jurisdiction of the lead agency." This regulation means that storm damage reduction measures that could be implemented by the Federal Emergency Management Agency (FEMA) are well within the scope of the current planning process.

The Service recommends that the Corps ask the FEMA to serve as a cooperating agency for this storm damage reduction project. The FEMA may have an entirely different approach to storm damage reduction. The FEMA deals with the aftermath of storms and the recovery process. The agency has knowledge of storm damage reduction through its Hazard Mitigation Program and the evaluation of land-use and control measures used to rate communities for the National Flood Insurance Program. The cooperation and input from the FEMA, especially in regard to removing structures in high hazard zones, would be a major step in dispelling the idea that the preferred alternative is biased toward the construction of an artificial beach-dune system.

The Service recommends that the NEPA document contain a single section that discusses the alternatives that would address the stated project purpose. This section should be completely free of any evaluation of the alternatives and no alternative should be eliminated for reasons other than failure to address the project purpose. If a given action, other than the required consideration of the no action alternative, would not address the stated project purpose, it should not be introduced. There is no point in discussing an alternative that does not address the project purpose. The Corps planning effort should not introduce an alternative that is clearly inappropriate in order to give the appearance that several options were considered. For example, a project aimed at preventing wind and rain damage from hurricanes in categories 1-5 over the entire Brunswick County shoreline would not need to consider the construction of an artificial beach-dune system or the relocation of houses away from the beach. In this case, improved construction standards may be the only reasonable action alternative. Likewise, a single alternative should not be fragmented into several design and construction options that are presented as project alternatives. For example, the Service considers the construction of an artificial beach-dune system as a single alternative. Variations in sand sources and differences in the design of the beach or dune are merely features of a single alternative, and these features should not be presented as project alternatives.

The alternatives section should conclude with a clear list of options for addressing the stated project purpose. If the project purpose is the reduction, rather than elimination, of storm damage, the actual extent of damage reduction should not be an issue in whether a given alternative is practical and feasible. If one alternative reduces storm damage by 10% and another alternative reduces damages by 50%, both alternatives still meet the stated project purpose. The extent to which a given alternative succeeds in reducing storm damage should be considered in the selection of the preferred alternative, but not in the development of alternatives. As noted, the evaluation of alternatives should be separated from their development. It may be that there is only a single action option and the no action alternative.

SECTION 8. SELECTION OF THE PREFERRED ALTERNATIVE

The basic alternative for storm damage reduction and beach erosion control in Brunswick County was established before the passage of NEPA (USACOE 1973, p. 1). In accordance with federal legislation approved on June 15, 1955, the Wilmington Corps District conducted investigations as part of a larger effort directed at hurricane damage on the eastern and southern seaboards. The Corps made recommendations for a "dune and beach restoration fills covering a total coastline reach of 25.2 miles. This recommended plan was authorized by the Flood Control Act approved on November 7, 1966. This authorization was based on information contained in House Document No. 511, entitled "Cape Fear to North Carolina - South Carolina State Line."

As noted in the previous section, several action alternatives were considered by the Corps. The construction of a dike or floodwall to encircle all developed portions of the Brunswick County shoreline was considered. However, the Corps determined that the cost of this structural solution "far exceeded the economic benefits" (USACOE 1973, p. 19). Data from the preauthorization study indicated that current benefits accruing from the provision of total flood protection would still be "incommensurate with the cost required to effect that type of solution." Therefore, the Corps was forced to conclude that protection could only be provided against storm surges from the ocean and no protection would be available for similar surges from the estuaries (USACOE 1973, p. 8).

The Phase 1 GDM rejected the option of constructing a series of offshore breakwaters solely on the basis of cost (USACOE 1973, p. 19). The Corps noted that such breakwaters could partially or completely "shield the shoreline." This alternative was considered during preauthorization studies, but was found to be "too costly." A reevaluation during the preparation of the GDM ". . . again revealed that such an engineering solution would involve prohibitive costs."

The Phase 1 GDM also considered a set of construction alternatives that included seawalls, groins, and sediments fill to restore the beach and dune (USACOE 1973, p. 20-21). Preauthorization studies evaluated these alternatives singularly and in combination. This review led to the conclusion that ". . . the most economical, functional plan would be the authorized project comprised of a beach and dune restoration fill with a program of periodic beach replenishment. . . ." The structural alternative were apparently not rejected on the basis of effectiveness or concerns about environmental impacts, but simply on the basis of costs.

The selection of a preferred alternative may be based on any number of criteria. The major recommendation of the Service is that the decision process be fully explained. The factor or factors that lead to the elimination of a given alternative should be explained in this section. Any economic limitation on the overall storm damage reduction effort may be introduced in the section. If economics is the overriding factor in the selection of the preferred alternative, this fact should be introduced in this section.

The selection among the alternatives discussed in the preceding section may be somewhat confused by the degree to which the purpose of storm damage reduction has been intertwined with the goal of erosion control/beach restoration. Storm damage reduction and beach erosion control seem, at times, to be two entirely different problems. However, the impact of beach erosion is clearly related to the damage that it may cause to beachfront structures.

In a letter dated August 16, 1999, the Corps informed the Service that the project would, in concept, consist of the construction and maintenance of a berm and dune system that would tie into the existing dune and vegetation line. The Service has no information regarding the selection process of the preferred alternative. In fact, many aspects of the actual project have not been determined.

The Service hopes that the EIS will clearly separate the goals of storm damage reduction from those of erosion control/beach restoration prior to the development of alternatives. This distinction is very important because the options for erosion control/beach restoration have been clearly defined and the creation of artificial beach-dune systems is generally considered the least environmentally damaging. On the other hand, the goal of storm damage reduction can be achieved in many ways, and in this case the creation of an artificial beach-dune system has the greatest potential for environmental harm (Table 16).

After the development of alternatives, the EIS should clearly indicate the factors leading the selection of the preferred alternative. In general, the major factors, which may overlap to some extent, would be: (1) effectiveness; (2) sustainability; and, (3) the long-term impacts to other coastal features.

The issue of effectiveness is critically important. The EIS should clearly describe the level of storm for which protection is sought, types of storm damage for which the project would provide protection, and the geographic extent of this protection. As noted, an artificial beach-dune system would not protect against damage by strong wind, heavy rain, some flooding from the ocean, and all flooding by the storm surge ebb coming from the sound. Furthermore, surges associated with category 4 and 5 hurricanes would be expected to wash over the proposed artificial dune with a height of 13 feet above mean sea level. Hurricane Fran, a category 3 storm, produced a storm surge of 12-14 feet on Topsail Island in 1996 (Pilkey et al 1998, p. 29). The storm destroyed dunes, cut swash channels, and undercut buildings. The wind damage of Hurricane Fran was extensive. The benefits of the proposed artificial beach-dune system would be generally limited to the weakest hurricanes. Conversely, alternatives which seek to remove structures from high risk zones can be completely effective for the storms used in the program's design.

The second factor in the selection process should address the issue of sustainability. This relates directly to the interrelated factors of durability and the periodic requirement for additional expenditures. While sustainability applies to all alternatives, this consideration is especially critical to the alternative for creating an artificial beach-dune system. The artificial beach-dune system would be under constant attack by both fair- and foul-weather waves of a rising sea. It

would be dependent on funds to move a finite amount of offshore sand to the shore. Artificial beaches have a record of not lasting as long as original predictions. The Corps' predictions of sand requirements for renourishment at Wrightsville Beach, North Carolina, have been consistently exceeded (Figure 19). In some of the most extreme cases, expensively replenished beaches have vanished within months in a single, fierce storm. In 1982 a five million dollar beach at Ocean City, New Jersey, disappeared in two and a half months (Pilkey and Dixon 1996, p. 86).

Third, the environmental impacts of each alternative should be considered in the selection of the preferred option. One alternative should have been identified as the least environmentally damaging option earlier in the EIS. This would be the alternative that produced the least overall environmental impacts on the natural environment of the project area. This consideration should fully account for the cumulative impacts which similar sand placements (both formal nourishment projects and beach disposal operations) are creating along the southern North Carolina coast. The NEPA process does not require that the least environmentally damaging alternative be selected. If this alternative is not the preferred alternative, the EIS should outline the factors that lead to the rejection of this alternative.

Overall, the Service requests that planning for storm damage reduction in Brunswick County have the maximum "transparency" leading up to the selection of a preferred alternative. That is, the EIS should present a clear, logical path from the project need to the selection of the preferred alternative. This transparency may require the separation of certain considerations that have been combined in the past. The Service recommends that the Corps' planning follow the broad outline given above. In brief, this process would include:

1. A statement of need, or a problem to be addressed, that is phrased in a manner that does not favor or eliminate any broad type of action;

2. A statement of purpose that would state the level of storm, the type(s) of storm damage, and the portion of the project area for which protection is sought;

3. A section on the development of a range of reasonable alternatives that meet the project purpose, but is free from concurrent evaluation and exclusion of any reasonable alternative;

4. A section that evaluates each alternative for costs and impacts on the human and natural environment, but only compares the alternatives; and,

5. A distinct section that identifies a preferred alternative and the factors that led to its selection

Such a selection process will convey substantial credibility to the alternative selected.

SECTION 9. DESCRIPTION OF THE PREFERRED ALTERNATIVE

The Phase I GDM for Yaupon and Long Beaches called for a continuous dune and beach restoration fill extending a distance of 47,600 linear feet (9.0 miles) along the oceanfront from the west end of Long Beach to and including Yaupon Beach (USACOE 1973, p. 59). The restoration fill would have a vegetated dune with a crest elevation of 25 feet at an elevation of 15 feet above mean sea level. The dune portion of the fill would be fronted by a storm berm having a width of 50 feet at an elevation of 12 feet above mean sea level. The berm would have a gently sloping beach which closed with the existing nearshore bottom at depths varying from 27 to 29 feet below mean sea level. The project fill would advance the shoreline to a position approximately 125 feet seaward of its original location following sorting action.

In planning for the GRR, the Corps has provided the Service with a general overview of the project. Some important aspects of the project have not been established.

The eastern part would extend approximately 62,200 linear feet (11.78 miles) from Fort Caswell near the mouth of the Cape Fear River westward to Lockwoods Folly Inlet (Figure 1). On Holden Beach, west of the inlet, the project would extend 37,600 feet (7.12 miles) from the inlet westward to the end of the public road. Overall, the total project limits would cover 99,800 feet (18.9 miles).

The work proposed along the beach would involve the construction and maintenance of a berm and dune system that will tie into the existing dune and vegetation line. The constructed dunes would be vegetated with American beachgrass and sea oats. The initial construction would include the main project, transition fillets, and enough advance placement fill to maintain project dimensions until the first maintenance event (beach renourishment). The exact amount of required fill has not been determined and will not be known until project dimensions are finalized. The Corps estimates that the frequency of maintenance (beach renourishment) will be every three years. Initial construction is currently scheduled for FY 2004 for Oak Island/Caswell Beach, east of Lockwoods Folly Inlet, and FY 2005 for the section on Holden Beach.

Four borrow sources were evaluated initially. For the Oak Island/Caswell Beach reaches: Jaybird Shoals, Yellow Banks (an upland site), Eastern Channel (near Lockwoods Folly Inlet), and Lockwoods Folly Inlet. Jaybird Shoals is just west of the mouth of the Cape Fear River and south of Caswell Beach (Figure 1). The area of Eastern Channel and Lockwoods Folly Inlet are shown in Figure 10. The Yellow Banks is an active confined disposal site immediately north of the Atlantic Intracoastal Waterway and north of the Town of Oak Island. An offshore additional site along with the four sites mentioned above is under consideration for the Holden Beach section. In late July 2000 the Corps added a fifth potential borrow area, Frying Pan Shoals, directly south of Cape Fear (Figure 1). Vibracore sampling indicates that the material is suitable for beach placement. Samples from this area also indicate material suitable for beach placement. Eastern Channel is located directly behind the west end of Oak Island and is connected to Lockwoods Folly Inlet. No sediment samples have been taken from Eastern Channel. If this area is selected as a borrow source alternative, further investigation and borings will be performed. Vibracore borings have shown that sediment in Lockwoods Folly Inlet and its bar are excellent for beach placement. The offshore borrow sources under investigation include the shoreface seaward to the state's three-mile jurisdictional limit between Lockwoods Folly Inlet and the western limits of Jaybird Shoals.

SECTION 10. IMPACTS OF THE PREFERRED ALTERNATIVE

As noted earlier, several critical design and construction aspects for this project have not been established. These features, such as the time of year for dredging/beach placement and the extent of dune construction, will profoundly affect the types and magnitude of project impacts. However, based on all available information from the Corps, project impacts will be described and evaluated. Two broad categories of project impacts will be considered: direct and indirect, or secondary, impacts. Finally, the long-term ramifications of initiating an artificial beach-dune system on a barrier island will be considered.

Direct Project Impacts

Direct impacts refer to those consequences of a given action which occur at generally the same time as the action and in the immediate vicinity of the action. Direct impacts are generally easier to observe and quantify, but they are not necessarily the most serious and long-lasting impacts. In fact, even dramatic, direct impacts to organisms and habitats may soon dissipate and resilient ecosystems can return to pre-project levels in relatively short spans of time.

Dredging will kill the plants and animals within the sand removed from borrow sites. The NRC report states (1995, p. 118) that "The primary biological effect of dredging borrow sites is the removal of benthic assemblages inhabiting the surficial substrate."

The preferred alternative would increase turbidity during the dredging of sand at the offshore borrow sites. Silt and clay particles within the borrow material would become suspended by the dredge. The increased turbidity would be harmful to planktonic invertebrates, fish, and marine mammals. The suspended sediment would reduce light penetration beyond the actual area dredged and reduce primary production.

Hardbottom areas indicated by SEAMAP (1998), Riggs et al. (1996, 1998), Cleary (1999, 2000a, 2000b), and McLeod et al. (2000) could be destroyed by sedimentation associated with dredge and fill activities. It is difficult to forecast the exact magnitude and areal extent of sedimentation produced by dredging. However, sediment with certain characteristics, e.g., high silt and clay content and currents, could cover hardbottom areas many miles from the dredging site with a damaging layer of sediment.

The mining of offshore sand in areas used for wintering by commercially important fish could adversely affect these species. The project could jeopardize the spawning stock biomass of inter-jurisdictional species which provide recruits for much of the mid-Atlantic coast. Fish in the area would be disturbed by the turbidity caused by initial construction and periodic dredging for replacement of sand. Dredging may remove habitat used by these species, such as hardbottoms or underwater sand berms or mounds that provide shelter. Dredging would destroy benthic prey organisms and could cause mobile prey species to move out of the work area.

Burial of nearby hardbottoms by dredge and fill activities has been shown to reduce the abundance of fish species and individuals in Florida (Lindeman and Snyder 1999). Lindeman and Snyder (1999) state that "Because of behavioral and morphological constraints on flight responses, high mortalities are probably unavoidable for many cryptic [fish] species, newly settled life stages, or other site-associated taxa subjected to direct habitat burial" (p. 520). Nearshore, shallow hardbottoms were found to carry a large number of newly settled stages, and therefore Lindeman and Snyder (1999) conclude that burial as a result of dredge and fill activities may have amplified impacts if conducted just prior to peak larval recruitment, which is in spring and summer in their study area. Thus we are concerned that the timing of open ocean mining and placement of sediments from this project may be a critical factor in the magnitude and frequency of impacts to adjacent hardbottoms.

