1.0 INTRODUCTION

This Final Environmental Impact Statement (FEIS) has been prepared in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended[1] [42 United States Code (USC) 4321-4347], to disclose and address the environmental effects of proposed shore protection activities on the barrier island of Holden Beach in Brunswick County, North Carolina (NC). The Wilmington District, United States Army Corps of Engineers (USACE) is evaluating a request from the Town of Holden Beach (Applicant) for Department of the Army (DA) authorization pursuant to Section 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act (RHA) to implement a 30-year Shore Protection Project for protection of the east end ocean shoreline bordering Lockwoods Folly Inlet (LFI). The NEPA requires federal agencies to consider the environmental effects of their actions; including issuing federal permits and other regulatory approvals for non-federal projects. The USACE is the lead federal action agency responsible for NEPA compliance and management of the NEPA/EIS environmental review process for the Applicant's proposed action. This FEIS has been prepared to fulfill the NEPA environmental review obligations of the USACE in making a decision to issue or deny Section 404/Section 10 permits for the Applicant's proposed action. The review of this FEIS through the NC State clearinghouse process will also fulfill the environmental review obligations of state agencies pursuant to the NC State Environmental Policy Act (SEPA) (GS 113A-1-13).

1.1 Project Overview

Holden Beach is an approximately (~) 8.1-mile-long barrier island located ~15 miles west of Cape Fear along the southeastern coast of NC (Figure 1.1). The east-west oriented island faces the Atlantic Ocean to the south and is separated from mainland Brunswick County to the north by the Atlantic Intracoastal Waterway (AIWW). LFI separates the island from Oak Island to the east, and Shallotte Inlet separates the island from Ocean Isle to the west. While most of the Holden Beach oceanfront shoreline has experienced long-term net erosion over the last 70 years, erosion has been most severe along the easternmost (East End) shoreline reach within ~1.2 miles of LFI, where average long-term erosion rates range from -3 to -8 ft/yr [North Carolina Division of Coastal Management (NCDCM) 2011]. Chronic erosion has contributed to dune breaching and flooding along the East End and has resulted in the loss of approximately 27 oceanfront properties since 1993. The Applicant is proposing to mitigate chronic and ongoing East End erosion through the construction of a terminal groin at the eastern terminus of the oceanfront beach bordering LFI and periodic nourishment of the ~0.8-mile East End oceanfront shoreline reach between LFI and Blockade Runner Drive. The Applicant's proposed action and the alternatives that were evaluated as part of the NEPA EIS process are described in detail in Section 3.0 of this FEIS.

[1] PL 91-190, January 1, 1970, as amended by PL 94-52, July 3, 1975; PL 94-83, August 9, 1975; PL 99-160, November 25, 1985; PL 100-202, December 22, 1987; PL 100- 404, August 19, 1988; PL 101-144, November 9, 1989, and PL 102-389, October 6, 1992

Figure 1.1. Study Area - Holden Beach East End Shore Protection Project

1.2 Overview of the NEPA EIS Process

The Council on Environmental Quality (CEQ) NEPA implementing regulations (40 CFR 1500-1508) direct federal agencies to prepare a detailed EIS for major federal actions that significantly affect the quality of the human environment. As defined by the CEQ regulations, the "human environment" encompasses the natural and physical environment and the relationship of people with that environment (i.e., socioeconomic factors such as public health and safety, jobs, property values, and aesthetics). The NEPA EIS process is an interdisciplinary impact analysis approach that emphasizes the evaluation of reasonable alternatives, public involvement, and an unbiased assessment of environmental effects. The purpose of an EIS is to support informed decision making by federal agencies based on an understanding of environmental consequences. The information presented in this FEIS will support the USACE decision-making process, which will include an evaluation to determine the Least Environmentally Damaging Practicable Alternative (LEDPA) and the selection of a course of action for implementation. The USACE will document its decision and conclude the NEPA process through the issuance of a Record of Decision (ROD). This FEIS has been prepared in accordance with the CEQ regulations, USACE Procedures for Implementing NEPA (33 CFR 230), and USACE NEPA Implementation Procedures for the Regulatory Program (33 CFR Part 325 Appendix B). An overview of the major steps in the NEPA process as they have been applied to the evaluation of the Applicant's proposed action is provided below.

Scoping

Scoping is the process used to engage the public in defining the range of issues and alternatives that will be addressed in an EIS. The NEPA scoping process for the Applicant's proposed action was initiated by the USACE through the publication of a Notice of Intent (NOI) in the Federal Register (FR) on 24 February 2012 (77 FR 11085-11086). The NOI stated the intent of the USACE to prepare a Draft EIS (DEIS), briefly described the proposed action, and outlined opportunities for the public to participate in the DEIS scoping process. The NOI initiated a 30-day public comment period that was open from 24 February to 26 March 2012. Additionally, the NOI invited the public to participate in a public scoping meeting that was held at the Holden Beach Town Hall on 8 March 2012. A synopsis of the public scoping meeting comments and copies of all written comments received are provided in Appendix A.

Draft Environmental Impact Statement

With due consideration of the comments received through scoping, a DEIS was prepared to evaluate the environmental effects of the proposed action and a range of reasonable alternatives. The USACE announced the release of the DEIS for public review and comment through the publication of a Notice of Availability (NOA) in the Federal Register on 28 August 2015 (80 FR 52264-52265). The DEIS was made available to the public through publication on the USACE Wilmington District website. The NOA initiated a 45-day public comment period that was open from 28 August to 13 November 2015. Additionally, the NOA invited the public to comment on the DEIS through participation in a public meeting that was held at the Holden Beach Town Hall on 24 September 2015. A transcript of the public meeting and copies of all written comments received on the DEIS are provided in Appendix B.

Final Environmental Impact Statement

This FEIS has been prepared to address public and agency comments on the DEIS. Additional information and analyses have been incorporated as necessary to address all substantive DEIS comments. The responses of the USACE to individual public and agency comments are presented in Appendix B. When applicable, Appendix B identifies the FEIS section and page number where new information and/or revisions have been incorporated in response to specific comments. The USACE will announce the release of this FEIS for an additional 30-day public review and comment period through the publication of an NOA in the Federal Register. The FEIS will also be made available to the public through publication on the USACE Wilmington District website. The USACE will consider all FEIS comments in making a final decision on the Applicant's proposed action.

Record of Decision

After considering all comments on the FEIS, the USACE will select a course of action for implementation and conclude the EIS process through the issuance of a ROD. The ROD will identify the selected course of action and explain the basis for the agency's decision. The ROD will describe how the relative impacts of the alternatives, proposed mitigation measures, and public comments were considered and factored into the decision-making process. The USACE will post the ROD and a Public Notice (PN) announcing its release on the Wilmington District web site. The ROD will constitute the agency's final decision on the Applicant's proposed action.

1.3 Agency Coordination and Involvement

The USACE is the lead federal action agency responsible for NEPA compliance and the preparation of this FEIS. Participation by other federal, state, and local agencies has been encouraged throughout the NEPA process. Concurrent with the initiation of public scoping, the USACE formed an EIS Project Review Team (PRT) consisting of federal and state agencies, local governments, and other organizations representing a wide range of interests in the EIS process (Table 1.1). The PRT was established as an outreach mechanism to facilitate agency and stakeholder involvement in the EIS scoping process. A principal objective of the PRT process was to identify and address agency scoping issues and concerns early in the planning process. PRT meetings were held at the Holden Beach Town Hall on 6 September 2012 and 30 May 2013. Project Review Team meeting notes and lists of participants are provided in Appendix A.

Table 1.1. Project Review Team.

Name	Representing	Email
Lead Federal Agency		
Hughes, Emily	USACE Wilmington District	Emily.b.hughes@usace.army.mil
Pruitt, Carl	USACE Wilmington District	Carl.e.pruitt@usace.army.mil
Castens, Pam	USACE Wilmington District	Pamela.G.Castens@usace.army.mil
Horton, Todd	USACE Wilmington District	James.T.Horton@usace.army.mil
Federal Agencies		
Rhode, Fritz	NMFS	Fritz.rohde@noaa.gov
Ellis, John	USFWS	John_Ellis@fws.gov
Fox, Becky	EPA	fox.rebecca@epa.gov
State Agencies		
Huggett, Doug	NCDCM	Doug.huggett@ncdenr.gov
Howell, Jonathan	NCDCM	jonathan.howell@ncdenr.gov
Coats, Heather	NCDCM	Heather.coats@ncdenr.gov
Steenhuis, Joanne	NCDWR	Joanne.Steenhuis@ncdenr.gov
Dunn, Maria	NCWRC	Maria.dunn@ncwildlife.org
Schweitzer, Sara	NCWRC	sara.schweitzer@ncwildlife.org
Godfrey, Matthew	NCWRC	Matthew.godfrey@ncwildlife.org
O'Neal, Jessi	NCDMF	Jessi.Oneal@ncdenr.gov
Deaton, Anne	NCDMF	anne.deaton@ncdenr.gov
Gledhill-Earley, Renee	NCSHPO	renee.gledhill-earley@ncdcr.gov
Local Government		
Holden, Alan	Holden Beach Mayor	Holden@atTheBeachNC.com
Hewett, David	Holden Beach, Town Manager	dhewett@hbtownhall.com
Wiggins, Amanda	Holden Beach, Parks and Recreation	recsvs@hbtownhall.com
Other Stakeholders		
Foster, Steve	Oak Island, Town Manager	sfoster@ci.oak-island.nc.us
Marwitz, Tony	Holden Beach Turtle Patrol	marwitzathbeach@mindspring.com
Giles, Mike	Coastal Federation	capefearcoastkeeper@nccoast.org
Williams, Dr. Allen	Holden Beach Renourishment Association	extractor2@hotmail.com
Varnam, Jackie	Brunswick Catch	nanasemail@atmc.net
Rader, Douglas	Environmental Defense Fund	
Fisher, Andy	Long Bay Artificial Reef Association	agitatorfisher@bellsouth.net
Third Party Preparer		
York, Dawn	Dial Cordy and Associates	dyork@dialcordy.com
Ingle, Rahlff	Dial Cordy and Associates	ringle@dialcordy.com
Dial, Steve	Dial Cordy and Associates	sdial@dialcordy.com
Project Design Team		
Way, Fran	Applied Technology & Management	fway@appliedtm.com
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Jenkins, Dr. Mike	Applied Technology & Management	mjenkins@appliedtm.com
Roessler, Todd	Kilpatrick Townsend	troessler@kilpatricktownsend.com
Levitas, Steve	Kilpatrick Townsend	slevitas@kilpatricktownsend.com
Cleary, Dr. Bill	Geologist	wcleary@charter.net

The DEIS was made available to federal, state, and local environmental agencies for a 45-day review and comment period. The USACE requested comments from other federal agencies including the US Environmental Protection Agency (USEPA), the US Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). In compliance with SEPA, the DEIS was distributed to state and local agencies for review through the NC State Clearinghouse process. The Clearinghouse is responsible for publishing NOAs in the NC Environmental Bulletin, forwarding NEPA documents to state/local agencies, and compiling all agency comments. Copies of all federal, state, and local comments and the responses of the USACE to those comments are provided in Appendix B. This FEIS will be made available to federal, state, and local agencies for an additional 30-day review and comment period. Upon completion of the State Clearinghouse review process for this FEIS, no additional SEPA coordination will be required. The USACE will consider all agency comments on the FEIS in making a final decision on the Applicant's proposed action.

The USACE Section 404/Section 10 permitting action requires consultation under a number of other federal laws. Although these additional consultations are conducted independently of NEPA under separate federal authorities, they are an important component of the EIS scoping and review process. As the lead federal action agency, the USACE consulted with the USFWS and NMFS pursuant to Section 7 of the Endangered Species Act (ESA) (16 USC 1536) and the Fish and Wildlife Coordination Act (FWCA) (16 USC 661 et seq.) and with NMFS pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (16 USC 1801 et seq.). As part of the ESA Section 7 consultation with the USFWS and NMFS, the USACE prepared a Biological Assessment (BA) to evaluate the effects of the proposed action on listed species and critical habitats. The USFWS responded through the issuance of a Biological Opinion (BO) dated 21 July 2016 (Appendix C). NMFS provided comments pursuant to the ESA in a letter dated 30 August 2016 (Appendix B). As part of the MSFCMA consultation with NMFS, the USACE prepared an Essential Fish Habitat (EFH) Assessment to evaluate the effects of the proposed action on federally managed fishery species and EFH habitats. NMFS provided comments pursuant to the MSFCMA and the FWCA in a letter dated 30 August 2016 (Appendix B). The USFWS provided comments pursuant to the FWCA through the DEIS public/agency review process in a letter dated 2 October 2015 (Appendix B). The USACE has also consulted with state agencies that are charged with implementing federal regulatory programs; including the NCDCM) pursuant to the Coastal Zone Management Act (CZMA), the North Carolina Division of Water Resources (NCDWR) pursuant to Section 401 of the CWA, and the North Carolina State Historic Preservation Office (NC SHPO) pursuant to Section 106 of the National Historic Preservation Act (NHPA) (16 USC 470 et seq.). Additional information on applicable federal and state laws and agency coordination is provided in Sections 1.4 and 1.5.

1.4 Applicable Federal Laws and Executive Orders

The USACE Section 404/Section 10 federal regulatory action triggers additional regulatory consultation and compliance requirements under a number of other federal environmental laws and executive orders. Those most relevant to the proposed action are briefly described below.

Section 10 of the Rivers and Harbors Act of 1899 (RHA)

Section 10 of the RHA (33 U.S.C. 403) authorizes the USACE to issue permits for work in navigable waters; including construction, excavation, and the deposition of material. Navigable waters are those that are "subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce" (33 CFR Part 329). USACE Section 10 regulatory authority extends seaward to the 3-nm limit between state and federal waters. As previously described, the issuance of Section 10 permits for beach nourishment and dredging activities is a federal action requiring environmental review pursuant to NEPA.

Sections 404 and 401 of the Clean Water Act of 1972 (CWA)

Section 404 of the CWA (33 USC 1344) authorizes the USACE to issue permits for the discharge of dredged or fill material into waters of the US, including wetlands. USACE regulatory authority under Section 404 extends seaward to the 3-nautical mile (nm) limit between state and federal waters. As previously described, the issuance of Section 404 permits for beach nourishment and dredging activities is a federal action requiring environmental review pursuant to NEPA. Pursuant to the CWA, the USACE may only issue a Section 404 permit for the Least Environmentally Damaging Practicable Alternative (LEDPA). When an EIS is required, a LEDPA determination is included in the ROD. Section 401 of the CWA (33 USC 1341) delegates federal authority to the state to issue 401 Water Quality Certifications for the discharge of dredged and fill material into Waters of the State. All projects that require a federal Section 404 permit for the discharge of dredged and fill material also require a corresponding 401 Water Quality Certification from the NCDWR.

Section 7 of the Endangered Species Act of 1973 (ESA)

Pursuant to Section 7 of the ESA (16 USC 1536), federal agencies are required to consult with the USFWS and the NMFS to ensure that actions they undertake, fund, or authorize are not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. As in the case of NEPA, the issuance of Section 404/10 permits by the USACE is a federal action that triggers Section 7 consultation. The USACE consulted informally with the USFWS and NMFS on the Applicant's proposed action through the PRT meetings and other channels of communication. To facilitate the consultation process, the USACE prepared a Biological Assessment (BA) to evaluate the effects of the proposed action on listed species and critical habitats. The USACE initiated formal Section 7 consultation through submittal of the BA to the USFWS and NMFS. The Section 7 process concluded with the issuance of a BO by the USFWS (Appendix C) and an informal consultation response letter from NMFS (Appendix B).

Magnuson-Stevens Fishery Conservation and Management Act of 1996 (MSFCMA)

The MSFCMA (16 USC 1801 et seq.) requires federal agencies to consult with NMFS to ensure that actions they undertake, fund, or authorize incorporate Essential Fish Habitat (EFH) conservation into the planning process. EFH habitats are defined as those "necessary to fish for spawning, breeding, feeding, or growth to maturity." The Fisheries Management Councils (FMCs), with assistance from NMFS, are responsible for identifying and delineating EFH in Fishery Management Plans (FMPs). The USACE is lead federal action agency responsible for consulting with NMFS on the Applicant's proposed action. The USACE prepared an EFH Assessment report describing the affected resources, anticipated impacts, and measures that were incorporated to mitigate EFH impacts. Submittal of the EFH Assessment to NMFS initiated formal consultation, and the process was concluded by the issuance of an EFH concurrence letter by NMFS (Appendix B).

Fish and Wildlife Coordination Act of 1958 (FWCA)

The FWCA (16 USC 661 et seq.), as amended, requires federal agencies to incorporate fish and wildlife resource conservation into the planning process for water resources development projects that they undertake, fund, or authorize. Section 2(b) of the FWCA requires the federal action agencies for water resource projects to consult with the USFWS, NMFS, and state fish and wildlife agencies to ensure that conservation is fully incorporated. The USFWS and NMFS are responsible for identifying potential adverse impacts on fish and wildlife resources and developing recommendations to avoid, minimize, and/or compensate for impacts. The NMFS provided integrated comments pursuant to both the FWCA and the MSFCMA in a letter dated 30 August 2016 (Appendix B). The USFWS provided comments pursuant to the FWCA through the DEIS public/agency review process in a letter dated 2 October 2015 (Appendix B).

Marine Mammal Protection Act of 1972 (MMPA)

The MMPA (16 USC 1361 et seq.) prohibits the take of marine mammals in US waters and authorizes programs to conserve, protect, and recover declining marine mammal populations. Although take is generally prohibited, the MMPA makes allowances for limited take through permits and incidental take authorizations. The responsibilities for implementing the MMPA are divided between the NMFS (cetaceans and pinnipeds) and the USFWS (manatees, dugongs, sea otters, walruses, and polar bears). In regard to the Applicant's proposed action, the MMPA does not impose any specific consultation requirements on the federal action agency; however, the USFWS and NMFS review federal actions potentially affecting marine mammals under their jurisdictions through the ESA Section 7 and FWCA consultation processes and the NEPA review process.

Migratory Bird Treaty Act of 1918 (MBTA)

The MBTA (16 USC 703 et seq.) prohibits the take of migratory birds and authorizes the USFWS to implement programs to conserve, protect, and recover declining migratory bird populations. The MBTA does not make any allowances for incidental take; however, incidental take for species listed as threatened or endangered under the ESA may be authorized through the ESA Section 7 consultation process. In regard to the Applicant's proposed action, the MBTA does not impose any specific consultation requirements on the federal action agency; however, the USFWS comments on federal actions potentially affecting migratory birds through the FWCA consultation and NEPA review processes.

Coastal Zone Management Act of 1972 (CZMA)

The CZMA (16 USC 1451 et seq.) established a cooperative program between the federal government and the coastal states for the management and protection of coastal resources. The CZMA is carried out primarily by the coastal states through the development and implementation of federally approved coastal management programs. As described in greater detail below, NC's coastal management program was established by the NC Coastal Area Management Act of 1974 (CAMA).

National Historic Preservation Act of 1966 (NHPA)

Pursuant to Section 106 of the NHPA (16 USC 470 et seq.), federal agencies are required to consider the effects of actions they undertake, fund, or authorize on historic properties that are listed or may be eligible for listing in the National Register of Historic Places (NRHP). Federal action agencies are required to consult with the Advisory Council on Historic Preservation (ACHP) and/or State Historic Preservation Offices (SHPOs) to identify historic properties potentially affected by proposed actions, assess the effects, and mitigate adverse impacts. The consultation provisions of Section 106 apply to state lands, including submerged lands underlying state waters. The USACE initiated consultation with the NC SHPO through the State Clearinghouse EIS review process. The SHPO responded through the Clearinghouse that it had no comment on the Applicant's proposed action (Appendix B).

Executive Order (EO) 11988 - Floodplain Management

EO 11988 directs federal agencies to take action to reduce the risk of flood loss; minimize the impact of floods on human safety, health and welfare, and restore and preserve the natural and beneficial values of floodplains. Pursuant to EO 11988, federal agencies have a responsibility to evaluate the effects of their actions to ensure that flood hazards and floodplain management are considered and addressed in the actions they authorize, fund, or implement.

EO 11990 – Protection of Wetlands

EO 11990 directs federal agencies to take action to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities. Pursuant to EO 11990, federal agencies are to avoid undertaking or providing assistance for new construction in wetlands unless the agency determines that: 1) there is no practicable alternative to such construction and 2) the proposed action includes all practicable measures to minimize harm to wetlands. In making such determinations, federal agencies may take into account economic, environmental, and other pertinent factors.

EO 12898 - Environmental Justice

EO 12898 directs federal agencies to identify and address disproportionately high and adverse environmental and human health effects of their actions on minority and low-income populations. Pursuant to EO 12898, federal agencies must develop environmental justice strategies to ensure that their programs, policies, and activities are conducted in a manner that does not exclude persons (including populations) from participation in, deny persons the benefits of, or subject persons to discrimination under their programs, policies, and activities because of their race, color, or national origin.

EO 13112 - Invasive Species

EO 13112 directs federal agencies to use their authorities to prevent the introduction, establishment, and spread of invasive species. Federal agencies are directed to evaluate their actions and avoid authorizing, funding, or implementing actions that are likely to promote the introduction, establishment, or spread of invasive species.

1.5 Applicable State Laws and Regulations

The proposed action is also subject to the environmental review provisions of SEPA and a number of state regulatory authorizations; including a Major Permit issued by the NCDCM under the NC CAMA, a Water Quality Certification issued by the NCDWR under Section 401 of the CWA, and an Erosion and Sedimentation Control Plan authorization issued by the NC Division of Land Resources (NCDLR) under the NC Sedimentation Pollution Control Act. State laws that are most relevant to the proposed action are described below.

North Carolina State Environmental Policy Act of 1971 (SEPA)

SEPA (GS 113A-1-13) is a law requiring state agencies to consider the environmental effects of their actions through an environmental review process that is essentially the state-level equivalent of the federal NEPA review process. In the case of federal actions, the NEPA process also fulfills the requirements of SEPA. The SEPA specifies that federal NEPA documents must be reviewed through the State Clearinghouse process, which is standard USACE practice for all regulatory EIS documents. The State Clearinghouse in the NC Department of Administration is responsible for implementation and administration of the SEPA review process. The Clearinghouse forwards SEPA/NEPA documents for review and comment to state/local agencies and publishes NOAs in the NC Environmental Bulletin soliciting agency review and comment. The Clearinghouse provides for a 30-45 day agency comment period, and is responsible for compiling agency comments. Upon completion of the FEIS State Clearinghouse review process, no additional SEPA coordination will be required.

North Carolina Coastal Area Management Act of 1974 (CAMA)

North Carolina's coastal management program was established by CAMA (GS 133A-100 et seq.). The coastal management program is implemented jointly by the state and local coastal county governments. The NCDCM implements state CAMA responsibilities, which include the designation of Areas of Environmental Concern (AECs), the establishment of management objectives and use standards for development activities within AECs, and issuance of state CAMA Major Permits for work in AECs and excavation or filling in estuarine waters, tidelands, marshlands, and state-owned lakes pursuant to the NC Dredge and Fill Law (GS 113-229). AECs are state-designated areas of natural importance that fall under four broad categories: the estuarine and ocean system, ocean hazard system, public water supplies, and natural and cultural resource areas. The Applicant's proposed action encompasses work in AECs associated with the estuarine and ocean system and the ocean hazard system, and will require a CAMA Major Permit from the NCDCM. At the county and municipal level, CAMA policies are implemented through the development and implementation of state-approved Land Use Plans (LUPs), which establish the local rules and policies for managing land use in compliance with the state's coastal management program. The CAMA also authorizes the NCDCM to review federal actions, including federal permitting actions, for compliance with the consistency provisions of the federal CZMA. Federal actions must demonstrate consistency with the key elements of the state's coastal management program; including state coastal management rules and policies established in Chapter 7 of Title 15A of the NC Administrative Code, the policies set forth in approved local LUPs, and the NC Dredge and Fill Law.

NC Senate Bill 110 and NC Coastal Policy Reform Act of 2013[2] *(Senate Bill 151 - Ratified)*

In June 2011, the General Assembly of North Carolina ratified Senate Bill 110 (Session Law 2011-387; An Act To Authorize The Permitting And Construction Of Up To Four Terminal Groins at Inlets Under Certain Conditions). The Act authorized the Coastal Resources Commission (CRC) to permit the construction of a terminal groin under a terminal groin pilot project provided the applicant demonstrated that specific criteria as outlined in the bill were met.

[2] Short Title for: An Act to Amend Marine Fisheries Laws; Amend the Laws Governing the Construction of Terminal Groins; and Clarify that Cities May Enforce Ordinances within the State's Public Trust Areas

The NC Coastal Policy Reform Act (NCCPRA) of 2013 incorporated subsequent provisions in the 2015 NC State Budget which allowed for the issuance of Major Permits for two additional terminal groins, raising the cap on terminal groins from four to six. Pursuant to the NCCPRA and its implementing regulations (NCGS 113A-115.1), applicants for terminal groin permits are required to provide: evidence that structures or infrastructure are threatened by erosion; an EIS prepared pursuant to SEPA; a list of property owners and local governments that may be affected by the groin along with proof that each has been notified of the groin permit application; a construction and maintenance plan for the groin and its associated beach fill component prepared by a professional engineer licensed to practice in NC; a plan for the management of inlet, estuarine, and ocean shorelines that are adjacent to and under the influence of the inlet; and proof of financial assurance sufficient to implement long-term maintenance and monitoring, mitigation measures, and modification or removal of the groin if necessary. The complete NCCPRA legislation is provided in Appendix D, and the Applicant's Inlet Management Plan is provided in Appendix E.

Easements in Lands Covered by Water (NCGS 146-12)

The ownership of submerged lands (below MHW) in navigable waters is vested in the state. Pursuant to NCGS 146-12, projects that place certain structures on state-owned submerged lands or place fill in navigable waters to raise state-owned submerged lands above the MHW line require an easement from the NC Department of Administration. The process of applying for an easement is integrated with the CAMA Major Permit application process.

NC Sedimentation Pollution Control Act of 1973 (SPCA)

The SPCA authorizes the NC Division of Energy, Mineral and Land Resources (NCDEMLR) to approve erosion and sedimentation control plans for all land-disturbing activities other than agriculture and mining. The SPCA requires the development and implementation of effective temporary and permanent control measures to prevent accelerated erosion and off-site sedimentation. An erosion and sedimentation control plan must be submitted by the applicant and approved by the NCDEMLR before any land disturbance is initiated on sites one acre or larger.

2.0 PURPOSE AND NEED

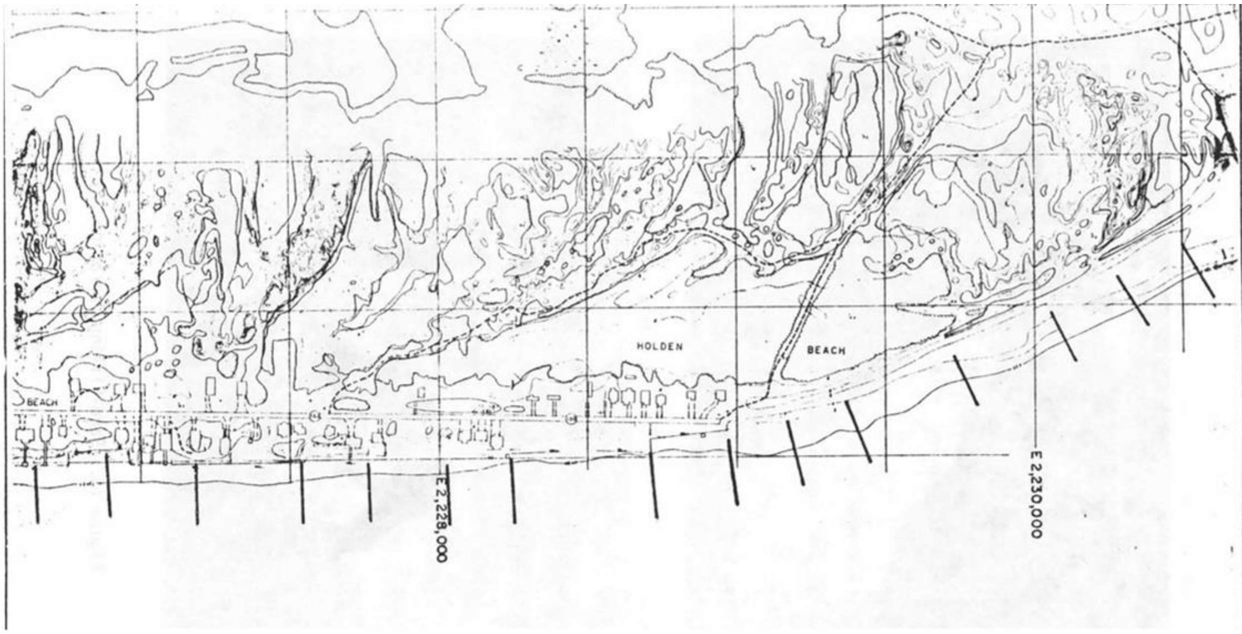
2.1 Project Purpose

The purpose of the Holden Beach East End Shore Protection Project (Proposed Action) is to mitigate ongoing and chronic erosion at the East End of Holden Beach and to protect and secure public infrastructure, roads, homes, businesses, rental properties, beaches, recreational assets, and protective dunes.

The Proposed Action would establish a comprehensive shoreline protection program, under the independent authority of the Town of Holden Beach, to restore and maintain the island's East End beach. The purpose of the Proposed Action is to mitigate ongoing and chronic East End shoreline erosion, which is projected to continue for the foreseeable future, and provide for the short- and long-term protection of residential structures, Town infrastructure, recreational assets, and natural resources. Furthermore, based on a growing need for additional shore protection beyond that provided by federal navigation projects, and the trend of declining federal funding for nourishment projects, an independent shore protection program under the authority of the Town is being proposed to ensure that the East End shoreline will be adequately protected.

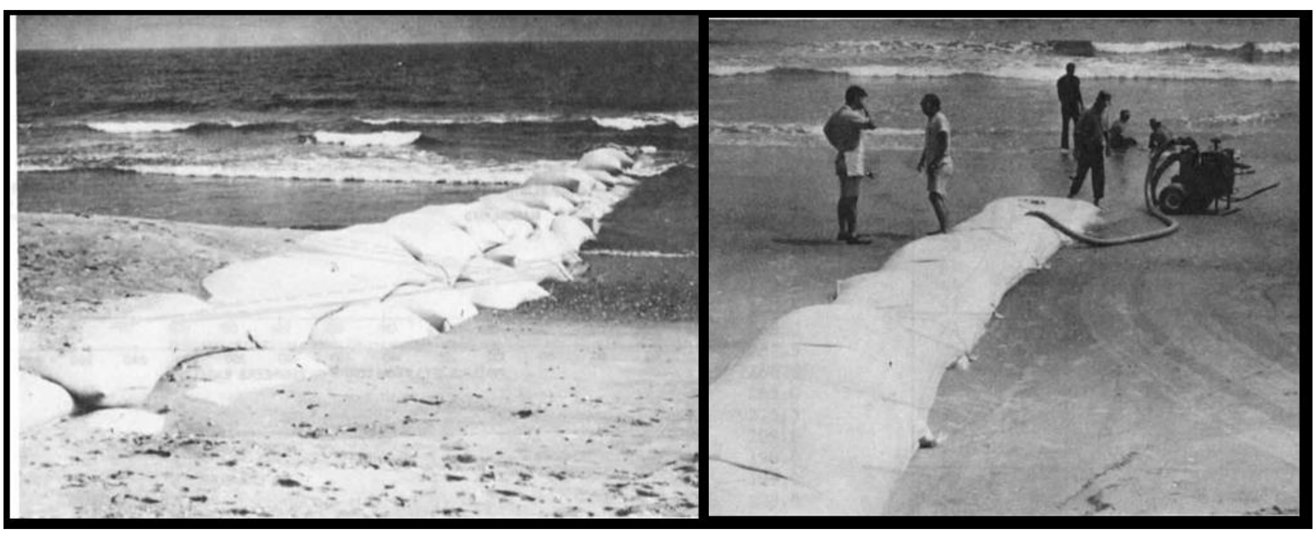
2.2 Background

While the majority of the Holden Beach oceanfront shoreline has experienced long-term net erosion over the last 70 years, the most severe erosion has occurred along the island's easternmost reach within ~1.2 miles of LFI. Average long-term erosion rates along the East End reach, ranging from -3 to -8 ft/yr, are among the highest in the state (NCDCM 2011). Efforts by the Town and the USACE to mitigate East End erosion have been ongoing since the late 1960s. Since 1967, the USACE has placed navigation dredged material on the East End every one to two years in conjunction with maintenance dredging of the AIWW Lockwoods Folly Inlet Crossing (LFIX) channel. In 1972, an experimental sand-filled nylon bag groin field was constructed along the East End shoreline with funding from the NC Office of Water and Air Resources. A total of 15 shore-perpendicular sand bag groins ranging in length from 143 to 285 ft were installed in an effort to stabilize ~4,000 ft of the East End oceanfront beach (Machemehl 1976) (Figures 2.1 and 2.2). Post-construction beach profile monitoring showed the groin field to be effective in terms of sediment accretion and beach fill stabilization. However, the groin field was designed as a temporary interim solution with an estimated lifespan of just two years. Furthermore, the nylon bags were easily damaged by sharp objects, and several were destroyed during the post-construction monitoring period.



Source: Machemehl 1976

Figure 2.1. Layout of 1970s Sandbag Groin Field on East End of Holden Beach



Source: Machemehl 1976

Figure 2.2. East End Sandbag Groin Field Construction 1970s

As described in the Holden Beach Master Plan (Appendix F), the Town has historically relied on USACE placements of LFIX navigation dredged material for nourishment of the East End reach to the east of Station 40 + 00 (Blockade Runner Drive) (Photos 2.1, 2.2, and 2.3). Past efforts

Photo 2.1. View to east of 2014 USACE LFIX East End placement project.

Photo 2.2. View to east of 2014 USACE LFIX East End placement and dune restoration project.