A completely separate occurrence of turbidity would result from the placement of the sediment on the shoreline. While dredging turbidity may be high, it is generally a short-term phenomenon. However, turbidity resulting from fine material in the beach may occur for a long time after the sand has been deposited.

In 1994 offshore vibracore samples were taken 1-3 miles off the shoreline of Ocean Isle Beach, immediately west of the present project area (USACOE 1997a, p. A-14; pp. B11/12). The area investigated was selected to be near enough to the project site for dredging to be practical, but distant enough so that removal of material would not affect beach sediment transport processes. Most of the material in the early samples was silty sand, clayey sand, or sandy clay. The Corps determined that all this material would be environmentally unsuitable for use as beach fill because of high turbidities following placement of silty or clayey materials (USACOE 1997a, p. B-11). This work determined that ". . . suitable borrow material seemed to occur only in erratic pockets, and the search for offshore borrow areas was abandoned without success."

Turbidity may be measured in terms of nephelometric turbidity units (NTU). The State of Florida restricts the level of turbidity that can occur outside a predetermined mixing zone to 29 NTUs above corresponding background samples (NRC 1995, p. 114). A beach nourishment study by Saloman and Naughton (1984) revealed that turbidity was relatively low during nourishment with the exception of points where material with a high organic content was dredged and deposited on the beach. At one site where the dredge encountered mud, turbidities were as high as approximately 172 NTUs. At another site, where deposited material was nearly all clean sand, the turbidities immediately after dumping ranged from 2.6 to 15.4 NTUs. During a Hilton Head, South Carolina, beach nourishment project, limited surveys near the outfall pipe found turbidity levels of 50 to 150 NTUs above background levels in areas extending approximately 656 feet (200 meters) from the outfall (Van Dolah et al. 1992).

State water quality regulations require that in waters classified as SC (Saltwater, Class C), turbidity due to discharge must not exceed 25 NTUs (North Carolina Department of Environment Health, and Natural Resources 1991). Beach disposal of dredged material at Atlantic Beach, North Carolina, resulted in turbidities as high as 250 NTUs in the vicinity of the discharge pipe, but rapidly decreased with distance from the discharge pipe (USACOE, 1990). Reilly and Bellis (1978) found that after beach nourishment, the total suspended solids load in the nearshore waters adjacent to the beach nourishment project was much higher than the load of "normal sea water."

Fish and invertebrates may smother when gills are clogged due to high levels of suspended solids. Reduced light penetration decreases primary productivity. Planktonic larvae of both vertebrates and invertebrates found in the surf zone may be adversely affected by high turbidity levels (NRC 1995, p. 114). Van Dolah et al. (1992) found that macrofaunal communities in the lower intertidal zone and subtidal areas of the beach declined after nourishment. However, recovery was rapid and this was attributed to the similarity of beach fill material to the natural sediments and to the placement of fill material high on the beach.

Placement of sediment on the beach will kill the existing infauna through suffocation or loss of access to food. The burial of organisms, such as coquina clams, mole crabs, amphipods, polychaetes and other invertebrates in both the surf zone and beach will usually result in temporary elimination of these organisms with the exception of highly mobile species or species able to withstand prolonged periods of burial.

Reilly and Bellis (1978) studied the effects of depositing 1.2 million cubic yards of sand on the beach at Bogue Banks North Carolina. Sediments were deposited at a depth of 6.6 feet (2 meters) and as a result of nourishment, the intertidal zone was moved 250 feet (75 meters) seaward in one day. Nourishment occurred between December 1977 and June 1978. The researchers sampled the intertidal organisms before and after sand placement at the nourished beach and at a nearby control beach. On the nourished beach they found complete mortality of mole crabs and coquina clams after sediment placement.

Dr. William Cleary of the University of North Carolina at Wilmington has studied the movement of sand off recently renourished beaches in New Hanover County, Wrightsville Beach and Carolina Beach. He found that there are many more hardbottom areas in the nearshore zone within 1 or 2 miles of shore than was previously thought and the distribution of rock is very patchy. Cleary (1999) found the hardbottom rock outcrops offshore Oak Island to be covered by less than an inch to perhaps six feet of sediment.

“The availability of specific hardbottoms for development of a benthic community, as well as the structure of that community, are greatly influenced by specific habitat controls including composition, geometry, and morphology of the hardbottom and the distribution and thickness of the Holocene surface sand sheet” (Riggs et al. 1996, p. 844). “[s]urficial sediment patterns...control the composition and spatial distribution of benthic communities” (Riggs et al. 1998). Thus any project that could remove or add to the surface sediments via dredging and filling will influence the availability of the hardbottom habitats, their benthic communities and the structure of those communities.

The Service is concerned that the perpetual beach fill maintenance, particularly when combined with beach disposal of dredged sediments from the Wilmington Harbor deepening project, may have cumulative impacts to the hardbottom ecosystem as millions of cubic yards of sediment are introduced to the nearshore system on a regular basis either from turbidity and siltation or from potentially increased erosion rates on adjacent beaches.

Rakocinski et al. (1996) found that macrobenthic assemblages in nearshore, sandy-beach environments are less resilient to the impacts of beach construction projects than more diverse offshore assemblages. These nearshore assemblages respond to such projects with "decreased species richness and total density, enhanced fluctuations in those indices, variation in abundances of key indicator taxa, and shifts in macrobenthic assemblage structure" (Rakocinski et al. 1996, p. 326).

Other studies have documented only limited or short-term alterations in abundance, diversity, and species composition of nearshore infaunal communities sampled off new beaches (NRC 1995, p. 115). However, several of these studies had inadequate sampling designs that may have precluded detection of significant alterations in the populations or community parameters measured (Nelson 1991, 1993). The NRC (1995, p. 115) concluded that " . . . efforts should be directed toward obtaining a better understanding of functional changes in the trophic contribution of benthic assemblages to the fish and crustaceans species that rely on the benthos as a major food resource."

Sediment placement during the sea turtle nesting and hatching season, May 1 through November 15, can lower reproductive success. Creation of the artificial beach-dune system during this season could result in the loss of sea turtles through disruption of adult nesting activity and by burial or crushing of nests or hatchlings. While a nest monitoring and egg relocation program would reduce these impacts, nests may be inadvertently missed or misidentified as false crawls during daily patrols. In addition, nests may be destroyed by operations at night prior to beach patrols being performed. Even under the best of conditions, about seven percent of the nests can be misidentified as false crawls by experienced sea turtle nest surveyors (Schroeder 1994).

Besides the potential for missing nests during a nest relocation program, there is a potential for eggs to be damaged by their movement or for unknown biological mechanisms to be affected. Nest relocation can have adverse impacts on incubation temperature (and hence sex ratios), gas exchange parameters, hydric environment of nests, hatching success, and hatchling emergence (Limpus et al. 1979, Ackerman 1980, Parmenter 1980, Spotila et al. 1983, McGehee 1990). Relocating nests into sands deficient in oxygen or moisture can result in mortality, morbidity, and reduced behavioral competence of hatchlings. Water availability is known to influence the incubation environment of the embryos and hatchlings of turtles with flexible-shelled eggs, which has been shown to affect nitrogen excretion (Packard et al. 1984), mobilization of calcium (Packard and Packard 1986), mobilization of yolk nutrients (Packard et al. 1985), hatchling size (Packard et al. 1981, McGehee 1990), energy reserves in the yolk at hatching (Packard et al. 1988), and locomotory ability of hatchlings (Miller et al. 1987).

Comparisons of hatching success between relocated and *in situ* nests have noted significant variation ranging from a 21 percent decrease to a 9 percent increase for relocated nests (Florida Department of Environmental Protection, unpubl. data). Comparisons of emergence success, moving up out of the nest onto the beach, between relocated and *in situ* nests have also noted significant variation ranging from a 23 percent decrease to a 5 percent increase for relocated nests (Florida Department of Environmental Protection, unpubl. data). A 1994 Florida Department of Environmental Protection study of hatching and emergence success of *in situ* and relocated nests at seven sites in Florida found that hatching success was lower for relocated nests in five of seven cases with an average decrease for all seven sites of 5.01 percent (range = 7.19 percent increase to 16.31 percent decrease). Emergence success was lower for relocated nests in all seven cases by an average of 11.67 percent (range = 3.6 to 23.36 percent) (A. Meylan, Florida Department of Environmental Protection, in litt., April 5, 1995).

A final concern about nest relocation is that it may concentrate eggs in an area resulting in a greater susceptibility to catastrophic events. Hatchlings released from concentrated areas also may be subject to greater predation rates from both land and marine predators, because the predators learn where to concentrate their efforts.

The placement of pipelines and the use of heavy machinery on the beach during a construction project may have adverse effects on sea turtles. This equipment can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls and unnecessary energy expenditure. Human and macroinvertebrate traffic (e.g., ghost crabs) can also be impeded by this heavy equipment.

Another impact to sea turtles is disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchlings from artificial lighting. Visual cues are the primary sea-finding mechanism for hatchlings (Mrosovsky and Carr 1967, Mrosovsky and Shettleworth 1968, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting is a well documented cause of hatchling disorientation and misorientation on nesting beaches (Philbosian 1976; Mann 1977; Florida Department of Environmental Protection, unpubl. data). In addition, research has also documented significant reduction in sea turtle nesting activity on beaches illuminated with artificial lights (Witherington 1992). Therefore, construction lights along a project beach and on the dredging vessel may deter females from coming ashore to nest, disorient females trying to return to the surf after a nesting event, and disorient and misorient emergent hatchlings from adjacent non-project beaches. Any source of bright lighting can profoundly affect the orientation of hatchlings, both during the crawl from the beach to the ocean and once they begin swimming offshore. Hatchlings attracted to light sources on dredging barges may not only suffer from interference in migration, but may also experience higher probabilities of predation to predatory fishes that are also attracted to the barge lights. This impact could be reduced by using the minimum amount of light necessary (may require shielding) or low pressure sodium lighting during project construction.

Depending on the time of year for sediment placement, work on the beach would disrupt feeding and roosting by shorebirds, including the piping plover. The elimination of beach infauna would remove a food source in the project area.

Marine mammals are highly mobile and range widely along the Atlantic coast. While dredging and beach disposal may be disruptive to normal travel routes and foraging patterns, these animals are likely to move to less disturbed areas. However, the dredging vessels must avoid hitting marine mammals and special observers may be necessary to watch for marine mammals.

Indirect Project Impacts

Removal of sand from the offshore borrow areas may permanently alter the physical characteristics of the areas and impact the benthic flora and fauna adapted to existing conditions. The long-term physical alterations produced by sand removal from marine habitats have not been well documented (NRC 1995, p. 118). The majority of follow up studies from offshore borrow sites have shown decreases in the mean grain size, including, in some cases, increases in the percentage of silts and clays in the borrow site (NRC 1995, p. 118). Offshore holes may fill with finer grain material (NRC 1995, p. 118). The finer material or other significant alterations in the physical characteristics of the substrate may not be suitable for the organisms that formerly occupied bottom sediment of the borrow area.

The recovery period for benthic communities that are lost to dredging is quite variable, ranging from a few months to several years (NRC 1995, p. 120). While the abundance and diversity of benthic fauna may return to pre-dredging values, several studies have documented changes in the species composition of the benthos that lasted more than a year, particularly in areas where bottom sediment composition was altered (Johnson and Nelson 1985, Bowen and Marsh 1988, Van Dolah et al. 1992, 1993, Wilber and Stern 1992). Benthic organisms inhabiting the potential offshore borrow areas serve as food for commercially important species and are essential in marine food chains (Figure 11). For example, adult spot are benthic feeders, primarily eating polychaetes and benthic copepods. Atlantic croaker are also bottom feeders, preying on polychaetes and bivalves. Pink and white penaeid shrimp also prefer benthos.

The cumulative effects of the project on offshore fisheries may be the transformation of formerly preferred habitat into unsuitable or unusable habitat. This change could occur as a result of altered substrate characteristics, depth, or other physical parameters. In addition to harming commercial and recreational fishermen, the loss or degradation of this important fish habitat would adversely impact marine birds, such as the northern gannet and eastern brown pelican, and marine mammals, such as the humpback whale.

In addition to changes in species composition and abundance, the removal of offshore sand may also reduce primary productivity. Reduced primary productivity could result from the greater depth in the borrow areas after sand removal. The greater depth would reduce solar energy reaching the new bottom. Furthermore, even minor sedimentation reaching distant hardbottom areas would reduce productivity.

There may be a deterioration of nearshore habitat quality due to long-term turbidity from the artificial beach-dune system. Bush et al. (1996, p. 83) state that “Streams of turbid water from the surf zone of Miami Beach are still responsible for killing coral heads 14 years after the beach was emplaced.” Goldberg (1985) gives an example of a Florida nourishment project which resulted in damage to a nearby rocky environment 50 to 60 meters offshore. Material placed on the beach during a nourishment project quickly eroded off the beach and covered nearshore rocks. Seven years after the project, the rocks were still covered in fine sand and silt, and turbidity of the nearshore area remained high. Hurme and Pullen (1988) conclude that increased turbidity levels from winnowing of fine sediments in the fill can extend from a few months to seven years.

The sedimentation resulting from finer grain material washing off the artificial beach-dune system is similar to, but distinct from, that produced by dredging. Nearshore reef habitats that lie within the nearshore littoral zone may be destroyed by sand burial resulting from the redistribution of beach fill material (NRC 1995, p. 113-114). Studies have indicated that sand placed on Wrightsville Beach has washed off the beach and buried extensive hardbottoms on the inner continental shelf (Riggs, 1994, p. 17). These hardbottoms were prime fishing locations, but are now out of production due to a covering of two to six inches of sand. Riggs (1994, p. 17) concludes that “The business of beach nourishment and hardbottoms represents a very serious conflict, and a problem that’s going to get much bigger.”

The Corps noted (USACOE 1973, p. H-15) that the use of areas off the beaches (potential borrow area D) would produce high turbidity because of the silt and clay content of bottom sediment. Short-term effects associated with actual dredging operations would probably include destruction of shrimp producing areas. The effects of high turbidity levels on migrating organisms is unknown, but is potentially adverse. The placement of this fine grained material on the beaches would produce an extensive suspended sediment plume in the nearshore waters. Data at the time indicated that material at this area contained 31 to 81 percent silt and clay particles that would remain in suspension for long periods of time. The Corps also noted (USACOE 1973, p. H-15) that it was possible that the highly turbid water would enter Lockwoods Folly Inlet during flood tides and create “injurious effects” on oyster-producing areas.

When a beach is nourished, large volumes of sand are placed within the supralittoral and intertidal zones. Beach invertebrate populations are eliminated or greatly reduced. As noted, the direct, adverse impacts may be dramatic, but longer-term, indirect impacts related to altered beach characteristics and recruitment of a recovery population may have the greater impact on fish and wildlife resources that depend on beach invertebrates as a food source. Sand placement disturbs the indigenous biota inhabiting the subaerial habitats, which in turn affects the foraging patterns of the species that feed on those organisms (NRC 1995, p. 108). Dean (1999, p. 118-119) describes the artificial beach in Miami, Florida, as a quiet area without natural life.