Photo 2.3. 2014 USACE LFIX maintenance dredging.

by the Town to the east of Station 40 + 00 have included only limited emergency dune restoration activities in response to major storms. As indicated above, USACE placements of dredged material on the East End have occurred approximately every one to two years since the late 1960s. Since 2001, the East End has received nine USACE placements of dredged material averaging ~77,000 cy (Figure 2.3, Table 2.1). In addition to LFIX East End placements, the USACE placed navigation dredged material from the Wilmington Harbor deepening project on the island's Central Reach in 2001. As described in the Holden Beach Terminal Groin Work Plan (Appendix G) USACE East End projects are primarily federally funded, with the Town being responsible for 25 to 35 percent of the costs.

Town nourishment efforts have focused on the East End reach to the west of Station 40 + 00 and the island's Central Reach (Figure 2.3). From 2002-2014, nine Town nourishment projects collectively placed ~825,900 cy of material on various reaches of the oceanfront shoreline to the west of Station 40 + 00 (Table 2.1). The Town's recently completed (2017) Central Reach Project placed ~1.31 million cy of material from an offshore borrow area along 4.1 miles of shoreline. Town nourishment projects have been conducted under CAMA Major Permit No. 14-02, which authorizes beach fill placement from 240 Ocean Blvd East (Station 40 + 00) to 781 Ocean Blvd West (Station 260 + 00). The Town has coordinated a number of its nourishment projects with USACE East End placement events; for example, the Town's 2009 Central Reach nourishment project extended westward from the stopping point of the USACE's 2009 East End project. In 2014, the Town and the USACE collaborated in the placement of 188,000 cy from LFIX and the associated LFIX bend-widener channel along ~6,000 linear ft of the East End beach.

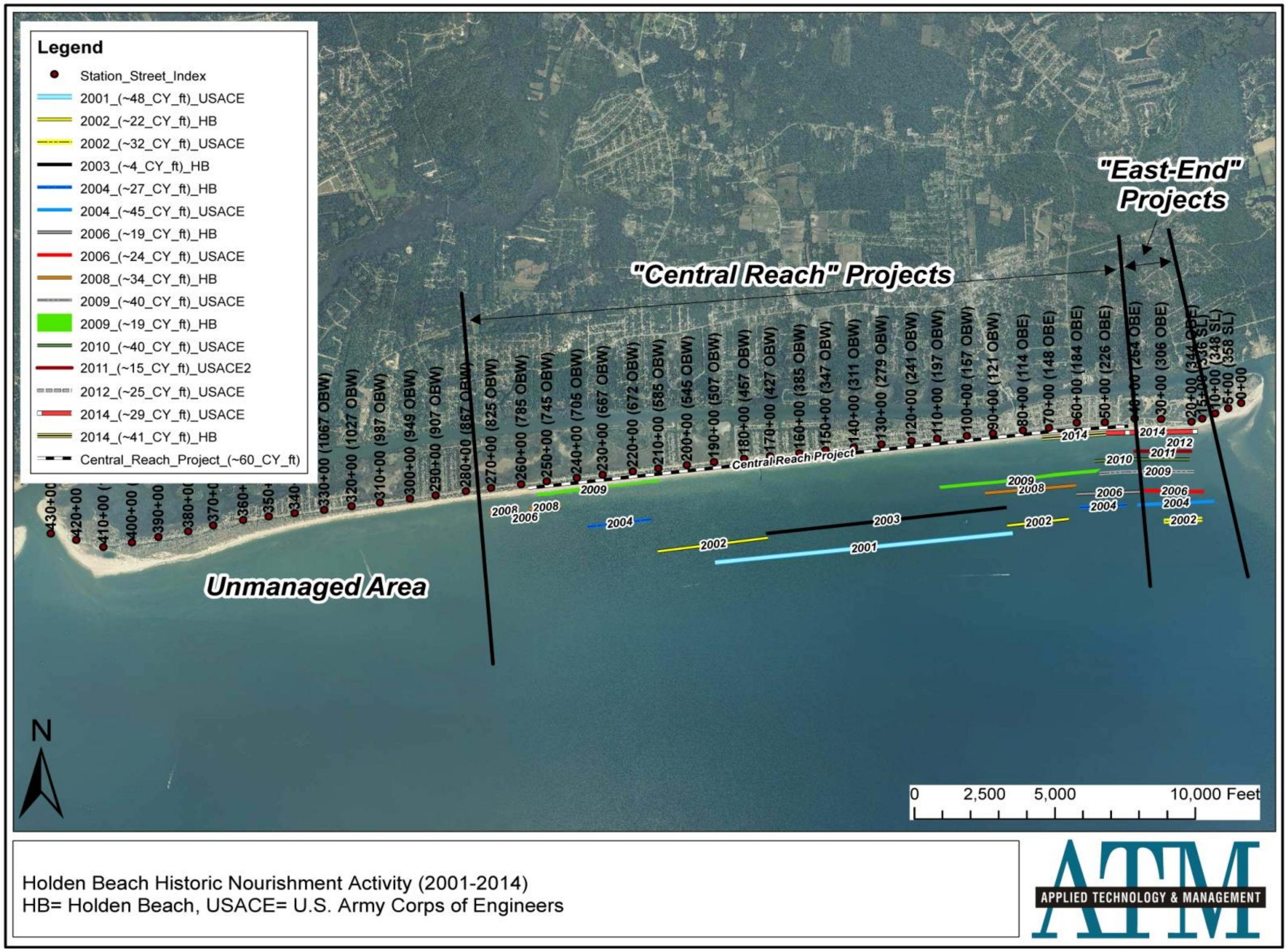


Figure 2.3. Holden Beach Fill Placements since 2001

Table 2.1. Town of Holden Beach nourishment summary 2001-2017.

Date	Primary Sponsor	Baseline Stations Nourished	Approximate Volume of Material Placed (cubic yards)	Material Source
12/01 – 02/02	USACE	87+00 – 192+00	525,000	Wilmington Harbor Deepening Project
3/07/02 – 4/30/02	Town of Holden Beach (Phase I)	66+00 - 90+00, 175+00 – 217+00	141,800	Oyster Harbor upland site
03/02 – 04/02	USACE	20+00 – 30+00	32,000	AIWW Maintenance Dredging
Winter 2002-2003	Town of Holden Beach	90+00 – 175+00	30,000	Boyd Street Disposal Area
9/04 – 11/04	USACE	15+00 – 40+00	113,230	LFI AIWW
12/03 – 4/04	Town of Holden Beach (Phase II)	46+00 – 68+00, 215+00 – 238+00	123,000	Smith borrow site
5/05/06 – 5/24/06	USACE	15+00 – 40+00	62,853	LFI AIWW
Spring 2006	Town of Holden Beach	40+00-60+00	42,000	Smith borrow site
Spring 2006	Town of Holden Beach	260+00 – 262+00	3,200	Smith borrow site
1/08 – 3/08	Town of Holden Beach	60+00 – 95+00, 245+00 – 270+00	201,000	Smith borrow site
12/08 – 2/09	USACE	20+00 – 40+00	100,000	LFI AIWW
03/09 – 4/09	Town of Holden Beach	55+00 – 110+00, 210+00 – 255+00	190,000	Smith borrow site
04/10	USACE	20+00 – 55+00	140,000	LFI AIWW
02/11	USACE	20+00 – 40+00	32,000	LFI AIWW
01/12	USACE	20+00 – 30+00	25,000	LFI AIWW
02/14	USACE	18+00 – 50+00	93,000	LFI AIWW
2014	Town of Holden Beach	50+00 – 73+00	95,000	LFI AIWW
2017	Town of Holden Beach	45+00 - 255+00	1,310,000	Offshore Borrow Site
Approximate Total Volume since 2001			**3,259,083**	

Source: Holden Beach 2014 Annual Beach Monitoring Report (ATM 2014)

Town nourishment projects have primarily utilized upland borrow sites and truck hauls to place volumes ranging from 30,000 to 200,000 cy (unit volumes of 3.5 to 35 cy/ft) (Table 2.1). However, there has been a growing demand by the residents of Holden Beach and neighboring Supply, NC to abandon truck haul projects and pursue alternate beach fill sources for the following reasons: 1) Poor sediment quality from upland sources [e.g., small grain size, high percent fines, and sediment color issues); 2) limitations on the effectiveness of small scale projects; 3) high cost of frequent small scale projects; and 4) the impacts of frequent truck hauls on traffic, roads, and tourism.

2.3 Need for the Proposed Action

The East End oceanfront shoreline of Holden Beach within ~1.2 miles of LFI has experienced severe and chronic erosion over the last 80 years. Average long-term erosion rates along the East End, ranging from -3 to -8 ft/yr (Figure 2.4), are the highest in Brunswick County and rank among the highest in the state (NCDCM 2011). The LFI ebb channel alignment over the majority of the past 80 years has promoted erosion along the East End of Holden Beach and accretion along the west end of Oak Island (Cleary 2008). Although regional sediment transport in the vicinity of LFI is predominantly westward, local transport patterns exhibit considerable variability due to the influence of the inlet (Thompson et al. 1999; OCTI 2008). Along the East End of Holden Beach within ~1.2 miles of LFI, large volumes of sediment move eastward and are transported into the inlet where they are retained within the inlet flood shoal system and the federal navigation channels (ATM 2013). The resulting effect on the east end beach is a localized reversal of the regional net westward transport pattern. Sediment retained in the inlet is permanently lost to the east end beach, thus accounting for much of the ongoing chronic erosion.

Despite regular placements of sand by the Town and the USACE over the last 50 years, the East End has experienced long-term net erosion and extensive property loss, including losses of 28 properties and structures since 1993 (Figure 2.5). Due to the lack of adequate shore protection, major storms such as Hurricane Hanna (2008) continue to cause dune breaching and flooding along the East End. Currently, there are nine permitted and installed sandbag structures along the East End between Lockwoods Folly Inlet and Blockade Runner Drive (Figure 2.6).

Frequent repeated beach fill placements, which are rapidly lost to erosion, are extremely costly and provide only short-term benefits that are insufficient to protect the East End of Holden Beach. Thus, a more effective and cost-efficient management strategy is needed to provide long-term shore protection for the East End of Holden Beach. As previously described, the Town's shore protection strategy for the majority of the East End (i.e., east of Station 40 + 00) has historically been one of reliance on frequent USACE placements of LFIX navigation dredged material. However, based on declines in federal funding for shore protection projects over the last two decades, the future of USACE East End sand placement projects is uncertain.

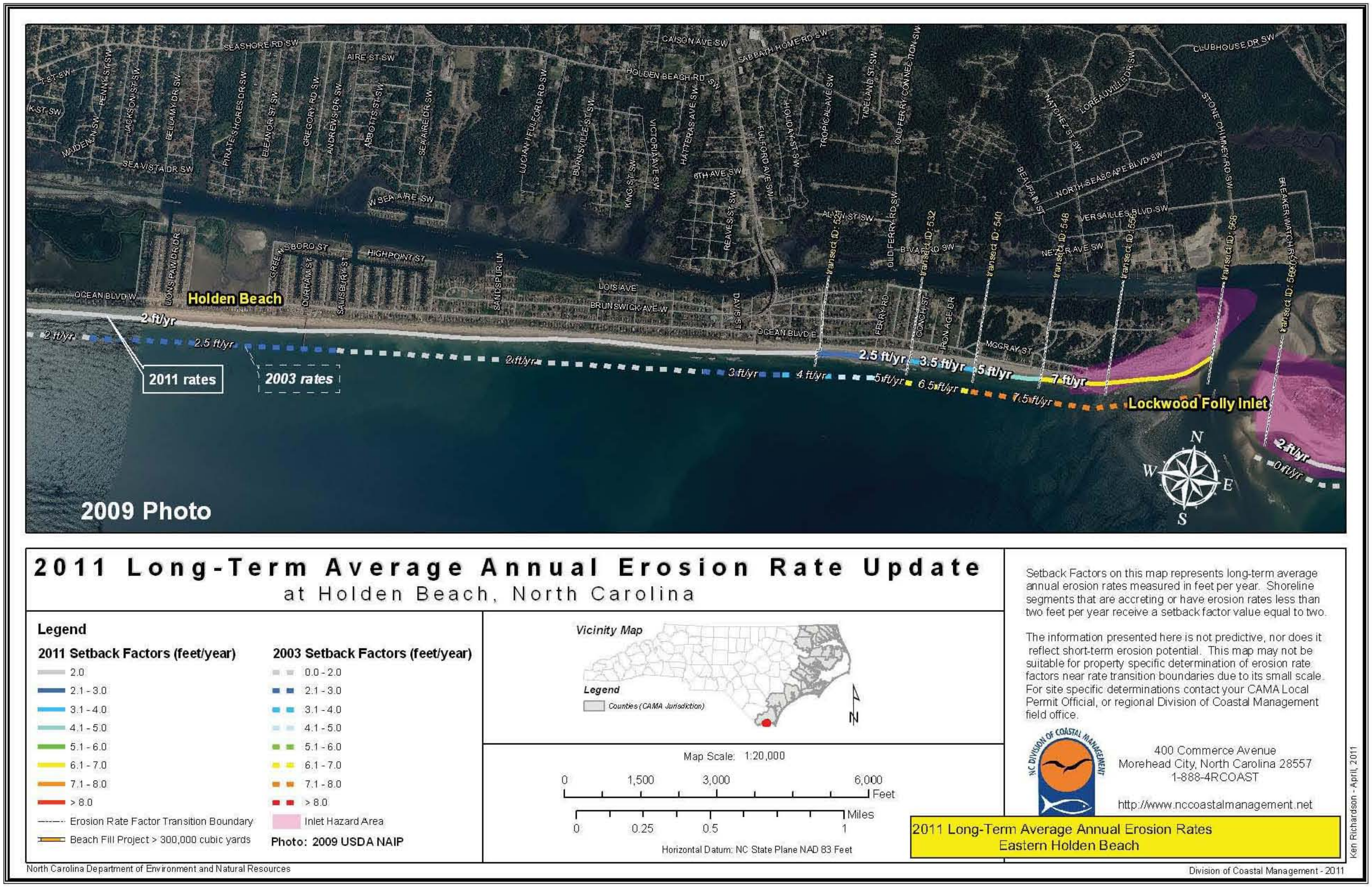


Figure 2.4. NCDCM Long-Term Shoreline Erosion Rates for the East End of Holden Beach (2003 vs 2011)

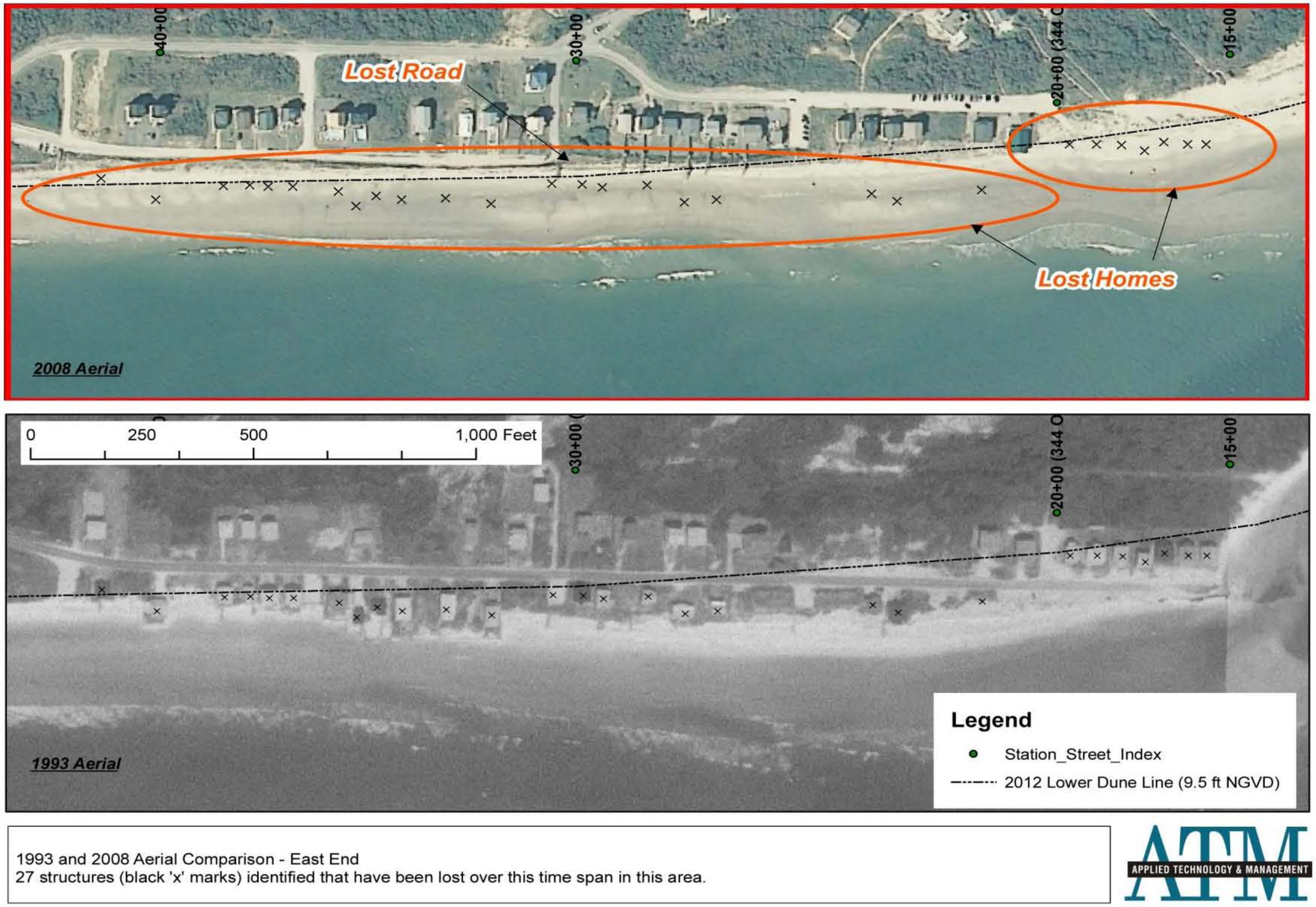


Figure 2.5. Holden Beach East End Shoreline Change and Property Loss 1993-2008

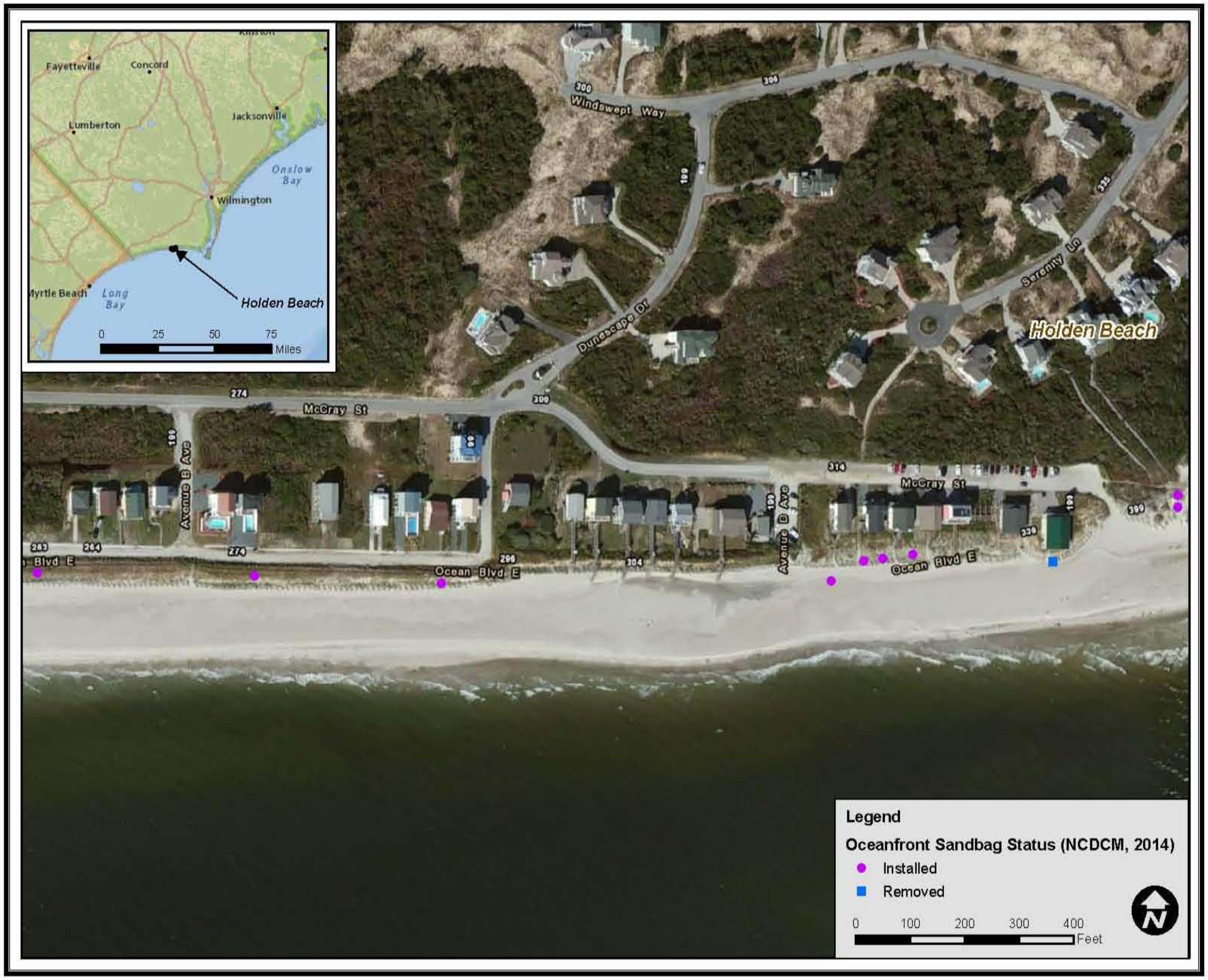


Figure 2.6. Permitted Sandbag Revetments on the East End of Holden Beach

Therefore, a long-term shore protection program under the autonomous authority of the Town of Holden Beach is needed is to ensure that the East End will be adequately protected.

3.0 PROJECT ALTERNATIVES

The NEPA and the CEQ regulations for implementing the NEPA (40 CFR 1500 *et. seq.*) require the identification and evaluation of reasonable alternatives that meet the purpose and need and are practical or feasible from a technical and economic standpoint. The USACE, in consultation with the PRT, evaluated and screened a wide range of preliminary alternatives during the EIS scoping process. The alternatives screening and evaluation process identified six alternatives as being reasonable and warranting full evaluation in this EIS (Table 3.1). This section describes the six reasonable alternatives that are carried forward and fully evaluated in this FEIS. Additionally, this section provides a summary of the preliminary alternatives that were eliminated from further consideration on the basis of being unreasonable.

Table 3.1. Project alternatives.

Alternative #1	No Action (Status-Quo)
Alternative #2	Abandon and Retreat
Alternative #3	Beach Nourishment
Alternative #4	Inlet Management and Beach Nourishment
Alternative #5	Short Terminal Groin and Beach Nourishment
Alternative #6	Intermediate Terminal Groin and Beach Nourishment

3.1 Alternatives

3.1.1 Alternative 1: No Action

Under the No-Action Alternative (Alternative 1), the Town would continue to rely solely on the USACE's beneficial use projects for shore protection of the East End of Holden Beach. East End Beneficial Use Projects are conducted under the authority of Section 145 of the Water Resources Development Act (WRDA) of 1976 as amended by the WRDA of 1986 (Section 933), the WRDA of 1992 (Section 207), and the WRDA of 1999 (Section 217). Section 145 authorizes the USACE to place suitable dredged material from navigation channels and inlets on local beaches at the request of a local government sponsor (e.g., the Town). As stipulated by Section 217, East End Beneficial Use Projects are funded under a cost-sharing ratio of 65 percent federal and 35 percent local. Since 2002, the East End has been nourished nine times with dredged material derived from the AIWW Lockwood Folly Inlet Crossing (LFIX) navigation channel. On average, these nourishment events placed ~77,000 cy of dredged material on the East End of Holden Beach at two-year intervals (Figure 2.1). The most recent beneficial use dredging project took place in the spring of 2017 (February – March), in which the Town and the USACE collaboratively placed a total of 188,000 cy on ~6,000 linear feet (ft) of the East End beach between Lockwoods Folly Inlet and Halstead Street (Stations 18 + 00 and 73 + 00). Figure 3.1 depicts the typical LFIX borrow area and East End placement footprint of the USACE project. The seven USACE projects conducted prior to 2014 placed volumes of beach-compatible material ranging from approximately 25,000 to 140,000 cy on an annual or bi-annual basis (although this is subject to funding).

The federally authorized LFIX Navigation Project encompasses ~7,500 ft of the main AIWW channel [12 ft deep mean low water (MLW) by 90 ft wide] and a seaward-adjoining 400-ft-wide bend widener (Figures 3.2 and 3.3). Due to federal budget constraints, the 400-ft-wide bend widener was not dredged in conjunction with beneficial use projects prior to 2010. However, using local and alternate federal sources of funding, the bend widener was dredged in conjunction with beneficial use projects in 2010 and 2014. Beneficial use projects involving only material from the main 90-ft-wide channel have placed between 32,000 and 113,000 cy of material on the East End of Holden Beach whereas inclusion of the 400-ft bend widener in 2010 and 2014 resulted in placement volumes of ~140,000 cy and ~188,000 cy, respectively. Local funding efforts for the bend widener are expected to continue, subject to the availability of funds. Furthermore, the state has recently passed legislation (H 707/S.L. 2013-138) that directs the NCDENR to pursue strategies that will aid local governments in the attainment of USACE and state CAMA permits for channel dredging and beach disposal of dredged materials. Therefore, although the exact frequency is not known, it is anticipated that the 400-ft bend widener would be included in beneficial use projects with some regularity under Alternative 1.

Although the long-term (30-year) status of federal Section 145 funding appears to be precarious, it is assumed for impact analysis purposes that East End Beneficial Use Projects under Alternative 1 would continue at an average frequency of every two years. Beach fill placement volumes would vary according to channel shoaling rates and the availability of funding for inclusion of the 400-ft bend widener. However, for impact analysis purposes, projects using only material from the main channel would presumably place ≤100,000 cy of material on the East End whereas projects using sand from both the main channel and the bend widener would place ~150,000 cy of material. Dredging and beach fill placement methods would be similar to those associated with current operations. Sand from the LFIX/bend-widener channel would be extracted by cutterhead pipeline dredges and pumped directly to the east end via submerged pipelines. Temporary containment berms would be constructed at the beach discharge points to allow for dewatering and suspended sediment redeposition, and bulldozers operating on the beach would distribute and grade the dewatered fill according to the beach profile design specifications. Front-end loaders would be used to transport and position emergent sections of the discharge pipeline on the beach (Photos 3.1 and 3.2). As nourishment activities progress, the emergent pipeline would be extended along the beach through the addition of extra sections of pipe.

Source: ATM 2013

Figure 3.1. USACE LFIX AIWW Dredging and Beach Placement Schematic

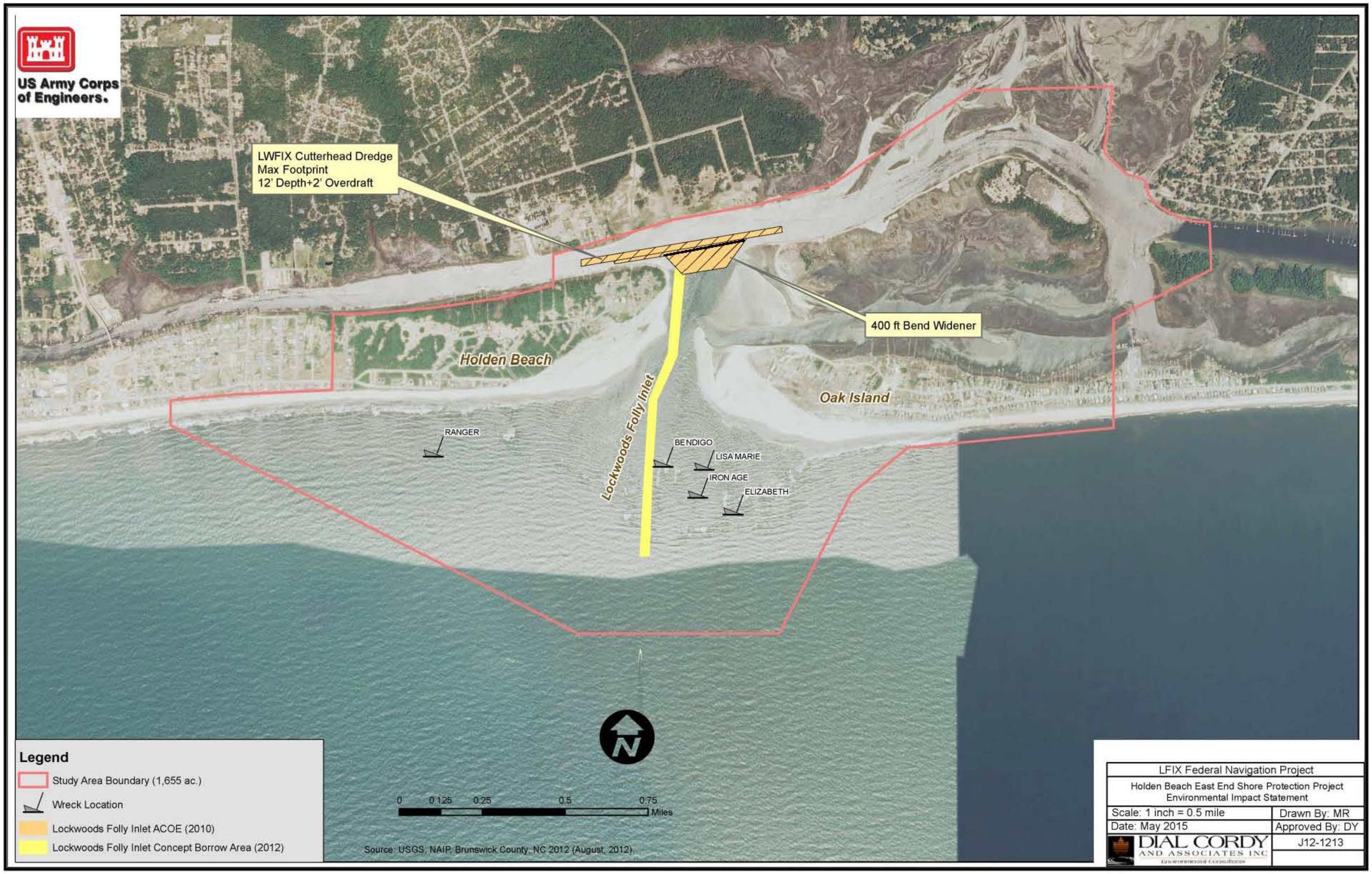


Figure 3.2. LFIX Federal Navigation Project (includes bend widener and AIWW)

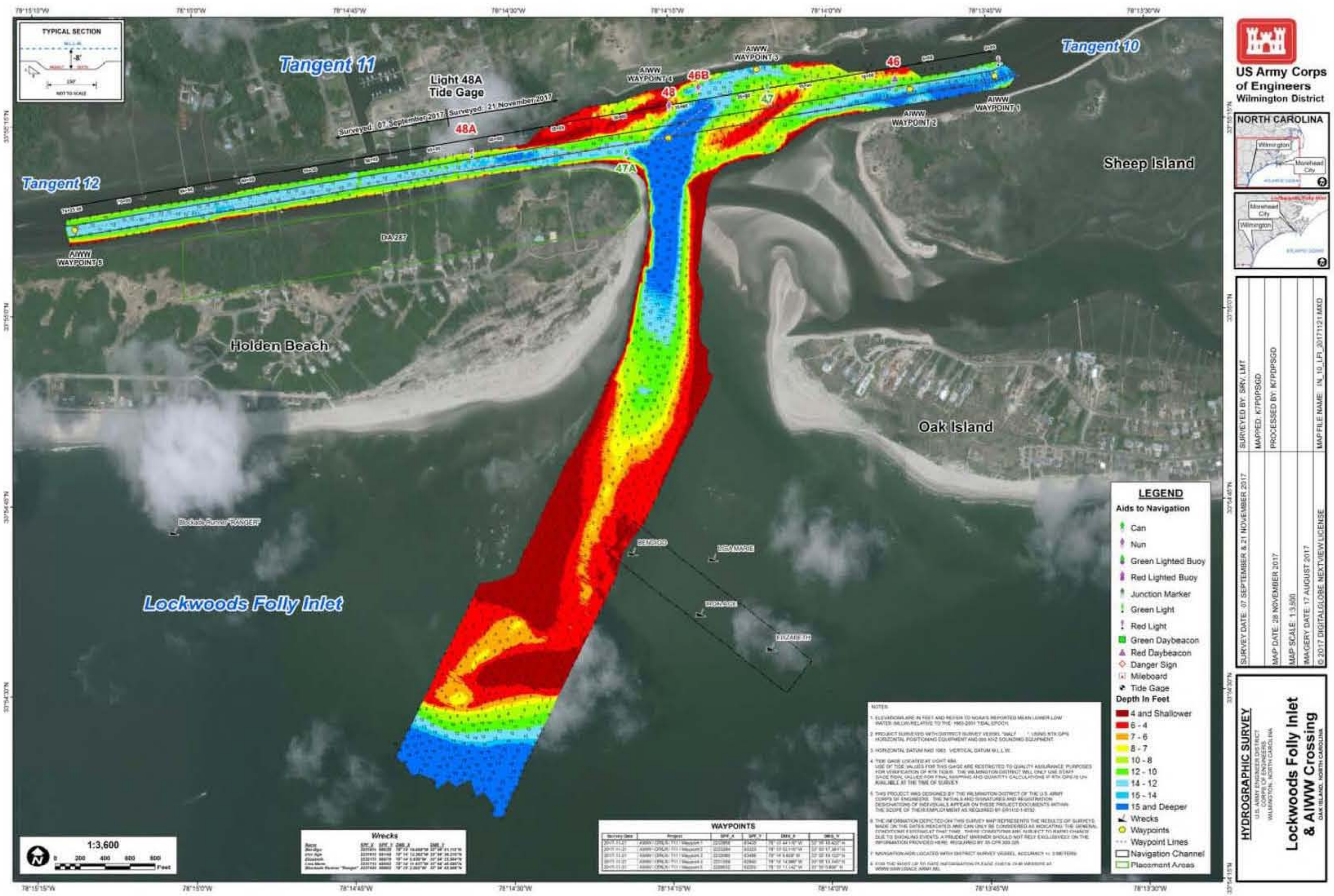


Figure 3.3. 2017 Hydrographic Survey of the LFIX and AIWW Crossing

Photo 3.1. View of temporary containment berm during the 2014 beneficial use project on the East End.

Photo 3.2. Equipment utilized during the 2014 beneficial use project on the East End.

Additional management activities under Alternative 1 would be expected to include the installation of sandbags and beach bulldozing and by individual property owners and/or the local municipalities. Pursuant to NC Coastal Management Rules, sandbags and beach bulldozing are allowed as temporary measures to protect threatened structures. The use of sandbags is limited to structures that are within 20 ft of the MHW line, and the use of beach bulldozing to restore frontal dunes (without a federal Section 404 permit) is restricted to the movement of sand above MHW under NC Coastal Management Rules. As stated in Chapter 2, approximately 9 properties on Holden Beach currently have sandbags, and it is expected that additional sandbags would be installed over time by individual property owners to temporarily protect their homes. Likewise, the use of beach bulldozing would be anticipated, especially as a post-storm emergency measure to repair damage to frontal dunes and berms.

3.1.2 Alternative 2: Abandon and Retreat

Under Alternative 2, the Town would not pursue a long-term management plan, and there would not be any federally implemented or federally permitted actions undertaken to mitigate erosion along the East End of Holden Beach. Thus, the USACE would not conduct any East End Beneficial Use Projects, and the Town would not implement any actions, such as beach nourishment, beach scraping, dune restoration, temporary sandbag placement, and inlet dredging, which require a federal dredge and fill permit.

Instead, the Town would develop and implement a 30-year managed retreat plan under which structures that are threatened with erosional damage would be either relocated to unimproved interior lots or demolished. This plan would establish an erosional threshold that would trigger preemptive relocations or demolitions prior to the point of imminent structural failure. According to the 2009 Holden Beach CAMA Land Use Plan, there are 910 vacant parcels encompassing 265 acres of usable (i.e., buildable) land in the Town of Holden Beach. If all this land was developed at a density of .25 residential units per acre, this would equate to 1,060 residential units. Since .25 acres per residence is less dense than what current zoning allows, there is sufficient buildable land for relocations.

In the absence of shore protection measures, East End shoreline recession would progress based on natural background erosion rates and storm-related losses. As described by the NC Beach and Inlet Management Plan (2011), the Brunswick County area has the highest storm surge potential along the North Carolina coast.

Although no new dredging would occur under Alternative 2, it is assumed that USACE maintenance dredging of the federal navigation channels within the Permit Area (i.e., LFIX and LFI channels) would continue under a regime similar to that of current operations; including pipeline dredging of the LFIX channel and side-cast dredging of the LFI Outer Bar ebb channel (Photo 3.3). However, in the absence of a local sponsor for beneficial use disposal, it is assumed that the USACE would place dredged material from LFIX in accordance with the federal standard, which would likely utilize an approved facility such as the adjacent Sheep Island Confined Disposal Facility (CDF).

Outer channel dredging is typically performed four times a year (quarterly) by side-caster, when funds are available. No federal funding was available for the fiscal year of 2012; however, the State, Brunswick County, Holden Beach, and Oak Island have collectively been able to fund interim USACE dredging of the outer channel through a memorandum of agreement (MOA) with the Wilmington District (Appendix H – Engineering Analysis).

Photo 3.3. View of sidecast dredge, the Merritt, working within the outer bar channel of LFI.

3.1.3 Alternative 3: Beach Nourishment

Under Alternative 3, the Town would assume responsibility for East End shore protection through the implementation of an independent, 30-year nourishment-only beach management plan. Under the proposed plan, the East End of Holden Beach would be nourished with ~100,000 to 150,000 cy of sand every two years. The conceptual beach fill placement area encompasses ~3,700 linear ft of the East End oceanfront beach between Blockade Runner Drive (~Station 40 + 00) and LFI (~Station 10 + 00) (Figure 3.4). Based on the preliminary beach profile design (Figure 3.5), nourishment events would include construction of a +9-ft-high [North American Vertical Datum (NAVD)], 50-ft-wide dune, a +7-ft-high (NAVD), 200-ft-wide berm, and a 90- to 170-ft-wide transition with a 15 percent slope that intersects ("toes in") with existing bathymetry.

The preferred source of beach fill under Alternative 3 would be the LFIX navigation channel and associated 400-ft bend widener (as shown in Figure 3.1). The LFIX has been a borrow area for beach nourishment since the 1970s. The dredged material is beach compatible (Table 3.2), and Station 20+00 on the East End (beginning of the beach fill placement at the eastern terminus of McCray Street) is conveniently less than 4,000 ft away. Based on dredging and survey data from 2012, there is approximately 110,000 cy of sedimentation available from the LFIX borrow area with inclusion of the 400-ft bend widener.

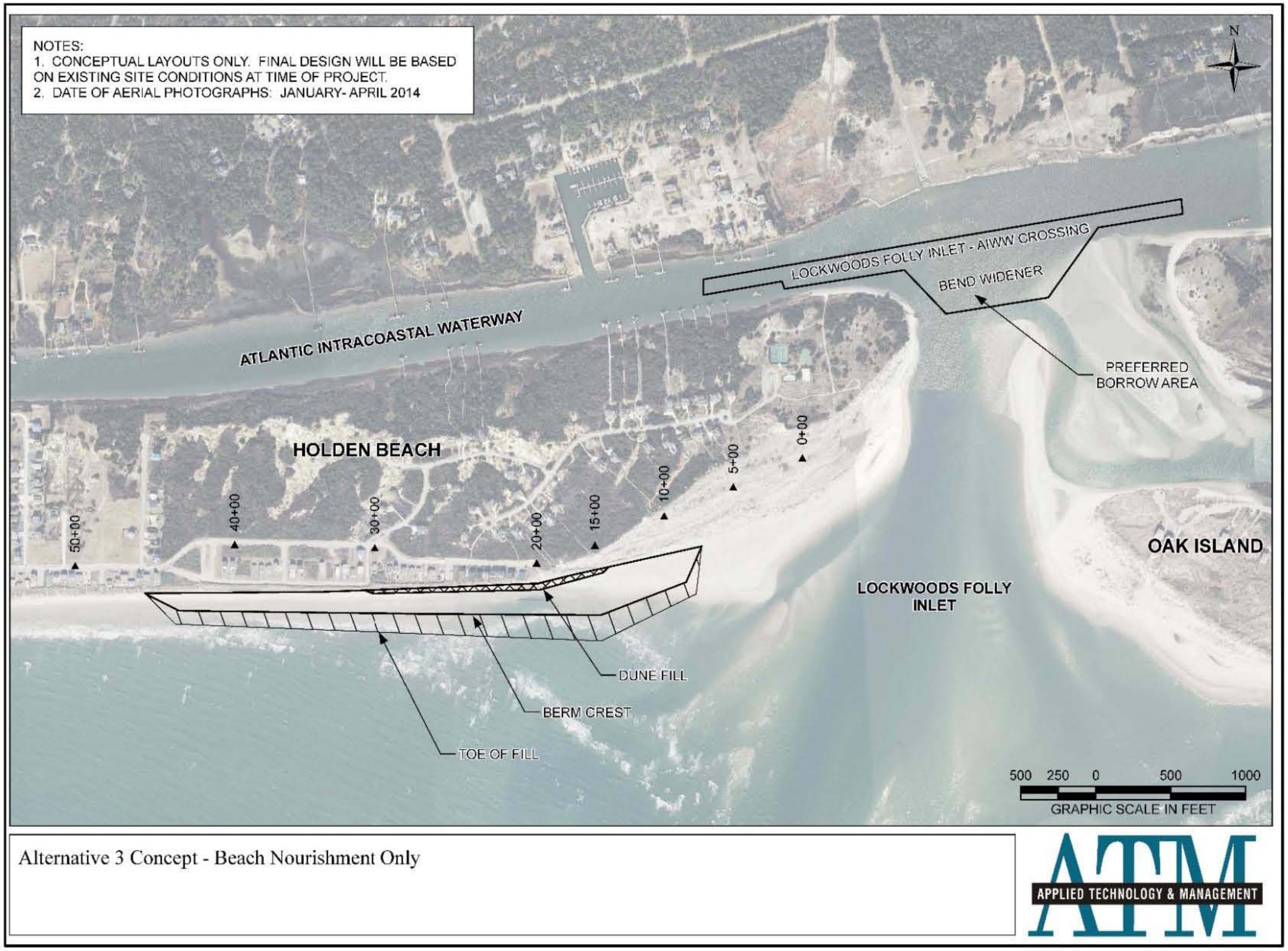


Figure 3.4. Alternative 3 – Conceptual East End Beach Fill Footprint

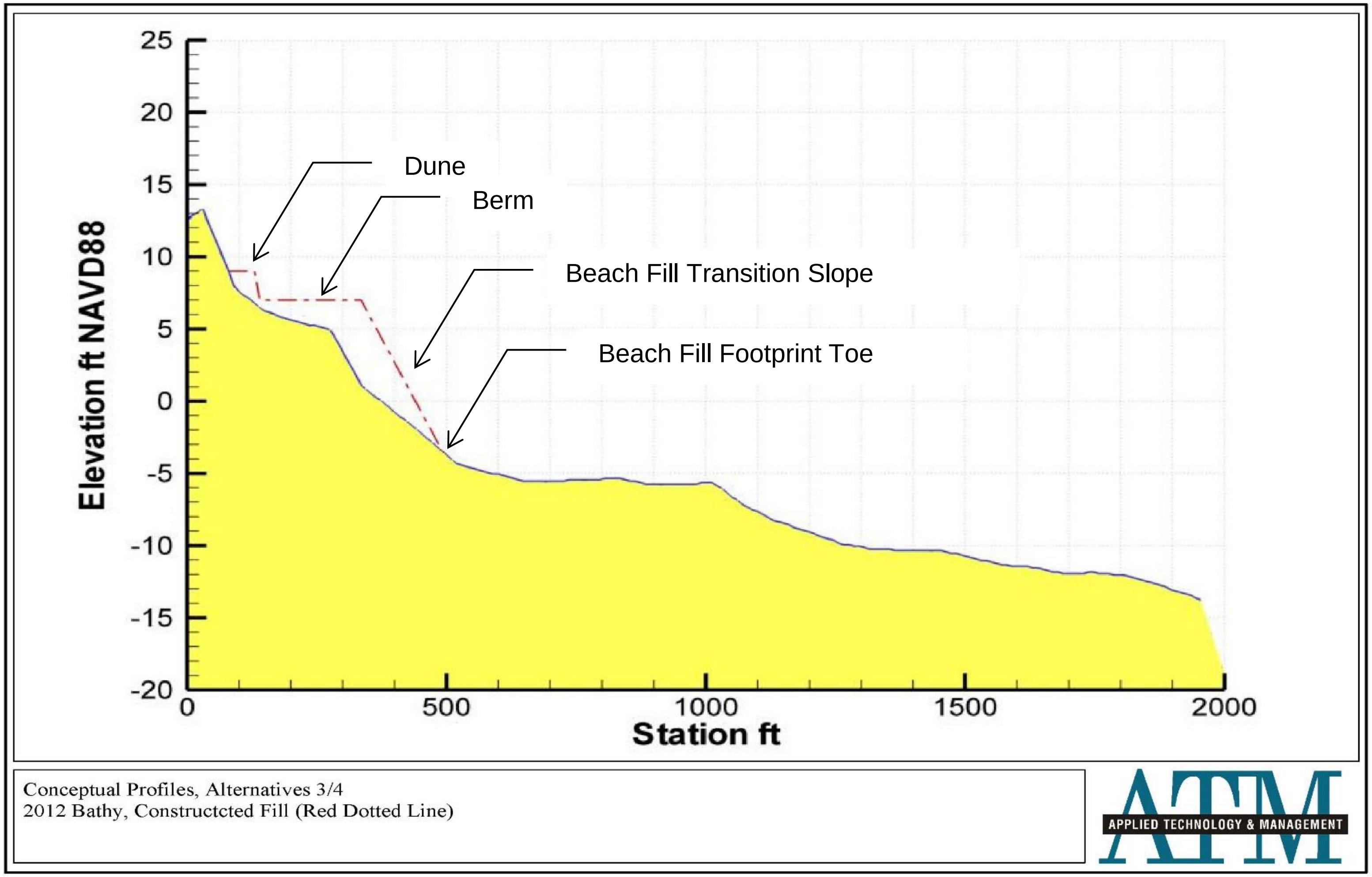


Figure 3.5. Alternative 3 – Conceptual East End Beach Fill Profile (Dune ~50 ft wide, Berm ~200 ft wide)

Table 3.2. Summary of borrow area alternatives with NCDCM sediment compatibility criteria.

	Mean Ave (mm)	Sorting	Percent Gravel	Percent Granular	Percent Fines	Percent Carbonate	Volume Available (Mcy)
Native Beach	0.24	0.72	0.6	N/A	2	2.7	N/A
NCDCM Sediment Criteria	N/A	N/A	Native + 5%	Native + 5%	Native + 5%	Native + 15%	N/A
NCDCM Threshold	N/A	N/A	5	5	7	17.7	N/A
Borrow Sites							
LFIX	0.41	0.81	2.7	1.1	6.1	10.9	0.11
Central Reach Offshore	0.35	1.26	2.1	3.4	5.0	12.4	3.3

Additional sedimentation or shoaling is anticipated prior to project construction. Accounting for losses during dredging and beach construction, it is estimated that ~120,000 to 180,000 cy of sand would be available for extraction from the LFIX/bend widener channel every two years. This projected availability is consistent with historical data, as the most recent AIWW and 400-ft bend widener project in spring 2017 placed ~188,000 cy of sand.

The LFIX borrow area is the preferred borrow area due to beach-compatible quality and sustainable quantities. However, in the case of a volumetric shortfall, supplemental beach fill would be acquired first from the inland segment of the LFI navigation channel and then from the Central Reach offshore borrow site (Figure 3.6). The Central Reach offshore borrow area (-33 to -39 ft NGVD29) is approximately 590 ac and is located 1.8 to 3 miles offshore of western Oak Island and southeast of the LFI. Estimated volume yield of compatible beach sand for a cut depth of 3.5 ft is 3.3 million cubic yards (Mcy). Assuming the permitted volume of 1.31 Mcy is placed on the Central Reach of Holden Beach, sufficient volume will be available for two to three more large (greater than 500,000 cy) projects. Although this offshore borrow area has a significant amount of compatible sediment (Table 3.2), it is not the preferred source by the Town due to the high costs of mobilizing an “ocean-certified” dredge. Only very large beach nourishment projects (greater than 500,000 cy) would justify its use.

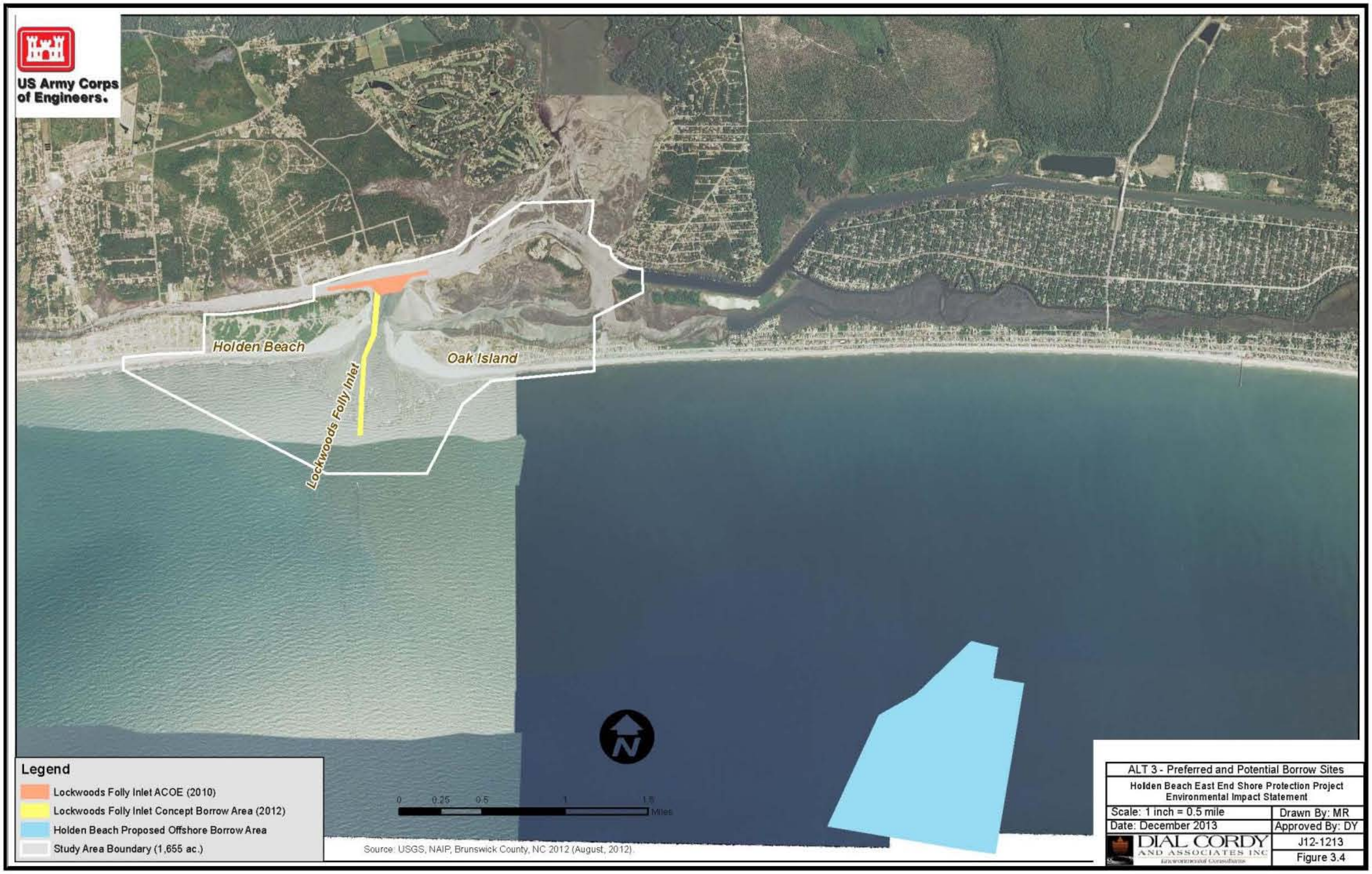


Figure 3.6. Alternative 3 – Preferred and Potential Borrow Sites

Sand from the LFIX, bend widener, and inland LFI navigation channels would be extracted by cutterhead pipeline dredges and pumped directly to the east end of Holden Beach via submerged pipelines. Supplemental operations at the Central Reach offshore borrow site would employ trailing suction hopper dredges in which case sand would be placed in hoppers onboard the dredges and transported to nearshore pump-out stations where the material would be discharged through a submerged pipeline leading to the east end. Temporary containment berms would be constructed at the beach discharge points to allow for dewatering and sediment redeposition, and bulldozers operating on the beach would distribute and grade the dewatered fill according to the beach profile design specifications. Front-end loaders would be used to transport and position emergent sections of the discharge pipeline on the beach. As nourishment activities progress, the emergent pipeline would be extended along the beach through the addition of extra sections of pipe.

3.1.4 Alternative 4: Inlet Management and Beach Nourishment

Under Alternative 4, the Town would assume responsibility for shore protection of the East End of Holden Beach through the implementation of an independent, 30-year inlet management and beach nourishment plan. The anticipated management regime, as defined by iterative modeling runs described in the Holden Beach ATM Engineering Analysis (Appendix H), would involve periodic relocations of the LFI outer ebb channel and concurrent East End nourishment events approximately every two years. Outer inlet channel relocation events would involve the construction of a new wider and deeper outer channel with a more westerly alignment towards the inlet shoulder of Holden Beach (Figure 3.7). The new 0.5-mile-long channel would extend seaward from the inlet throat across the LFI ebb tidal delta to the 14-ft (MLW) isobath. The new channel would be dredged to a uniform depth of 14 ft (MLW) and would have a variable width ranging from ~350 ft at the inlet throat to ~850 ft at the 14-ft isobath. Excavation of the new outer channel would require the extraction of ~500,000 cy of sediment from the ebb tidal delta. Approximately 120,000 to 180,000 cy of the total volume would be extracted by a cutterhead or hopper dredge for placement on the East End of Holden Beach, and the remaining ~320,000 to 380,000 cy would be removed by a side-cast dredge and returned to the adjacent ebb tidal delta via open water disposal. It is anticipated that sand derived from the outer inlet channel relocation events would meet all the beach fill requirements under Alternative 4. The beach nourishment footprint, beach profile design, fill placement volumes, and methods of construction would be the same as those described under Alternative 3.

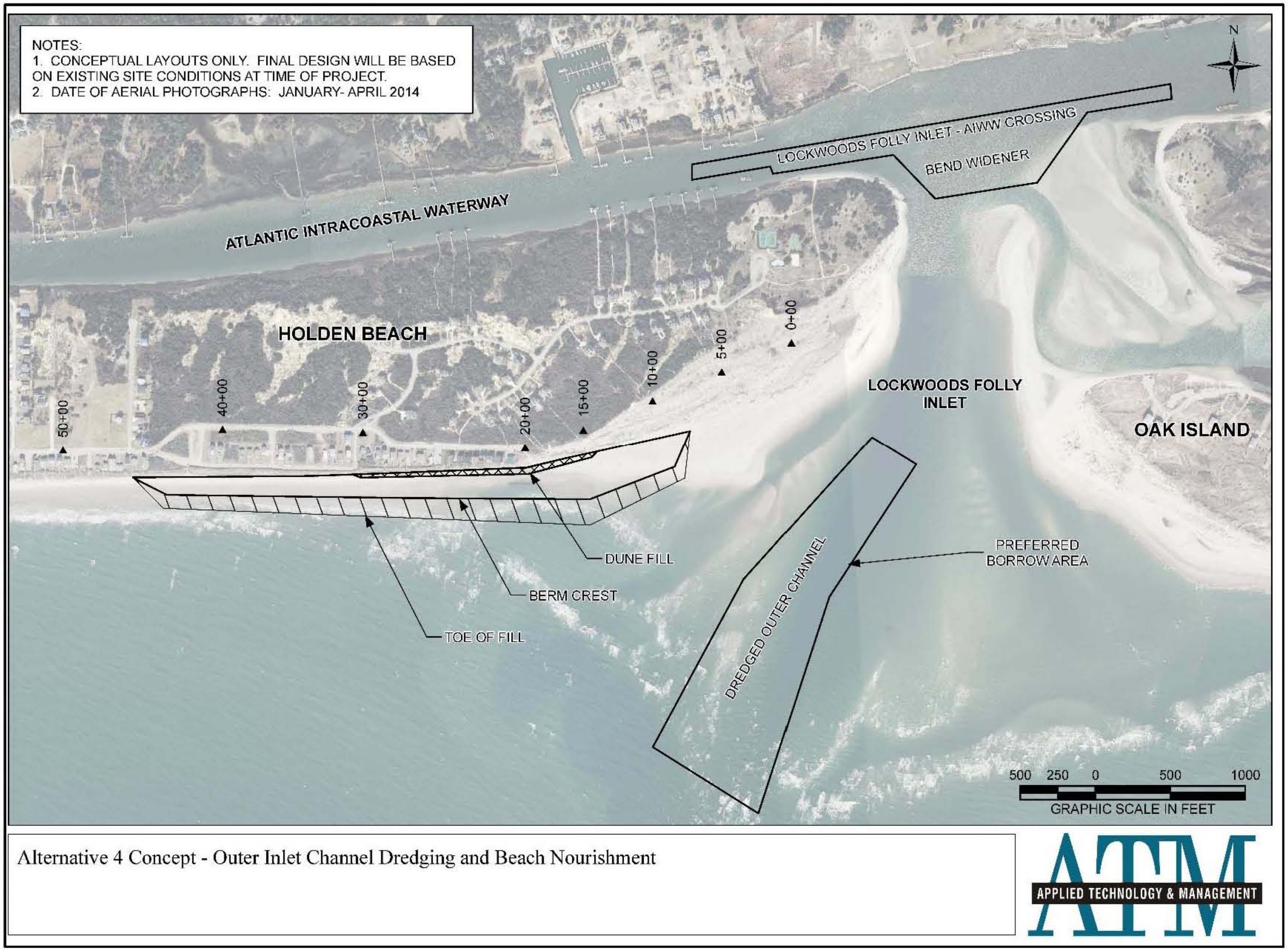


Figure 3.7. Alternative 4 – Conceptual Beach Fill and Outer Inlet Channel Footprint

3.1.5 Alternative 5: Short Terminal Groin and Beach Nourishment

Under Alternative 5, the Town would assume responsibility for shore protection of the East End of Holden Beach through the construction of an ~800-ft-long “short” terminal groin at the eastern end of the oceanfront beach between Stations 10+00 and 20+00 (Figure 3.8) and the implementation of an independent, 30-year beach nourishment plan. The proposed lengths of the groins were largely dictated on shoreline location and the need to protect the East End. The accompanying beach nourishment also varies with each structure, with more fill needed for longer structures (Appendix H – Engineering Analysis).

In general, the length of the terminal groin is dictated by the size of the inlet, the configuration of the end of the island, and the length of shoreline the groin is designed to stabilize (ATM 2013; Appendix H – Engineering Analysis). The design groin length is based on modeling as well as on existing structures within Long Bay and other nearby areas. Long Bay extends approximately 100 miles from Bald Head Island, NC down to North Island, South Carolina (SC) and displays a similar geology as well as similar tides and waves. Existing groin structures in Long Bay include Bald Head Island and Garden City, SC (Photo 3.4) and Pawleys Island, SC. Additional analysis on existing groins in other areas of the state (e.g., Oregon Inlet, Hatteras, and Fort Macon) and the region were also assessed. The North Carolina Terminal Groin Report also contains significant information on this topic.

The main stem of the short terminal groin would include a 550-ft-long segment extending seaward from the toe of the primary dune and a ~250-ft-long anchor segment extending landward from the toe of the primary dune. The groin would also include a 250-ft-long shore-parallel T-Head segment centered on the seaward terminus of the main stem. The T-Head feature on the seaward end of the short groin (~250 feet total) is included to enhance fillet formation of the beach fronting the eastern shoreline area. The short groin features a larger T-Head since a shorter groin in this location would be expected to have less of a stabilizing effect on the shoreline than the intermediate groin alternative (Alternative 6, described below). T-Heads also help to minimize formation of potential offshore rip currents and sand losses during extreme wave conditions (ATM 2013, Appendix H – Engineering Analysis). While the design does feature a T-Head, it is much smaller than traditional T-Head structures found in Florida and elsewhere. Photo 3.5 presents a Hunting Island, SC groin built in 2006/2007 with a smaller T-Head feature (like what is proposed for Alternative 5).

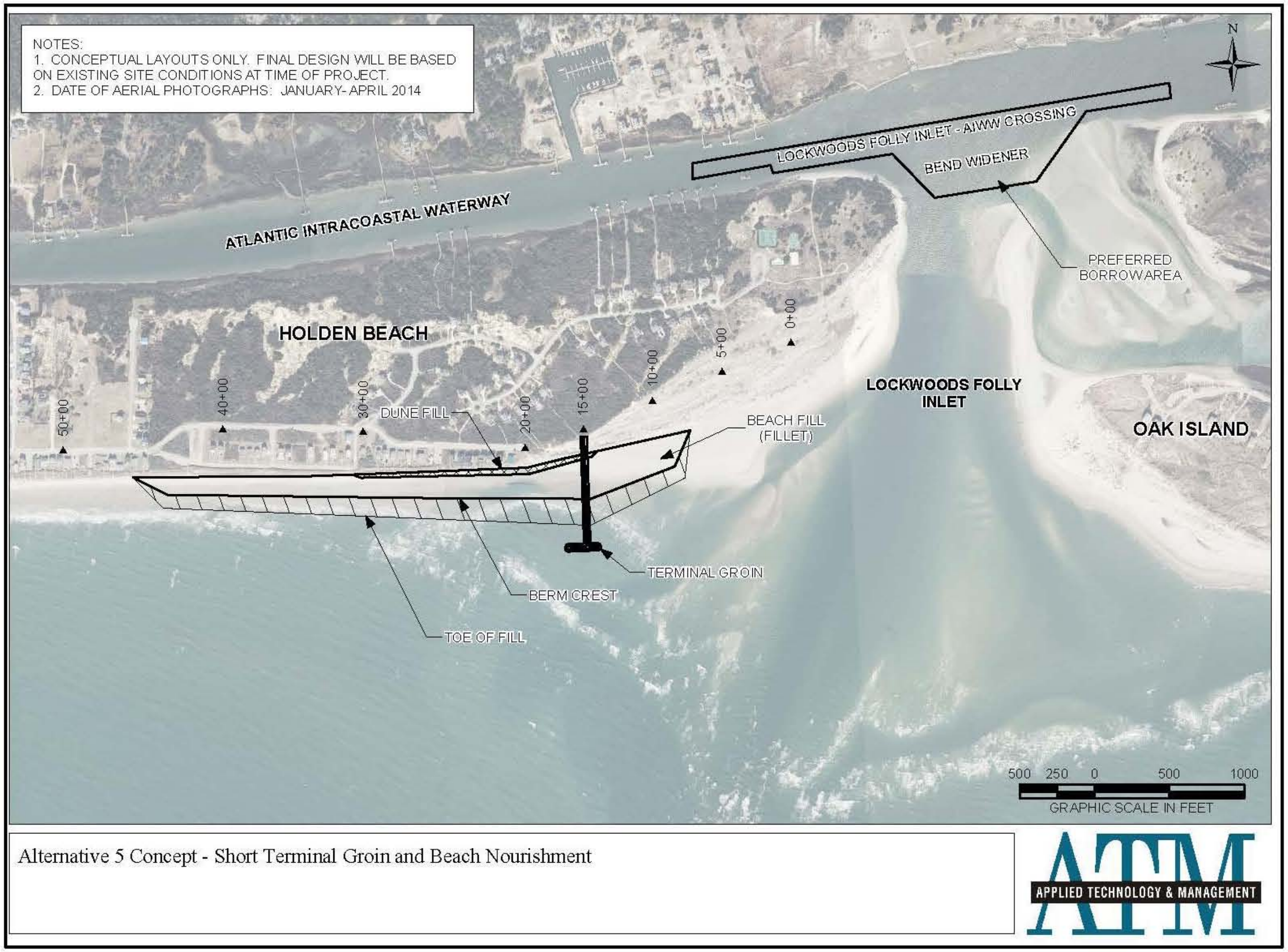


Figure 3.8. Alternative 5 – Conceptual Beach Fill and Short Terminal Groin Footprint

Photo 3.4. Garden City, SC, sheet-pile groin after construction during low tide.

Photo date: January 2003

Photo 3.5. Hunting Island, SC, groin at low tide.

The 250-ft anchor segment is designed to prevent flanking of the groin in the event of shoreline migration landward of the primary dune. In this regard, flanking is defined as erosion around the landward end of a structure which ultimately exposes the normally "dry" side of the structure to the water. The anchor segment would be entirely buried at the completion of groin construction and would remain buried so long as the position of the MHW line remains seaward of the initial post-construction primary dune line. The short groin is designed to be a relatively low-profile structure (Figure 3.9) to maximize sand overpassing and to minimize impacts to beach recreation and aesthetics. In addition to the 250-ft anchor segment, a portion of the adjoining groin segment across the upper dry beach would also be completely buried thus maintaining recreational beach access across the groin. The relatively low profile of the groin is designed to allow some sand overpassing even under eroded conditions at the end of the four-year nourishment cycle.

The short terminal groin would be constructed of 4- to 5-ft-diameter granite armor stone and, unlike conventional jetties/breakwaters/groins, would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for construction of the groin to the 25 percent void design ratio thus providing the "leaky" characteristic that allows sand to pass through the structure (Appendix H – Engineering Analysis). To prevent settlement of the stone and, if necessary, to facilitate modification or removal of the groin, a base layer of geo-textile matting (1 ft thick) would be installed below grade prior to the armor stone placement. The rubble mound (i.e., armor stone) component of the short groin would have a crest width of ~10 ft and a base width of ~40 ft while the underlying geo-textile base layer would have a slightly greater width of ~45 ft (Figures 3.9 and 3.10). The relatively short length of the groin and the large tidal range at Holden Beach would allow for construction of the groin entirely from shore. The final design of the structure is subject to change given conditions near the time of actual construction. It is anticipated that the East End public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

Nourishment events would place ~100,000 to 150,000 cy of sand (26.2-acre fill footprint from the dune out to the toe of fill) on the east end of Holden Beach every four years. The beach nourishment footprint and the basic dune/berm/toe profile design would be similar to those associated with Alternatives 3 and 4. However, the initial nourishment event would also include the construction of a wedged-shaped "groin fillet" sediment feature that would establish a gradual, transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the short groin. The seaward terminus of the short groin would extend ~300 ft beyond the MHW line position associated with the eroded 2012 East End of Holden Beach which is considerably less than the historical range of seaward shoreline positions at the eastern terminus of the oceanfront beach. Accounting for sand losses during beach construction, the proposed borrow site dredging regime under Alternative 5 would involve the extraction of ~100,000 to 150,000 cy of sand from the preferred LFIX/bend-widener borrow site every four years with the addition of potential supplemental sand acquisition from the inland LFI navigation channel and the Central Reach offshore borrow site.