Peterson et al. (2000) documented invertebrate populations following dredge spoil disposal from Bogue Sound placed on the beaches of Bogue Banks to be reduced by 86-99% (compared to control beaches) 5 to 10 weeks following fill placement. The authors conclude that "Failure of *Emerita* and *Donax* to recover from nourishment by mid summer when they serve as a primary prey base for important surf fishes, ghost crabs, and some shorebirds may be a consequence of the poor match in grain size and high shell content of source sediments and/or extension of the project too far into the warm season" (Peterson et al. 2000, p. 2).

Donoghue (1999) found the timing of beach fill placement, the time interval between fill placement episodes, the size and type of fill, and the compatibility of the fill material to the native sediments to be critical to the short- and long-term impacts to beach invertebrate populations. Fill placement during the invertebrate reproduction or recruitment periods in early spring and early fall depressed the populations of mole crabs and coquina clams for several months to years; ghost crab populations were similarly decreased as a result of fill placement on the beaches at Pea Island. The alterations to the geomorphology and sediment characteristics of the study beaches appear to be more controlling factors on invertebrate recovery periods than direct burial or mortality.

While species which move on and off the beaches during their life cycle may recolonize the new beach in time, species spending their entire life cycles in the intertidal regions of the beach may be more severely impacted by massive sand placement (Hurme and Pullen 1988). *Haustorius* sp., an amphipod found on many beaches, recovered very slowly after beach nourishment on Bogue Banks (Reilly and Bellis 1978). After nourishment, no amphipods were found on the beach until late summer and recovery then was probably due to recruitment from nearby areas.

Reilly and Bellis (1978) indicated that numbers of migrating, invertebrate consumers such as the speckled crab (*Arenaeus cribarius*), lady crab (*Ovalipes ocellatus*), ghost crab (*Ocypode quadrata*) and blue crab (*Callinectes sapidus*) were drastically reduced after nourishment activities. This may be attributable to greater turbidity causing resident populations to move elsewhere, a change in beach slope and offshore bars making approach to the beach difficult, or more likely a reduction in the abundance of prey. Vertebrate consumers, such as fish and shorebirds, may also be adversely affected by a reduction in prey species.

Coquina clams have been found to be "substrate sensitive" in their grain size preferences (Alexander et al. 1993). If the fill material significantly deviates from the native grain sizes, the ability of *Donax* spp. to burrow can be dramatically impaired. Bowman and Dolan (1985) found that mole crabs increase in abundance in specific grain sizes as well. Recent research at the University of North Carolina, Chapel Hill, Institute of Marine Sciences has found that both mole crabs and clams in small, medium and large size classes have a decreased ability to burrow in sediment with a high shell content (Lisa Manning, pers. comm., August 11, 2000). An impaired ability to burrow quickly will increase the invertebrates being washed out of their habitat and their susceptibility to predation.

Sand flowing onto the lower portion of the beach during the nourishment operation can increase the beach height in the intertidal zone from several centimeters to more than a meter (NRC 1995, p. 109). This significant change in the character of the intertidal zone can affect habitat suitability and feeding by beach invertebrates beyond the immediate impact of sediment placement.

Donoghue (1999) and Bowman and Dolan (1985) found that these dominant invertebrate species are also influenced by hydrodynamic parameters. Abundances of coquina clams, for instance, are concentrated on the downdrift sides of beach cusps, and there is evidence that these clams surf from one beach cusp to another on the wave swash (Donoghue 1999). The abundance of these patches of clams decreases with smaller cusps and changes in the hydrodynamic conditions. The ability to maintain burrows and optimize filter feeding appears to be directly related to both grain size and hydrologic parameters, both of which can be drastically altered by an artificial beach fill project. Thus we are concerned about the impacts of the beach disposal of dredged sediments, both in the short-term and long-term, to the beach invertebrate populations. These populations are a key facet of the coastal food web, and therefore decreased species abundances would reduce the prey base for shorebirds, surf fishes and beach macrofauna. Perpetual beach fill placement over a 50 year lifespan has the potential cumulative impact of permanently depressing beach invertebrate populations, especially at those areas that will already be receiving dredge disposal material from the Wilmington Harbor deepening project.

Bottom habitats in the nearshore surf zone often support a diverse array of biota that are directly or indirectly affected by beach nourishment operations (NRC 1995, p. 112-113). This community may be affected by burial of the bottom habitats, increased sedimentation, changes in nearshore bathymetry and associated wave action, and elevated turbidity.

Reilly and Bellis (1978) state that species of beach infauna recruited from pelagic larval stocks, such as mole crabs and coquina clams, will recover if nourishment activity ends before larval recruitment begins in the spring. In the spring, recruitment begins with juveniles and adults approaching the beach. In the Bogue Banks project, nourishment extended from December until June, a time that included the March recruitment period of coquina clams. No increase in coquina clams occurred until July 29, approximately two months after cessation of nourishment, and populations failed to reach pre-nourishment numbers found during the winter. At the control site, coquina clams also decreased during the winter as they moved offshore. However, during March, numbers at the control site increased to high levels. This study indicated that adult coquina clams were probably killed in their offshore wintering environment, and beach nourishment effects, most likely high turbidity, prevented normal pelagic larvae recruitment. The individuals that eventually arrived were post metamorphic adults likely to have diffused from area beaches via littoral drift.

Reilly and Bellis (1978) found the complete absence of mole crabs within one week of the beginning of the nourishment project at Bogue Banks. Numbers were also reduced at the control site as adults moved offshore to spend the winter. Overwintering adult mole crabs returned to the control site in April, and the young of the year from pelagic larval stocks returned later in the spring. The return of mole crabs at Bogue Banks lagged one month behind that at the control site and then only young of the year mole crabs appeared at the nourished beach. The lack of adults at the nourished beach resulted in drastic reduction in overall biomass of mole crabs.

Goldberg (1985) (as reported in Goldberg (1988)) found that one year after a nourishment project in Broward County, Florida, was completed, infauna just offshore was regaining taxonomic diversity, but abundance was still as low as 62 percent below pre-nourishment numbers. Saloman and Naughton (1984) looked at the effects of a nourishment project at Panama City Beach, Florida. They found significant decreases in species abundance and diversity of organisms in the swash zone during a 5 to 6 week period after nourishment. On the other hand, Gorzelaney (1983) (as reported by Stauble and Nelson (1985)) examined the biological impacts of nourishment project on Indialantic and Melbourne Beach, Florida. Nourishment occurred between mid-October and January, and the researcher found no negative long term effects to nearshore fauna.

Each episode of dredging and sand placement over the 50 years of project life would create all the direct impacts considered above. Therefore, the Service is concerned about the renourishment frequency which will depend of the life of each placement. Any indirect impacts which reduce the life of the artificial beach-dune system and increase the renourishment frequency will adversely affect fish and wildlife resources.

There are also indirect effects resulting from the lack of internal structure in an artificially constructed beach as opposed to a natural beach. The fill material may vary significantly in its mineralogical composition, organic content, grain size distribution and sedimentary characteristics. Over the lifespan of the project, with the continual maintenance of this artificial beach, there will be a semi-permanent to permanent change in the beach, which supports an entire ecosystem.

The indirect impacts considered here relate to changes that would be produced by removing sand from offshore borrow areas. Offshore sand resources serve to protect existing development, and their removal may offer short-term protection in exchange for greater long-term damage. Offshore dredging may remove offshore sand bars and shoals that provide important protection to the beaches. Offshore holes produced by dredging may either increase wave energy or change refraction patterns, or both (Kaufman and Pilkey 1983. p. 215). Wave energy and the stability of the beach may also be affected if the borrow site lies within the nearshore littoral zone (NRC 1995, p. 118).

Targeting inlet areas as borrow sources poses additional indirect impacts. Removal of substantial amounts of material from the tidal deltas at Lockwood's Folly Inlet or the Cape Fear River mouth may increase the fluctuation of adjacent shoreline erosion rates. The borrow pits may serve as a sediment sink and divert more sediment from the longshore transport system than background levels. The barrier spit habitats adjacent to tidal inlets in the project area are important habitats for fish and wildlife resources, which rely on the dynamic and ephemeral nature of inlets. Wave and current patterns and energies may be significantly altered, which may disrupt the natural cycle of dynamic equilibrium at the inlets.

Davis and Dolan (1993) state that "Because there is a close relationship between water depth and the height of waves in shallow water, any increase in water depth at the coast contributes to conditions that permit higher wave action closer to the shoreline, thus increasing the potential for damage." Kaufman and Pilkey (1983, p. 91) also point out that towns on Cape Cod are saved from the twenty-foot breakers of the North Atlantic by the annual formation of a large offshore bar made of sand eroded from the Cape. Offshore bars, small ridges of sand parallel to the shore, occur periodically offshore from most beaches. These bars dissipate the energy of breaking waves. The shallow water atop these offshore bars virtually trips incoming waves, forcing them to break (Pilkey and Dixon, 1996, p. 28).

Changes in offshore topography may alter the pattern of wave energy striking the beach through changes in wave refraction. Wave refraction is a physical phenomenon in which a part of a wave slows down while other parts continue to move at a different speed. The different speeds result in the bending of the wave, and the effect of wave refraction is to unevenly distribute wave energy along the shoreline (Thurman 1994, p. 236). Kaufman and Pilkey (1983, p. 85) also note that if one part of a wave touches bottom first, friction causes that part of the wave to slow down. Different velocities in different parts of the wave will cause a bending, or refraction, in the wave crest. In regard to the life of an artificial beach, the point is that variations in bottom contours may weaken or intensify wave energy. Greater wave energy striking the shore carries the beach away faster.

Problems associated with waves striking the beach at different angles are closely related to the issue of greater wave energy striking the beach. Variations in the direction of wave attack are related to the physical phenomenon of wave diffraction. Wave diffraction can be considered the bending of waves around objects (Thurman 1994, p. 236). Diffraction occurs when wave energy is bent by passing an obstacle; it is not related to refraction. Diffraction results because any point on a wave can be a source from which energy can propagate in all directions.

The proposed, artificial beach-dune system will represent the introduction of a large mass of material into a very dynamic shoreline. Waves from many directions are constantly hitting the shoreline. The introduced material would alter the waves approaching the shore and, to some extent, serve to redirect wave energy. The continuing, serious erosion problems at Wrightsville Beach, North Carolina, is associated with a seaward bulge in the shoreline (NRC 1995, p. 29). The bulge was created in 1966 when Moore Inlet was closed and filled by the Corps as part of a hurricane and shore protection project. The anomalous shape of Wrightsville Beach results in wave energy being concentrated along the bulge and wave breaker angles on the bulge transition that vary from normal breaker angles. These conditions alter the normal rates of sediment transport and cause increases in sediment transport away from the bulge in both the north and south directions.

While offshore sand sources offer environmental advantages over borrow areas in estuarine areas, dredging near the shore or within inlets creates holes that may alter wave patterns on the adjacent shoreline. Altered wave patterns influence the location and extent of erosion for decades after initial sand placement. Pilkey et al. (1980. p. 40) write that:

> ". . . Dr. Victor Goldsmith of the Virginia Institute of Marine Science warns that when a hole is dug on the shelf for replenishment sand, wave patterns on the adjacent shoreline will likely be affected. Off the Connecticut coast, wave patterns changed by a dredged hole on the shelf quickly caused the replenished beach to disappear."

The alteration of offshore contours, or bathymetry, has the potential to shift wave patterns and may even focus waves to create erosional "hot spots", localized areas of excessive erosion. The USMMS (1999) notes that:

> "Wave energy tends to concentrate behind a shoal because of wave refraction and diffraction. The combination of wave length and shoal geometry controls the response of waves as they interact with a shoal. Shoal responses may also depend on the shoal size and ambient water depth as well as the wave conditions. The MMS-funded Virginia coast study has found that Sandbridge Shoal does have the effect of concentrating wave energy for the waves that come from the north-northeast. . . . When a shoal is flattened (by dredging), the degree of wave energy concentration is likely to be reduced, resulting in greater wave energies hitting the coastal area. This may result in increased coastal erosion or unwanted, detrimental changes in longshore or nearshore current patterns. Significant coastal impacts could also be expected during storm events in that increased wave energies might potentially impact the coastal area."

Jay Bird Shoals, Frying Pan Shoals, and the ebb tidal delta at Lockwood's Folly Inlet all provide functions similar to the Sandbridge Shoal.

While changes produced in the beach slope relate to changes in wave energy, the impacts considered here are separated from the discussion of wave energy changes related to offshore sand removal given earlier. The removal of offshore sand would primarily affect large waves approaching the shoreline. However, a significant change in beach slope may affect smaller waves immediately before they strike the beach. Kaufman and Pilkey et al. (1983, p. 216) state that:

> "The net effect of replenishing only the upper beach is to steepen the beach profile. The beach wants to return to its natural, more normal shape. The steeper profile of replenished beaches is the reason they erode more rapidly relative to a natural beach."

The slope of a nourished beach in the intertidal zone is generally steeper after nourishment until the beach reaches a more stable profile (NRC 1995, p. 108). Beach nourishment on Bogue Bank caused the beach slope in the intertidal zone to increase from three to five percent (Reilly and Bellis 1978).

The steeper slope of the artificial beaches allow waves of greater energy to strike the shoreline. As waves approach the shore and encounter water depths less than one-half a wave length, friction removes energy and the waves slows down (Thurman 1994, p. 235). A gentle offshore slope removes more energy than a steep slope before the wave strikes the beach. At Grand Isle in Louisiana the Corps began pumping sand on the beach in 1976. However, the Corps could not convince homeowners to move their houses back and the new beach had to be placed too far seaward (Kaufman and Pilkey 1983, pp. 99-100). The underwater slope of the new beach was too steep and after three months the new beach had washed away.

Beach fill adds to the coastal sediment budget (Davison et al. 1992). The material considered above strongly suggests that large quantities of sand will be washed out of the beach-dune system. Storms are especially likely to remove large quantities of sand from the artificial beach (Figure 20). While some of it will be washed out to sea, a large quantity of sand will undoubtedly be picked up in the longshore current.

Dean (1999, p. 60-61) describes the movement of nourishment sand away from Hunting Island State Park, South Carolina. After a sand-pumping operation placed sand on the narrowing beaches of the park, the sand washed away and moved southward to the beaches of Fripp Island. In 1968 approximately 650,000 cubic yards of sand were placed on park beaches, but almost all this material was gone within 18 months (Dean 1999, p. 107-108). While this sand movement provided a brief respite for the beaches of Fripp Island, sand washed off any created beach may aggravate navigation through downdrift inlets.

Pilkey and Dixon (1996, p. 92) write that "Based on comparisons before and after replenishment, the erosion rate of replenished beaches appears to be almost always greater than the natural beach's erosion rate. The assumption that pre- and post-replenishment erosion are the same is an important reason predictions of beach replenishment durability are optimistic more often than not." Down current drift of sediment may accelerate the filling of navigation channels in down current areas, which would increase the frequency of dredging required to maintain the channel (NRC 1995, p. 113). The Corps anticipate these greater erosion rates and incorporate them into a project's maintenance needs (USACOE 2000a, 2000b).