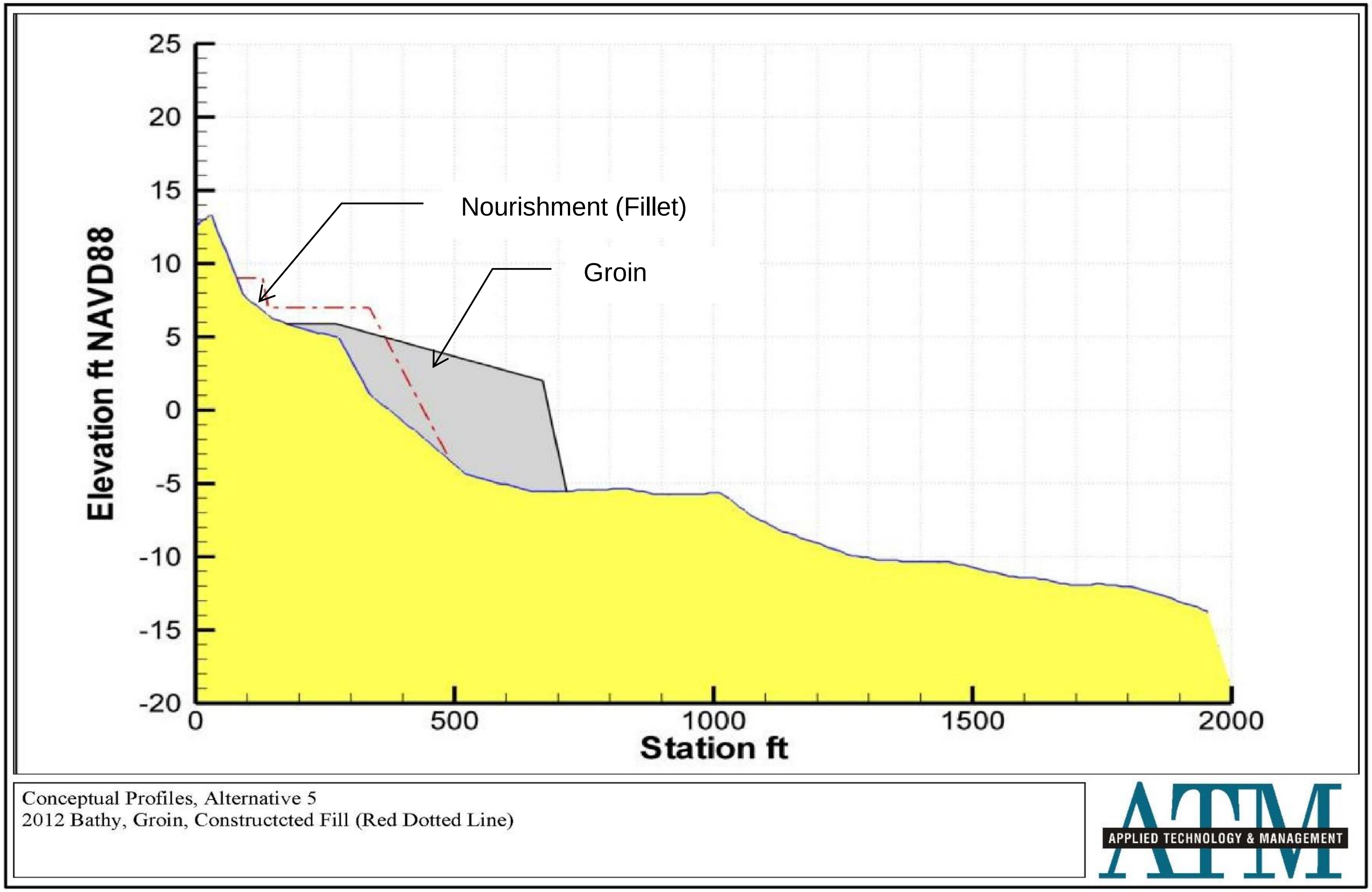
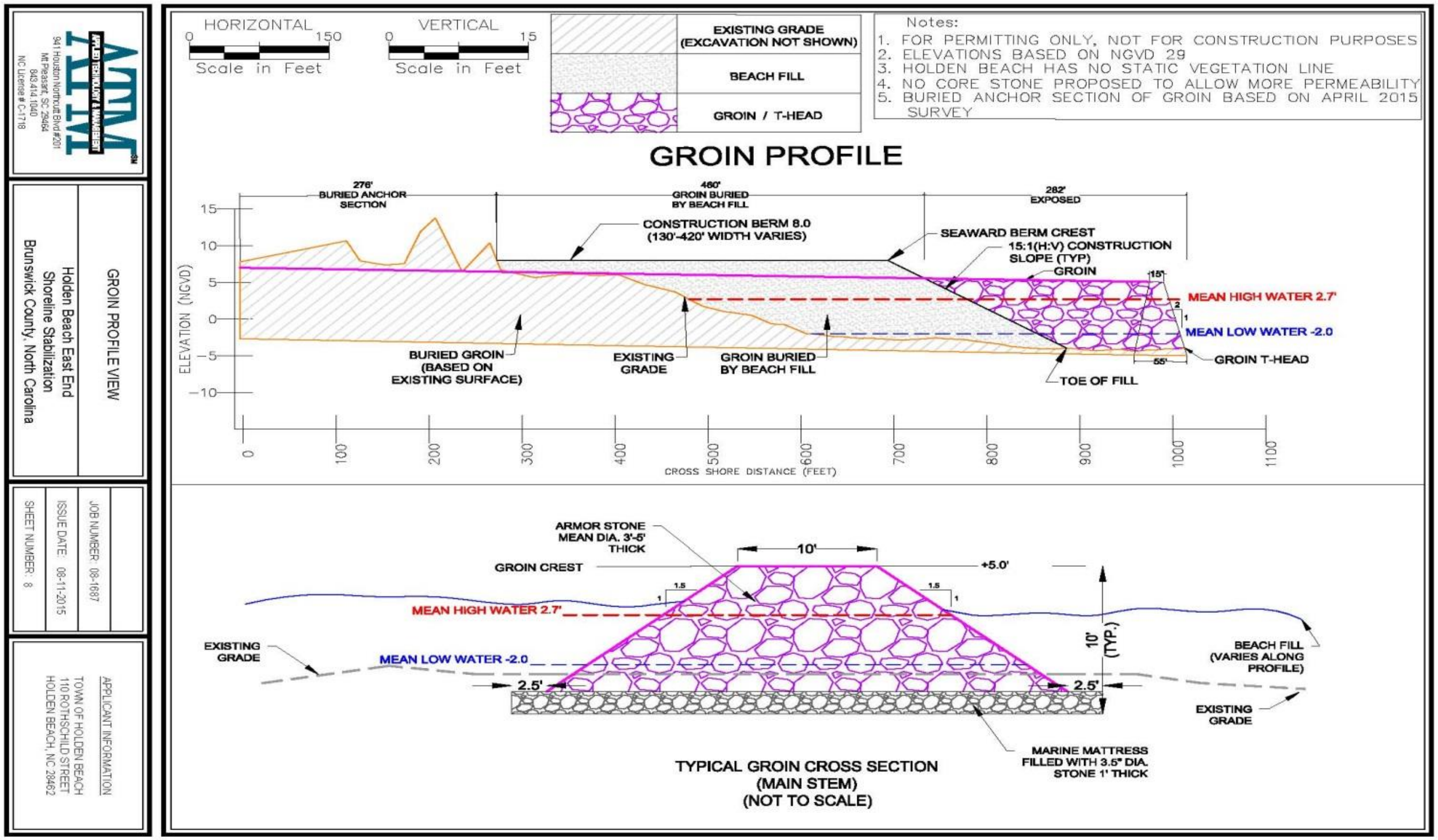


Figure 3.9. Alternative 5 – Short Groin Cross Section and Profile



Source: ATM

Figure 3.10. Typical Groin Profile and Cross Section

It is assumed that the combination of nourishment-related dredging events and interim USACE navigation dredging events would maintain dredging regimes in the LFIX and inland LFI channels that are similar to those associated with ongoing federal dredging operations.

3.1.6 Alternative 6: Intermediate Terminal Groin and Beach Nourishment (Applicant's Preferred Alternative)

Under Alternative 6, the Applicant's Preferred Alternative, the Town would assume responsibility for shore protection of the East End of Holden Beach through the construction of a ~1,000-ft-long intermediate terminal groin at the eastern end of the oceanfront beach between Stations 00+00 and 10+00 (Figure 3.11, Appendix I – Permit Sheets) and the implementation of an independent, 30-year beach nourishment plan (Appendix J – Holden Beach Resolution). The main stem of the intermediate terminal groin would include a 700-ft-long segment extending seaward from the toe of the primary dune and a ~300-ft anchor segment extending landward from the toe of the primary dune. The terminal groin would also include a 120-ft-long shore-parallel T-Head segment centered on the seaward terminus of the main stem. The intermediate terminal groin features a smaller T-Head since a longer groin in this location would be expected to have more of a stabilizing effect on the shoreline than the shorter groin alternative (Alternative 5). T-Head feature would help to minimize formation of potential offshore rip currents and sand losses during extreme wave conditions (Appendix H – Engineering Analysis).

The anchor segment would be designed to prevent flanking of the terminal groin in the event of shoreline migration landward of the primary dune. The anchor segment would be entirely buried at the completion of groin construction and would remain buried so long as the position of the MHW line remains seaward of the initial post-construction primary dune line. Similar to the short groin (Alternative 5), the intermediate groin would be designed to be a relatively low-profile structure (Figure 3.11) to maximize sand overpassing and to minimize impacts to beach recreation and aesthetics. In addition to the 300-ft anchor segment, a portion of the adjoining 700-ft segment across the upper dry beach would also be completely buried thus maintaining recreational beach access across the groin. The relatively low profile of the groin is designed to allow some sand overpassing even under eroded conditions at the end of the four-year nourishment cycle.

The intermediate terminal groin would be constructed of 4- to 5-ft-diameter granite armor stone and, unlike conventional groins, would not have a core component of smaller diameter stone (refer to Figure 3.10). The use of only larger armor stone would allow for construction of the groin to the 25 percent void design ratio thus providing the "leaky" characteristic that allows sand to pass through the structure. To prevent settlement of the stone and, if necessary, to facilitate modification or removal of the groin, a base layer of geo-textile matting (1 ft thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the groin would have a crest width of ~10 ft and a base width of ~40 ft while the underlying geo-textile base layer would have a slightly greater width of ~45 ft (Figure 3.12). The relatively short length of the intermediate groin along with the large tidal range at

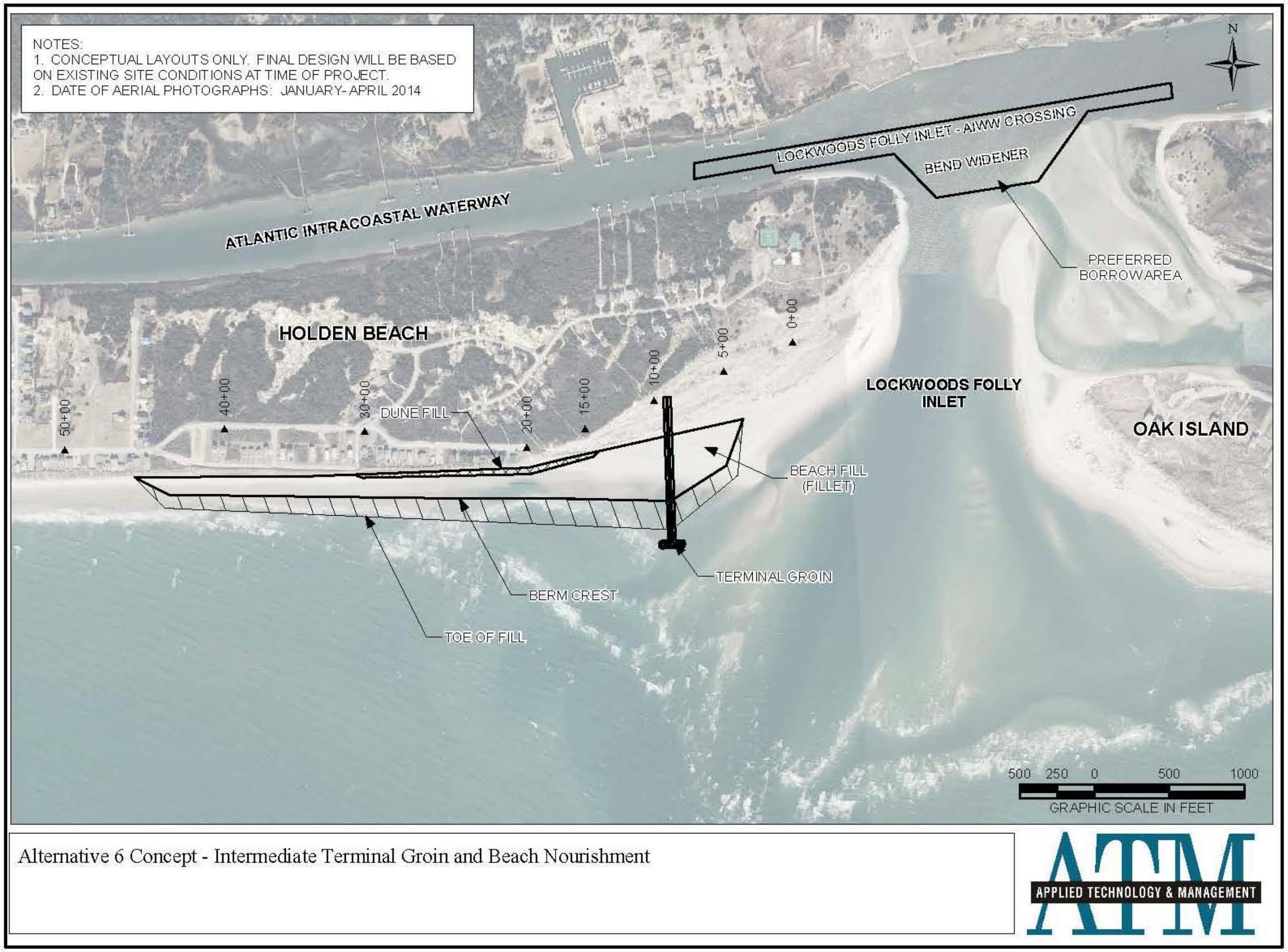
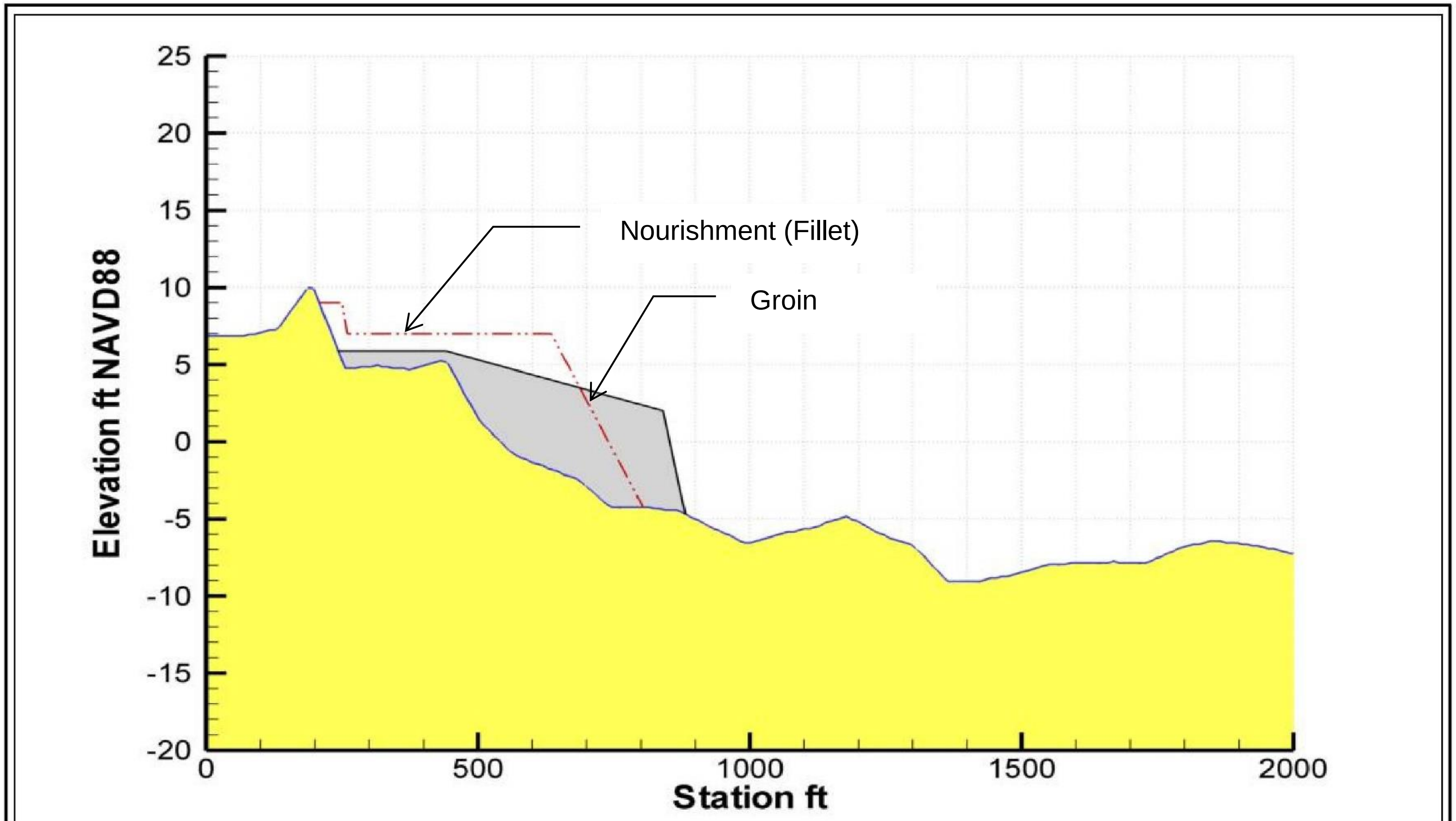


Figure 3.11. Alternative 6 – Beach Fill and Intermediate Terminal Groin Footprints



Conceptual Profiles, Alternative 6
2012 Bathy, Groin, Constructcted Fill (Red Dotted Line)

Figure 3.12. Alternative 6 – Intermediate Groin Cross Section and Profile

Holden Beach would allow for construction of the groin entirely from shore. It is likely that groin construction would be conducted with the use of sand work pads as the seaward tow of the groin is only in a few feet of water at MLW. The purpose of the temporary work pads, constructed of native beach material, is to minimize, or ideally eliminate, the need for a construction trestle. It is anticipated that the public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

The projected beach nourishment regime would involve the placement of ~100,000 to 150,000 cy of sand (32.5-acre fill footprint from the dune out to the toe of fill) on the East End of Holden Beach every four years. Compared to the short groin, the intermediate groin would be located ~300 ft farther east, resulting in a corresponding 300-ft relative increase in the lengths of the berm, toe, and groin fillet components under Alternative 6 (Figure 3.12, Appendix I – Permit Sheets). The greater length of the intermediate groin is designed to account for the landward shift in shoreline position as the east-west oriented oceanfront beach transitions to the north-south oriented inlet shoreline. The shore-perpendicular widths of the beach fill toe and groin fillet footprints in the vicinity of the intermediate groin structure would also increase slightly to account for the shift in shoreline position. Otherwise, the beach fill profile design would be similar to that of Alternatives 3, 4, and 5 and include a +9-ft NAVD high dune with a 50-ft-wide crest, a +7-ft NAVD high, 200-ft-wide berm, and a 90- to 200-ft-wide transition with a 15 percent slope. The anticipated borrow sites and dredging regimes would be the same as those described under Alternative 5.

3.2 Alternatives Considered but Eliminated from Further Evaluation

Based on the initial screening-level evaluation, the following alternatives were determined to be unreasonable and were excluded from further consideration in this EIS.

In addition to the six alternatives evaluated in this document, the USACE and PRT developed several alternatives that were eliminated from further consideration based on the results of modeling analyses. These eliminated alternatives included long groin construction with nourishment, long groin construction without nourishment, short groin construction with nourishment and inlet channel relocation, short groin construction without nourishment, and Eastern Channel dredging. The Eastern Channel dredging alternative is not the same as the recently constructed Lockwoods Folly River Habitat Restoration: Phase I Eastern Channel project completed in spring 2015 (Figure 3.13). The modeling results for these alternatives are described in detail in the East End Shore Protection Project Engineering and Modeling Report by ATM (ATM 2013, Appendix H).

The two long groin alternatives were eliminated based on model results showing significant downdrift (sediment transport) effects on the Holden Beach shoreline to the east of the groin structure (between the groin and LFI). Although the long groin under both alternatives effectively trapped sand to the west of the structure, adverse downdrift effects on the shoreline to the east were relatively high in comparison to the short and intermediate groin alternatives.

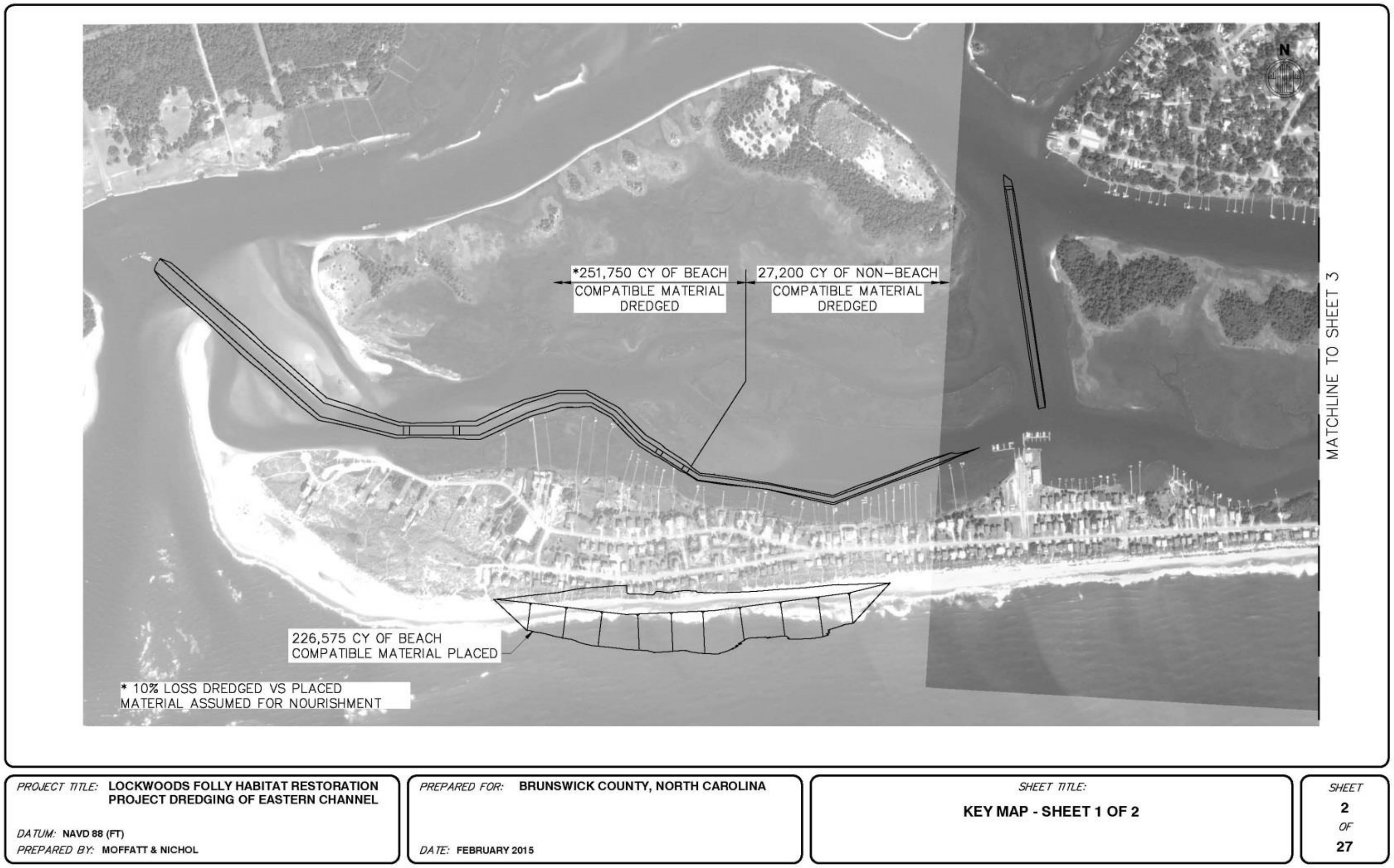


Figure 3.13. Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel

Disproportionate downdrift erosional effects under the long groin alternatives were attributable to rapid westward migration of the inlet ebb channel and associated increases in current velocities along the groin structure. Associated shoreline erosion along the eastern margin of the groin resulted in projected annual downdrift impacts of approximately 32,000 cy/yr under both long groin alternatives.

Elimination of the short groin with nourishment and inlet channel relocation alternative was based on model results showing significant effects on inlet processes of erosion and accretion and an associated large increase in net sediment loss along the East End of Holden Beach. The projected effects are related to the expanded depth and width of the relocated outer inlet channel which substantially increase the inlet tidal prism. As a result, the inlet throat ebb channel is highly unstable throughout the four-year simulation period. The principal ebb channel response is one of westward migration and associated increases in erosion along the inlet shoreline of Holden Beach. Westward migration of the ebb channel also affects shoal attachment along the inlet shoulder of Holden Beach, resulting in additional relative sediment loss along the east end beach.

Elimination of the short groin without nourishment alternative was based on a projected substantial increase in erosion along the East End inlet shoulder.

The Eastern Channel dredging alternative was eliminated based on model results indicating no significant mitigative effects on East End shoreline erosion. The relocated Eastern Channel maintains its depth and shifts the main inlet channel more towards the center of LFI. Furthermore, the modeling results show a northward shift in the AIWW towards the mouth of the newly dredged Eastern Channel at the northwestern corner of Sheep Island. However, the Eastern Channel modeling results do not show any significant effects on the adjacent shorelines of Holden Beach or Oak Island.

Additional sand borrow sites were also evaluated and eliminated from further consideration: two AIWW spoil islands (Monks Island and Sheep Island) and three upland sources (Turkey Trap Road, Smith, and Tripp sites). The AIWW spoil islands contain a mix of beach-compatible and non-compatible sediment which would be costly to separate (ATM 2013). Therefore, these islands are not included as potential borrow sites in this document. The upland sources were eliminated based on concerns related to frequent truck hauls and potential road impact/maintenance issues as well as limited volumetric availability and variability in sand color. However, the Town does value these upland sites as an emergency back-up source of sand. These sources have been used previously after major storms when sand is needed quickly for dune and beach berm repair (Personal communication, Fran Way, ATM, Holden Beach Engineer of Record, March 2015).

4.0 AFFECTED ENVIRONMENT

4.1 General Environmental Setting

The study area, based on the area of potential secondary and cumulative effects, is comprised of 1,655 acres (ac) and includes portions of Holden Beach and Oak Island on the coast of southeastern NC in Brunswick County (Figure 4.1). The barrier islands of Holden Beach (eight miles long) and Oak Island (12 miles long) are located west of Cape Fear and have an east-west orientation, facing Long Bay and the open Atlantic Ocean to the south, and separated from mainland Brunswick County to the north by tidal marshes and the AIWW. Holden Beach and Oak Island are separated by the LFI. The west end of Holden Beach is separated from Ocean Isle Beach by Shallotte Inlet. The Town of Oak Island is bordered to the east by Caswell Beach and to the north in part by the town of St. James.

The relatively narrow subaerial (above sea level) ocean beach along the eastern end of Holden Beach is backed by a narrow line of low vegetated foredunes and wide interior parabolic (crescent-shaped) dunes that protrude northward towards the AIWW (Figure 4.1). The majority of the interior dunes have been fully or partially developed for residential use. A few of the relatively undisturbed interior dunes on the extreme eastern end of the island continue to support patchy areas of maritime shrub and forest vegetation. The interior dunes are backed by a narrow fringe of tidal marsh that separates the island from the AIWW (Figure 4.1). Prior to construction of the AIWW in the 1930s, Holden Beach was accessible from the mainland at low tide via a continuous expanse of intertidal marsh (Cleary 2008). Construction of the 12-ft-deep by 90-ft-wide AIWW channel divided the marsh into a southern component regarded as part of the island of Holden Beach and a northern component associated with the mainland. The AIWW extends east across LFI and behind the west end of Oak Island where it crosses the Lower Lockwoods Folly River. The west end of Oak Island is backed by a narrow fringe of tidal marsh that separates the island from a waterway known as the Eastern Channel. A spoil island-marsh complex known as Sheep Island lies between the Eastern Channel and the AIWW to the north. The Lower Lockwoods Folly River estuary to the north of the AIWW contains an expansive estuarine complex of marsh islands, sandy shoals, shellfish beds, and tidal creeks (Figure 4.1) (Photos 4.1 and 4.2). Appendix K provides an historical overview of Lockwood Folly Inlet and associated habitats from the 1930s to the present.

The embayed section of the Atlantic Ocean overlying the continental shelf between Cape Fear, NC, and Cape Romain, SC, is known as Long Bay. The marine component of the study area encompasses the subtidal ocean bottom (benthic) and ocean water column (pelagic) habitats and communities that occur seaward of the

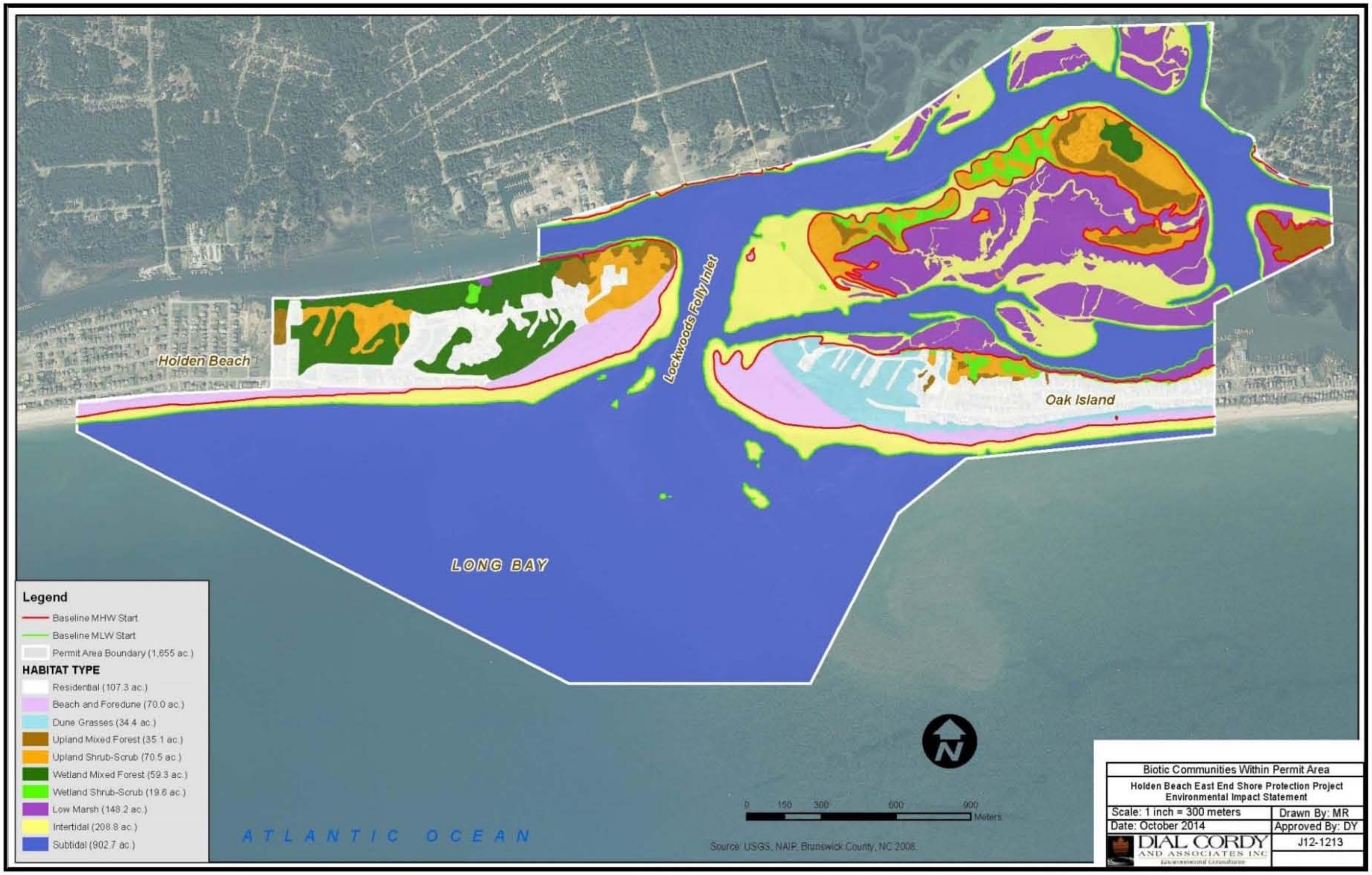


Figure 4.1. Study Area

Photo 4.1. View of tidal marsh along Eastern Channel, Oak Island, NC.

Photo 4.2. View to the north of Eastern Channel and LFI flood shoal system.

intertidal ocean beach to approximately the 40-ft isobath on the inner continental shelf of Long Bay (Figure 4.1). The subtidal seafloor extends below the low-tide line as a relatively steep, seaward-sloping surface known as the shoreface. Approaching onshore waves break as they interact with the shoreface forming the nearshore surf zone. The shoreface eventually flattens and matches the gentle slope of the inner continental shelf.

4.2 Physical Environment

4.2.1 Geomorphology, Geology, and Sediments

Holden Beach is an 8.1 mile transgressive barrier island with morphologically dissimilar eastern, central, and western reaches. The eastern (2.8 miles) and western (2.3 miles) ends of the island are relatively wide (~1,000-1,700 ft) with areas of large parabolic (crescent-shaped) dunes that reach elevations as high as 32 ft. In contrast, the intervening 3.0-mile central reach is narrow (~300 ft) with relatively low elevations of seven feet or less. The differing geomorphologies are primarily the result of significant changes that occurred from the late 1800s through the early 1900s (Cleary 2008). Prior to the 1930s, two tidal inlets extended across the present day central reach, dividing the eastern and western reaches into two separate islands. During the late 1800s and early 1900s, large parabolic dunes developed and migrated landward across both of the islands. The inlets separating the two islands closed during the 1930s, forming the low and narrow central reach that connects the relatively high and wide eastern and western reaches. The majority of the oceanfront shoreline has experienced long-term net erosion over the last 70 years. Erosion has been most severe along the eastern oceanfront shoreline, where average long-term erosion rates approach -8 ft/yr near Lockwoods Folly Inlet (NCDCM 2011). The narrow central reach, which is vulnerable to overwash, has experienced long-term erosion at rates averaging -1 to -2 ft/yr. Chronic erosion along the eastern reach is a function of the inlet ebb channel alignment over the majority of the past 70 years, which has promoted erosion along Holden Beach and accretion along Oak Island (Cleary 2008).

The inner continental shelf of Long Bay is a sediment-starved environment with a geological framework dominated by Cretaceous and Tertiary rock units. Inputs of new sediment to the inner-shelf/barrier island system are minimal, resulting in characteristically thin subaerial barriers that are perched on top of older rock units that constitute the shoreface (Riggs et al. 1995). The older shoreface/inner-shelf geologic units have a thin covering of modern sediment that is derived primarily from the erosion and reworking of the underlying hard strata. The shoreface along Holden Beach and Oak Island is dominated by Cretaceous to Eocene Age sandstones and limestones that are covered by a thin and discontinuous veneer of modern sediment (Cleary 2008). The hard strata are frequently exposed on the shoreface forming extensive hardbottom areas (Marden et al. 1999). Vibracore data indicate that the shoreface sediments along

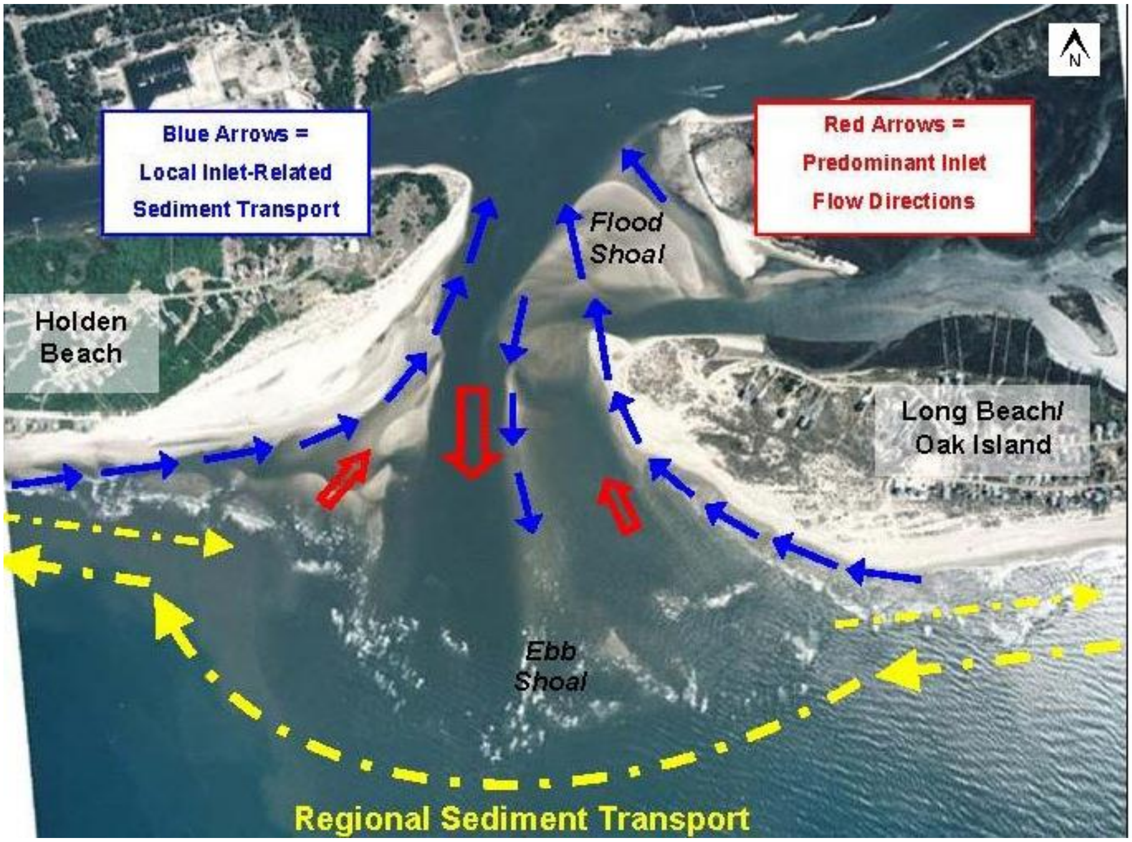
Holden Beach and Oak Island consist predominantly of gravelly muddy sands and muddy sandy gravels intercalated with muds and muddy sands (Cleary 1999; Cleary et al. 2000). The thickness of the modern sediment layer ranges from <1 inch in hardbottom areas to >11 ft in intervening areas.

The majority of the oceanfront beach on Holden Beach has experienced long-term net erosion over the last 70 years. Erosion has been the most severe along the island's easternmost two-mile-long reach where average long-term erosion rates range from -3 to -8 ft/yr (NCDCM 2011). A chronic erosion trend exists along the East End of Holden Beach, up to 2 kilometers (km) (about 1.2 miles) from LFI. The approximate influence of LFI is 2 km in both the eastern (Oak Island) and western (Holden Beach) directions (Cleary, 1996; Cleary, 1998). Since 2001, numerous beach nourishment projects have been implemented along this eastern reach to mitigate erosion (ATM 2013).

4.2.2 Sediment Transport

Along Holden Beach, the seaward extent of significant fair-weather sediment mobilization (i.e., depth of closure) occurs at a depth of approximately 30 ft (Cleary et al. 2001). Sediments mobilized on the shoreface by onshore waves are picked up by longshore currents and transported along the beach in a process known as longshore or littoral drift (Figure 4.2). Depending on incident wave conditions, longshore sediment transport along Holden Beach and the other Brunswick County beaches occurs in both westward and eastward directions. Westward longshore transport rates generally exceed eastward transport rates, resulting in a regional longshore transport pattern that is predominantly westward (Thompson et al., 1999; OCTI 2008). At LFI, transport modeling analyses predict westward longshore transport at a rate of 400,000 cy/yr and eastward longshore transport at a rate of 150,000 cy/yr, thus indicating a net westward transport rate of 250,000 cy/yr (OCTI 2008). West of the inlet along Holden Beach, predicted westward transport rates increase to a range of 400,000 – 600,000 cy/yr, whereas eastward transport rates increase to a range of 175,000 – 225,000 cy/yr. Although sediment transport is predominantly westward at a regional scale, local transport patterns exhibit considerable variability due to the influence of inlets, shoals, and local bathymetry (Thompson et al. 1999; OCTI 2008). As depicted in Figure 4.2, relatively large volumes of sediment move eastward along the east end of Holden Beach and are eventually transported into LFI where they are retained within the inlet flood shoal system and the federal navigation channels (ATM 2013). The resulting effect on the east end beach is a localized reversal of the regional net westward transport pattern within ~0.7 mile of LFI. Sediment retained in the inlet is permanently lost to the east end beach, thus accounting for much of the ongoing chronic erosion.

Sediments mobilized on the upper shoreface also move onshore and offshore in a process known as cross-shore transport. Offshore transport is primarily a storm driven response involving the formation of a nearshore sand bar, whereas onshore transport



Source: ATM 2013

Figure 4.2. Conceptual Regional and Local Net Sediment Transport Schematic at LFI (2004 aerial)

involving the movement of sandbars back onshore predominates during fair-weather wave conditions. A recent study of Long Bay beaches (North Myrtle Beach, Myrtle Beach, and Garden City) found the most active profile changes occurred in the surf-zone between the +2-meter (m) (+6.5-ft) NAVD contour (approximately the upper beach berm) and the -4-m (-13-ft) NAVD depth contour (Park et al. 2009). Seaward of the depth of closure (~30-ft contour) on the lower shoreface and inner shelf, significant sediment mobilization is strongly related to the passage of high-energy storms and associated increases in wave orbital velocities (Davis 2006). Although fine-grained [~0.125 millimeters (mm)] sediments are frequently suspended during the passage of routine cold/warm fronts and low pressure systems (Warner et al. 2012), full suspension conditions involving coarse sand particles are primarily associated with hurricanes and nor'easters (Davis 2006).

4.2.3 Hydrodynamics and Water Quality

Physical oceanographic processes in Long Bay are controlled primarily by interactions among the Gulf Stream, tides, and local wind stress. On the inner shelf (depths <20 m), wind stress is the principal driver of alongshore currents, and tides are responsible for much of the cross-shelf current (Pietrafesa et al. 1985a, 1985b). Wind-driven currents are strongly correlated with synoptic scale (two to 14 days) wind events that are driven by low/high pressure systems and associated cold/warm fronts (Pietrafesa et al. 1985b). The tidal regime is dominated by the lunar semidiurnal (two cycles/day) tidal constituent, which has a mean annual tidal range of approximately 4.72 ft and a spring tidal range of approximately 5.27 ft in the vicinity of Holden Beach. The salinity along Holden Beach varies considerably throughout the year and ranges from ~26 to 35 parts per thousand (ppt) (mean = 34 ppt). Wide variations in salinity reflect the influence of low salinity discharge from the Cape Fear River. Salinities are relatively low (<34 ppt) during peak flows in the late winter/spring and relatively high (>34 ppt) during the summer and fall when the discharge is low [Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS) 2015]. Discharge from the river also carries suspended sediments that lead to elevated turbidity levels in the immediate vicinity of the river mouth; however, turbidities west of the Cape Fear River along Oak Island are usually low (two to five NTU) regardless of discharge conditions (Durako et al. 2010).

Results from wave hindcast studies indicate that the inner shelf wave climate along Holden Beach is dominated by small (mean = three ft), short period (mean = 5.2 seconds) wind waves out of the southeast sector (Jensen 2010). During the spring and summer, prevailing winds are out of the southwest, and the predominant direction of wave approach is from the south. As the prevailing winds shift to the northeast in the fall, the predominant direction of wave approach shifts to the southeast. During the winter, the prevailing winds are out of the north-northwest, and the predominant direction of wave approach is from the east. The wave climate along Holden Beach is influenced by the Cape Fear River and its associated shoal complex which shelters the area from the high-energy northeast winds and waves that dominate the region. The sheltering effect results in a relatively low-energy wave regime dominated by small, short-period, southerly waves. Although protected against northeast winds and storm waves, the area is highly exposed to tropical storms and hurricanes approaching from the south (Jensen 2010.

4.2.4 Flooding and Flood Zones

The dominant source of flooding on Holden Beach is wind-driven surge created in the Atlantic Ocean by tropical storms and hurricanes. High winds can produce high velocity waves that can be much more damaging to oceanfront properties than high water levels alone. Storm surges can also propagate into the inlets, sounds, and estuaries; exposing properties along the inland waterways to a high risk of flooding. Although coastal flooding can also occur in association with extratropical nor'easters, these relatively minor flooding events do not influence the determination of flood zone boundaries (FEMA and State of North Carolina 2003). The NC Flood Mapping Program (NCFMP), through a cooperative agreement with FEMA, is responsible for maintaining and updating NC flood hazard risk maps [i.e., Flood Insurance Rate Maps (FIRMs)]. FIRMs delineate floodplains with 100-year and 500-year return intervals. Areas that fall within the 100-year floodplain have a one percent chance of flooding in any given year, and areas that fall within the 500-year floodplain have a 0.2 percent chance of flooding in any given year. Figure 4.3 depicts the distribution of flood zones in the study area. The majority of the oceanfront properties fall within Zone VE (Coastal High Hazard Area), which has a one percent or greater chance of flooding and an additional hazard associated with high velocity storm waves. Many of the waterfront properties along the AIWW fall within Zone AE, which corresponds to high risk areas within the 100-year floodplain. Some of the interior portions of the East End of Holden Beach fall within Zone X; which corresponds to areas outside of the 500-year floodplain.

4.3 Biological Resources

The study area includes a variety of biotic community types and sizes. Visual interpretations of biotic community types were digitally mapped using ArcView 9.3 software over high-resolution georeferenced digital multispectral aerial photographs as part of the initial pre-construction assessment of biotic communities. The methods employed for interpretation of aerial photography included visual analysis of color variations in the photographs to delineate habitats (dark areas = submerged land; white areas = sediment exposed above high tide line). Resolution of this imagery (< 2 ft) allowed for adequate delineation of the habitats and features within the study area. These habitat types are summarized in Table 4.1 and depicted in Figure 4.1. Additional details about the marine, beach and dune, and inlet and estuarine communities are included in Sections 4.2-4.4. Residential community acreages were calculated to take into account all possible community types within the study area.

Table 4.1. Biotic communities in the Permit Area.

Habitat Type	Size (ac)
Residential	107.3
Beach and Foredune	70.0
Dune Grasses	34.4
Upland Mixed Forest	35.1
Upland Shrub-Scrub	70.5
Wetland Mixed Forest	59.3
Wetland Shrub-Scrub	19.6
Low Marsh	148.2
Intertidal	208.8
Subtidal	902.7

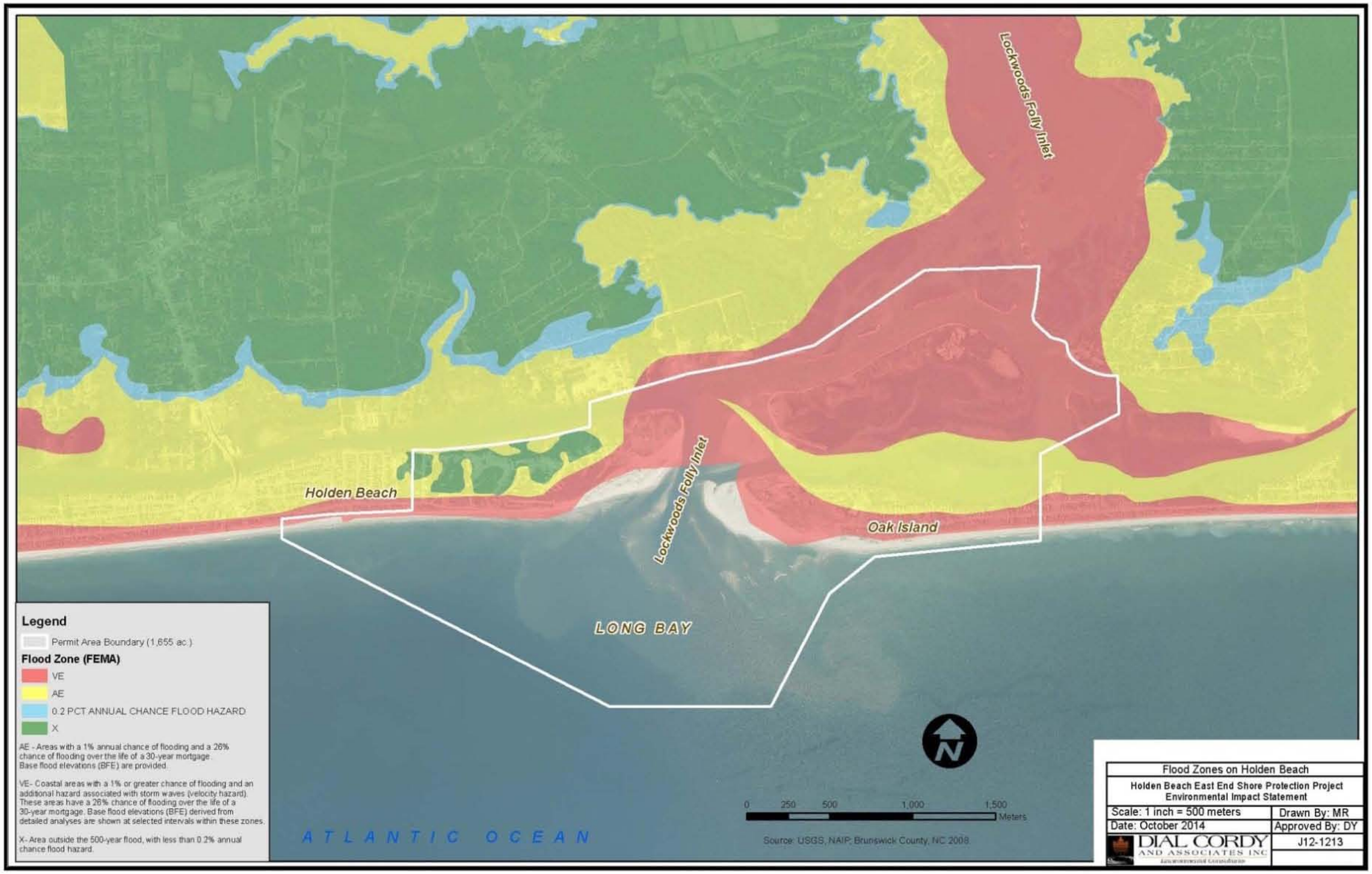


Figure 4.3. Study Area Flood Zones

4.3.1 Marine Habitats and Communities

4.3.1.1 Marine Benthic Communties

Marine Soft Bottom

Marine soft bottom habitats encompass all areas of the subtidal seafloor that are covered by a surface layer of unconsolidated sediment. Sediment transport processes on the shoreface and inner shelf are driven primarily by waves and wave-generated currents. Under fair-weather conditions, significant sediment mobilization is largely confined to the upper shoreface where seafloor sediments are agitated by onshore waves.

Seaward of the shoreface on the inner shelf, significant sediment mobilization is strongly related to the passage of high-energy storms and associated increases in wave orbital velocities (Davis 2006). Although fine-grained (~0.125 mm) sediments are frequently suspended during the passage of routine cold/warm fronts and low pressure systems (Warner et al. 2012), full suspension conditions involving coarse sand particles are primarily associated with hurricanes and nor'easters (Davis 2006).

Marine soft bottom habitats support a diverse community of benthic invertebrate infauna (burrowing organisms that live within the sediment) and epifauna (organisms that live on the surface of the sediment). Nearshore soft bottom communities along the southeastern NC coast are dominated by deposit- and filter-feeding invertebrates, including polychaetes, bivalve mollusks, nematodes, amphipod crustaceans, echinoderms (sand dollars), and gastropods (snails) (Hague and Massa 2010, Posey and Alphin 2002, Peterson and Wells 2000, Peterson et al. 1999). Soft bottom sites also provide important habitat for large, mobile decapod crustaceans (e.g., crabs and shrimp). Based on annual trawl surveys conducted by Posey and Alphin (2002), the large decapod assemblage in nearshore Long Bay is dominated by white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), and the iridescent swimming crab (*Portunus gibbesii*). Soft bottom habitats and their associated benthic invertebrate communities provide important habitat and food resources for many species of demersal (bottom-dwelling) fishes. The Southeast Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) has conducted annual nearshore (15- to 60-ft-deep) trawl surveys for demersal fishes in Long Bay since 1986. Catches have been consistently dominated by sciaenid fish which utilize estuaries during part of their life cycle (SEAMAP-SA 2000). Overall patterns of demersal fish abundance are strongly influenced by the high abundance of spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*). These two species have been consistently dominant, accounting for more than 36 percent of the total catch between 1990 and 1999. Other abundant demersal fishes in this region include the Atlantic bumper (*Chloroscombrus* *chrysurus*), scup (*Stenotomus* spp.), pinfish (*Lagodon rhomboides*), star drum (*Stellifer lanceolatus*), banded drum (*Larimus fasciatus*), gray trout (*Cynoscion regalis*), silver seatrout (*C. nothus*), southern kingfish (*Menticirrhus americanus*), and inshore lizardfish (*Synodus foetens*) (SEAMAP-SA 2000).

Many of the demersal fishes associated with marine soft bottom habitats are estuarine-dependent/ocean-spawning species that utilize estuarine waters for juvenile development before moving into the ocean as adults. During the fall and winter, large numbers of these estuarine-dependent species leave the estuaries and enter the nearshore ocean zone (Deaton et al. 2010). Peterson and Wells (2000) documented seasonal variations (November, February, and May) in demersal fish communities at inshore (~1 mile) and offshore (~5 miles) soft bottom sites off of North Carolina. In November, catches at the offshore sites were dominated by spot (>50 percent of total catch), pinfish, pigfish (*Orthopristis chrysoptera*), and croaker while the inshore sites were dominated by croaker, silver perch (*Bidyanus bidyanus*), Atlantic silversides (*Menidia menidia*), pinfish, and striped mullet (*Mugil cephalus*). In February, total catches at the offshore and inshore sites were reduced by 96 and 59 percent, respectively. Pinfish, Atlantic menhaden (*Brevoortia tyrannus*), and silversides collectively accounted for 96.4 percent of the total combined inshore/offshore catch in February. The combined inshore/offshore totals for spot and croaker were reduced by 98.9 and 99.8 percent, respectively, and catches of all other taxa decreased sharply, with the exception of silversides and pinfish at the inshore sites. During the May sampling period, large numbers of Atlantic silversides and Atlantic threadfin herring (*Opisthonema oglinum*) increased the total inshore catch. Peterson and Wells (2000) also analyzed the stomach contents of demersal fishes that were caught during the November sampling period and found that croakers and pinfish were primarily consuming polychaete worms, bivalves, grass shrimp (*Palaemonetes* spp.), and pinnotherid crabs. Silver perch, pigfish, and spot consumed polychaetes, grass shrimp, and other small bottom-dwelling crustaceans. Gray trout consumed grass shrimp, penaeid shrimp, and portunid crabs whereas kingfishes primarily consumed pinnotherid crabs, portunid crabs, and large polychaete worms.

Several other studies have investigated estuarine and nearshore larval and juvenile fish distribution and abundance near inlets along the SC and NC coast. An annotated bibliography (with emphasis on inlets in close proximity to the Cape Fear region) has been assembled by Bald Head Island and is included for reference (Appendix L).

Marine Hardbottom

The northern section of Long Bay between Cape Fear and Shallotte Inlet contains one of the highest concentrations of known hardbottom sites along the NC coast (Deaton et al. 2010). Offshore of Holden Beach and Oak Island, hardbottoms consisting of Cretaceous and Paleocene Age limestones and sandstones are frequently exposed on the shoreface and inner shelf (Marden et al. 1999). The extent and distribution of hardbottom areas within the study area have not been fully determined; however, extensive hardbottom data for the region have been compiled from sand resource studies and regional bottom-mapping efforts (Figure 4.4). A myriad of remote sensing investigations and vibracore analyses related to the USACE's Brunswick County Beaches Storm Damage Reduction Project have identified numerous hardbottom areas offshore of Holden Beach and Oak Island. Local hardbottom data from other sources have been compiled by the SEAMAP-SA as part of a regional mapping effort within the South Atlantic Bight (SEAMAP-SA 2001). The SEAMAP-SA dataset has facilitated the identification of potential borrow sites that are consistent with state regulations prohibiting dredging within 500 m of hardbottom habitats (15A NCAC 07H.0208). The proposed borrow site and a peripheral 500-m buffer zone for the current project were subjected to a more intensive remote sensing investigation in conjunction with the Central Reach Project. Analyses of acoustic and bathymetric data did not identify any potential hardbottom areas within the borrow site or buffer zone (Tidewater Atlantic Research 2011).

Hardbottom habitats exhibit varying degrees of colonization by marine algae and sessile invertebrates (e.g., sponges, soft corals, and hard corals). Marine macroalgae are the dominant colonizing organisms on NC hardbottoms with attached, sessile invertebrates typically accounting for ten percent or less of the total coverage (Peckol and Searles 1984). Dominant large, attached invertebrates include the soft corals *Titandeum frauenfeldii* and *Telesto fructiculosa* and the hard coral *Oculina arbuscula*. The small macroinvertebrate community is dominated by mollusks, polychaetes, and amphipods (Kirby-Smith 1989), and the most common large mobile invertebrates are the purple-spined sea urchin (*Arbacia punctulata*) and the green sea urchin (*Lytechinus variegatus*). Hard and soft corals are less prevalent on nearshore hardbottoms in NC compared to offshore and more southerly hardbottoms. In the nearshore environment, cooler water temperatures limit the growth of tropical corals (Kirby-Smith 1989, Fraser and Sedberry 2008), and macroalgae outcompete the dominant hard coral (Miller and Hay 1996). Along the NC coast, tropical reef-building corals are restricted to deep offshore waters (>20 miles from shore) (MacIntyre and Pilkey 1969, MacIntyre 2003).

Hardbottoms along the NC coast provide important foraging habitat and protective cover for tropical, subtropical, and warm-temperate reef fishes. Inner-shelf hardbottoms support a higher proportion of temperate fishes, such as the black sea bass (*Centropristis striata*), spottail pinfish (*Diplodus holbrookii*), and estuarine-dependent migratory species (Huntsman and Manooch 1978, Grimes et al. 1982). Lindquist et al. (1989) reported 30 species representing 14 families at a nearshore hardbottom site in Onslow Bay. Common species included juvenile grunts, round scad (*Decapterus punctatus*), tomtate (*Haemulon aurolineatum*), spottail pinfish, black sea bass, slippery dick (*Halichoeres bivittatus*), scup, pigfish, cubbyu (*Equetus umbrosus*), belted sandfish (*Serranus subligarius*), and sand perch (*Diplectrum formosum*). Nearshore hardbottom sites support spawning of smaller and more temperate reef species, such as black sea bass and sand perch, and also provide larval settlement sites and juvenile nursery

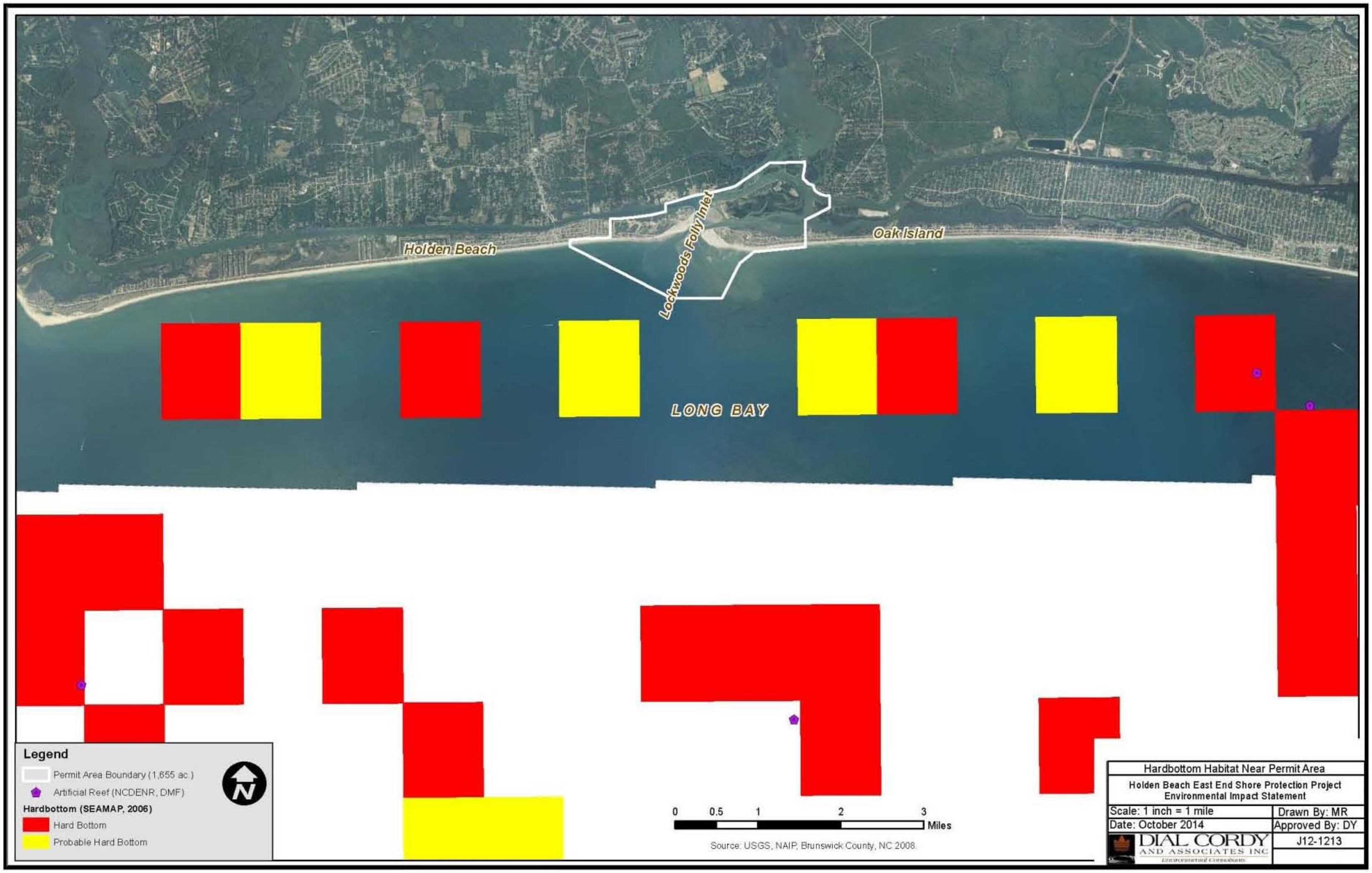


Figure 4.4. Hardbottom Habitat in the Vicinity of the Study Area

habitats for reef-associated fishes, including a number of taxa that are thought to spawn in deep offshore waters (Powell and Robins 1998).

4.3.1.2 Water Column

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

Ichthyoplankton (fish larvae) are an important component of the zooplankton community in the ocean water column. Powell and Robbins (1994) collected ichthyoplankton taxa representing 66 families along an inshore-offshore transect in Onslow Bay. Abundance and diversity were lowest at inner shelf sampling stations and highest at mid-to-outer shelf stations. A follow-up study targeting the water column above hardbottom sites yielded taxa from 110 families (Powell and Robbins 1998). During late fall and winter, estuarine-dependent species such as Atlantic menhaden, spot and Atlantic croaker, were an important component of the zooplankton community. Ichthyoplankton from estuarine-dependent species that spawn in the sounds and inlets [e.g., pigfish, silver perch and weakfish (*C. regalis*)] were found in the ocean water column shortly after the spring/early summer spawning period. Reef fish larvae were most abundant during the spring, summer and early fall (Powell and Robbins 1998).

4.3.2 Beach and Dune Communities

4.3.2.1 Intertidal Ocean Beach

The intertidal ocean beach is alternately inundated and exposed by twice-daily ocean tides and waves. The intertidal zone is a high-energy environment where sediments are continually reworked and sorted according to grain size. Sediments are generally coarse and highly sorted (sediment sizes are similar) with relatively little organic matter. Wave action in the intertidal zone generally precludes the growth of benthic algae; however, waves result in the continuous re-suspension of inorganic nutrients which support phytoplankton productivity. Phytoplankton production (primarily diatoms) supports benthic invertebrate filter feeders which are an important food resource for surf zone fishes and shorebirds. The dominant benthic macrofauna of NC intertidal beaches are mole crabs (*Emerita talpoida*), coquina clams (*Donax variablis* and *D. parvula*), several species of haustoriid amphipods and the spionid polychaete (*Scolelepis squamata*) (Deaton et al. 2010).

Leber (1982) described seasonal variations in the composition of intertidal macroinvertebrate communities along Bogue Banks. Mole crabs and coquina clams dominated the macroinvertebrate community for most of the year. Mole crab densities were highest from April through October, and densities of the coquina clam were highest from May through November. Densities of both species declined sharply in the late fall, and these species were completely absent between mid-January and mid-February. Recolonization by juveniles and adults of both species was evident by late February. Densities of the coquina clam were highest from May through August; this species disappeared from the intertidal zone in late August and remained absent until the following March. Haustoriid amphipods (*Haustorius* spp. and *Amphiporeia virginiana*) dominated the benthic community for a brief period during early winter, but were present in low numbers throughout the remainder of the year. Peterson et al. (2006) detected seasonal changes in polychaete abundance. Densities of intertidal polychaetes (*Scolelepis squamata*) increased after March, peaked during the warmer months, and declined in the fall.

At high tide, the inundated intertidal beach provides foraging habitat for surf zone fishes. The most common surf zone species along southeastern NC include Atlantic menhaden, striped anchovy (*A. hepsetus*), bay anchovy, rough silverside (*Membras martinica*), Atlantic silverside, Florida pompano (*Trachinotus carolinus*), spot, gulf kingfish (*M. littoralis*) and striped mullet (Ross and Lancaster 1996). The intertidal beach also provides important foraging habitat for shorebirds and waterbirds that probe or search the surface of wet intertidal sediments for benthic invertebrates. Shorebirds and waterbirds are present year-round, but are most abundant along the NC coast during spring and fall migration periods. Grippo et al. (2007) described shorebird and waterbird utilization of oceanfront beach habitats along Holden Beach and Oak Island between 2002 and 2003. The most abundant shorebirds were sanderlings (*Calidris alba*), willets (*Tringa semipalmata*), ruddy turnstones (*Arenaria interpres*), and semipalmated plovers (*Charadrius semipalmatus*). The most abundant waterbirds were laughing gulls (*Leucophaeus atricilla*), ring-billed gulls (*Larus delawarensis*), brown pelicans (*Pelecanus occidentalis*), and herring gulls (*L. argentatus*). Overall shorebird and waterbird abundance was highest during the fall.

4.3.2.2 Dry Ocean Beach and Dune

The dry upper beach is a highly dynamic environment that is continuously reworked by wind and water. Although located above the mean high tide line, the upper beach is subject to inundation by high spring tides (lunar tides) and storm tides. Vegetation of the upper beach is sparse and dominated by a few herbaceous species consisting primarily of annual succulents (Schafale and Weakley 1990). Dune grass communities occur on the frontal active dune system immediately landward of the ocean beach. This community type is dominated by grasses such as sea oats (*Uniola paniculata*), American beach grass (*Ammophila breviligulata*), seaside little bluestem (*Schizachyrium littorale*) and other herbaceous species that are adapted to this highly dynamic and stressful environment. Continuous salt spray, excessive drainage and shifting sands exclude most other plant species (Schafale and Weakley 1990).