Pilkey and Dixon (1996, p. 78) write that beach "replenishment frequently leads to more development in greater density within shorefront communities that are then left with a future of further replenishment or more drastic stabilization measures." Dean (1999, p. 106) also notes that the very existence of a beach nourishment project can encourage more development in coastal areas. In fact, the artificial dunes constructed in the 1930s are primarily responsible for the present state of development on the Outer Banks. Following completion of a beach

nourishment project in Miami during 1982, investment in new and updated facilities substantially increased tourism there (NRC 1995, p. 31). Increased building density immediately adjacent to the beach often resulted as older buildings were replaced by much larger ones that accommodated more beach users. Such development is in itself an incentive to maintain the beach in order to sustain revenues derived from recreational activities and tourism and to protect the investment from erosion and storm damage or loss. Overall, shoreline management creates an upward spiral of initial protective measures resulting in more expensive development which leads to the need for more and larger protective measures.

However, the security offered by an artificial beach-dune system on a barrier island surrounded by a rising sea can only be temporary. Burgess (1994. p. 21) states that "Some contend that these blankets of shuttled sand are giving coastal residents a false sense of security and discouraging responsible building." Leatherman (1988, p. 90) also writes that: "Although man-made dunes can halt barrier migration in the short-term, barrier dunes will eventually be breached by overwashes and inlets during severe storms along an eroding shoreline. Dunes, therefore, have no long-term adverse effects on barrier island dynamics. Stabilized dunes have, however, encouraged development in highly hazardous areas by offering **a false sense of security** to backbarrier environment." [emphasis added]

In some respects, an artificial beach-dune system may be considered a seawall made from smaller particles, sand grains instead of giant boulders. Kaufman and Pilkey (1983, p. 213-214) state that:

> Dr.. Robert Dolan . . . finds [on the Outer Banks] that the dunes have acted much like a seawall. Because they are too high to permit overtopping and too continuous to allow inlets and breakthroughs, except under extreme conditions, the ocean's energy has been concentrated on the beaches . . . The beaches have narrowed and the offshore profile is growing steeper, creating stronger waves. . . . Waves strike this steep face with greater impact than a gentle slope, and storm erosion is fast and spectacular. **The protection the dunes first offered seems to have lasted just long enough to attract enough development behind them for a major disaster.**" [emphasis added]

In this regard, it is interesting that seawalls composed of large stones are almost universally considered harmful to the beach. However, an artificial beach-dune system built to almost the same dimensions, but made of sand, is often viewed as a more environmentally sound solution to a receding shoreline.

Impacts to Yellow Banks – Use of the targeted Yellow Banks borrow area will yield different impacts than those borrow areas found under water. This potential borrow area is already disturbed as it is a disposal site for dredging of the Atlantic Intracoastal Waterway. The history of disposal at this site is unknown to the Service at this time, however, so the degree of ecological succession since the last disposal operation is not known. It is likely that the fringes of this disposal area provide wetland habitat, however. The central part of the disposal area probably provides terrestrial benefits to wildlife, including colonial waterbird nesting and loafing habitat, songbirds, and terrestrial mammals. If any dead trees are present, they may provide roosting and nesting habitat for herons and osprey. Removal of substantial volumes of sediment from this area would disrupt the existing ecological functions of the site, and the volume is not likely to be enough for long-term maintenance of the artificial beach-dune system.

Adverse Impact on Freshwater/Groundwater Resources - Additional growth and population increases will put pressure on existing freshwater supplies. Rain is the only source for recharging island groundwater which flows downward and laterally under its own weight. This one-way flow of water prevents salt water from intruding into surface layers where high chlorine concentrations would kill terrestrial plants. Overpumping of groundwater in excess of recharge by precipitation can significantly lower the water table and eventually draw salt water inland. Changes in this groundwater level will be reflected in the extent and health of the freshwater communities. To the extent that new development leads to a lowering of the water table, freshwater wetlands would be adversely affected.

Adverse Effects of Increased Wastewater - Additional development and population growth would also stress existing facilities for wastewater disposal. If adequate efforts are not made in a timely manner, ground water and estuarine water bodies may become contaminated. Such contamination would be harmful to a variety of fish and wildlife resources.

Impacts on Shorebirds - Increased development on Brunswick County beaches may have eliminated nesting and overwintering habitat for shorebirds in the area. The dynamic spits adjacent to both Lockwood's Folly and Shallotte Inlets are proposed for designation as critical habitat for the threatened piping plover, for instance. Many shorebirds nest, forage, loaf and rest on beaches, spits and their associated habitats. North Carolina is distinct in that its geographical location provides both nesting and overwintering habitat for birds that migrate along the Atlantic flyway. These birds prey on invertebrate populations found in the project area as well. By reducing or eliminating their prey base, potentially destabilizing their habitat, and encouraging more development encroachment on the remaining habitat, major beach construction projects such as this have significant impacts on avifauna.

Impacts to People – Large-scale, long-term beach construction projects such as this proposal for Oak Island and Holden Beach also have direct and indirect impacts on people. The heavy equipment used to construct the proposed project may be present for many months. This equipment blocks recreational access, is noisy during operation, and if used at night the lights and noise may prevent adjacent property-owners from a peaceful night's rest. Recreational and commercial fishermen will be prevented from using waters in and near the borrow areas for months.

An artificial beach-dune system does not look like a natural system, and reduces the inherent aesthetics of the coast. Artificial levee-dune ridges can block recreational access to the beach. The beach itself may become very hard and difficult to walk on if the fill material is full of broken shells. Construction of sand castles may be impossible with the poorly sorted sediments. Mud content may decrease recreational use due to its dirtiness or lack of aesthetics. Escarpments impede recreational access to and from the water. Surf fishermen are already advised to stay away from nourished and bulldozed beaches as they "become 'dead' beaches, without natural life" (Simpson 2000). Bird watchers likely follow the same advice since shorebirds will have nothing more to feed upon than the surf fishes.

Indirect Impact on Sea Turtles

Changes in the physical environment - Creation of an artificial beach-dune system may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings (Nelson 1987, Nelson and Dickerson 1987).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could negatively impact sea turtles regardless of the timing of projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson et al. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success (i.e., false crawls occurred more frequently) have been documented on severely compacted nourished beaches (Fletemeyer 1980, Raymond 1984, Nelson and Dickerson 1987, Nelson et al. 1987), and increased false crawls may result in increased physiological stress to nesting females . Sand compaction may increase the length of time required for female sea turtles to excavate nests and also cause increased physiological stress to the animals (Nelson and Dickerson 1988c). Nelson and Dickerson (1988b) concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

These impacts can be minimized by using suitable sand and by tilling the beach after nourishment if the sand becomes compacted. The level of compaction of a beach can be assessed by measuring sand compaction using a cone penetrometer (Nelson 1987). Tilling of a nourished beach may reduce the sand compaction to levels comparable to unnourished beaches. However, a pilot study by Nelson and Dickerson (1988c) showed that a tilled nourished beach will remain uncompacted for up to 1 year. Therefore, the Service requires multi-year beach compaction monitoring and, if necessary, tilling to ensure that project impacts on sea turtles are minimized. A root rake with tines at least 42 inches long and less than 36 inches apart pulled through the sand is recommended for compacted beaches. Service policy calls for beaches to be tilled if compaction levels exceed 500 pounds per square inch (psi).

A change in sediment color on a beach can change the natural incubation temperatures of nests in an area, which, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the timeframe for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Escarpments - On nourished beaches, steep escarpments may develop along the water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson et al. 1987). Escarpments can hamper or prevent access to nesting sites. Researchers have shown that female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (e.g., in front of the escarpments, which often results in failure of nests due to prolonged tidal inundation). This impact can be minimized by leveling any escarpments prior to the nesting season.

Indirect Impacts on Piping Plovers

Factors contributing to the decline of the piping plover are: (1) habitat loss and degradation due to development and shoreline stabilization; (2) disturbance by humans and pets; and, (3) predation (USFWS 1996b, p. 33). Much of the plover's historic habitat along the Atlantic Coast has already been destroyed or permanently degraded by development and human use. The construction of houses and commercial buildings on and adjacent to barrier beaches directly removes plover habitat and results in increased human disturbance. While legal restrictions on coastal development may slow the future pace of physical habitat destruction, the trend in habitat availability for this species is inexorably downward. The decrease in habitat availability, especially with regard to the dynamic nature of these coastal areas, may force birds to nest in suboptimal habitats which could be detrimental to future reproductive efforts.

A more subtle, but equally ominous, threat to the plover is the decrease in the functional suitability of the plover's habitat due to accelerating recreational activity on the Atlantic Coast. Functional habitat loss occurs when suitable nesting sites are made unusable because high human and/or animal use precludes the birds from successfully nesting. Population growth along both the United States and Canadian coasts fosters an ever increasing demand for beach recreation. In 1993 only 32% of the U. S. Atlantic Coast population of piping plovers nested on federally owned beaches where at least some protection can be afforded under the ESA. The remaining 68% nested on state, town, or privately-owned beaches where they face increasing disturbance from humans, domestic animals, and development.

Barrier island beaches preferred by piping plovers are dynamic, storm-maintained ecosystems. Natural coastal processes, such as overwash fans and accreting spits, are important for creating piping plover habitat. The construction and maintenance of artificial dune systems along with efforts to prevent the closure of barrier island inlets appear to lead to a reduction in piping plover nesting habitat. Using inlets as borrow sources for these projects further threatens the habitats of these birds. Dune maintenance conducted to protect an access road on Island Beach State Park in New Jersey may be one of several factors contributing to very low density of piping plovers (USFWS 1996b, p. 35). On Cape Lookout National Seashore, a roadless area, piping plovers have nested at several closed inlets, a habitat type that is not present on Hatteras Island which is traversed by a state highway protected by an artificial dune system (USFWS 1996b, p. 35).

Ramifications of the Preferred Alternative

While it is comforting to view the preferred alternative in the relatively short term of only a few decades, many very disturbing problems arise when the time frame is expanded outward to 50, 100, or more years. Pilkey et al. (1998, p. 107) summarized the ultimate paradox of using artificial beach-dune systems in order to protect structures by noting that "You can have buildings or you can have beaches; in the long run you cannot have both." This is the fundamental issue: barrier islands are areas of shifting sand which must move in the face of a rising sea in order to continue their existence. Efforts to fix the location of the islands will ultimately lead to their destruction, or at least the destruction of the natural characteristics upon which important fish and wildlife resources depend.

There should be a fundamental difference in the perspective toward beach stabilization on barrier islands and beaches directly tied to the mainland. Mainland beaches may be renourished for decades without posing a threat to long-term viability of inland ecosystems. In contrast, on barrier islands a commitment to protect structures in their current location will keep the island from transgressing landward. The line of dunes will prevent cross island overwashes. By preventing overwash, the frontal dunes on the island's ocean side preclude new marsh growth and increases the soundside erosion rate (Pilkey et al. 1980, p. 29). Eventually erosion of sound side marshes will also become a threat to structures and additional efforts will be required to protect development from the sound. The combined effects of a rising sea and protective structures will eliminate the estuarine marshes that are such a valuable nursery habitat for fish.

Aside from the impacts considered above, the initiation of a program to create and maintain an artificial beach-dune system has serious ramifications for the entire barrier island ecosystem. First, this program represents a commitment to protect structures in their present location despite a rising sea level that would, under natural conditions, force the island to move landward. Second, this commitment will be extremely difficult to reverse. Pilkey et al. (1998, p. 107) note that once shoreline engineering is started, it can't be stopped. Third, maintaining structures in their present location will become increasingly expensive. Current plans for renourishment at three year intervals may shrink to a two year cycle and after several decades annual sediment placement could be required. However, renourishment at any interval depends on an economical source of sand and at some point the cost of moving sand will become prohibitive. At this point, the value of the structures behind the artificial beach-dune system will have increased many times over. Where a phased-in program of relocation and retreat from the beaches would cause serious social and economic hardships in the present, by the middle of the next century such a program could be out of the question and seawalls may be the only politically acceptable solution to preserve development. Seawalls, on both the beaches and sound side marshes, would eventually eliminate existing habitat values at the margins of the barrier island.

The cumulative impacts of the proposed project will be significant. Federal and private nourishment projects already occur at or are planned for Ocean Isle, Caswell Beach, Bald Head Island, Kure Beach, Carolina Beach, Masonboro Island, Wrightsville Beach, and Figure Eight Island. The Wilmington Harbor deepening project will dispose of almost 5 million cubic yards of material on Bald Head, Caswell, Oak Island and part of Holden Beach. Thus Sunset Beach is the only developed beach in all of Brunswick and New Hanover Counties that would not be regularly disrupted with beach construction projects.

The cumulative impacts of this widespread artificial beach-dune construction are immense. Few to no natural beaches will be left to supply spawning and recruitment populations for invertebrates to recolonize the artificial beaches. The Service is concerned that this extensive and perpetual human disruption of the natural beach ecosystem lead will to permanently depressed or eliminated invertebrate populations in New Hanover and Brunswick Counties. The invertebrates serve as indicator species for the health and integrity of the entire sandy beach ecosystem. Shorebirds and juvenile fish will not be able to forage on the beaches. Research is indicating that the surf zone is an important nursery area for some species of fish, and that these fish have high site fidelities (Ross and Lancaster 1996). The surf zone has been designated as Essential Fish Habitat by the South Atlantic Marine Fisheries Council because of the ecological functions it provides for aquatic resources. Any semi-permanent artificial modification of that habitat may lead to significantly depressed fish populations. Likewise, migratory avifauna may not be able to stop over in southern North Carolina and fuel up for continuation of their long migration journeys.

The integrity of the benthic and pelagic nearshore and offshore ecosystem will also be compromised by a 50 year commitment to repetitively remove portions of the substrate all over New Hanover and Brunswick Counties. Hundreds of millions of cubic yards of sediment will be dredged out of the benthic ecosystem and used to bury large portions of the nearshore benthic ecosystem. Several studies have shown that nourishment sediment moves offshore the project beach (Reed and Wells 2000; Thieler et al. 1995), and that over time the need for sediments increases over the life of the project rather than decreases (Trembanis et al. 1998). The cumulative impacts of these massive dredge and fill projects is the wholesale manipulation of the continental shelf and its associated habitats. The perpetual artificial relocation of hundreds of millions of cubic yards of sediment from one place to another will lead to a long-term, far-reaching degradation of the seafloor and both its hardbottom and sandy habitats.

SECTION 11. COMPARISON OF IMPACTS

Section 7 discussed the range of alternatives that can contribute to reducing the damage caused by coastal storms. In general these options may be divided in two broad categories. First, artificial barriers may be thrown up in an attempt to keep out the ocean. These options do nothing to prevent wind damage and unless they are extremely high and very water tight do little to prevent flooding and storm surge damage in major storms. Second, there can be a combination of land use polices and construction standards which attempt to move buildings out of harm's way and fortify them when, not if, high wind, waves, and wave reach them. These options apply to storm damage reduction and not directly to problems associated with shoreline recession which are not within the scope of the stated objective for this project.