North Carolina is part of the breeding range of several beach-nesting shorebirds and waterbirds including the American oystercatcher (*Haematopus palliatus*), willet, piping plover (*Charadrius melodus*), Wilson's plover (*C. wilsonia*), black skimmer (*Rynchops niger*), least tern (*Sternula antillarum*), common tern (*Sterna hirundo*) and gull-billed tern (*Gelochelidon nilotica*) (Parnell et al. 1995). Although dry ocean beach and dune habitats on NC's undeveloped and unstabilized barrier islands provide nesting habitat for shorebirds and colonial waterbirds, nesting on developed islands is restricted to inlet habitats. During 2007 and 2011 coastwide nesting surveys, no waterbird nests were observed on the developed barrier islands in Brunswick County (Cameron 2007, Schweitzer 2011). Many of the same shorebirds and waterbirds that utilize the intertidal ocean beach for foraging are likely to also use the dry beach for foraging and/or loafing (Photo 4.3).

Photo 4.3. Colonial waterbirds resting on the Oak Island western spit.

Photo taken by DC&A April 20, 2015

4.3.2.3 Maritime Upland Forest Communities

Maritime upland forests occur on interior stabilized dune ridges that are protected from overwash and the most extreme salt spray. Dominant species in this habitat include evergreen shrubs and trees such as wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*), red cedar (*Juniperus virginiana*), live oak (*Quercus virginiana*), sand laurel oak (*Q. hemisphaerica*) and loblolly pine (*Pinus taeda*) (Schafale and Weakley 1990). The stature of the vegetation is controlled by exposure to salt spray with dense salt-pruned shrub thickets characterizing sites near the ocean and a stunted canopy of larger trees characterizing sites along the backside of the island. Maritime shrub/forest communities on Holden Beach are naturally limited by the island's narrow width and low topography, and concentrated development on the island's larger dunes has eliminated most historical occurrences of this community type. Existing communities are patchily distributed across the large, relatively undisturbed parabolic dunes on the extreme eastern end of the island (Schafale and Weakley 1990).

4.3.3 Inlet and Estuarine Communities

4.3.3.1 LFI Complex

Lockwoods Folly Inlet separates Holden Beach from Oak Island and links the Lockwoods Folly River/AIWW estuarine system with the Atlantic Ocean. The tidal regime in LFI is dominated by the lunar semidiurnal (2 cycles/day) tidal constituent with a mean tidal range of ~4.2 ft and a spring tidal range of ~4.8 ft (NOAA Water Level Station TEC2869). Salinities in the AIWW between LFI and Lockwoods Folly River range from ~29 to 36 ppt (NCDWQ 2007). Salinities inside the mouth of the Lockwoods Folly River (~2,600 ft north of the AIWW) range from ~8 to 39 ppt (Ambient Monitoring Station 19480000). Turbidity levels are well below the state water quality standard of 25 NTU with an observed range of ~1 to 18 NTU in the AIWW (Ambient Monitoring Stations 19530000 and 19510000) and a range of ~1 to 23 NTU inside the mouth of the Lockwoods Folly River (Stations 19480000 and 19500000). Concentrations of total suspended solids (TSS) in the AIWW range from ~7 to 51 milligrams/Liter (mg/L), whereas concentrations inside the mouth of the Lockwoods Folly River range from ~3 to 48 mg/L (NCDWQ 2002, 2007, 2012). The main deepwater (ebb) channel through the inlet is periodically dredged by the USACE under a federal navigation project. The federal project authorizes maintenance of a channel 8 ft deep and 150 ft wide between the ocean and the AIWW. Lockwoods Folly Inlet was dredged 62 times between 1980 and 2007 with an average of 68,415 cy of material removed per dredging event. Dredging has been performed primarily by sidecaster dredges (NCDENR 2011).

Although the inlet has a history of migration along the west end of Oak Island, its position has remained relatively stable since the late 1930s. The inlet ebb channel alignment for most of the past 75 years has been oriented to the southeast along the

Oak Island shoulder, resulting in chronic erosion on the East End of Holden Beach and long-term accretion on the west end of Oak Island. Between 1974 and 1984, the ebb channel shifted to the southwest reversing the erosion/accretion pattern. In 2001, an ebb delta breaching event resulted in the realignment of the ebb channel to a shore-normal orientation. The new alignment led to a reconfiguration of the ebb tidal delta which, in turn, initiated a period of accretion along the East End of Holden Beach. Changes in the ebb channel alignment and flood channel complex alter the symmetry and breakwater effect of the ebb delta. The symmetry of the ebb delta also determines the zone of attachment of swash bars on the adjacent shoulders of Holden Beach and Oak Island. The inlet's influence on erosional and accretional processes extends ~2 km along the oceanfront shorelines of both islands (Cleary 2008, Cleary et al. 2001).

The inlet spit-shoal complex encompasses a diverse collection of shifting sand habitats. Accreting sand spits along the opposing inlet shorelines and detached shoals associated with the ebb and flood tidal deltas form a complex assemblage of subtidal, intertidal, and supratidal flats and shoals. The spit-shoal complex is part of a high-energy inlet system in which habitats are continually destroyed, recreated and redistributed by natural erosional and depositional processes. Ephemeral inlet flats and shoals provide important habitat for breeding, migrating and wintering shorebirds and waterbirds. As development and artificial beach stabilization have increased along NC's barrier islands, shorebirds and waterbirds have become increasingly dependent on inlet habitats. These habitats are especially important to migrating and wintering shorebirds and waterbirds, including dunlin (*C. alpina*), short-billed dowitcher (*Limnodromus griseus*), sanderling, semipalmated sandpiper (*C. pusilla*), black-bellied plover (*Pluvialis squatarola*), western sandpiper (*C. mauri*), laughing gull, royal tern (*Thalasseus maximus*), black skimmer, herring gull, and brown pelican (Rice and Cameron 2008).

Tidal inlets are a critical conduit for adult and larval ocean-spawning/estuarine-dependent fishes that spawn offshore on the continental shelf and use estuarine habitats for juvenile development. Larvae spawned offshore are transported shoreward by the prevailing currents and eventually pass through tidal inlets and settle in estuarine nursery habitats. Juveniles remain in the estuarine nursery areas one or more years before moving offshore and joining the adult spawning stock (Deaton et al. 2010). Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by along-shore currents and transported to the inlet (Churchill et al. 1999). The results of a long-term larval fish sampling program at Beaufort Inlet indicated that the most abundant larval taxa passing through the inlet are spot, pinfish, croaker, menhaden, speckled worm eel (*Myrophis punctatus*), flounders, pigfish, gobies (Gobiidae) and striped mullet (Taylor et al. 2009). Overall larval densities within the inlet were generally highest from late May to early June and lowest in November (Hettler and Chester 1990).

4.3.3.2 Estuarine Communities

The back-barrier estuary behind the East End of Holden Beach is occupied by the AIWW and relatively narrow fringing marshes. The Lower Lockwoods Folly River estuary to the north of the AIWW contains an expansive estuarine complex of marsh islands, sandy shoals, shellfish beds, and tidal creeks. The AIWW borders a spoil island-marsh complex known as Sheep Island which is separated from the estuarine shoreline of Oak Island by the Eastern Channel. The estuarine shoreline of Oak Island is occupied by a narrow band of tidal marsh.

Intertidal and Subtidal Flats and Shoals

Intertidal flats and shallow soft bottom habitats support a highly productive benthic microalgal community. Benthic microalgae, along with phytoplankton and detritus, support a diverse community of benthic infaunal and epifaunal invertebrates including nematodes, copepods, polychaetes, amphipods, decapods, bivalves, gastropods and echinoderms (SAFMC 1998, Peterson and Peterson 1979). Large mobile invertebrates that move between intertidal and subtidal habitats with the changing tides include blue crabs (*Callinectes sapidus*), horseshoe crabs (Limulidae) and penaeid shrimp. Mobile predatory gastropods (e.g., whelks and moon snails) occur along the lower margins of submerged tidal flats, and fiddler crabs (*Uca* spp.) are common on exposed flats during low tide (Peterson and Peterson 1979). Benthic invertebrates are an important food source for numerous predatory fishes that move between intertidal and subtidal habitats; these fishes include spot, Atlantic croaker, flounders (Paralichthys sp.), inshore lizardfish, pinfish, red drum (*Sciaenops ocellatus*) and southern kingfish. Planktivores [e.g., anchovies, killifish (*Fundulus* spp.) and menhaden] and detritivores [e.g., striped and white mullet (*M. curema*) and pinfish] also forage on tidal flats and shallow soft bottom areas. Intertidal flats function as an important nursery area for numerous benthic-oriented and estuarine-dependent species, especially Atlantic croaker, penaeid shrimp, flounder and spot (SAFMC 1998). A number of resident estuarine fishes and invertebrates, as well as seasonal migratory fish, spawn over estuarine soft bottom habitats. The majority of these estuarine-spawning species are resident forage finfishes that spawn in estuaries during the warmer months.

Submerged Aquatic Vegetation

Submerged Aquatic Vegetation (SAV) include several species of aquatic vascular plants such as common eelgrass (*Zostera marina*), shoalgrass (*Halodule wrightii*) and widgeongrass (*Ruppia maritima*), that occur in NC estuaries. SAV beds occur on subtidal and occasionally intertidal sediments in sheltered estuarine waters. Environmental requirements include unconsolidated sediments for root and rhizome development, adequate light reaching the sediments and moderate to negligible current velocities (Thayer et al. 1984, Ferguson and Wood 1994). In NC, eelgrass is more common in shallow, protected estuarine waters during the winter and spring. During the summer when water temperatures are above 25–30°C, shoalgrass is more abundant in these waters, and eelgrass dominates only in deeper waters and/or on tidal flats with continuous water flow and where water temperatures are lower (SAFMC 1998). Coast-wide mapping conducted by the SAV Cooperative Habitat Mapping Program indicates that SAV beds are uncommon along the Brunswick County coast. SAV in the study area may occur in a few small patches in the Eastern Channel behind Oak Island and in the Lower Lockwoods Folly River (Figure 4.5). According to the NCDMF, no SAV occurs in the Eastern Channel (personal communication, NCDMF, Anne Deaton, 22 May 2014). The current absence of SAV in the Eastern Channel was confirmed via groundtruthing by DC&A in September 2014.

SAV beds provide important structural fish habitat and perform important ecological functions, including primary production, structural complexity, energy regime modification, sediment and shoreline stabilization, and nutrient cycling. SAV beds produce large quantities of detritus which is broken down by invertebrates, zooplankton and bacteria and transferred to higher trophic levels through the estuarine-detrital food web. Water quality enhancement and fish utilization are especially important functions of SAV that enhance coastal fisheries (Deaton et al. 2010). Fish and invertebrates use SAV as nursery, refuge, foraging and spawning habitat. Invertebrates occurring on SAV leaves include protozoans, nematodes, polychaetes, hydroids, bryozoans, sponges, mollusks, barnacles, shrimp and crabs. Sampling in NC's estuaries has documented over 150 species of fish and invertebrates in SAV beds; of these species, 34 fish and six invertebrates are important commercial species (NCDMF 1990).

Large predatory species such as Atlantic stingrays (*Dasyatis sabina*), bluefish, flounders, red drum, sharks, spotted seatrout (*C. nebulosus*), weakfish and blue crabs are attracted to SAV beds due to their high concentrations of prey (e.g., juvenile finfish and shellfish) (Thayer et al. 1984). Important commercial and recreational fish that utilize SAV as juveniles during the spring and early summer include Atlantic croaker, black sea bass, bluefish, flounders, gag grouper (*Mycteroperca microlepis*), herrings, mullets, red drum, snappers, spot, spotted seatrout, weakfish, and southern kingfish. Bay scallops, hard clams, penaeid shrimp, and blue crabs use SAV for attachment and protection. SAV is considered an EFH for red drum, penaeid shrimp, and species in the snapper-grouper complex (SAFMC 1998). SAV also provide an important food source for waterfowl, sea turtles, and sea urchins. Birds, such as egrets, herons, sandpipers, terns, gulls, swans, geese, ducks, and osprey feed in SAV beds (Ferguson and Wood 1994). Birds, fishes, echinoderms, turtles, and manatees feed directly on SAV (SAFMC 1998).

Shell Bottom

Shell bottom habitats include oyster reefs, aggregations of non-reef-building shellfish species [e.g., clams and scallops (*Argopecten irradians*, *A. gibbus*)] and surface concentrations of broken shells (i.e., shell hash). The eastern oyster (*Crassostrea*

Figure 4.5. Potential Submerged Aquatic Vegetation in the Vicinty of the Study Area

virginica) is the dominant and principal reef-building species of estuarine shell bottom habitats in NC. Non-reef-building shellfish species that occur at densities sufficient to provide structural habitat for other organisms include scallops, pen shells (*Atrina seratta* and *A. rigida*) and rangia clams (*Rangia cuneata*) (SAFMC 2009). Shell bottom habitats perform a number of important ecological functions such as water filtration, benthic-pelagic coupling, sediment stabilization and erosion reduction (Deaton et al. 2010, SAFMC 2009, and Coen et al. 2007). Oysters and other suspension-feeding bivalves reduce turbidity in the water column by filtering particulate matter, phytoplankton and microbes. The consumption of particulates also results in the transfer of material and energy from the water column to the benthic community (i.e., benthic-pelagic coupling). Shell bottom structural relief alters currents and traps and stabilizes suspended solids, thus further reducing turbidity. By moderating waves and currents, oyster reefs and other shell bottom habitats reduce shoreline erosion. Shell bottom habitat within the intertidal and subtidal strata in and near the study area is depicted in Figure 4.6.

The hard surfaces provided by existing oyster reefs and shell hash function as important larval settlement and accumulation sites for recruiting oysters, hard clams and other shellfish (NCDMF 2008b). Studies summarized by Deaton et al. (2010) have documented the importance of shell bottom as foraging, spawning and nursery habitat for numerous species of invertebrates and fish. Shell bottom structure concentrates macroinvertebrates [e.g., grass shrimp and mud crabs (*Scylla* spp.)] and small forage fishes (pinfish and gobies) which, in turn, attract larger predatory fish such as Atlantic croaker, black drum (*Pogonias cromis*), pigfish, southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), and spotted seatrout. Shell bottom habitats are utilized as spawning areas by a number of finfish and decapod crustaceans, including anchovies, blennies (Blennidae), gobies, mummichog (*F. heteroclitus*), oyster toadfish (*Opsanus tau*), sheepshead minnow (*Cyprinodon variegatus*), grass shrimp and blue crabs. Numerous finfish and decapod crustaceans including anchovies, black sea bass, blennies, gobies, oyster toadfish, pinfish, red drum, sheepshead, spot, weakfish, penaeid shrimp, blue crabs, and stone crabs (*Menippe mercenaria*) also utilize shell bottom habitats as nursery areas (Deaton et al. 2010).

Tidal Marsh

Tidal salt and brackish marshes occur along the margins of tidal estuarine waters at salinities ranging from 0.5 to >35 ppt (Wiegert and Freeman 1990). The vegetative community is dominated by emergent, salt-tolerant, herbaceous species including smooth cordgrass (*Spartina alterniflora*), salt-meadow grass (*S. patens*), salt reed-grass (*S. cynosuroides*), black needlerush (*Juncus roemerianus*), glasswort (*Salicornia* spp.), salt grass (*Distichlis spicata*), sea lavender (*Limonium* spp.), bulrush (*Scirpus* spp.), sawgrass (*Cladium jamaicense*) and cattail (*Typha* spp.). The waterway behind the west end of Holden Beach is naturally constricted and the associated marshes are limited to a relatively narrow fringe (~50 to 100 ft wide) along both the island and mainland shorelines. The back-barrier environment between Oak Island and Sheep Island

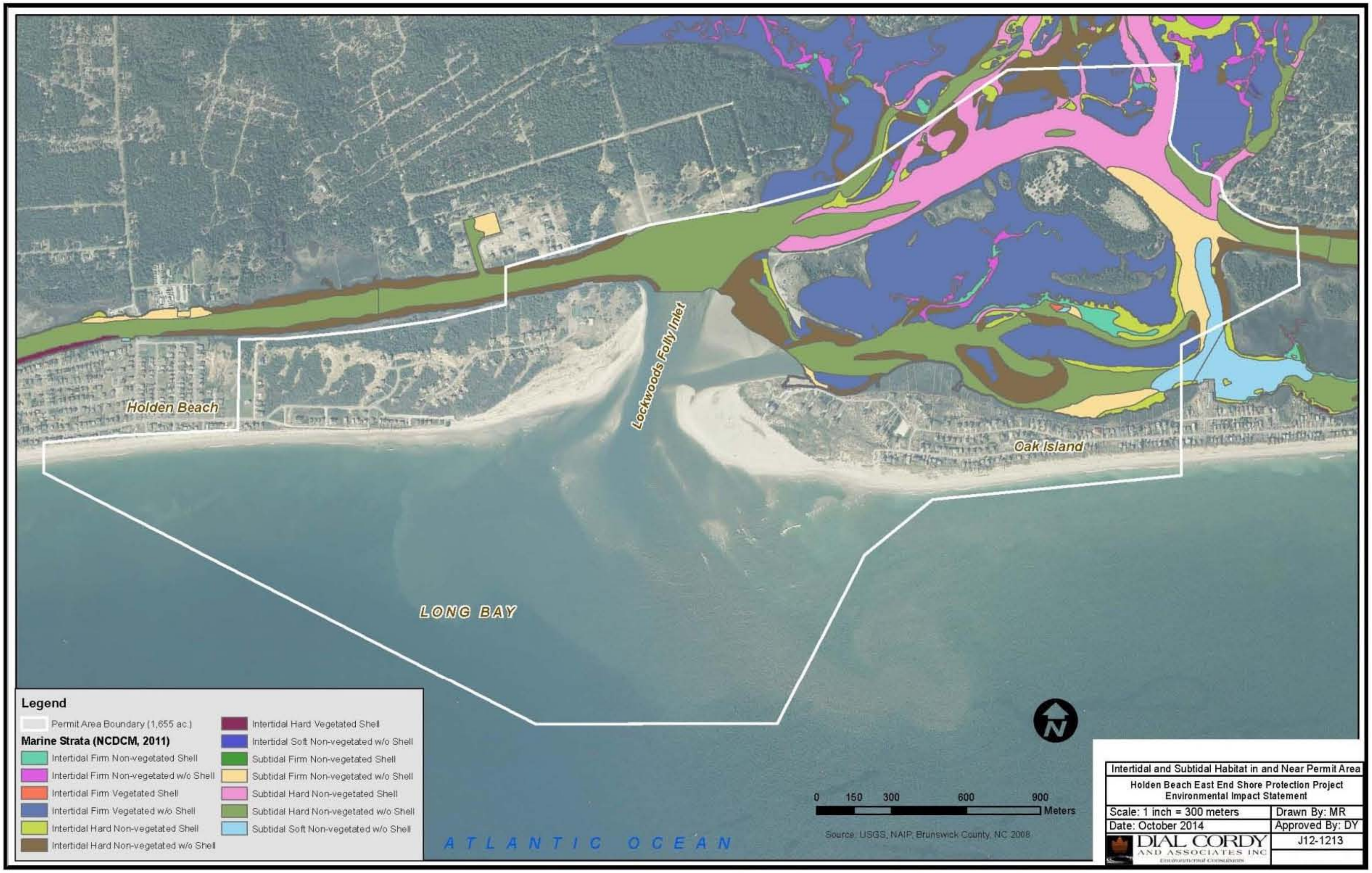


Figure 4.6. Intertidal and Subtidal Habitat in the Vicinity of the Study Area

contains a more extensive complex of fringing marshes, detached marsh islands and tidal creeks. The estuarine environment north of the AIWW in the Lower Lockwoods Folly River contains an expansive marsh island complex with an intricate network of small tidal creeks (Wiegert and Freeman 1990).

Salt and brackish marshes exhibit high primary productivity in the form of detritus, microalgae and bacteria (Hackney et al. 2000). Tidal flooding connects the marsh with adjacent estuarine waters allowing utilization by fish and other aquatic organisms. Slow-moving or sessile species residing in salt/brackish marsh and contributing to secondary production include fiddler crabs, mud snails, amphipods, oysters, clams, and Atlantic ribbed mussels (Geukensia demissa) (Wiegert and Freeman 1990). Marshes provide habitat for numerous species of decapods and fish. Resident marsh species such as grass shrimp, killifish, mummichogs, sheepshead minnows, gobies, bay anchovies, and silversides provide an important link between marsh primary production and transient predatory fish populations (Wiegert and Freeman 1990, SAFMC 1998). Tidal marshes are utilized as nursery and/or foraging areas by economically important species such as red drum, flounder, spotted seatrout, spot, Atlantic croaker, and blue crab. In NC, penaeid shrimp and red drum are considered critically linked to marsh edge habitat (SAFMC 1998). Other species (e.g., Atlantic menhaden) that are not directly associated with marsh habitats derive substantial food resources from the marsh in the form of exported detritus and microalgae. Along with the shallow soft bottom and shell bottom areas, the bordering salt and brackish marshes along the NC coast are an important nursery habitat for estuarine-dependent species. The majority of the Primary and Secondary Nursery Areas in NC are located in soft bottom areas surrounded by salt/brackish marsh (Deaton et al. 2010).

4.3.4 Endangered, Threatened, and Rare Species and Species of Concern

4.3.4.1 Federally Listed Species

This section includes background information on the federally listed species that may occur in the study area. These species are designated as threatened or endangered under the ESA. A total of 14 species are currently listed and include three marine mammal species, three bird species, five sea turtle species, two fish species, and one plant species (Table 4.2).

4.3.4.1.1 <u>Marine Mammals</u>

Thirty-seven marine mammal species may occur off the southeastern NC coast based on sightings, strandings and bycatch data and known habitat associations and distributions [see Jefferson et al. 2008 and summaries in Department of Navy (DoN) 2008a and DoN 2008b). These species include 32 cetaceans (whales, dolphins, and porpoises), four pinnipeds (seals) and one sirenian (manatee). All marine mammal

Table 4.2. Federally listed species.

Common Name	Scientific Name	Status
North Atlantic right whale	*Eubalaena glacialis*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
West Indian manatee	*Trichechus manatus*	Endangered
Piping plover	*Charadrius melodus*	Threatened[1]
Red knot	*Calidris canutus rufa*	Threatened
Wood stork	*Mycteria americana*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened[2]
Green sea turtle	*Chelonia mydas*	Threatened[3]
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	Endangered
Seabeach amaranth	*Amaranthus pumilus*	Threatened

[1]The Great Lakes breeding population is currently listed as endangered while the Northern Great Plains and Atlantic Coast breeding populations are currently listed as threatened. All piping plovers are considered threatened when on their wintering grounds.
[2]Four distinct population segments (DPSs) of the loggerhead turtle are designated as threatened while five DPSs are designated as endangered under the ESA. The Northwest Atlantic Ocean DPS, which occurs in NC, is designated as threatened.
[3]Although this species as a whole is listed as threatened, the Florida (FL) and Mexican Pacific nesting stocks of the green turtle are listed as endangered. The nesting area for green turtles encountered at sea cannot be determined; therefore, a conservative management approach is to assume that green turtles in the offshore environment may be from the endangered populations.

species are protected under the Marine Mammal Protection Act (MMPA). Of the 37 species with known or potential occurrence off southeastern NC, the following seven are listed as endangered under the ESA: the North Atlantic right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), sei whale (*Balaenoptera borealis*), fin whale (*B. physalus*), blue whale (*B. musculus*), sperm whale (*Physeter macrocephalus*), and West Indian manatee (*Trichechus manatus*). Sei, blue, and sperm whales are most likely to occur in deeper waters offshore of the study area (Hain et al. 1985, Wenzel et al. 1988, Waring et al. 1993, Prieto et al. 2011). Fin whales have been recorded in shallow waters close to shore along the US east coast [e.g., Geo-Marine Inc. (GMI) 2010, DoN 2008a and 2008b] but are more common in waters deeper than the nearshore waters of the study area. Therefore, the North Atlantic right whale, humpback whale and West Indian manatee are the ESA-listed marine mammal species most likely to occur in the study area and are discussed below.

<u>North Atlantic Right Whale</u>

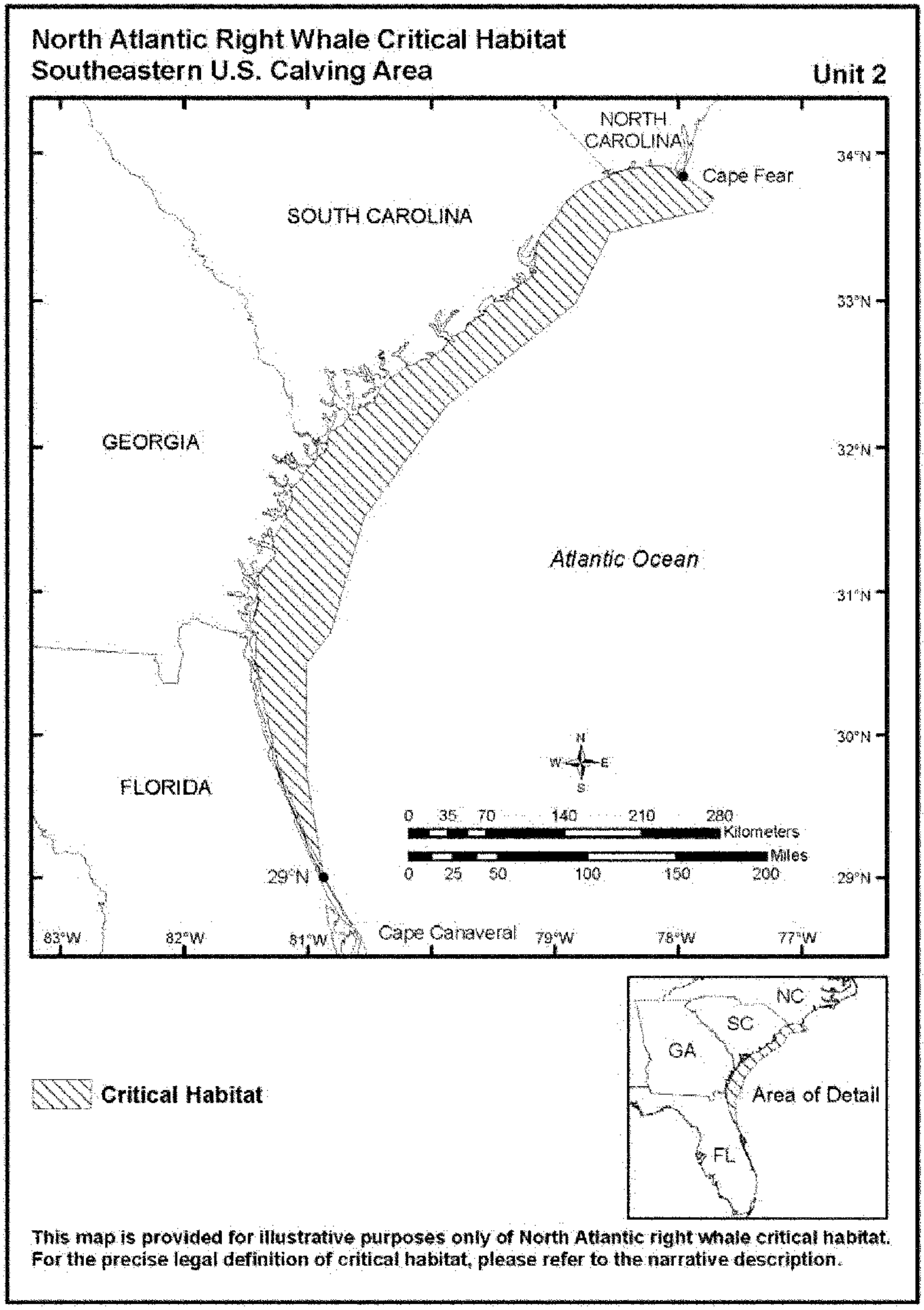
Status, Habitat, Distribution

The North Atlantic right whale is one of the world's most endangered large whale species [Clapham et al. 1999, Perry et al. 1999, International Whaling Commission (IWC) 2001] and is classified as endangered under the ESA. The most recent best estimate of cataloged right whales in the western North Atlantic is 510 individuals and is based on the number of photographed whales in the North Atlantic Right Whale Consortium database in 2012 (Pettis 2013). According to the most recent NMFS Stock Assessment Report, the minimum population size for the western North Atlantic stock is 455 individuals and is based on the number of recognized whales in the North Atlantic Right Whale Catalog that were known to be alive in 2010 (Waring et al. 2014).

The North Atlantic right whale ranges throughout the North Atlantic Basin but occurs primarily along the eastern coasts of the US and Canada (Brown 1986, Winn et al. 1986, Jacobsen et al. 2004, Jefferson et al. 2008, Hamilton et al. 2009, Silva et al. 2012). Most sightings of this species are recorded in well-known, frequently used habitat areas, including the coastal waters of Georgia (GA) and Florida (FL), within Cape Cod and Massachusetts Bays in the northeastern US, east of Cape Cod in the Great South Channel and in Canadian waters in the Bay of Fundy and over the Scotian Shelf (Winn et al. 1986, NMFS 2005).

North Atlantic right whale critical habitat is currently designated for feeding grounds in Cape Cod Bay and the Great South Channel and for calving grounds off GA and northern FL (59 FR 28793). However, as of February 2015, NOAA Fisheries has proposed to expand the designated critical habitat for endangered North Atlantic right whales to include calving grounds from southern North Carolina to northern Florida (Figure 4.7). The southeast right whale calving area consists of all marine waters from Cape Fear, NC, southward to 29° N latitude (approximately 43 miles north of Cape Canaveral, FL) within the area bounded on the west by the shoreline and the 72 COLREGS line. The proposed northern critical habitat areas include important physical and biological features that provide foraging areas where the whales' preferred prey, copepods (tiny planktonic crustaceans), are abundant. The proposed southern habitat area includes physical features that support calving and nursing with optimal physical oceanographic features including calm sea surface conditions, specific sea surface temperatures (45°F to 63°F), and water depths of 20 ft to 92 ft.

Right whale occurrence is concentrated in these areas in February through June and November through March, respectively (Winn et al. 1986, Hamilton and Mayo 1990, Kenney et al. 1995, Nichols et al. 2008). Many right whales undergo seasonal migrations between these feeding and calving grounds (Winn et al. 1986, Kenney 2001), and new regulations to expand critical habitat to include portions of the mid-Atlantic migratory corridor have been proposed (75 FR 61690). However, there is relatively little information on the geographic and temporal extent of the migratory corridor (Firestone et al. 2008, Schick et al. 2009). A review of sightings data collected in the mid-Atlantic found that 94 percent of all right whale sightings were within 56 km from shore (Knowlton et al. 2002). Not all individuals in the population complete this migration and the seasonal distribution of many whales is unknown. Right whales are often detected in these well-known habitat areas outside of the 'typical' time periods (Winn et al. 1986, Kenney 2001, Patrician et al. 2009). Right whales have been recorded in the mid-



Source: Office of Federal Register, 2015

Figure 4.7. North Atlantic Right Whale Southeastern Calving Critical Habitat

Atlantic year round (e.g., DoN 2008a and 2008b, Whitt et al. 2013). Some individuals have been sighted throughout the fall and winter on the northern feeding grounds, and a large portion of the population may spend the winter in several northern areas such as the Gulf of Maine and Cape Cod Bay (Cole et al. 2013, Clark et al. 2010, Mussoline et al. 2012).

Occurrence in the Study Area

The coastal waters of the Carolinas are part of the migratory corridor for the North Atlantic right whale (Winn et al. 1986, Knowlton et al. 2002). Right whales are expected to occur from the shoreline to the offshore boundary of the study area but not in the inshore portions of the study area. Right whales have been recorded off NC throughout the year [see DoN 2008a and 2008b); therefore, right whales may occur in the study area during any time of the year. Sighting records suggest that there is some overwintering along the NC coast (Reeves and Mitchell 1988, Kraus et al. 1993). Between Cape Hatteras and GA, Knowlton et al. (2002) identified a pattern of sightings recorded between 1974 and 2002. Most sightings were recorded during March and April, few to no sightings were from May through October (survey effort was lower during summer and early fall) and some sightings were from November through February. Sightings near Wilmington, NC, occurred from October through April with a peak during February and March (Knowlton et al. 2002).

<u>Humpback Whale</u>

Status, Habitat, Distribution

The humpback whale is designated as endangered under the ESA. Humpback whales occurring in US North Atlantic waters belong primarily to the Gulf of Maine feeding stock although individuals from Canadian populations have also been sighted in US waters including the mid-Atlantic (Barco et al. 2002). The minimum population estimate for the Gulf of Maine stock is 823 individuals and is based on mark-recapture studies from 2008 (Waring et al. 2014).

Although humpback whales typically travel over deep oceanic waters during migration, their feeding and breeding habitats are mostly in shallow coastal waters over continental shelves (Clapham and Mead 1999). Females with calves occur in significantly shallower waters than other groups of humpback whales, and breeding adults use deeper, more offshore waters (Smultea 1994, Ersts and Rosenbaum 2003). No critical habitat has been designated for the humpback whale.

Humpback whales occur worldwide in all major oceans and most seas and are known to make long-distance, seasonal migrations (Jefferson et al. 2008). In the western North Atlantic, humpbacks are widely distributed and their occurrence is strongly seasonal. During spring and summer in US waters, the largest numbers of humpback whales are found off the northeast and mid-Atlantic coasts [Cetacean and Turtle Assessment

Program (CETAP) 1982, Whitehead 1982, Kenney and Winn 1986, Weinrich et al. 1997, Hamazaki 2002, Stevick et al. 2008]. During the winter, many individuals migrate to calving grounds in the West Indies (Dawbin 1966, Whitehead and Moore 1982, Smith et al. 1999, Stevick et al. 2003); however, significant numbers of humpbacks have been found at mid- and high latitudes during this time suggesting that not all individuals in this stock undergo a seasonal migration (Dawbin 1966, Clapham et al. 1993, Swingle et al. 1993, Charif et al. 2001, Clapham 2009). Mid-Atlantic waters [New Jersey (NJ) to NC] may be a supplemental winter feeding ground for humpbacks (Barco et al. 2002). Humpbacks have been sighted in mid-Atlantic waters during all seasons (Barco et al. 2002).

Occurrence in the Study Area

The humpback whale is one of the most common baleen whales to strand along the NC coast (Byrd et al. 2014). Strandings recorded between 1997 and 2008 were all of immature humpback whales. According to Wiley et al. (1995), juveniles may spend time feeding at mid-latitudes instead of migrating as far south as adults. Most NC humpback whale sightings are concentrated off Cape Hatteras during winter and spring. Few sightings and strandings have also been recorded during these seasons off southeastern NC (see summaries in DoN 2008a and 2008b). Because humpack whales are known to occur year-round in the mid-Atlantic, they may occur in the nearshore waters of the study area during any season, but are most likely to be found farther north at the feeding grounds during the summer.

<u>West Indian Manatee</u>

Status, Habitat, Distribution

The West Indian manatee is designated as endangered under the ESA. The West Indian manatee population in FL is considered a distinct stock. The current minimum population estimate for this stock is 4,824 manatees based on a synoptic survey of warm-water refuges in January 2014 [Florida Fish and Wildlife Conservation Commission (FWCC) 2014].

West Indian manatees occur in shallow waters generally close to shore in estuarine and river mouth habitats (Rathbun et al. 1982). Preferred feeding habitats include shallow seagrass beds close to deep channels in coastal and riverine habitats (e.g., Lefebvre et al. 2000, USFWS 2001a). West Indian manatees are frequently located in secluded canals, creeks, embayments and lagoons near the mouths of coastal rivers and sloughs. These areas serve as suitable locations for feeding, resting, mating and calving (USFWS 2001a). Estuarine and brackish waters, including natural and artificial freshwater sources, are typical West Indian manatee habitat (USFWS 2001a). West Indian manatees rarely occur in offshore waters where abundant seagrass and vegetation are not available (Reynolds III and Odell 1991); however, sighting and tracking data indicate that some animals have ventured offshore (e.g., Reynolds III and Ferguson 1984, Lefebvre et al. 2001, Alvarez-Alemán et al. 2010). Critical habitat is designated for the West Indian manatee in FL (41 FR 41914).

The West Indian manatee occurs in warm, subtropical and tropical waters of the western North Atlantic from the southeastern US to Central America, northern South America and the West Indies (Lefebvre et al. 2001). During winter months, the FL population confines itself to inshore and inner shelf waters of the southern half of peninsular FL where they utilize warm-water springs, heated industrial effluents and other warm-water sites (Laist et al. 2013, Lefebvre et al. 2001). As water temperatures rise in spring, West Indian manatees disperse from winter aggregation areas. West Indian manatees are frequently reported in coastal rivers of GA and SC during warmer months (Lefebvre et al. 2001). They have been sighted as far north as Massachusetts (MA) (Beck 2006).

Occurrence in the Study Area

West Indian manatees have been recorded in estuarine and coastal waters of NC during all seasons with summer and fall having the most reports (Cummings et al. 2014, Schwartz 1995). Schwartz (1995) suggested that West Indian manatees may be expanding their range into NC waters. Based on opportunistic data collected from July 1991 through September 2012, a total of 99 sightings and nine strandings of manatees have been recorded in NC (Cummings et al. 2014). Although almost all of the strandings were recorded in southeastern NC, sightings were reported throughout NC and were most common in the AIWW. However, manatees were also observed in sounds, bays, rivers, creeks, marinas and the open ocean. Sightings peaked during June through October when water temperatures were at least 20°C (Cummings et al. 2014). Based on their known habitat associations and the previous NC records, manatees may occur throughout the freshwater, estuarine and nearshore coastal waters in or near the study area during any time of year.

4.3.4.1.2 Birds

Three species of federally protected birds are most likely to occur in the study area: the piping plover, the red knot (*C. canutus rufa*) and the wood stork (*Mycteria americana*). Background information on these birds and their occurrence in the study area are discussed in more detail below.

Piping Plover

Status, Habitat, Distribution

The population of piping plovers that breeds in the Great Lakes watershed is listed as endangered while all other piping plovers are designated as threatened under the ESA. All piping plovers are considered threatened when on their wintering grounds because the Great Lakes, Great Plains, and Atlantic piping plover populations cannot be separated here. The most recent abundance estimate of Atlantic Coast piping plovers is

1,849 breeding pairs based on data from 2009 (USFWS 2011). In NC, the breeding pairs increased from 30 to 54 between 1986 and 2009 (USFWS 2011).

Piping plovers breed in three discrete geographic areas: the Atlantic Coast from NC to Newfoundland, the Great Lakes region and the Northern Great Plains region. The three populations migrate between their respective breeding grounds and wintering sites that include coastal areas from NC to Texas (TX), Mexico, and the Caribbean (USFWS 2011). Members of the Atlantic Coast breeding population arrive on the breeding grounds and initiate courtship in late March and early April. In NC, the breeding season extends from April through August. Nests in NC may be found in mid- to late-April; piping plovers continue to nest during May and June [Personal communication, S. Schweitzer, North Carolina Wildlife Resource Commission (NCWRC), September 2014]. Chicks and fledglings may be present in May, June, July and August (Personal communication, S. Schweitzer, NCWRC, September 2014).

Southward fall migration to the wintering grounds occurs in NC during August, September and October (Personal communication, S. Schweitzer, NCWRC, September 2014). The migratory routes and wintering ranges of the three breeding populations overlap but are not fully understood (USFWS 2009). In NC, relatively large numbers of piping plovers have been sighted during migration at several sites including Oregon Inlet, Ocracoke Inlet/Portsmouth Flats and New Drum Inlet within the Cape Hatteras and Cape Lookout National Seashores (McConnaughey et al. 1990, USFWS 1996a). Critical habitat for the wintering population of piping plovers is designated along the coasts of NC, SC, GA, FL, Alabama (AL), Mississippi (MS), Louisiana (LA), and TX (66 FR 36038, 73 FR 62816, 74 FR 23476). Piping plovers overwinter in NC between November and early March. Northern spring migration from NC back to the breeding grounds occurs in March and April (Personal communication, S. Schweitzer, NCWRC, September 2014).

Piping plovers nest on coastal beaches, sandflats along the accreting ends of barrier islands, and washover and blowout areas between dunes. Nests consist of shallow scraped depressions in the sand, are often lined with shell fragments, and are typically located in areas with little or no vegetation (Cohen et al. 2008, USFWS 1996a). Wintering plovers on the Atlantic coast are found at accreting ends of barrier islands, along sandy peninsulas and near coastal inlets. Preferred foraging habitats include sandflats adjacent to inlets or passes, sandy mudflats along prograding spits and overwash areas. Roosting sites generally include inlet and adjacent ocean and estuarine shorelines and nearby exposed tidal flats (USFWS 1996a).

Occurrence in the Study Area

Piping plovers occur along NC's coast year-round; they nest on beaches during the spring and summer, stop over during spring and fall migrations, and overwinter on beaches and around inlets. Therefore, they may occur in the study area during any time of year. Sightings have been recorded throughout the LFI area (NCWRC data, Figure

4.8). See Appendix M for more details about these records. Breeding sites in NC are primarily confined to undeveloped and unstabilized barrier islands along the northern section of the coast, primarily within the Cape Lookout National Seashore, Cape Hatteras National Seashore, Pea Island National Wildlife Refuge, and on Lea and Hutaff Islands (USFWS 2009, Dinsmore et al. 1998). A few pairs nest sporadically along the southern coast as far south as Brunswick County. Nesting was first confirmed on the west end of Holden Beach in July 1993 (Slack 1994), and a nest was recorded on Oak Island in May 1989 (NCWRC data, Figure 4.8). Breeding sites along developed barrier islands are restricted to the accreting ends of the islands along tidal inlets, and piping plovers in NC are very rarely seen on developed ocean facing beaches; these areas are not considered suitable habitat (Cameron 2009). Inlet habitats along many of NC's developed barrier islands, including the west end of Oak Island along LFI and the west end of Holden Beach along Shallotte Inlet, provide important habitat for migrating and wintering plovers from all three breeding populations (Cameron et al. 2006). Recent bird surveys conducted along the Holden Beach beachfront by a local bird expert found as many as 24 piping plovers in this area in March and April (Holden Beach Beachfront Shorebird Survey Report 2014). Additional sightings in the study area were recorded by birders on Holden Beach's East End in July 2007 and in LFI during August 2010 and March 2014 (eBird 2014).

Two critical habitat units for the Atlantic coast wintering population are designated in and near the study area (66 FR 36038). The LFI Unit (NC-16) covers 90 ac and extends from the west end of Oak Island (West Beach Drive) west to the mean lower low water (MLLW) line at LFI and includes emergent sandbars south and adjacent to the island (Figure 4.8). This unit includes land from MLLW on the Atlantic coast to the MLLW adjacent to the Eastern Channel and AIWW. The Shallotte Inlet Unit (NC-17) covers 296 ac and includes the west end of Holden Beach and the unnamed island emergent shoals to MLLW within the inlet (Figure 4.8).

<u>Red Knot</u>

Status, Habitat, Distribution

The *rufa* subspecies of the red knot was recently listed as threatened under the ESA due to loss of breeding and nonbreeding habitats, potential disruption of natural predator cycles on breeding grounds, reduced prey availability in the nonbreeding range and frequent and severe asynchronies in the timing of annual migration relative to favorable weather and food conditions (79 FR 73706). Population abundance estimates are not available for the breeding range of the rufa red knot (hereafter referred to as "red knot") because this subspecies is thinly distributed across large remote areas of the Arctic during the breeding season (USFWS 2013). Recent counts of red knots wintering in the southeast US totaled 3,814 to 3,939 in 2011 with 157 of those birds occurring in NC (USFWS 2013). Seasonal surveys conducted between 1992 and 1993 on the Outer

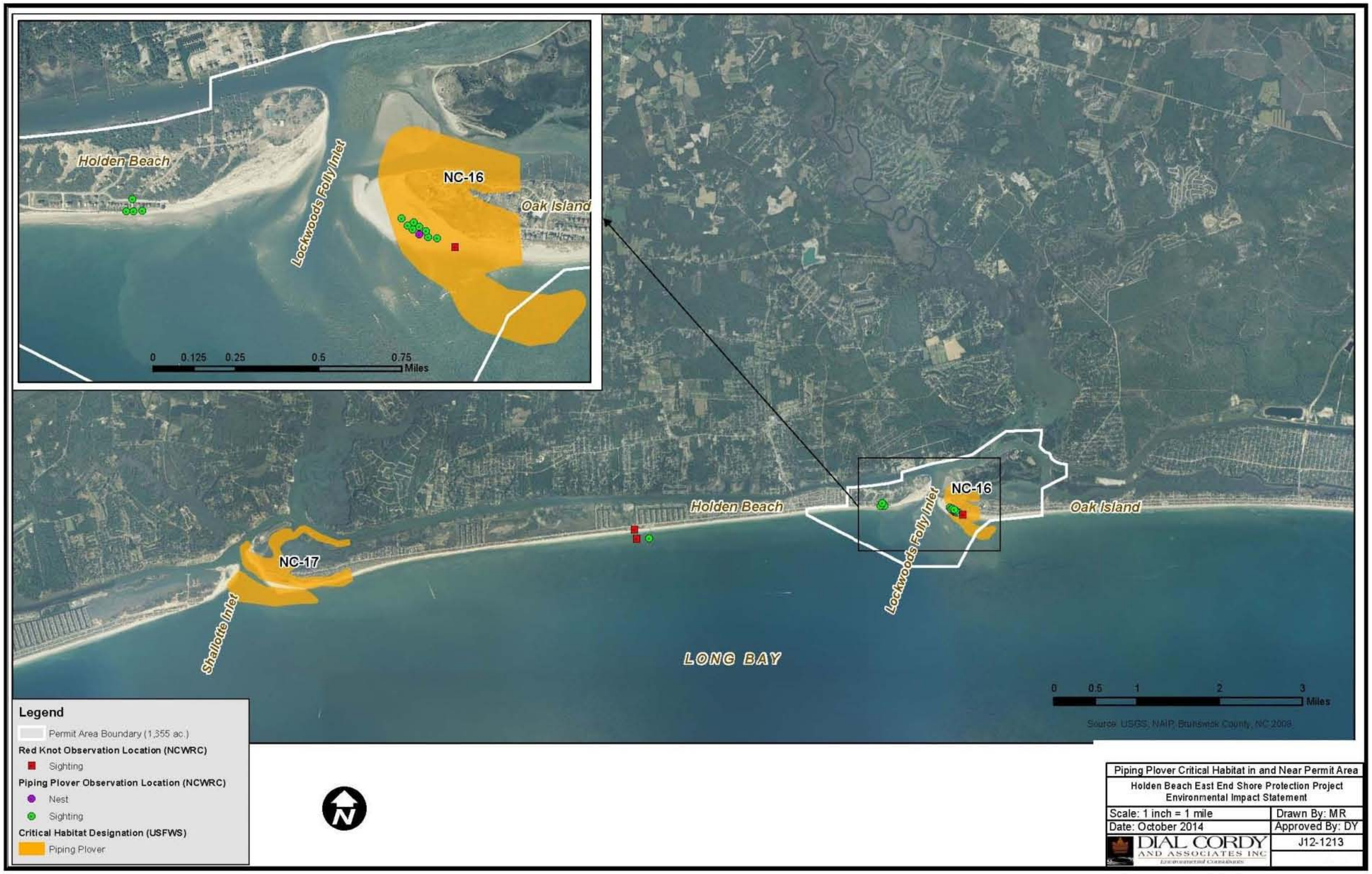


Figure 4.8. Shorebird Critical Habitat, Sightings, and Nests in the Vicinity of the Study Area

Banks resulted in totals of 4,088 and 1,334 red knots during spring and fall, respectively, with a peak count in May (Dinsmore et al. 1998). The most recent peak count from the National Park Service's long-term monitoring program was 854 red knots in the Outer Banks during May 2013 (National Park Service 2013a).

Red knots breed in the central Canadian Arctic and occur in three main wintering groups: short distance migrants that winter in the southeastern US, medium distance migrants that winter on the northern coast of Brazil and long distance migrants that winter in Tierra del Fuego (southern tip of South America) (Niles et al. 2012). In the southeastern US, red knots overwinter primarily in FL and GA (Niles et al. 2008). However, red knots are known to winter as far north as Virginia (VA) (Niles et al. 2012). Major stopover sites during the southbound migration include MA, Connecticut (CT) and Rhode Island (RI). During the northbound migration, stopover sites along the US Atlantic coast include the primary stopover in Delaware Bay, although some red knots stop farther south between VA and FL (Gillings et al. 2009, Niles et al. 2008). In NC, red knots use the Outer Banks as a stopover site during spring and fall migrations, and they also overwinter there (Niles et al. 2012, Dinsmore et al. 1998). Overwintering red knots may be hatch-year and/or subadult red knots (Personal communication, S. Schweitzer, NCWRC, September 2014). Red knots are most abundant in NC during the spring migration (April-June), particularly in May (Personal communication, S. Schweitzer, NCWRC, September 2014). Fall migrants arrive in July with a small peak in September (Dinsmore et al. 1998).

Preferred wintering and migration habitats include muddy or sandy coastal areas, particularly the mouths of bays and estuaries and unimproved tidal inlets and tidal flats. Wintering habitat in the southeastern US also includes peat banks, salt marshes, brackish lagoons and mangroves. In this region, red knots forage along sandy beaches, in tidal mudflats, along peat banks and along barrier islands (Niles et al. 2008). Preferred prey in nonbreeding habitats include horseshoe crab eggs, snails, clams and crustaceans (Cohen et al. 2010, Niles et al. 2008, Tsipoura and Burger 1999).

Occurrence in the Study Area

Red knots have been observed in NC during all seasons (Dinsmore et al. 1998), therefore, they may occur in the study area during any time of the year. They are most common in NC during the migration seasons (mid-April through May and July to mid-October) (Personal communication, K. Matthews, USFWS, September 2014) and appear to be most abundant in May during the spring migration (Personal communication, S. Schweitzer, NCWRC, September 2014). Known stopover sites for red knots in Brunswick County include Tubbs Inlet and Ocean Isle Beach during April (Niles et al. 2008) and Bald Head Island during May/June (USACE 2014a). Aerial surveys conducted by the Center for Conservation Biology (College of William and Mary), NC Audubon, and NCWRC during May 2009, 2011, and 2012 recorded groups of red knots ranging from 15 to 56 on Holden Beach and Oak Island (Long Beach)

(Personal communication, S. Schweitzer, NCWRC, September 2014) (Figure 4.8) (See Appendix M for more details about these records). Additional sightings in the study area were recorded by birders on Holden Beach near the western boundary of the study area in October 2012 and on the western tip of Oak Island during May 2011 (eBird 2014). During recent bird surveys conducted along the Holden Beach beachfront between mid-November 2013 and late April 2014, researchers observed scattered small groups of red knots along the beachfront in December and January and groups of 10-25 red knots in the marshes and mudflats on the northern side of Holden Beach in late November (Holden Beach Beachfront Shorebird Survey Report 2014). Note that the global positioning system (GPS) coordinates were not available for these sightings; therefore, they are not included in Figure 4.8.

Wood Stork

Status, Habitat, Distribution

In June 2014, the US breeding population of the wood stork was reclassified from endangered to threatened under the ESA (79 FR 37078). This breeding population in MS, AL, FL, GA, SC, and NC was also designated as a Distinct Population Segment (DPS). A distinct population segment is the smallest division of a taxonomic species permitted to be protected under the ESA. The current breeding range includes peninsular FL, the coastal plain and large river systems in GA and SC, and southeastern NC. Nesting periods vary geographically. In southern FL, wood storks lay eggs as early as October and fledge in February or March. However, in northern and central FL, GA, and SC, storks lay eggs between March and late May with fledging occurring in July and August (79 FR 37078). Wood storks are not true migrants, but they generally disperse following breeding. Beginning in late May, following breeding in FL; most fledglings, immatures, and adults disperse in peninsular FL and northward (Coulter et al. 1999).

The breeding population has been increasing; three-year population averages of total nesting pairs have been higher than 6,000 since 2003. Between 2011 and 2013, the average total nesting pairs for FL, GA, SC, and NC was 9,692 (79 FR 37078). This species has been increasing in the Carolinas over the past 20 years possibly due to a northward shift in the breeding populations (LeGrand 2013). The first colony in NC was recorded at Lays Lake, Columbus County in 2005 and consisted of 32 nesting pairs (USFWS 2007). Since then, the number of nesting pairs at this colony have been continuously increasing; the most recent pairs recorded here were 220 in 2010 based on the Wood Stork Colony Dataset (1970-2010) maintained by the University of Florida (http://www.wec.ufl.edu/faculty/frederickp/woodstork/). In 2013, three colonies and 205 nesting pairs were documented in NC (79 FR 37078). In addition to the Lays Lake colony, the new colonies were found just east of Tabor City (Columbus County) and along the Black River (Bladen/Pender Counties line) (LeGrand 2013).

Wood storks use a wide variety of freshwater and estuarine wetlands for nesting, feeding and roosting sites. Nesting colony sites are in freshwater and marine-estuarine forested habitats, primarily in cypress swamps. However, depending on the location, colony sites may consist of other plants such as dead oaks, mangroves, cactus, black gum, willow and buttonbush (Coulter et al. 1999). Storks tend to use the same colony site over many years as long as the site remains undisturbed and there is sufficient feeding habitat in the surrounding area (USFWS 1997). Feeding habitat consists of natural and artificial wetlands where prey species are available and water depths are appropriate [<50 centimeters (cm)] (Coulter et al. 1999). However, wood storks are also known to feed in shallow brackish and saltwater pools and channels (LeGrand 2013). Wood storks also use man-made wetlands for foraging and breeding. Some of these man-made wetlands include storm water treatment areas and ponds, golf course ponds, borrow pits, reservoirs, roadside ditches, agricultural ditches, drainages, flow-ways, mining and mine reclamation areas and dredge spoil sites (USFWS 2007). Roosting sites are generally in trees over water, but storks may also rest on the ground close to feeding sites (Coulter et al. 1999).

Occurrence in the Study Area

Wood stork occurrence has been increasing in NC, particularly the southeastern portion of the state. Wood storks are considered summer residents and post-breeding visitors to several areas of coastal NC (LeGrand 2013). They are common at the primary breeding site at Lays Lake in Columbus County and the post-breeding site at Twin Lakes, the mainland portion of Sunset Beach in Brunswick County. They are rare but increasing in other portions of Columbus and Brunswick Counties, Robeson County, along the Black River and as far north as the Outer Banks. They may occur during any time of the year, but are primarily sighted from early June to November (LeGrand 2013). During the winter, most wood storks retreat to FL and southern GA after dispersing widely throughout the coastal plain of the southeast US after the breeding season (Coulter et al. 1999). Although they are very rare in NC during the winter, there are several records of this species during December, January, and February (LeGrand 2013). Wood storks return to their breeding sites by April (LeGrand 2013).

Wood storks have been sighted on Holden Beach, Oak Island and in the Lockwoods Folly River; most of these sightings have been recorded during the months of July, August and October in recent years (2012-2014) (eBird 2014). Between October 2012 and July 2014, nine sightings were documented on Holden Beach and ranged from Holden Island Point on the west end of the island to the eastern tip. This East End sighting of two wood storks is in the study area and was recorded in July 2013 (eBird 2014). Other sightings on Holden Beach are also recorded along the beachfront and in the marsh areas. A total of four sightings of wood storks were recorded on Oak Island between October 1987 and July 2013 (eBird 2014). All except one of these sightings were inland of the beachfront. Wood storks were recently sighted in the Lockwoods

Folly River just north of the study area boundary in October 2014. Additional sightings of wood storks were recorded in this same area in August 2013 (eBird 2014).

4.3.4.1.3 Sea Turtles

Five species of sea turtles are known to occur along the NC coast: the leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and Kemp's ridley (*Lepidochelys kempii*). The Kemp's ridley sea turtle is the only one of these species that occurs sporadically in this region. The other four species are regular inhabitants.

NC waters provide important transitional habitats for juvenile and adult sea turtles. Juvenile sea turtles frequent these waters year-round and exhibit seasonal foraging movements (migrating north along the coast in the early spring to coastal developmental habitats and south in the fall as waters cool) (Morreale and Standora 2005). Adult sea turtles may be found foraging in shallow, coastal (Hawkes et al. 2007) or offshore waters (Hopkins-Murphy et al. 2003). Shelf waters also serve as habitat for adult sea turtles (Hopkins-Murphy et al. 2003). Adult loggerhead, leatherback and green sea turtles are known to nest on NC's ocean facing beaches in the summer (Schwartz 1989; Rabon et al. 2003).

Leatherback Sea Turtle

Status, Habitat, Distribution

Leatherback sea turtles are listed as endangered under the ESA (NMFS and USFWS 1992). Recent abundance estimates for adult leatherbacks range from 34,000 to 94,000 individuals in North Atlantic waters [NMFS and USFWS 2007a, Turtle Expert Working Group (TEWG) 2007]. Critical habitat for Atlantic leatherbacks is designated in the Caribbean at Sandy Point, St. Croix, US Virgin Islands (44 FR 17710).

Late juvenile and adult leatherback sea turtles are known to range from mid-ocean to continental shelf and nearshore waters (Schroeder and Thompson 1987, Shoop and Kenney 1992, Grant and Ferrell 1993, Dodge et al. 2014). Juvenile and adult foraging habitats include both coastal feeding areas in temperate waters and offshore feeding areas in tropical waters (Eckert and Abreu-Grobois 2001). Leatherback nesting beach habitat is generally associated with deep water, strong waves and oceanic currents, but shallow waters near mud banks are also utilized for nesting (TEWG 2007).

A regular, seasonal occurrence of leatherbacks is known along the northeast US Atlantic coast. Leatherbacks foraging in the western North Atlantic prefer waters from 16 to 18ºC (Thompson et al. 2001, James et al. 2006); their lower thermal limit is in sea surface temperatures (SSTs) between 10 to 12ºC (Witt et al. 2007). In the late winter and early spring, leatherbacks are distributed primarily in tropical latitudes (Stewart and Johnson 2006); survey data show that around this time of year, individuals begin to move north along the North American Atlantic coast. By February and March, the majority of leatherbacks found in US Atlantic waters are distributed off northeast FL. This movement continues through April and May when leatherbacks begin to occur in large numbers off the coasts of GA and the Carolinas (NMFS 1995 and 2000). Leatherbacks become more numerous off the mid-Atlantic and southern New England coasts in late spring and early summer, and by late summer and early fall leatherbacks may be found in the waters off eastern Canada (CETAP 1982, Shoop and Kenney 1992, Thompson et al. 2001, Dodge et al. 2014).

Leatherback nesting occurs on isolated mainland beaches in tropical and temperate oceans (NMFS and USFWS 1992) and to a lesser degree on some islands, such as the Greater and Lesser Antilles. In the US, the densest nesting is on the Atlantic coast of FL (Stewart and Johnson 2006). Sporadic nesting occurs in GA, SC, and NC (Rabon et al. 2003). Nesting activities in NC were reported in June/July 1998 and in April/June 2000 along Cape Hatteras National Seashore and in June 2000 at Cape Lookout National Seashore (Rabon et al. 2003). The most recent nesting activity for this species in NC was two sites in 2009 (one on Cape Hatteras and one on the northern Outer Banks), two sites in 2010 (one on Bald Head Island and one on Holden Beach), and five sites in 2012 (four at Cape Lookout and one at Cape Hatteras) (Seaturtle.org 2014).

Occurrence in the Study Area

NC waters may be utilized by foraging leatherbacks or individuals in transit. The coastal area immediately adjacent to Cape Hatteras is recognized as a migratory pathway for leatherbacks (Lee and Palmer 1981). Leatherbacks are found year-round in NC waters (Schwartz 1989); therefore, they may occur in the study area during any time of year. The majority of leatherback sightings and strandings off southeastern NC have been recorded during spring (DoN 2008a). The greatest concentrations of leatherbacks are expected to occur in NC from mid-April through mid-October (Keinath et al. 1996). Sporadic nesting activity has occurred in NC; one of these nest sites was on Holden Beach in 2010 near the study area boundary (NCWRC data).

Loggerhead Sea Turtle

Status, Habitat, Distribution

The loggerhead sea turtle is composed of nine DPSs. The Northwest Atlantic Ocean DPS occurs in NC and is designated as threatened under the ESA (76 FR 58868). Five recovery units (nesting populations) are identified in the Northwest Atlantic: (1) Northern - FL/GA border to southern VA; (2) Peninsular FL – FL/GA border south through Pinellas County, FL (excluding Key West); (3) Dry Tortugas – islands west of Key West, FL; (4) Northern Gulf of Mexico - Franklin County, FL, west through TX; and (5) Greater Caribbean – Mexico through French Guiana, The Bahamas, and Lesser/Greater Antilles (NMFS and USFWS 2008). The Peninsular FL population represents approximately 87

percent of all nesting effort in the Northwest Atlantic Ocean DPS (Ehrhart et al. 2003). Turtle nests in NC totaled 557 nests in 2013; the majority of these nests were loggerheads with a few green turtles and one Kemp's ridley (Seaturtle.org 2014).
Loggerheads occur worldwide in habitats ranging from coastal estuaries, bays and lagoons to pelagic waters (Dodd 1988). Early juvenile loggerheads are primarily oceanic, occurring in pelagic convergence zones where they are transported throughout the ocean by dominant currents, such as the North Atlantic Gyre (Caldwell 1968, Carr 1986, Bolten et al. 1994, Witherington 1994). Late juveniles and adult loggerheads most often occur on the continental shelf and along the shelf break of the US Atlantic and Gulf coasts as well as in coastal estuaries and bays (CETAP 1982, Shoop and Kenney 1992). Subadult and adult loggerhead turtles tend to inhabit deeper offshore feeding areas along the western Atlantic coast from mid-FL to NJ and most likely forage on benthic prey (Hopkins-Murphy et al. 2003, Roberts et al. 2005, Hawkes et al. 2007).

In the US North Atlantic, loggerheads commonly occur in shelf waters as far north as the New York Bight (CETAP 1982, Shoop and Kenney 1992). Loggerhead distribution along the US Atlantic coast is strongly seasonal and is dictated primarily by SSTs. Loggerheads prefer SSTs between 13 and 28°C (Mrosovsky 1980); they tend to become lethargic in SSTs below 15°C and may become incapacitated ("cold-stunned") at temperatures below 10°C (Schwartz 1978, Mrosovsky 1980). Loggerheads occur north of Cape Hatteras primarily in late spring through early fall (May and October) with a peak occurrence in June; however, sightings are recorded in mid-Atlantic and northeast waters year round (CETAP 1982, Lutcavage and Musick 1985, Shoop and Kenney 1992). During the summer, loggerheads may be found regularly in shelf waters from Delaware Bay to Hudson Canyon, including Long Island Sound and Cape Cod Bay (Burke et al. 1991, Shoop and Kenney 1992, Prescott 2000, UDSG 2000). As SSTs decrease in the winter, most individuals move south of Cape Hatteras to overwinter (Epperly et al. 1995a, Mitchell et al. 2002, Hawkes et al. 2011). From November to April, loggerheads are primarily found off the coast of southern NC in the South Atlantic Bight (Griffin et al. 2013). However, stranding and sighting data indicate that not all loggerheads leave mid-Atlantic and New England waters during the winter (Burke et al. 1991).

Critical habitat for the Northwest Atlantic Ocean DPS was recently designated for terrestrial and marine areas in the Atlantic and Gulf of Mexico (79 FR 39756, 79 FR 39856). The USFWS-designated terrestrial critical habitat areas include 88 nesting beaches in NC, SC, GA, FL, AL, and MS (79 FR 39756). These critical habitat areas include a total of 38 units encompassing 393.7 km of the Atlantic Ocean shoreline designated for the Northern Recovery Unit: eight units in NC, 22 in SC and eight in GA. These units comprise approximately 86 percent of the documented nesting within the recovery unit. Three of the eight units in NC are within Brunswick County and include portions of Bald Head Island (LOGG–T–NC–06), Oak Island (LOGG–T–NC–07) and Holden Beach (LOGG–T–NC–08) (79 FR 39756).

The NOAA-designated marine critical habitat for the Northwest Atlantic Ocean DPS includes some nearshore reproductive areas directly offshore of nesting beaches from NC through MS, winter habitat in NC, breeding habitat in FL, constricted migratory corridors in NC and FL and *Sargassum* habitat in the western Gulf of Mexico and in US waters within the Gulf Stream in the Atlantic Ocean (79 FR 39856). The nearshore reproductive areas are adjacent to high-density nesting beaches used by hatchlings egressing to the open-water environment and by nesting females transiting between the beach and open water during the nesting season and extend 1.6 km offshore. The winter habitat in NC includes warm-water habitats between Cape Hatteras and Cape Fear near the western edge of the Gulf Stream (between the 20- and 100-m isobaths) that are used by a high concentration of juveniles and adults during the winter months. The constricted migratory corridor off NC consists of waters between 36°N and Cape Lookout from the edge of the Outer Banks barrier islands to the 200-m isobath. This corridor overlaps with the northern portion of winter habitat off NC and serves as a migratory pathway for loggerheads transiting to neritic foraging areas in the north and back to winter, foraging and/or nesting areas in the south. The majority of loggerheads pass through this migratory corridor in the spring (April to June) and fall (September to November), but loggerheads are also present in this area from April through November (79 FR 39856).

Occurrence in the Study Area

Seasonal water temperatures influence loggerhead occurrence offshore NC, but loggerheads are resident year round south of Cape Hatteras. Therefore, loggerheads may be found in the study area during any time of year. Sea turtle nesting and hatching season in NC extends from May 1 through November 15 (Holloman and Godfrey 2008); 2005-2014 nesting activity along Oak Island and Holden Beach was typically recorded between May and August (NCWRC data). Based on all nesting data from 1998-2013, the nesting density (nests per 1 km) was relatively high for both Oak Island (4.12) and Holden Beach (3.37) (Hernandez 2014). Average nests per year on Oak Island and Holden Beach are approximately 64 and 35, respectively (Hernandez 2014). In 2013, 93 loggerhead nests were recorded on Oak Island and 71 were recorded along Holden Beach. The number of loggerhead nests recorded in 2014 was well below average at 31 on Oak Island and 19 on Holden Beach (NCWRC data). Nesting sites have been recorded in and near the study area during each year between 2005 and 2014 (Figures 4.9 and 4.10). See Appendix N for more information about the location of nesting sites in the study area during each of these years.

Two terrestrial critical habitat units for nesting loggerheads are designated within the study area (79 FR 39756) (Figure 4.11). The Oak Island unit (LOGG–T–NC–07) extends from the mouth of the Cape Fear River to LFI and includes lands from the MHW line to the toe of the secondary dune or developed structures. This unit protects the high-density nesting of loggerheads in this area. The adjacent Holden Beach unit (LOGG–T–NC–08) supports the potential expansion of nesting. This unit extends from

Figure 4.9. Loggerhead Turtle Nesting in the Vicinity of the Study Area (2005 - 2014)

Figure 4.10. Loggerhead Turtle Nesting in the Vicinity of the Study Area (2005 - 2014)

Figure 4.11. Loggerhead Turtle Critical Habitat in the Vicinity of the Study Area

LFI to Shallotte Inlet and includes lands from the MHW line to the toe of the secondary dune or developed structures. The marine critical habitat designated within the study area includes a nearshore reproductive area within unit LOGG–N–5 which includes Pleasure Island, Bald Head Island, Oak Island and Holden Beach in New Hanover and Brunswick Counties, NC. This unit consists of nearshore habitat from Carolina Beach Inlet around Cape Fear to Shallotte Inlet (crossing the mouths of the Cape Fear River and LFI) from the MHW line to 1.6 km offshore (Figure 4.11).

<u>Green Sea Turtle</u>

Status, Habitat, Distribution

The green sea turtle is designated as threatened under the ESA with the FL and Mexican Pacific coast nesting populations listed as endangered (NMFS and USFWS 1991). The nesting area for green turtles encountered at sea cannot be determined; therefore, a conservative management approach is to assume that green turtles in the offshore environment may be from the endangered populations. Recent population estimates for green turtles in the western North Atlantic are not available (NMFS 2006a). Juvenile green turtles are the second most abundant sea turtle species in NC summer developmental habitats (Epperly et al. 1995b). The only designated critical habitat for this species is in Puerto Rico (63 FR 46694).