From these options the Corps has proposed the creation of an artificial beach-dune system and the impacts associated with that option have been considered in Section 10 that divides project impacts into direct and indirect categories. Table 17 presents a comparison of the direct environmental impacts associated with the two broad options for storm damage reduction. The table shows that the creation of the artificial beach-dune system is much more harmful to the environment than a combined program of higher construction standards and land use planning. In fact, the latter produces none of the adverse impacts associated with the former.

Table 18 compares the indirect impacts of the two options. In this comparison it is assumed that both options will allow development to continue. Therefore, the indirect impacts associated with future development would be the same for both options. However, nine of the 11 impacts discussed would only occur with the creation of an artificial beach-dune system. One impact of special interest to the Service is the exacerbation of navigation problems at Lockwood's Folly Inlet. The predominant longshore current may carried sediment placed on the beach into the navigation channel. If dredging were increased, the channel could become impassible for commercial fishing vessels.

The Service acknowledges that these yes-no dichotomies simplify very complex impacts and do not address the efficacy of the two approaches. However, these assessments do not fully consider the very long-term problems that can occur with a perpetual commitment of maintaining an artificial beach-dune system, such as exhausting the supply of sand near the project area and the ever rising cost of each sand placement. Despite any over simplification and omissions, these tables indicate that the artificial beach-dune system would produce greater adverse impacts on the natural resources of the project area.

There are advantages to the strategy of relocating buildings away from the shoreline. Bush et al. (1996, p. 101) summarized these as:

1. Removes threats to buildings

2. Allows natural shoreline processes to continue;

3. Preserves the beach; and,

4. Good possibility of one-time-only cost.

These authors also note that relocation is a viable coastal management tool and does not need to be considered only for single-family houses. In the final analysis, if any structure is moved back from the shoreline, the potential for storm damage reduction has been achieved.

SECTION 12. CONSERVATION MEASURES

Fish and wildlife conservation measures, as specified in the FWCA, consist of "...means and measures that should be adopted to prevent the loss of or damage to such wildlife resources (mitigation), as well as to provide concurrently for the development and improvement of such resources (enhancement)." Mitigation, as defined by the Council on Environmental Quality and adopted by the Service in its Mitigation Policy, includes:

1. avoiding the impact altogether by not taking a certain action or parts of an action;

2. minimizing impacts by limiting the degree or magnitude of the action and its implementation;

3. rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

4. reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and,

5. compensating for the impact by replacing or providing substitute resources or environments.

These five actions should be viewed as the proper sequence for formulating conservation measures.

Enhancement measures are those which result in a net increase in resource values under the with-project condition compared to the without-project condition. For any given type, kind, or category of resource being evaluated, there must be compensation (i.e., full replacement) for all project-associated losses before any enhancement of that given resource can occur.

The stated purpose of this project is the reduction of storm damage. The Service supports this goal. However, the barrier islands, the offshore ocean, and the estuarine sounds are valuable fish and wildlife habitat. These habitats have been heavily impacted in recent decades and the trend of greater human impacts appears likely to continue. Therefore, it is imperative that careful planning seek to achieve the stated project goals with minimal environmental impacts.

In seeking to reduce storm damage, it is only logical to require buildings to be separated from destructive forces. However, complications arise when the distance between structures and destructive forces does not remain the same from year to year and actually decreases over time. When the landscape can shift significantly in a matter of days, the risk of destruction for a given building may change from low to high very quickly. With regard to the ocean shoreline approaching buildings that were once far from the sea, there are basically two choices (Table 15). There can be a comprehensive program of selective removal, improved construction standards, tighter zoning regulations, and retrofitting existing structures. Alternatively, an artificial barrier may be constructed between the structures and the sea in an effort to leave the structures in place and hold back the ocean. The former alternative provides a pattern for the long-term accommodation of limited development on barrier islands and the latter sets the stage for expensive, repetitive efforts that will fail over the long term.

The creation of an artificial beach-dune system on a thin barrier island or barrier spit poses concerns that are fundamentally different from the same procedure employed directly on the mainland. On the mainland, sand can be added for decades in the face of a rising sea level without significant harm to adjacent uplands. However, a barrier island, or even a barrier spit in the present case, is surrounded by water which is currently rising and may rise at an increased rate in the future. Even a water tight barrier on only one side of an island is a futile gesture; the water will come in from all the unprotected sides. Furthermore, engineered structures which hinder the natural, landward transgression of barrier islands in the face of a rising sea set the stage for the eventual destruction of the islands. In the distant future, development must either accommodate the movement of the islands or permanent development will survive on isolated slivers of sand completely ringed by dikes dozens of feet high; there would be no beaches or estuarine marshes as we know them now. The latter scenario would be devastating to the fish and wildlife resources that depend on habitats associated with natural barrier islands.

Conservation measures associated with any storm damage reduction endeavors on Brunswick County beaches fall into three categories. First, the NEPA planning process must be employed to clearly define the project purpose and develop the widest range of alternatives. Second, specific measures to minimize adverse direct impacts of the preferred alternative must be developed. Finally, measures to eliminate or reduce the serious, long-term indirect impacts of the preferred alternative must be considered. The Service position on these three aspects is given below.

Conservation Measures Related to NEPA and Selection of a Preferred Alternative

The Corps has presented a preferred alternative, the creation of an artificial beach-dune system. The only alternatives mentioned to date have been the "no action" course and modifications to the design and construction of the proposed system. In light of the serious long-term consequences of creating and maintaining an artificial beach-dune system, compliance with the NEPA planning process is important. The initial stage of the NEPA process is the purpose and need statement. These two aspects of a project are often viewed as inseparable, but in fact they are distinct aspects of the planning process. In this case, the need is clear and undisputed. Brunswick County beaches are extremely vulnerable to both tropical hurricanes and southwesters. There is a need to reduce storm damage.

The project purpose arises from the stated need, and establishes the extent to which the project hopes to satisfy this need. It is impossible to eliminate all damage from coastal storms on the Brunswick County coast. Therefore, certain parameters must be developed that set clear boundaries on what the project can and cannot be expected to accomplish. The Service sees three important factors in defining the project purpose. First, the level, or category, of storm for which the project is intended to provide protection must be defined. There is enough general data on hurricanes and southwesters to define the level of storm, based on storm surge characteristics, to provide this criterion. The range of options would vary considerably between protecting against hurricanes in categories one and two as opposed to a category five hurricane such as Camille (1969) which was more powerful than Hugo (1989) or Andrew (1992). Second, the actual type of storm damage to be reduced should be specified. Third, the area to be protected should be defined based on the first two criteria discussed. These three factors form the purpose of the project.

Development of Alternatives

The key issue from a NEPA standpoint will be the extent to which various alternatives are developed and evaluated. Based on the project purpose, the widest possible range of alternatives must be developed. In this regard the Corps should not be limited to measures for which it has jurisdiction. It is within the scope of the NEPA planning process to determine that the best alternative is a measure or series of measures that must be undertaken by others.

The development of alternatives should not be overly influenced by economic or political considerations at this stage of planning. The factors of cost and the desires of the local community may come into play during the evaluation of alternatives, but not in the creation of alternatives. For example, the project purpose may be defined as the protection of structures in the ocean erodible zone (area) from ocean storm waves (type of damage) of hurricanes up to category 3 (level of storm). In this instance, a possible alternative would be to remove all structures in this precise area that were susceptible to ocean storm wave damage from the specified hurricanes. Not all structures in the specified area would need to be removed. Structures elevated well above the expected level of storm waves associated with a category 3 hurricane would require no action. Other houses below the expected level of wave attack could be retrofitted to withstand the attack of the specified storm category. The relocation of threatened, beachfront structures in conjunction with improved building standards must be considered a viable alternative for damage reduction from hurricanes below the major categories, 4 and 5, in which case no form of human intervention, either artificial beaches or strict building codes, would probably be of much benefit.

Evaluation of Alternatives and Selection of Preferred Alternative

After alternatives are developed, the Corps should explain the evaluation of each alternative and the process leading to the selection of a preferred alternative. The selection of the preferred alternative should be based on an overall consideration of cost, social impacts, and environmental impacts. While the first two categories are more measurable, they should not be allowed to completely override environmental concerns.

At this stage, the planning process should consider the durability of each alternative. For example, the Corps should consider that maintaining an artificial beach may not work in areas of high natural erosion. In this regard, the Corps should examine the combined effects of sea level rise and natural shoreline recession at 30, 40, and 50 years of project life. Such an examination may show that maintenance of the artificial beach-dune system may become untenable due to costs or dwindling sand supplies over many decades.

With a clearly defined purpose, the costs and social disruptions of alternatives to the artificial beach-dune system may be quite low. The alternatives evaluation should always remain focused on the specific project purpose, i.e, the area, the type of damage, and the level of storm. It would be clearly inappropriate to imply that the artificial beach-dune system would significantly reduce all forms of storm damage in all categories of storms. A tightly focused evaluation may show that the proposed artificial beach-dune system provides protection for such low intensity storms that only a relatively few structures directly on the shoreline would be protected while other structures, conforming to established set backs and building codes would not benefit from the new beach-dune system.

The stated goal of storm damage reduction may have a greater chance of success if smaller scale sediment placements were coupled with improved zoning and construction standards (NRC 1995, p. 31). For example, if the project purpose is to protect structures in the ocean erodible area from storm waves of hurricanes in categories 1-3, then a combination of selective structure removal, retrofitting existing structures, increased standards for new structures, and repairing of the dune line could prove to be the best combination of cost and environmental protection.

Finally, the NEPA process needs to fully evaluate this project's preferred alternative in light of similar projects and dredge spoil disposal operations throughout New Hanover and Brunswick Counties. Virtually every developed beach in those two counties except Sunset Beach would be undergoing artificial beach construction projects if this project were implemented. A full cumulative impacts analysis should be conducted and added to this project's environmental impacts and costs.

<u>Conservation Measures for the Direct Impacts of the Artificial Beach-Dune System</u>

If the NEPA planning process should lead to the selection of the artificial beach-dune system that the Corps has already indicated to be the preferred alternative, there should be plans to minimize the direct impacts of the project. Appendix B lists the direct, indirect and cumulative impacts to the physical environment of creating the artificial beach-dune system with sediment taken from offshore borrow areas. The NEPA documentation should evaluate each of these physical impacts by translating them into biological impacts to the ecosystems of which they are a part.

Table 17 lists some of the direct biological impacts of creating such an artificial beach-dune system. The first biological impact, elimination of the offshore benthic community, can be minimized, but this community will be lost in the areas used for borrow material. The other nine impacts can be mitigated by measures that fall into two broad categories. These are ensuring that the offshore sand is compatible with existing beach sand and selecting the work season. For some direct impacts, such as disrupting offshore fish, conservation measures may involve both sediment compatibility and seasonal work schedule.

Measures for the Offshore Benthic Community

No studies concerning the effects of dredging sand from borrow sites off the North Carolina coast have been conducted. Therefore, impacts associated with offshore sand mining are unknown, and mitigation requirements are difficult to predict. Hurme and Pullen (1988) recommend pre-project, baseline surveys in all potential borrow sites. Offshore monitoring is needed to determine the effects offshore sand mining has on marine communities in and adjacent to borrow areas and the shoreline. Special attention should be given to identifying hardbottoms and to monitoring the effects on hardbottom habitats which may be near proposed borrow areas. Stender et al. (1991) and Maier et al. (1992) used side scan sonar and underwater television cameras to identify live bottom sites near potential offshore sand borrow sites in South Carolina. The purpose of these surveys would be to avoid important benthic resources such as clam beds or active spawning areas.

The Corps should provide contractual opportunities to local universities to conduct aquatic resource surveys before, during and after the project construction period to document and gather important data on valuable fish and wildlife resources and impacts to their populations and distributions. A before-after-control-impact methodology should be used. These data should be made available to the Service, NMFS and all interested parties to better define impacts of 50 year dredge and fill projects on aquatic resources.

Measures Related to Sand Compatibility

Four of the ten direct impacts given in Table 17 relate to the issue of sediment compatibility. These impacts are offshore turbidity and sedimentation (caused by dredging) along with nearshore turbidity and sedimentation (caused by beach disposal). The Corps should ensure that all material placed on the beach is compatible with natural beach material. The dredging of material with a high percentage of silt and clay would produce increased turbidity and sedimentation (NRC 1995, p. 108).

The best conservation measure for reducing turbidity and subsequent sedimentation is to avoid using any material with silt and clay particles. At the very least, the project should not dredge material that consists of more than ten percent silt and clay or contain significant amounts of organic material.

Borrow sediments should match the native sedimentological parameters as closely as possible. Alterations to the grain size, color and composition could create unsuitable habitat for sea turtle nesting and beach invertebrate colonization and recovery. The greater the deviation from the natural grain characteristics present on the disposal beaches, the greater the potential impacts to all organisms using or living on the beaches. Deposition of disposal material during recruitment or nesting seasons could increase recovery times for invertebrate populations and reduce the abundance of sea turtle and shorebird nests or success of existing nests.

Beach nourishment should not result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content. These parameters should be similar to the original beach sand. Any changes could result in adverse impacts on sea turtle nest site selection, digging behavior, clutch viability, and emergence by hatchlings (Nelson and Dickerson 1987, Nelson 1988). The beach invertebrate populations that live in burrows also would be impacted adversely by such changes.

To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. A change in sediment color on a beach could change the natural incubation temperatures of nests in an area, which, in turn, could alter natural sex ratios. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the timeframe for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season. Bleaching would also be limited to surficial sediments exposed to sunlight.

There is a potential for adverse impacts from contaminants within the dredged sediments. All fish and wildlife resources would benefit by avoiding the introduction of toxic substances into the aquatic and upland habitats of the project area. Certain harmful substances may be contained in the bottom sediments along the new channel alignment and material in existing dredge spoil disposal sites. It is important that toxic substances in toxic amounts are not introduced into the beaches and nearshore ecosystems of the project area.

Wilmington Channel is a major point of entry along the East Coast of the U.S., and as such has seen a great deal of vessel traffic from all over the world. Ballast exchange by freighters that have traveled all over the world could introduce unknown biological and chemical contaminants to the Cape Fear River in the project area. Transfer of petrochemicals, tar, turpentine, and other industrial materials exposes the project area to potential contamination. Various industries along the banks of the Cape Fear River are known to use and discharge toxicants; the Cape Fear basin includes many known or suspected hazardous waste sites. The Service is concerned that the number and diversity of known point-source and non-point source pollution inputs to this system may result in contaminants-related issues with any dredge spoil in this project excavated from the Cape Fear River system or disposal islands.

In 1998 the EPA and the Corps adopted a new Inland Testing Manual (ITM) as a guideline for contaminants testing and evaluation for dredging inland waters, including disposal on dredge spoil islands. The ITM provides a four-tier assessment process for contaminants testing, and the Tier One Assessment is basically a documentation procedure that searches known literature, studies and tests for the project area. Based upon the results of this review, new analysis of sediments may be conducted or determined unnecessary. Either way, the Tier One Assessment documents the decision-making process.

The Service recommends that the Corps conduct a Tier One Assessment for the borrow sediments in this project, including those in any spoil islands scheduled for pumpout. This conservation measure would minimize the risk of contamination to fish and wildlife resources in all disposal areas. A Tier One Assessment, performed in accordance with ITM guidelines, should be included in the environmental documents for the project. That assessment should include documentation of the significance of contaminant-related risks, and it should identify the need for any additional assessment. Should any sediments contain toxicants that exceed reasonable screening values for contaminant effects (e.g., EPA Region 4 screening guidelines; NOAA and USGS-BRD derived screening guidelines), appropriate measures should be taken to manage the contaminants.

Measures Related to the Annual Work Schedule and Operations

Four of the ten direct impacts given in Table 17 are best addressed by determining an annual work schedule. These impacts are: (1) mortality of beach invertebrates; (2) reduced sea turtle nesting success; (3) disturbance of shorebirds; and, (4) disturbance of offshore marine mammals. An overview of the seasonal occurrence, or specific period of vulnerability, of major species or groups of species is given in Table 19.

Table 19 indicates that there is no single month, or even a single season, when all adverse impacts to important fish and wildlife resources could be avoided. As might be expected, overall biological activity for these resources is less during the colder months. From a strictly biological point of view, the least harmful six-month period would be the months of October through March. However, this period coincides with rough seas in the ocean off the project area and the need to frequently mobilize and demobilize dredging equipment adds to the project cost. It is very difficult to assign relative importance to the various fish and wildlife resources in the project area. The value of undisturbed wintering habitat for offshore fish is difficult to weigh against the value of an undisturbed summer beach for sea turtles, shorebirds and beach invertebrates. However, strictly based on a consideration of area utilized by the various resources of concern, there is more offshore fisheries habitat than beach. While overwintering fish may be able to move several miles away from the dredging vessel, the thin strip of beach used by sea turtles, mole crabs, and coquina clams is very limited. Therefore, from a conservation point of view the least damaging time for dredging and beach disposal is during the colder months of the year.

Throughout the 50-year project life, work schedules must be addressed for both initial construction and sediment replacement operations. The Service realizes that the rough seas during the winter months can limit actual work time. In fact, production during the winter may only equal 25% of that which can be accomplished during the summer. However, winter dredging offers clear advantages to the fish and wildlife resources. Therefore, the Service proposes that initial construction be accomplished by using at least two dredging vessels that commence work on or after November 15. These vessels would work as weather allows through

the winter and attempt to finish initial construction by March 31. If some work remained after March 31, these vessels would continue work into the spring until work was completed.

Sediment replacement operations should follow a similar pattern, but with a reduced work period. Replacement operations should be limited to the period from November 1 through the end of February. The use of one or two vessels would depend on the volume of material to be moved. Since bad weather could limit winter production, the dredge vessel(s) could continue until the end of March. If a single vessel is used, the Corps should be able to forecast a production rate by the end of December. If it is apparent by the end of December that a single vessel may not be able to complete sediment movements by the end of February, a second dredge should be added to ensure completion of the sediment replacement operation by the end of March at the latest.

The mechanics of pumping out the dredge materials onto the beach would generate other direct and indirect impacts to coastal fish and wildlife. Pipelines, either from a hopper pumpout or a hydraulic dredge, would be laid on the beach and in the nearshore waters. Such pipelines would create a physical barrier for not only wildlife resources but people using the beach as well. Pipelines running parallel to the shoreline would impede sea turtle access to nesting habitat. Macrofauna such as ghost crabs would also have difficulty reaching foraging areas in or near the intertidal zone. The slurry being pumped out of the pipeline would require dewatering and heavy equipment to adjust the fill dimensions. As the slurry that is 80% or more fluid dewaters, sediment plumes will extend off of the beach. Juvenile surf fishes could be impacted with respiratory stress or trauma that is either lethal or sublethal. Filter-feeding molluscs in the immediate nearshore area could also be suffocated or traumatized. The heavy equipment on the beach used to move the fill could compact the sediments, destroy existing invertebrate burrows and run over nests of sea turtles or shorebirds. Compaction of the sediments could render them unsuitable for sea turtle nesting, burrow excavation and invertebrate recolonization.

Hopper dredges have been known to incidentally take sea turtles present in the water column near the dredging activities. The number of sea turtles and other aquatic species killed or fatally wounded by such activities would logically increase with the increased abundance of these species in the water. The Service is concerned that use of hopper dredges year-round would have the additional impact of increased takes of federally listed resources as populations increase during spring and fall migration periods as well as the summer foraging and nesting season. Limiting hopper dredging activity to those seasonal windows already agreed upon between the Corps and NMFS and the Service would minimize the potential number of takes of these species.

Accurate data are needed to assess the impacts of hopper dredging on sea turtles. A significant conservation measure for these protected species would be trained observers on all hopper dredges to count the number of turtles killed during dredging. Data on dredging impacts to sea turtles would be useful in refining seasonal restrictions on dredging and in implementing equipment modifications to protect sea turtles.

Colonial waterbird nesting season extends from May 1 to October 31. Disturbances to disposal islands utilized by these birds during their nesting season could increase abandonment of nests and lead to decreased reproduction success rates. Active pumpout of these islands to the project beaches would destroy any nests present during the nesting season. Noise and any potential fumes accompanying dredging activities within or adjacent to disposal islands may discourage usage of the islands for nesting. Night-time dredging activities with lights could further disrupt colonial waterbirds not only nesting on disposal islands, but those resting or foraging on the islands.

Conservation measures to benefit reproduction by colonial waterbirds are primarily related to avoiding disturbances of the birds during the sensitive breeding season. While sand removal from a nesting site is an extreme example, measures must also consider more subtle disturbances such as the noise, fumes, lights, and movements associated with dredging. The activities associated with dredging cause stress and excessive flight responses among breeding birds. Dredging activities near nest sites can ultimately cause the birds to abandon nests. Therefore, dredging activities and sand removal from breeding areas should not occur at or near nesting sites of colonial waterbirds during the breeding season of April 1 through October 31.

Direct Impacts to Specific Fish and Wildlife Resources

The most effective strategy for avoiding impacts to fish, and fisheries, in and near the proposed borrow sites is not to construct the project. Fisheries resources would be protected by relocating structures jeopardized by the retreating beachfront, rather than providing artificial protection against natural processes. A third option is to seek alternative sources of material for constructing the proposed project other than offshore deposits which lie within significant wintering grounds for major stocks of highly important ecological, commercial and recreational fishery resources. This could include upland sites, as well as alternative ocean or estuary sites, if they can be located, where resource values may be less and where Essential Habitat (EH) or Essential Fish Habitat (EFH) has not been designated.

Direct impacts to nearshore and offshore fisheries would be minimized by ensuring strict compatibility of dredged sediment with existing beach sand and working during a period of low biological activity. The nearshore and offshore areas are important spawning, feeding, and migratory areas for a variety of species. Hardbottoms, artificial reefs, surf zones and Frying Pan Shoals have been designated as EFH. The Corps should carefully consider these designations and develop a policy regarding dredging in areas of essential fish habitat. The outline of this policy should be included in the project EIS.

If sediment placement extends into the sea turtle nesting season, May 1 through November 15, the Corps must ensure that a program of nest monitoring and relocation is initiated with adequate funding. Such programs are a routine part of sediment placement on nesting beaches. However, if there is any chance that beach sediment placement may occur during the sea turtle nesting season, Section 7 of the Endangered Species Act requires that the Corps prepare a Biological

Assessment and initiate formal consultation with the Service.

The placement of sediment on area beaches should be done to match the shape and slope of the natural beach. Often beach nourishment results in a steep escarpment between the beach fill area and the natural offshore slope. Such a change in beach profile may cause access problems for nesting sea turtles or obstruct hatchling sea turtles on their way to the ocean. Shorebirds and macrofauna feeding in the swash zone would be impaired by scarps that form at the mean high water line. Human recreational use of the beach's intertidal zone may also be hampered.

Efforts should be made to ensure that the beach profile after nourishment is a natural, gently sloping beach rather than a layered beach with sharp escarpments. If the nourished beach profile develops high escarpments, they should be leveled to grade into the natural profile. Immediately after completion of sand placement on beaches and prior to the sea turtle nesting seasons, monitoring should be conducted to determine if escarpments are present and escarpments should be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities. Escarpments may be created during the nesting and incubation season that require the use of heavy equipment to grade. However, the use of bulldozers or other heavy equipment on the beach is harmful to existing nests. The use of heavy machinery can cause sand compaction on nourished beaches (Nelson et al. 1987, Nelson and Dickerson 1988a). Heavy equipment may crush nests over which it passes. Such heavy equipment should be kept off the beaches during the nesting and incubation season, May 1 through November 15.

As a specific measure to benefit sea turtles in the project area, the Corps should recommend to all local governments that individuals working on state-sanctioned sea turtle conservation projects be exempted from local regulations which hinder their work. For example, the state's effort to record sea turtle nests on the beach could be facilitated by allowing volunteer monitors to use motorized vehicles on the beach during their monitoring work. If such access is prohibited by local laws, exceptions should be granted for sea turtle patrols. A request for a particular exemption should be made in writing from a state employee of the NCWRC and not from individual volunteers.

While marine mammals are highly mobile and range over wide areas, there must be measures to ensure that whales and porpoises are not directly harmed by the dredging and transport of sediment. Such measures may include observers on the dredging vessels. The Corps should initiate informal consultation with the NMFS which has jurisdiction under the Endangered Species Act for marine mammals and the shortnose sturgeon. If early consultation determines that the project may adversely affect any protected species, the Corps must initiate formal consultation with the NMFS.

Conservation of beach invertebrates is directly linked to the annual scheduling of work. If species such as the beach digger, mole crab, and coquina clam are on the beach during sediment placement, these individuals will be killed. While some invertebrates remain on the beach the entire year, others such as the mole crab and coquina clam move off the beaches during the colder months. The Corps should develop a monitoring program to quantify the impact of the project on beach invertebrates; ranging from the nearshore subtidal zone, through the intertidal zone and subaerial beach, to the toe of the dune.

<u>Conservation Measures for the Indirect Impacts of the Artificial Beach-Dune System</u>

Measures Related to Bottom Characteristics that Influence Flora and Fauna

Certain construction techniques can minimize long-term harm to offshore organisms. The ability of a benthic community to repopulate a borrow area is influenced by the size and configuration of the borrow area, its exposure to waves and currents, the similarity of sediment surrounding the area, the new sediment-water interface, and possible changes in water quality (Hurme and Pullen 1988). Shallow dredging over an extensive area may cause less environmental harm than deep pit dredging (Thompson 1973 as cited in Hurme and Pullen 1988). Shallow dredging may minimize the possibility of deep holes filling with finer grain sand and thereby changing the nature of the bottom substrate.

Offshore shoals and underwater ridges are desirable habitats for many species of fish, and Hurme and Pullen (1988) write that " . . . little is known about the potential effects of modifying the general offshore bathymetry on fisheries." These authors suggest that long-term adverse impacts can be minimized by:

1. Leaving a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment unless exposing a new substratum is desired; and,

2. Taking borrow material from broad, shallow pits in deeper water with an actively shifting bottom.

To fully assess the impacts to offshore borrow areas, the Corps should sponsor a long-term monitoring program to evaluate the recolonization of these borrow areas. It may be possible to do a comparison of wide, shallow dredging and localized deep dredging in the early years of the project. If statistically valid data indicates that there have been no long-term adverse impacts from localized deep dredging, then that method could be adopted for the remainder of the 50-year life of the project.

The Corps should also undertake a program to ensure that hardbottom areas are not impacted by sedimentation. USMMS (1990), Zullo and Harris (1993), Harris and Laws (1994), Riggs et al. (1996), SEAMAP (1998), Riggs et al. (1998), Cleary (1999), and Cleary (2000b) indicate that hardbottoms exist in or near the proposed borrow areas. Fine sediment in the dredged material can be carried over considerable distances and blanket these areas. To monitor impacts on hardbottoms the Corps should fund a program to measure sedimentation and biological productivity in selected hardbottoms in all areas surrounding the borrow areas. This program could select the nearest hardbottom in each octant (one-eighth of a circle or an arc of 45°) around both the northern and southern borrow areas. The limit of the area should not be restricted to only those area considered “near” the borrow site, but should extend out to at least 25-30 miles. The area of exposed hard substrate would be compared from year to year and some measure of biological productivity made. After initial construction, the annual changes in exposed substrate and productivity between years with dredging and years of no dredging should provide evidence as to whether dredging, or even sediment coming off the beaches, is adversely affecting these important habitats.

Measures Related to Offshore Primary Productivity

Any reduction in offshore primary productivity may also be avoided by shallow dredging over wide areas to reduce a depth increase, i.e., sand should be taken off in thin layers rather than creating a series of deep holes. If the Corps finds it necessary to take sand from only limited areas, there should be an effort to assess the impact on primary productivity. Such a program could be based on procedures used in Onslow Bay off the southern coast of North Carolina (Cahoon et al. 1990; Cahoon 1992; and Cahoon and Cooke 1992).

Measures Related to Long-term Turbidity and Sedimentation from the Beach

While turbidity coming directly from the beach and the resulting sedimentation is generally considered to be a short-term phenomenon, the use of sediment with a high content of silt and clay as well as a high percentage of very fine and fine sand allows these problems to become chronic. This problem can only be minimized by ensuring that sediment with silt and clay is not placed on the beaches. The conservation measures mentioned above to reduce short-term problems would be applicable to this potential long-term environmental impact.

Measures Related to Invertebrate Populations on the Beach

The direct impacts of placing large quantities of sediment on beach invertebrates were discussed in Section 10. However, such placements can also have long-term adverse impacts if the populations are not given time to recover. Species which annually move offshore and then return to the beaches in the spring, e.g., mole crabs and coquina clams, are much more likely to recolonize a nourished beach at the first recruitment period after sand placement. Hackney et al. (1996, p. 109) conclude that accomplishing renourishment before larval recruitment will ensure rapid recovery of these species. However, more sedentary species, such as digger amphipods of the genus *Haustorius*, have much slower rates of recolonization. In the North Carolina beach nourishment study of Reilly and Bellis (1978, p. 67), the authors concluded that the life history and behavior of *H. canadensis* did “. . . not favor its return to the nourished area quickly.” The point of these concerns is that shorter intervals between new sediment placements may cause populations to diminish to point where a given species never returns to the placement area.

The ability for invertebrates to return to the sediment placement area is also influenced by the length of the project and the length of time between nourishment episodes. Since surviving populations on the edges of the placement area may supply the colonists for the placement area and dispersal may be limited, the shorter the placement area, the greater the opportunity for adjacent populations to reach the entire length of new beach. In this regard, a series of small projects spaced over several years may be more beneficial to beach invertebrates than a single large project which covers many miles of beach. Such a procedure would allow beach invertebrates to colonize the impacted zone from nearby, unaffected beaches.

A solution to the long-term impacts of beach sediment placement on beach infauna is difficult. Overall, beach invertebrates would appear to benefit from smaller placements that are spaced several years apart. From the timing perspective, longer intervals between beach placements are preferred. This would seem to favor larger projects at greater intervals. From a space perspective, shorter projects are favored, and this would seem to favor smaller projects that may require a shorter interval between placements.

The concept of nourishing a large beach in more frequent (but smaller) sand placements on disjunct beach segments separated by undisturbed stretches of beach rather large, intensive efforts at longer intervals has been considered. Hackney et al. (1996, p. 109-111) state that this procedure would minimize impacts on beach invertebrates by facilitating recruitment from nearby undisturbed beaches. Pilkey and Dixon (1996, p. 83) cite a 1972 study from Virginia Beach, Virginia, that determined that small, annual nourishments were superior to large nourishments spaced several years apart. This conclusion was due in part to the fact that larger volumes of sand disappeared more rapidly than smaller volumes. While such a scheme would produce more frequent sand placement, each placement would be smaller and allow for unimpacted sections between impacted sections. On balance such a procedure is likely to benefit the long-term viability of beach invertebrate populations.

Measures Related to the Frequency of Sand Dredging and Placement

As noted in Table 18, several indirect project impacts could lead to greater erosion in the project area. These impacts were associated with an altered offshore and nearshore bathymetry that can produce increased wave energy striking the beach, altered wave patterns, and a steeper beach profile that also allowed greater wave energy to strike the beach. These factors, either together or especially in combination, can increase the removal of the new sediment. The Service's concern about increased sediment removal stems from the fact that such removal would decrease the time between sediment additions. More frequent sediment additions increase all the direct impacts of dredging and sediment placement.

Hurme and Pullen (1988) state that ". . . any mining which would substantially change the form of the existing bathymetry should be undertaken with caution." As part of the recommended caution, several measures may minimize the risk of increasing the rate of loss for the new sediment. These measures are:

1. Sand should be dredged in thin layers over a wide area rather than creating deep holes;
2. Existing offshore sand shoals should not be removed;
3. Borrow areas should be seaward of the active shoreface of the beach; and,
4. The best source of sand may be on the Outer Continental Shelf

Pilkey et al. (1998, p. 97) write that it is generally best to take marine sand from a location as far from the beach as possible to reduce the impact of sea floor changes on wave patterns. The Corps should study the changes that would occur in the offshore bathymetry and present a conclusion about the effects creating deeper water will have on wave energy reaching the beaches and the possibility for even greater rates of shoreline recession.

A major conservation measure would be a thorough assessment of the erosion rates on beaches that would receive sediment. This assessment would be essentially a measure of the longevity of the artificial beach and the program must be a long-term commitment. If the erosion rate increases, a condition that leads to a decrease in beach longevity, the Corps will need to consider a broader array of measures to protect loss of fish and wildlife habitat. Associated biological productivity and cumulative impacts to ecological populations and communities, including Federally-listed species, should also be measured and monitored over the life of the project. Data gathered should be regularly analyzed, and measured impacts should be mitigated through coordination with the Service, NMFS and other relevant agencies.

If cost becomes the overriding factor in determining the borrow areas and these borrow areas are within the active shoreface of the beach, it is likely that current predictions about the survival of the created beach and thus the time between required sediment additions are overly optimistic. If the conservation measures to minimize future erosion given above are deemed to be too costly, there is a possibility that increased erosion rates and the need to add sand more frequently may, over several decades, eliminate any cost savings made by selecting borrow areas close to the beach.

Measures Related to Navigation Through Inlets

Targeting Lockwood's Folly Inlet and Jaybird Shoals as potential borrow areas is likely to modify the sediment transport rates and pathways around each end of Oak Island. Removing substantial volumes of sediment from inlet sand bodies may alter wave patterns, ocean bars and navigational channels. The EIS should evaluate whether there will be an increase or decrease in channel shoaling and wave patterns hazardous to boaters resulting from use of these borrow areas.

A single severe storm season could wash thousands of cubic yards of new sand off the Brunswick County beaches towards the adjacent inlets and navigation channels in a relatively short time.

Without adequate planning and resources for additional dredging the channel would become blocked to commercial and recreational fishing vessels. There is no reason not to establish specific procedures within the storm damage reduction project to avoid a crisis situation at these important passageways.

The NEPA documentation for this proposed project should fully investigate the potential rates of sediment losses from the beach fill by adding millions of cubic yards of material to a sand-starved coastal system. The probable pathways that this sediment will follow, including to nearshore and offshore hardbottoms, should be evaluated. The likely sediment traps or downdrift systems that receive this sediment should be assessed, and indirect and cumulative effects of such increased sediment supply should be discussed in the EIS.

Measures Related to Increased Development

The creation of an artificial beach-dune system is likely to lead to greater development, the increased withdrawal of freshwater, and the generation of additional wastewater. These events would be the result of a greater sense of security which leads to the construction of more and larger tourist facilities. The new artificial beach would also draw additional tourists to the project area. There are no conservation measures which can be associated with the current project to address these future impacts. While the current Land Use Plan (LUP) supports the current growth trend, Brunswick County also supports, to the extent possible, plans to accommodate future growth while simultaneously maintaining and improving the quality of life for current and future residents (Brunswick County, 1993, p. 85).

In addition to the habitat losses associated with future development, there is a concern for a spiraling cycle of increased development and ever greater efforts to protect increasingly valuable property. If the current project conveys the idea that a firm commitment has been made to halt beach recession, increased development will occur near the beach. As the artificial beach-dune system washes away, the value of structures at risk from storm damage will be much greater than today. Therefore, a future benefit-cost analysis will justify greater expenditures to create the next beach-dune system which will in turn generate additional development in the ever enlarging shadow of the constructed dune.

With a constantly rising sea level, the cost of the beach-dune system (which will slowly evolve toward an all encompassing dike) will simply become too expensive in spite of the value of the structures it protects. Simple economics will force a decision between extremely costly relocations or allowing costly destruction. This is the same decision that could be made today at a much lower overall cost. During the years that the decision is deferred, the quality and quantity of fish and wildlife habitat is likely to decline significantly.

At the present time, the issue of reducing storm damage can be addressed best through the NEPA planning process. For this reason the Service has stressed the need for a thorough development and analysis of alternatives to initiating the artificial beach-dune system.

SECTION 13. RECOMMENDATIONS

In accordance with the FWCA, the Service offers the recommendations in this section to avoid, minimize, and mitigate adverse impacts on fish and wildlife resources. These brief recommendations are the culmination of all the information presented and analyzed in the preceding sections of this report. These recommendations should not be considered without a thorough understanding of the entire report, specifically the conservation measures presented in Section 12. Recommendations will be presented in the same three broad categories introduced in the preceding section, but a single number sequence will be followed for the entire section.

A clear presentation of the steps taken in the NEPA planning process is essential. In the first step, the statement of purpose and need, the need for storm damage reduction is clear. However, the purpose of this specific project requires greater attention. A clear statement of purpose would serve to disentangle the goals of storm damage reduction from the restoration a recreational beach lost to a rising sea. While these goals are often viewed as two sides of the same coin, the options for each goal are different. Table 16 indicates that the alternatives for beach replacement and storm damage reduction projects have, with some overlap, a different array of alternatives. For example, creating an artificial beach is the least environmentally damaging alternative for beach stabilization, but the most environmentally damaging alternative for storm damage reduction. To fully explain the NEPA planning process, the Service recommends the following measures:

1. An EIS that includes all of the available scientific data developed since the 1973 General Design Memorandum for this project should be prepared due to the significance of the environmental impacts. The EIS should define the level of storm for which protection is sought; the type(s) of storm damage which would be reduced; and, those locations within the project area for which protection is desired.

2. Regarding the project purpose, the Service recommends that the EIS clarify the relationship between reducing damage to structures and shoreline stabilization, i.e., beach erosion control. If shoreline stabilization is sought to reduce damage to structures, it is redundant to mention it in addition to damage reduction. If the Corps seeks to stabilize the shoreline for reasons other than reducing property damage, this goal may be independent of damage reduction, but the rationale for seeking shoreline stabilization independent of damage reduction should be explained. This clarification is requested because a recent Draft EIS for the Dare County Project (USACOE 2000b, p. 8-3) noted that relocating all buildings away from the shoreline would reduce storm damage, but would not halt shoreline recession. This statement suggests that shoreline stabilization is sought for reasons other than reduction in property damage.

3 On a dynamic coastline such as the project area, a clear understanding of major natural forces is essential in developing effective alternatives. In that regard, the EIS should incorporate the latest information on global sea level rise and the role that a rising ocean

has on ocean encroachment on fixed man-made structures. Furthermore, the EIS should explain the differences between inland erosion and the adjustment of coastal shorelines to a rising sea. Inland erosion does, in fact, pick up sediment and carry it away from its site of origin and may move sediment from the mountains to the sea. On the other hand, coastal shoreline adjustment may simply move sediment from the ocean side of a barrier island to the back side of the island by the process of island overwash. This is a natural geologic mechanism whereby the islands are able to move to higher ground and remain above a rising sea. Therefore, the Service recommends that the EIS fully consider the positive role of shoreline adjustment and differentiate coastal shoreline adjustment from inland forms of erosion.

4 The EIS should have a separate section to develop the entire range of alternatives that achieve the desired storm damage reduction. This section may discuss costs, social impacts, and agencies other than the Corps which would implement a given alternative. However, no alternative should be eliminated in this section. Two references (Bush et al. 1996 and Pilkey et al. 1998) should be consulted. The alternatives analysis should include an evaluation of using hazard mitigation grant program buy-outs or relocations, elimination of subsidies on hazardous development, an in-lieu fee program for buy-outs to compensate the local tax base, and doing nothing.

5 Once all alternatives have been completely developed, the EIS should have a separate section that clearly outlines the selection of the preferred alternative. The Corps should balance the desired level of storm damage reduction against social and environmental impacts in the selection of the preferred alternative. Important issues that the EIS should address regarding the artificial beach-dune alternative are:

a. The EIS should discuss the impact of rising sea level on the project over its 50 year lifespan The targeted borrow areas may be depleted of sediments at the end of 50 years, yet the perceived need for the project will remain the same or increase due to more development pressure. The EIS should compare a one-time capital cost of structure relocation compare to a commitment to maintain the beach as a storm buffer virtually forever.

b. The proposed artificial beach-dune system may provide protection against only low intensity storms (e.g., hurricane categories 1 and 2) and protect structures in a very limited area. The EIS should determine whether a program of selective relocation, strict zoning/setback requirement, retrofitting existing buildings, and stricter building codes for new buildings is more cost efficient than the large and unpredictable costs of building and maintaining an artificial beach-dune system.

c. Appendix B lists the potential direct, indirect and cumulative impacts to the physical component of the ecosystems affected by the proposed project. The EIS should discuss the potential direct, indirect and cumulative impacts to the biological and chemical components of these ecosystems resulting from these physical impacts.

d. The EIS should completely evaluate the cumulative impacts of maintaining an artificial beach-dune system on every developed beach in New Hanover and Brunswick Counties except Sunset Beach. A full cumulative impacts analysis as outlined by the Council on Environmental Quality (CEQ 1997) and as required by case law (i.e., Montana Council of Trout Unlimited, et al, v. U.S. Army Corps of Engineers et al, U.S. District Court, Montana District, Billings Division, May 11, 2000) should be conducted.

6. The EIS should include an analysis of changes in wave patterns and wave energy striking the shoreline that would occur as a result of removing sand from offshore borrow pits and inlet sand bodies. The analysis should present a determination on the impacts that changes in the offshore and nearshore bathymetry would have on wave energy reaching the beaches and the possibility for even greater rates of sediment removal and shoreline recession. This analysis should specifically discuss wave energy impacts that would exist in the 50th year of the project when depths in some offshore areas may be increased by several feet.

Current plans call for the construction of an artificial beach-dune system. This alternative would produce direct, adverse impacts on fish and wildlife resources and their habitats. Adverse impacts should be avoided where possible, and where they cannot be avoided they should be mitigated. The Service offers the following recommendations to avoid, minimize, or mitigate these direct impacts:

7. The Corps should establish a program to monitor dredging impacts on primary productivity and benthic invertebrate community composition. The monitoring program currently under development for the Wilmington Harbor deepening project may serve as a baseline, guidance and/or starting point to gather data for this project's EIS. The program should assess the biomass and species composition of organisms that recolonize borrow areas. The program should include pre-project baseline data and post-project data at one-, three-, five-, and ten-years after dredging. The program should use at least one area among each of the two targeted islands and five borrow areas, plus control areas for each. At three, five, and ten years after sediment removal, data collected should be compared with offshore fisheries data (e.g., species composition, diversity, food habits, landings, catch per unit effort, and other appropriate information) to produce an overall evaluation of dredging impacts on offshore fisheries. If these comprehensive evaluations indicate that fisheries resources have been adversely affected, the Corps should work with the Service, National Marine Fisheries Service (NMFS), North Carolina Wildlife Resources Commission (NCWRC), and the North Carolina Division of Marine Fisheries

(NCDMF) to develop a mitigation program for the remaining decades of the project.

8. The Corps should provide contractual opportunities to local universities to conduct aquatic resource surveys before, during and after the project construction period to document and gather important data on valuable fish and wildlife resources and impacts to their populations and distributions in all borrow and fill areas. These data should be made available to the Service, NMFS, NCWRC, NCDMF, and all interested parties.

9. To minimize both the direct and indirect impacts of turbidity and subsequent sedimentation, the Corps should ensure that the project does not use sediment which consists of more than ten percent silt and clay particles. These construction restrictions would not only reduce turbidity, but would also prolong the life of the artificial beach-dune system and thereby increase the time between beach-dune reconstructions. The project EIS should contain a Sand Suitability Analysis in accordance with procedures of the Corps' Coastal Engineering Research Center or those currently under development with the Service's geologist. Borrow sediments should match the native grain size distribution and sorting level, mineral composition, color, shape and organic content to better mimic the native habitat.

10. A Tier One Assessment according to the Inland Testing Manual (ITM) adopted by the Corps and the EPA in 1998 should be conducted on borrow sediments for the project that are removed from disposal islands, inland waterways and navigational channels, and such documentation should be included in the EIS. Should any sediments contain contaminants or toxins that exceed EPA standards, appropriate measures should be taken to manage the contaminants.

11. Since there is no single period of the year when work could be scheduled to avoid adverse impacts to all the fish and wildlife resources in the project area (Table 19), the best way to minimize adverse impacts is to reduce the duration of construction. Reduced construction time can be achieved by the simultaneous use of more than one dredge. On balance, the most limited resources, e.g., an undisturbed beach, would benefit from dredging during the winter months. Therefore, the Service recommends that initial construction be accomplished by using at least two dredging vessels that commence work on or after November 15. These vessels would work as weather allows through the winter and attempt to finish initial construction by March 31. If some work remained after March 31, these vessels would continue work into the spring until work was completed. Sediment replacement operations should follow a similar pattern, but with a reduced work period. Sand replacement operations should be limited to the period from November 15 through the end of February. Scheduling beach disposal outside the larval recruitment period of beach invertebrates will ensure better recovery for these species.

12. The interval between renourishment episodes should be as long as possible to minimize the potential for severe semipermanent to permanent cumulative impacts to the

ecosystems in the project area. Beach fill should be monitored with subaerial and subaqueous profiles on a regular basis (perhaps quarterly and after every storm) to determine the longevity of the material's placement, and thus how long the material affects the biological substrate.

13. The project length should be as short as possible to reduce impacts to invertebrate populations and facilitate recovery via recruitment from nearby undisturbed areas. Caswell Beach should be considered for exclusion as a placement area due to its receipt of maintenance dredging materials from the Wilmington Harbor deepening and realignment project.

14. Heavy equipment used to manipulate fill sediments placed on the beach should be kept to a minimum, perhaps only one regular size bulldozer on any given beach at any given time. Heavy equipment should not be stored on the beach, and night work should use the minimum amount of light necessary (which may require shielding) or low pressure sodium lighting during project construction.

15. All dredging activities should comply with existing agreements with the NMFS and the U.S. Fish and Wildlife Service as to timing and types of allowable dredges. Hopper dredges should not be used during the summer sea turtle nesting season or spring and fall migration periods when species numbers in inland waters are high. Observers should be present on all hopper dredges to monitor for incidental takes of sea turtles year-round. All takes should be documented and reported to the Service and NMFS, and appropriate conservation measures coordinated in the event of excess takes. The Corps should coordinate with the NMFS to develop procedures to avoid adverse impacts to marine mammals that may occur in the area of the offshore borrow sites.

Beyond the broad measures given above, the Service recommends the following measures to benefit specific resources:

16. Dredging activities should not occur adjacent to disposal islands during the colonial waterbird nesting season of April 1 to October 31 to minimize disturbance to such nests. Construction activities that could disturb colonial waterbirds with noise, lights and fumes should be minimized at all times of the year. Potential screening/blocking or other appropriate conservation measures should be coordinated with the North Carolina Colonial Waterbird Management Committee and other relevant agencies.

17. Spoil islands should not be pumped out or refilled during the colonial waterbird nesting season to minimize disturbances to nesting habitat and existing nests.

18. If sediment placement extends into the sea turtle nesting and hatching season, May 1 through November 15 of any year, the Corps must initiate formal consultation in

accordance with Section 7 of the Endangered Species Act. Sediment placement during this period will require a program of sea turtle nest monitoring and relocation. Furthermore, the Corps should incorporate into formal project plans measures designed to help state-approved sea turtle monitoring programs.

19. The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act of 1996 (Public Law 104-297) requires that essential fish habitat (EFH) be identified. The surf zone, live/hardbottoms, artificial reefs and Frying Pan Shoals have already been designated as EFH. The Corps must consult with the NMFS regarding the impact of the proposed project on those species for which the proposed borrow sites and adjacent areas have been determined to constitute EFH. Fishery management councils are mandated to comment to the Corps regarding the impact of the proposed project on anadromous species; therefore, the New England, Mid-Atlantic and South Atlantic Fishery Management Councils (SAFMC), as well as the Atlantic States Marine Fisheries Commission, should be contacted and provided with an opportunity to review the Corps' environmental documents for the proposed project.

    The consultation process in the Southeast Region of the NMFS is addressed in NMFS (1999) that contains a list of the species managed by the SAFMC and NMFS, their EFH, and the geographically defined Habitat Areas of Particular Concern (HAPC) identified in Council Fishery Management Plans. In North Carolina, the SAFMC identified the sandy shoals of Cape Fear, within the study area, as an HAPC.

    Consultation requirements in the Magnuson-Stevens Fishery Conservation and Management Act direct federal agencies to consult with NMFS when any of their activities may have an adverse effect on EFH (NMFS 1999; see also National Oceanic and Atmospheric Administration (NOAA) 1999 for information on the NMFS northeast region). The EFH rules define an **adverse effect** as "any impact which reduces quality and/or quantity of EFH...[and] may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific or habitat wide impacts, including individual, cumulative, or synergistic consequences of actions." Since the proposed project would result in the removal from the study area of several million cubic yards of substrate during the course of the proposed 50-year project life, it would appear that this project meets the criteria for constituting an adverse effect and that the Southeast Region of NMFS should be contacted by the Corps for that purpose.

20. Beach fill should be monitored for compaction and escarpment formation. Immediately after completion of sand disposal on beaches and prior to sea turtle nesting seasons, monitoring should be conducted to determine if escarpments are present and escarpments should be leveled as required to reduce the likelihood of impacting sea turtle nesting and hatching activities.

21. The project should include an annual monitoring program on beach and subtidal invertebrates that form an important food resource for shorebirds and surf fishes. The project should include a requirement for a pre-project assessment of beach invertebrate biomass and community composition, i.e., the number of species present, and incorporate data expected to be gathered during monitoring of the Wilmington Harbor deepening project and from the New Jersey Erosion Control Project (Asbury Park to Manasquan Section Beach; see Appendix C for the Executive Summary). The program should have adequate control areas such as Sunset Beach and the area to the south of Fort Fisher. There should be an additional requirement to quantify changes in biomass and community composition at one-. three-, five-, and ten years after initial construction. If an assessment indicates a significant decline in either biomass or the number of species present when compared to control areas, there should be definite procedures in place to develop mitigation for this community.

The most significant environmental impacts of the proposed 50-year effort of sand removal and beach placement will be indirect. In this regard, it is necessary to look beyond the impacts of the initial construction and consider the many sand replacement operations that are currently scheduled at three year intervals, but over the decades are likely to become more frequent.

The loss of the offshore benthic community during dredging is a direct project impact. However, the more serious issue regarding this community is its ability to recover from dredging and continue to provide the primary production to support consumers at higher trophic levels in offshore waters. The avoidance of any significant increase in depth along with maintenance of the sediment characteristics of offshore bottoms would help maintain primary productivity. While the assessments in Recommendation 7 would seek to quantify impacts on the benthic community, the Service recommends the following measures to minimize the long-term impacts on all offshore benthic organisms:

22. Dredging should leave a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment; and,

23. Dredging should not create numerous deep pits that are likely to refill with much finer material and permanently alter the nature of the substrate.

24. The Corps should ensure that no hardbottom habitats are affected by sedimentation produced by the project, either as a result of offshore dredging or sediment washing off the beach. This goal may be accomplished by actual surveys of the borrow sites and the review of data provided by the Southeast Monitoring and Assessment Program (SEAMAP). If hardbottoms are adversely affected, the project should include specific measures to mitigate any adverse impacts.

Fish and wildlife resources will benefit by prolonging the life of the artificial beach-dune system. Measures which prolong the life of the beach-dune system will minimize all the direct impacts discussed in Section 10 as well as minimize the cumulative impacts by allowing time for impacted population to recover. Therefore, the Service recommends that:

25. Borrow areas should be located seaward of the active shoreface of the beach and inlet systems to avoid significant changes in the bathymetry over which waves approach project area beaches.

26. Existing offshore sand shoals or sand bars should not be removed for use in creating the beach-dune system.

27. The borrow area should be monitored regularly with both bathymetric surveys (preferably multi-beam or Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS)) and benthic organism surveys to establish recolonization rates and success or failure. Bathymetric surveys would generate data on changes to the borrow pit due to altered current or wave patterns, which could suspend portions of sediments and lead to siltation or increased local turbidity levels. Any measured impacts over the life of the project should be mitigated through coordination with the Service, NMFS and other relevant agencies.

28. Beaches scheduled to receive periodic sand placements in perpetuity should be monitored long-term for increased erosion rates, decreased biological productivity and cumulative impacts to fish and wildlife resources, especially Federally-listed species such as sea turtles, piping plovers, and seabeach amaranth. Any measured, long-term impacts arising over the lifespan of the project and its maintenance should be mitigated through coordination with the Service, NMFS and other relevant agencies.

To ensure that this project does not exacerbate navigation of nearby inlets, the Service recommends:

29. The EIS should fully discuss: (1) the potential rates of sediment losses from the beach fill based on grain size data (the Sand Suitability Analysis); (2) the impact of using inlet sand bodies as borrow materials on inlet shoaling, wave patterns and adjacent shoreline erosion rates; (3) the likely pathways that may carry over a million cubic yards of sand per year for 50 years away from the beach; and, (4) the likely locations that would ultimately receive the sediment carried away from the beach.

The Service has serious concerns about the ability of an artificial beach-dune system to provide long-term protection for structures on a barrier island, or barrier spit, surrounded by a rising sea. The measures given in this section should help to avoid or minimize some of the adverse environmental impacts. While some measures may add to project costs, any additional costs should be weighed against the gains in environmental quality. Some of these gains, such as protecting offshore fisheries, would have a measurable economic benefit that should be considered in the alternative selection process. Other recommendations seek to extend the period between sand replacement operations and such measures would reduce overall costs. Therefore, the Service requests that these recommendations be incorporated into the NEPA planning process for storm damage reduction in Brunswick County.

SECTION 14. SUMMARY AND POSITION OF SERVICE

The data and analysis presented in this report have led the Service to a number of findings and conclusions. These findings have been thoroughly considered in the development of our position on the proposed alternative for storm damage reduction in the project area.

Summary of Findings

Barrier islands and spits are inherently dangerous places for any man-made structures such as roads, houses, or utility infrastructure. The islands are subject to the full force of both tropical hurricanes and, to a lesser extent, winter storms. Early residents recognized this fact of life and built their homes as far from the ocean as possible. The faith in modern technology, government sponsored insurance that the private sector finds too risky, and a relative lull in destructive storms from the early 1960s to the late 1980s have resulted in expensive development on an ocean shoreline that is retreating in the face of a rising sea. As the ocean moves closer to fixed structures the risk of storm damage increases. The Service recognizes the increasing risk of storm damage and supports the goal of reducing such damage.

The Service is also concerned that constructing artificial beaches is often presented as the only way to save a recreational beach. This is clearly a false argument. If the ocean destroyed barrier island beaches, they would have disappeared thousands of years ago. The real issue is not whether barrier islands will have recreational beaches, but where these beaches will be located. Powerful hydrologic and geologic forces are trying to move the beaches to higher ground as sea level rises. Beachfront property owners want the beach in front of their homes, not under or behind them. A truly impartial observer might conclude that it is the beachfront property owners that are destroying the recreational beaches by pushing the sand back into the sea every time an ocean overwash moves the beach landward. If the fact of barrier island migration was widely accepted, recreational facilities would adapt and tourists would continue to enjoy the beaches with little regard for the fact that the beach moved a few yards every year. Overall, the preservation of recreational beaches and the tourist economy which they support provides no justification for constructing artificial beaches.

On the other hand, the key question regarding storm damage reduction is not whether it is a desirable goal, but the best method to achieve this goal on a barrier island. The Corps, with the support of local interests, has proposed the creation of an artificial beach-dune system between the ocean and structures on the shoreline. Current planning documents do not fully explain the alternatives that were considered or the reasoning leading to the selection of this alternative. The Service finds that this decision requires greater support than has been made available to date. For instances, the majority of the targeted borrow and fill areas are within areas designated as Essential Fish Habitat, the Corps has not provided justification for disturbing these areas to meet the project purpose and need.

Our desire for greater justification is based on three points. First, the creation of an artificial beach-dune system from sand dredged in other areas of the coastal system is not the innocuous procedure that it may once have been considered. Construction and 50 years of maintenance for an artificial beach-dune system would significantly alter the diverse ecosystems of the project. The material presented in Section 10 clearly indicates that some direct impacts may be serious, but they are usually short-lived and localized. The more serious impacts are the secondary, indirect impacts which may seem inconsequential on a year to year basis, but which accumulate over the years and decades without ever allowing the affected resources to return to pre-project levels. Within the past 10 years new data have been presented on the serious impacts these projects have on natural beach communities, offshore communities, nesting sea turtles, and even commercially important fisheries. Unfortunately, these findings have usually been based on only a few years of study, and the longer-term, cumulative impacts have yet to be reported. The selection of a preferred alternative should be based on thorough evaluation of impacts over a period of at least 50 years.

Second, there is a fundamental difference in the long-term ramifications between constructing beaches and dunes on a mainland shoreline and the same construction on a barrier island. Sand may be added to a beach that is a part of the mainland without a threat to the long-term existence of the uplands behind the beach. However, a barrier island or spit is surrounded by a rising sea that may rise at an accelerating rate. Barrier islands must move landward to stay above the rising sea. An artificial barrier along only one side of an island cannot provide real long-term protection. Such a barrier signifies a commitment to hold back the sea and protect structures in their present location. In time, an artificial beach-dune system will prove inadequate as damaging seas sweep around the edges and come in from the sound. Sea level rise combined with the natural reaction of the barrier islands to migrate landward makes the long-term maintenance of structures in a fixed location impossible. If the original commitment remains unchanged, the barrier island eventually must be ringed by a continuous dike that will destroy both the beach and the estuarine wetlands on the sound margin. This is a basic concern of the Service.

Third, there are proven alternatives to constructing beaches and dunes for storm damage reduction that have not been adequately considered. As noted, constructed beaches are less harmful than hard structures for controlling shoreline recession. However, constructed beaches are the most environmentally damaging alternative for storm damage reduction. A combined program of selective removal and relocation of structures, strict zoning laws that fully consider the natural rate of shoreline recession, and improved building standards may actually be more economical and efficient over the long term. Current planning has not adequately considered alternatives to beach-dune construction. This appears to be the result of a poorly defined purpose for the project. The NEPA document should state the level of storm for which protection would be provided, the types of storm processes for which protection would be provided, and the area to be protected. With a clearly defined purpose the widest possible range of alternatives could be developed and evaluated.

The Service finds that current planning for storm damage reduction in Brunswick County has not presented evidence that all direct and indirect environmental impacts of constructing an artificial beach-dune system were fully considered in the selection of the beach-dune system. The construction and maintenance of such a system would have profound impacts on the barrier island ecosystem over the 50 years of official project life. The project EIS should demonstrate an understanding of these impacts in the selection of best means to reduce storm damage in the project area.

Position of the Service

Overall, the Service supports the goal of storm damage reduction. The Service also supports the planning process of the NEPA. However, at the current time the Corps has not clearly defined either the type of damage to be reduced or the area to be protected. Such definitions are necessary to fully develop and evaluate the greatest range of alternatives. Furthermore, current planning has not adequately considered the unique nature and geological forces acting on these barrier islands. Such considerations are critical in fully describing the long range, secondary impacts of the project. In regard to a very serious, potential project impact, the Corps and the Service must work together to ensure that the placement of millions of cubic yards of sand on project area beaches is not allowed to result in semi-permanent to permanent cumulative impacts.

In the past the Service has expressed concern about the environmental impacts of other projects to modify the beaches of Brunswick and New Hanover Counties. The large construction effort needed to construct and maintain an artificial beach-dune system, essentially in perpetuity, will certainly create significant direct, indirect, and cumulative adverse environmental impacts. While the Service supports a non-structural approach to storm damage reduction, a thorough consideration of the environment during planning for any alternative can avoid many of the most severe impacts and minimize others.

While the Service has serious reservations about the long-term efficacy of an artificial beach-dune system to protect existing structures on a barrier island, the decision to postpone the day of reckoning ultimately lies with the citizens of the project area and their elected representatives. If the thorough evaluation of all social and environmental factors required by the NEPA planning process should confirm that an artificial beach-dune system is the best overall alternative, we believe that the incorporation of the Service's recommendations given in this report into the design and construction of the project will avoid or minimize many of the most serious adverse impacts on the fish and wildlife resources in the project area. Those impacts that cannot be avoided should be mitigated.

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APPENDICES