Post-hatchling and early-juvenile green turtles reside in convergence zones in the open ocean (Carr 1987, Witherington and Hirama 2006). Once green turtles reach a carapace length of 20 to 25 cm, they migrate to shallow nearshore areas (<50 m in depth) where they spend the majority of their lives as late juveniles and adults. The optimal developmental habitats for late juveniles and foraging adults are warm, shallow waters (3 to 5 m in depth) with an abundance of SAV, and also areas in close proximity to nearshore reefs or rocky areas (e.g., Holloway-Adkins and Provancha 2005, Witherington et al. 2006).

Green turtles found in US waters come from nesting beaches widely scattered throughout the Atlantic (Witherington et al. 2006). Along the US east coast, green turtles are found as far north as MA (NMFS and USFWS 1991). Juvenile green turtles utilize estuarine waters as far north as Long Island Sound, Chesapeake Bay and NC sounds as summer developmental habitat (Epperly et al. 1995b, Epperly et al. 1995c, Musick and Limpus 1997). NC waters, especially Pamlico and Core Sounds, serve as important neritic developmental habitat for benthic-stage green turtles (Epperly et al. 1995a, Epperly et al. 1995c). The highest proportions of green turtles in NC waters are observed in the fall (Epperly et al. 1995b) in conjunction with the southward migration of juvenile greens moving to warmer waters for the winter (Mendonça 1983).

Most nesting in North America occurs in southern FL and Mexico (Meylan et al. 1995) with scattered records in the FL Panhandle, AL, GA, and the Carolinas (NMFS and

USFWS 1991, Peterson et al. 1985, Schwartz 1989). Green turtle nesting in NC has primarily been documented at Onslow Beach, Caswell Beach and Bald Head Island and near Cape Hatteras (Peterson et al. 1985, Schwartz 1989).

Occurrence in the Study Area

During spring, summer and fall, green turtles occur in waters offshore of NC. South of Cape Hatteras, green turtles may occur year-round in waters between the shoreline and the 50-m isobath, where their preferred habitats of seagrass beds and worm-rock reefs are found. Green turtles have been recorded off southeastern NC year-round (see summaries in DoN 2008a). Therefore, this species may occur in the study area during any time of year and may nest there. In 2013, a total of 40 green turtle nests were recorded in NC; over half of these nests were documented at Cape Hatteras National Seashore (National Park Service 2013b), and one of these nests was on Holden Beach (Seaturtle.org 2014).

<u>Hawksbill Sea Turtle</u>

Status, Habitat, Distribution

The hawksbill sea turtle is designated as endangered under the ESA. This species is second only to the Kemp's ridley sea turtle in terms of endangerment (NMFS and USFWS 1993, Bass 1994). The most recent estimate of hawksbill abundance in the Atlantic Ocean was 3,072 to 5,603 nesting females based on historical and recent estimates of nesting colonies from around the Atlantic Basin (NMFS and USFWS 2007b). Critical habitat for this species is designated in Puerto Rico (63 FR 46693).

As post-hatchlings and small juveniles, hawksbill turtles inhabit oceanic waters where they are sometimes associated with driftlines and floating patches of *Sargassum* (Parker 1995, Witherington and Hirama 2006). The developmental habitats for juvenile benthic-stage hawksbills are the same as the primary feeding grounds for adults; they include tropical, nearshore waters associated with coral reefs, hardbottoms or estuaries with mangroves (Musick and Limpus 1997). Coral reefs are optimal habitat for juveniles, subadults and adults (NMFS and USFWS 1993, Diez et al. 2003). Late juveniles generally reside on shallow reefs less than 18 m deep. However, as they mature into adults, hawksbills move to deeper habitats and may forage to depths greater than 90 m. Benthic-stage hawksbills are seldom found in waters beyond the continental or insular shelf unless they are transiting between distant foraging or nesting grounds (NMFS and USFWS 1993).

In the Atlantic Ocean, this species is found throughout the Gulf of Mexico, the Greater and Lesser Antilles and southern FL, as well as along the mainland of Central America south to Brazil (NMFS and USFWS 1993). The hawksbill is rare north of FL (Lee and

Palmer 1981, Keinath et al. 1991, Parker 1995, Plotkin 1995, USFWS 2001b). Small hawksbills have stranded as far north as Cape Cod, MA (NMFS 2006a).

Occurrence in the Study Area

Hawksbill sea turtles are not known to nest in NC. Sightings and strandings of this species have been recorded off NC throughout the year (see summaries in DoN 2008a and 2008b). Epperly et al. (1995b) reported the incidental capture of one hawksbill in Pamlico Sound. Few sightings have been recorded in nearshore waters off southeastern NC near the study area during summer (see DoN 2008a). Occurrences of this species in the study area are possible year round but would be rare.

<u>Kemp's Ridley Sea Turtle</u>

Status, Habitat, Distribution

The Kemp's ridley sea turtle is designated as endangered under the ESA (35 FR 18319); this is considered the world's most endangered sea turtle species (USFWS and NMFS 1992). The worldwide population declined from tens of thousands of nesting females in the late 1940s to approximately 300 nesting females in 1985 (TEWG 2000).

Kemp's ridley turtles occur in open-ocean and *Sargassum* habitats of the North Atlantic Ocean as post-hatchlings and small juveniles (e.g., Manzella et al. 1991, Witherington and Hirama 2006). Large juveniles and adults move to benthic, nearshore feeding grounds along the US Atlantic and Gulf coasts (Morreale and Standora 2005). Habitats frequently utilized include warm-temperate to subtropical sounds, bays, estuaries, tidal passes, shipping channels and beachfront waters where their preferred prey, including the blue crab, occurs (Lutcavage and Musick 1985, Landry and Costa 1999, Seney and Musick 2005). Their most suitable habitats are less than 10 m deep with SSTs between 22° and 32°C (Coyne et al. 2000). Seagrass beds, mud bottom and live bottom are important developmental habitats (Schmid and Barichivich 2006). Postnesting Kemp's ridleys travel along coastal corridors generally shallower than 50 m (Morreale et al. 2007).

Feeding grounds and developmental habitats are along the Atlantic and Gulf coasts of the US. Some Kemp's ridley juveniles migrate as far north as New York (NY) and New England as early as June (Morreale and Standora 2005). During the winter, they migrate south to warmer waters off FL (Marquez-M. 1994). They typically migrate within the nearshore waters along the mid-Atlantic coast (Morreale and Standora 2005, Morreale et al. 2007); juveniles and adults often travel inshore of the 18-m isobath (Renaud and Williams 2005).

Individuals are known to overwinter south of Cape Hatteras, although the majority of Kemp's ridley turtles stay in FL near Cape Canaveral during the winter (Henwood and

Ogren 1987). Individuals that overwinter off southern NC may subsequently move into warmer waters (e.g., Gulf Stream or areas off SC) during the mid-winter (Renaud 1995, Morreale and Standora 2005). For example, an individual tagged in Beaufort in 1989 remained in Onslow Bay during the winter and moved into the Gulf Stream when temperatures cooled close to shore in January 1990 (Renaud 1995). Kemp's ridley turtles utilize habitats in NC from April through October (Morreale and Standora 2005).

Occurrence in the Study Area

Sightings and strandings have been recorded off NC year round (see summaries in DoN 2008a and 2008b). Therefore, Kemp's ridley sea turtles may occur in the study area during any time of year. Occasional Kemp's ridley nests have been recorded in NC over the past few years; the first known nest in Cape Hatteras was in 2011 (National Park Service 2013b). Recent nests include one at Cape Lookout in 2014 and two in 2012 (Cape Lookout and northern Outer Banks) (Seaturtle.org 2014). No nests have been recorded in the study area. Strandings of Kemp's ridley turtles have been recorded on the southeastern NC coast in and near the study area during all seasons (see summaries in DoN 2008a and 2008b).

4.3.4.1.4 Fishes

Two species of federally protected fish are most likely to occur in the study area: the shortnose sturgeon (*Acipenser brevirostrum*) and the Atlantic sturgeon (*Acipenser oxyrinchus*). Background information on these sturgeons and their occurrence in the study area are discussed in more detail below. The US DPS of smalltooth sawfish (*Pristis pectinata*) is listed as endangered under the ESA from FL to Cape Hatteras, NC (68 FR 15674, 70 FR 69464). Although there have been historical records of this species in NC (Core Sound, Bogue Sound, New River and Cape Lookout) (NMFS 2006b), this DPS occurs only off southern FL (NMFS 2003). Therefore, the smalltooth sawfish is not expected to occur in the study area and is not discussed further.

Shortnose Sturgeon

Status, Habitat, Distribution

The shortnose sturgeon is designated as endangered under the ESA (32 FR 4001). NMFS recognizes 19 DPSs of shortnose sturgeon inhabiting 25 river systems from Saint John River, New Brunswick, Canada to St. Johns River, FL. One of these includes a DPS in the Cape Fear River, NC (NMFS 1998). However, few surveys have been conducted in the rivers and bays along the NC coast, and it is unknown if a reproducing population(s) of shortnose sturgeon exists [Shortnose Sturgeon Status Review Team (SSSRT) 2010]. Based on tagging and re-capture data analyzed in 1995, the most recent population estimate of shortnose sturgeon in the Cape Fear River is less than 50 individuals (Cape Fear River Partnership 2013).

The shortnose sturgeon inhabits rivers and estuaries. Although this species may move to the mouths of estuaries and nearby coastal waters, populations are primarily confined to natal rivers and estuarine habitats. Adults spawn in freshwater, but regularly enter saltwater habitats (NMFS 1998). In estuarine systems, the shortnose sturgeon occurs in areas with little or no current over a bottom comprised primarily of mud and sand. Sturgeons prefer freshwater swamps or areas with fast flows and gravel cobble bottoms in the riverine areas (Gilbert 1992). Adults are found in deep waters (10 to 30 m) in winter and in shallow waters (2 to 10 m) in summer. Juveniles are nonmigratory, typically inhabiting deep channels of swiftly flowing river above the salt wedge (Burkhead and Jenkins 1991).

Migrational patterns of shortnose sturgeons vary with fish size and home river location. Pre-spawners generally move upstream to spawning grounds in spring and summer, and post-spawners move back downstream in fall and winter to wintering areas with movements usually restricted to the areas above the saltwater/freshwater interface. Shortnose sturgeons are not known to participate in coastal migrations (NMFS 1998). Spawning begins from late winter/early spring (southern rivers: January to March) to mid to late spring (northern rivers: April to May) when water temperatures increase to 8° to 9°C. Spawning usually ceases when water temperatures reach 12° to 15°C (O'Herron et al. 1993, Kynard 1997).

Shortnose sturgeons were thought to be extirpated from NC waters until an individual was captured in the Brunswick River in 1987 (Ross et al. 1988). Subsequent gill-net studies (1989-1993) resulted in the capture of five shortnose sturgeons which confirmed the presence of a small population in the lower Cape Fear River (Moser and Ross 1995). A capture was reported in 1998 in western Albemarle Sound (Armstrong and Hightower 1999). Surveys in the Neuse River during 2001 and 2002 failed to capture any shortnose sturgeons (Oakley and Hightower 2007). Additional surveys are currently underway in the Roanoke, Chowan, and Cape Fear River Basins (NMFS 2010a). The current distribution of shortnose sturgeons in NC is thought to include only the Cape Fear and Pee Dee Rivers (SSSRT 2010). The Cape Fear River Estuary likely serves as a migration or staging corridor for spawning (SSSRT 2010).

Occurrence in the Study Area

The shortnose sturgeon has not been recorded in or near the study area. However, genetic studies indicate that some individuals move between the various populations (Quattro et al. 2002, Wirgin et al. 2005). The lack of records near the study area may be due to a lack of survey effort. There is no documentation of a reproducing population of shortnose sturgeon in the Lockwoods Folly River, but this species may use the inlet and nearshore waters of Oak Island and Holden Beach as a feeding/staging area during coastal migrations (Personal communication, J. Facendola, NCDMF, October 2014). They are not expected to occur in the Eastern Channel or other inshore portions of the study area (Personal communication, F. Rohde, NMFS, October 2014).

Atlantic Sturgeon

Status, Habitat, Distribution

Five distinct Atlantic sturgeon (*Acipenser oxyrinchus*) population segments along the Atlantic Coast are listed under the ESA (77 FR 5914, 77 FR 5880). The New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs are designated as endangered while the Gulf of Maine DPS is listed as threatened. The Carolina DPS includes Atlantic sturgeon originating from the Roanoke, Tar/Pamlico, Cape Fear, Waccamaw, Pee Dee, and Santee-Cooper Rivers (77 FR 5914). The existing spawning populations in each of these rivers are thought to have less than 300 adults spawning each year [Atlantic Sturgeon Status Review Team (ASSRT) 2007].

Atlantic sturgeon spawn in freshwater but spend most of their adult life in the marine environment. Spawning adults generally migrate upriver in the spring/early summer (Smith and Clugston 1997). Spawning is believed to occur in flowing water between the salt front and fall line of large rivers. Post-larval juvenile sturgeon move downstream into brackish waters and eventually move to estuarine waters where they reside for a period of months or years (Moser and Ross 1995). Subadult and adult Atlantic sturgeons emigrate from rivers into coastal waters where they may undertake long range migrations. Migratory subadult and adult sturgeon are typically found in shallow (10 to 50 m) nearshore waters with gravel and sand substrates (Collins and Smith 1997, Stein et al. 2004). Although extensive mixing occurs in coastal waters, Atlantic sturgeons return to their natal rivers to spawn (ASSRT 2007).

In NC, spawning occurs in the Roanoke, Tar-Pamlico, and Cape Fear River systems and possibly in the Neuse River (ASSRT 2007). Based on tagging data collected between 1988 and 2006, shallow nearshore waters off NC represent a winter (January-February) aggregation site and an important area of Atlantic sturgeon winter habitat (Laney et al. 2007).

Occurrence in the Study Area

The Atlantic sturgeon occurs in the Cape Fear River system just east of the study area. Subadults and adults are known to migrate in nearshore waters. Although there is no documentation of a reproducing population of Atlantic sturgeon in the Lockwoods Folly River, this species may use the inlet and nearshore waters of Oak Island and Holden Beach as a feeding/staging area during coastal migrations (Personal communication, J. Facendola, NCDMF, September 2014). The NCDMF's independent gillnet survey program has caught several Atlantic sturgeon off Oak Island during the winter sampling period (Personal communication, J. Facendola, NCDMF, September 2014). Atlantic sturgeons are not expected to occur in the Eastern Channel and other inshore portions of the study area (Personal communication, F. Rohde, NMFS, September 2015.

4.3.4.1.5 Plants

The only ESA-listed plant species occurring in the study area is the seabeach amaranth (*Amaranthus pumilus*). This species and its occurrence in the study area are discussed below.

Seabeach Amaranth

Status, Distribution, and Habitat

The seabeach amaranth is designated as threatened under the ESA (58 FR 18035). Extant populations currently range from NY to SC. In NC, populations occur in Core Banks, Shackleford Banks, Brunswick County, Cape Hatteras, Ocracoke Island, Hammocks Beach State Park, Camp Lejeune, Bogue Banks and Wrightsville. The number of plants across NC has decreased from 19,978 in 2005 to 165 in 2013 (personal communication, Kathy Matthews, USFWS 2014 data). No critical habitat is designated for this species.

The seabeach amaranth is an annual plant found only along the Atlantic coastal plain where it inhabits barrier island beaches (Beacham 1994). Its primary habitat includes overwash flats at the accreting ends of the islands, lower foredunes, and upper strands of noneroding beaches (at the wrackline). Seabeach amaranth is usually found on a nearly pure silica sand substrate that is sparsely vegetated with annual herbs (forbs) and, less commonly, perennial herbs (mostly grasses) and scattered shrubs (USFWS 1996b). This natural community or vegetation type is classified by Schafale and Weakley (1990) as Upper Beach although seabeach amaranth can be found on sand spits 50 m or more from the base of the nearest foredune (USFWS 1996b). Seeds germinate from April through July, flowering begins as early as June in NC, and seed production begins in July or August with a peak in September. The reproductive season may extend into January (USFWS 1996b).

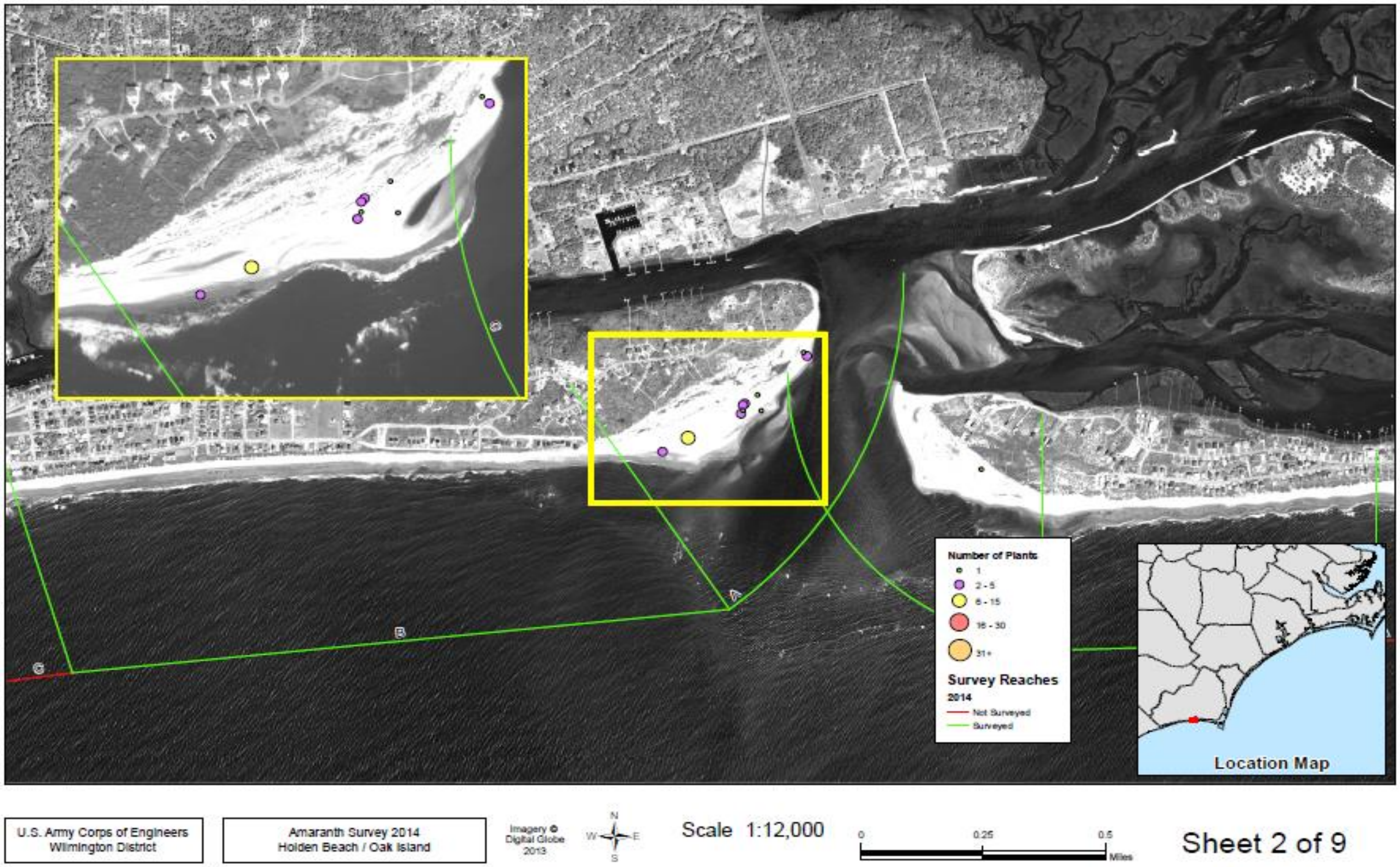
Occurrence in the Study Area

The USACE has conducted comprehensive annual surveys for seabeach amaranth on NC beaches since 1999. Surveyed populations have generally declined since 2010 (USACE 2014b). On Holden Beach, seabeach amaranth has been found along the entire oceanfront beach and both inlet shorelines; however, since 1999, it has been consistently found along the western half of the island. The total number of plants observed between 2010 and 2013 ranged from 434 to 46 plants (USACE 2014b). A total of 349 plants were recorded on Holden Beach during the 2014 annual survey conducted in July and August; 26 of these plants are on the East End of Holden Beach in the study area (USACE 2014b) (Figure 4.12).

Based on USACE survey data from 2009 through 2014, the majority of seabeach amaranth plants have been documented on the western tip of Oak Island (Personal communication, Dale Suiter, USFWS Raleigh office, 12 November 2014). Since 1992, there has been an extensive decrease in the presence of seabeach amaranth plants from a high of 5,826 plants surveyed on the western end of Oak Island to one plant surveyed in 2013 (USACE 2014b, USACE data). Decreased habitat availability on this portion of Oak Island has negatively affected the seabeach amaranth population there since 2010. The most recent survey conducted in July and August 2014 confirmed one plant on the western end of Oak Island in the study area (USACE 2014b) (Figure 4.12).

4.3.4.2 State-Listed Species and Federal Species of Concern

Animal and plant species listed by the State of NC as threatened, endangered or of special concern are afforded protection under the NC ESA (G.S. 113-331 to 113-337) and the NC Plant Protection Act of 1979 (G.S. 196 106-202.12 to 106-202.19). State laws are primarily in place to protect listed species from poaching and illegal trafficking. In addition to state protected species, county rare species lists maintained by the North Carolina Natural Heritage Program (NCNHP) include "significantly rare" taxa that exist in the state in small numbers. Some state-listed species are also identified by the USFWS as federal species of concern (FSC). FSC is an informal designation that applies to former Category 2 (C2) candidate species that were removed from the official federal candidate list in 1996. Although former C2 species no longer have any official federal status, many of the USFWS regional offices continue to include FSC taxa on county species lists that are distributed for environmental project reviews. Although these species are not protected under the ESA and are not subject to Section 7 consultation, the USFWS advocates the consideration of these species during the NEPA process. The NCNHP rare species list for Brunswick County includes a number of state-listed and FSC species that may occur in marine, estuarine, and/or barrier island habitats (Table 4.3).



Map from USACE (2014b)
Note: Inset is of seabeach amaranth located on East End of Holden Beach

Figure 4.12. Seabeach Amaranth in the Study Area in 2014

Table 4.3. State-listed species.

Common Name	Scientific Name	State Status[2]	Federal Status[3]	Habitat
Wilson's plover	***Charadrius wilsonia***	**SC**		**Beaches, inlet flats, estuarine islands [breeding evidence only]**
Common ground dove	*Columbina passerina*	SR		Dunes, edges of maritime forest/shrub
Little blue heron	*Egretta caerulea*	SC		Maritime forest/shrub [breeding sites only]
Snowy egret	*Egretta thula*	SC		Maritime forest/shrub [breeding sites only]
Tricolored heron	*Egretta tricolor*	SC		Maritime forest/shrub [breeding sites only]
Gull-billed tern	*Gelochelidon nilotica*	T		Sand flats [breeding sites only]
American oystercatcher	***Haematopus palliatus***	**SC**		**Estuaries, oyster beds, mudflats [breeding evidence only]**
Bald eagle	*Haliaeetus leucocephalus*	T		Mature forests near large water bodies [nesting], lakes and sounds
Least bittern	*Ixobrychus exilis*	SC		Fresh/brackish marshes
Painted bunting (Eastern subspecies)	***Passerina ciris ciris***	**SC**	**FSC**	**Maritime forest/shrub**
Brown pelican	*Pelecanus occidentalis*	SR		Maritime islands [breeding sites only]
Glossy ibis	*Plegadis falcinellus*	SC		Maritime forest/shrub [breeding sites only]
Black skimmer	*Rynchops niger*	SC		Sand flats [breeding sites only]
Least tern	***Sternula antillarum***	**SC**		**Beaches, sand flats, dunes [breeding sites only]**
Loammi skipper	*Atrytonopsis loammi*	SR	FSC	Grassy areas near the coast
Giant swallowtail	***Papilio cresphontes***	**SR**		**Maritime forest/shrub**
Southern oak hairstreak	*Satyrium favonius favonius*	SR		Maritime forests
A liverwort	*Cheilolejeunea rigidula*	SR-P		Maritime forests
Diamondback terrapin	*Malaclemys terrapin*	SC	FSC	Salt/brackish marshes
Spreading sandwort	*Arenaria lanuginosa* var. *lanuginosa*	SR-P		Maritime grasslands and forests
Georgia sunrose	*Crocanthemum georgianum*	E		Maritime forests
Coral bean	***Erythrina herbacea***	**E**		**Maritime forests**
Southern seaside spurge	***Euphorbia bombensis***	**SR-T**		**Ocean beaches**
Beach morning-glory	***Ipomoea imperati***	**T**		**Ocean beaches and dunes**
Large-seed pellitory	*Parietaria praetermissa*	SC-V		Maritime forests
Seabeach knotweed	*Polygonum glaucum*	E		Ocean and sound beaches
Rhynchospora odorata	**Fragrant beaksedge**	**SC-V**		**Maritime wet grasslands**
Sesuvium maritimum	Slender seapurslane	SR-O		Ocean beaches, marshes
Sideroxylon tenax	Tough bumelia	T	FSC	Maritime forest and scrub
Solanum pseudogracile	Graceful nightshade	SR-T		Dunes
Solidago villosicarpa	**Coastal goldenrod**	**E**	**FSC**	**Edges and openings in maritime forests**
***Trichostema* spp.**	**Dune bluecurls**	**SR-L**	**FSC**	**Dunes, openings in maritime forest and scrub**
Yucca gloriosa	**Moundlily yucca**	**SR-P**		**Dunes**

[1]Bold = Species that have been observed in or near the study area based on NCNHP Element Occurrence records (NCNHP 2014).
[2]E = Endangered, T = Threatened, SC = Special Concern, SC-V = Special Concern Vulnerable (all known populations are historical or extirpated), SR = Significantly Rare, SR-T = Significantly Rare Throughout (species is rare throughout its range), SR-L = Significantly Rare Limited (range of the species is limited to NC and adjacent states), SR-P = Significantly Rare Peripheral (species is at the periphery of its range in NC, generally more common elsewhere within its range), SR-O = Significantly Rare Other (species range is sporadic or does not correspond to any of the other SR categories)
[3]FSC = Federal Species of Concern

4.4 Cultural Resources

As a consequence of nearly 400 years of sustained maritime activity, the waters off Brunswick County, including the mouth of the Cape Fear River, contain the remains of innumerable historical shipwrecks. Abandoned shipwrecks and other cultural resources that occur on submerged lands of the state are protected under the Federal Abandoned Shipwreck Act of 1987 and Chapter 121, Article 3 of the NC GSs (Salvage of Abandoned Shipwrecks and Other Underwater Archaeological Sites). Pursuant to Section 106 of the National Historic Preservation Act of 1966, projects affecting submerged lands of the state must be evaluated for potential effects on underwater cultural resources that are listed or may be eligible for listing in the National Register of Historic Places.

At least 22 historical shipwrecks dating from the early 1700s through World War II have been recorded near LFI (Hall 2011). The remains of four Civil War vessels at LFI are listed in the National Register of Historic Places under the Cape Fear Civil War Shipwreck District (Figure 4.13). The U.S.S. *Iron Age* and two sidewheel steamer blockade runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade runner (*Ranger*) is located ~1 mile west of the inlet (Photo 4.4). A remote sensing survey for potential cultural resources within the proposed borrow site was conducted by Tidewater Atlantic Research (Hall 2011). The survey identified a single magnetic anomaly and no acoustic targets. Data analyses indicated that the magnetic anomaly was a single, isolated object most likely consisting of modern debris.

4.5 Public Interest Factors

The decision whether to issue a permit by the USACE is based on an evaluation of the probable impacts of the proposed activity and its intended use on the public interest. All factors which may be relevant to the proposal are considered in this document including economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife values, floodpain values, navigation, water quality, and in general, the needs and welfare of the people (33CFR320, Section 320.4).

4.5.1 Socioeconomic Resources

Population

Demographic statistics for Holden Beach and the west end of Oak Island (Census Tract 203.8) are presented in Table 4.4. The 2010 US Census reported a total of 575 permanent residents on Holden Beach and a total of 1,648 permanent residents on western Oak Island. The overwhelming majority of the permanent residents (97.6 percent) reported their race as “White” in 2010. All other single race groups combined

Figure 4.13. Shipwrecks Located in LFI

Photo 4.4. Exposed boilers of the Bendigo (left foreground) and the USACE dredge boat, Currituck, Site 0001LFI.

Source: Wilde-Ramsing and Angley 1985

Table 4.4. Demographic summary.

	Holden Beach	Oak Island Tract 203.8	Total
Total permanent resident population	575	1,648	2,223
White, percent	96.9	97.9	97.6
Black/African American, percent	0.9	0.4	0.5
American Indian/Alaska Native, percent	0.2	0.5	0.4
Native Hawaiian/Pacific Islander, percent	0.0	0.1	0.1
Asian, percent	0.0	0.1	0.1
Some Other Race, percent	1.4	0.1	0.4
Two or More Races, percent	0.7	0.9	0.9
Hispanic or Latino origin, percent	2.4	0.6	1.1
Population aged 65 years or older, percent	19.9	13.4	15.1
Median household income	$52,206	$52,319	-
Population below poverty level, percent	9.2	6.1	7.1
Housing units	2,335	2,126	4,461
Permanently Occupied	296	789	1,085
Seasonal use	1,732	1,145	2,877
Vacant	307	192	499

Source: US Census Bureau (2010a, 2010b)

accounted for 1.1 percent of the population, and the remaining residents (1.3 percent) were classified as either "Some Other Race" or "Two or More Races." In addition to race, 1.1 percent of the residents identified their ethnic origin as Hispanic or Latino. The resident population includes a substantial number of retirees with 15.1 percent of the population aged 65 or older and 34.4 percent of the households reporting retirement incomes. Median household incomes for Holden Beach and Oak Island are $52,206 and $52,319, respectively. In contrast to the relatively small permanent population on Holden Beach, the estimated peak seasonal population during the summer is approximately 13,000 and includes permanent residents, seasonal residents and persons renting private units on a monthly or weekly basis. The peak seasonal estimate does not account for day-trip visitation which may add as many as 1,000 additional people to the peak season population (Imperial et al. 2009). Oak Island has an estimated island-wide (Town of Oak Island and Caswell Beach) peak season population of around 32,000 and an island-wide permanent resident population of 6,531.

Housing

The 2010 US Census reported a total of 4,461 housing units on Holden Beach and western Oak Island; this total includes 1,085 permanently occupied units; 2,877 seasonal units; and 499 vacant units (Table 4.5). As indicated by the large number of seasonal units, over half of the housing units are secondary vacation homes that are occupied or rented out on a seasonal basis. Detached single family homes account for 91.3 percent of the units on Holden Beach and western Oak Island (Table 4.5). Buildings with two or more units account for 6.7 percent of the total followed by row houses (1.3 percent) and mobile homes (0.7 percent).

Table 4.5. Housing characteristics.

Units in Structure	**Holden Beach**	**Oak Island Tract 203.8**	**Total**	**Percent of Total**
1 unit, detached	2,111	2,035	4,146	**91.3**
1 unit, attached	36	25	61	**1.3**
2 or more units	210	94	304	**6.7**
Mobile home	30	0	30	**0.7**
Total housing units	2,387	2,154	4,541	**100**

Source: US Census Bureau 2010a

Economy

According to the North Carolina Department of Commerce, direct traveler expenditures in Brunswick County amounted to $418 million in 2011. Additional economic impacts attributable to travel spending included 4,670 jobs; a $75.8 million payroll; and $46.7 million in state and local tax revenues (US Travel Association 2011). In 2008, beach recreation on Holden Beach generated over $54 million in direct traveler expenditures (Table 4.6). The total estimated impact on sales and business activity due to direct beach recreation expenditures and economic multiplier effects was nearly $95 million. In 2005-2006, direct expenditures and multiplier effects attributable to beach recreation on Holden Beach supported an estimated 1,299 jobs. The economic impact of Holden Beach is also reflected in its contribution to the county tax base. According to the North Carolina Department of Revenue, the value of taxable real property on Holden Beach accounted for 16.7 percent ($1.2 billion) of the overall Brunswick County property tax base in 2011/2012 (Table 4.7). Substantial economic impacts are also attributed to the area's inlets and waterways. In 2008, the estimated total economic impact of recreational fishing charters and private boating trips through Brunswick County's inlets exceeded $70 million, and commercial fishery activity associated with Lockwoods Folly Inlet generated $900,157 in total economic impacts (NCDENR 2011).

Table 4.6. Economic impact of beach recreation.

Beach	2005-2006 Total Jobs Supported	2008 Direct Expenditures	2008 Total Impact Sales/Business Activity
Holden Beach	1,299	$54,097,121	$92,858,134
Oak Island/Caswell Beach	898	$37,424,734	$64,239,849
Total	**2,197**	**$91,521,855**	**$157,097,983**

Source: NCDENR 2011

Table 4.7. Value of taxable real property FY 2011/2012.

	Taxable Real Property[1]
Town of Holden Beach	$1,201,909,702
Town of Oak Island	$2,394,448,315
Total	**$3,596,358,017**
County	**$21,516,090,139**

[1]North Carolina Department of Revenue (www.dor.state.nc.us/publications/property.html)

Economic Costs and Benefits

Alternative actions for the Holden Beach East End Shore Protection Project each create a unique array of costs and benefits. These include market costs, such as construction and engineering costs associated with active mitigation, potential economic losses associated with upland damage, risk to coastal real estate and infrastructure, and non-market costs and benefits, such as those associated with effects on the natural environment, aesthetic appeal, habitats and species.

This section describes the potential scope of these values for each of the six alternative actions under consideration for the Holden Beach East End Shore Protection Project. Monetary measures are provided for values that are readily identifiable and measurable based on existing data, such as construction and maintenance costs for the alternatives that involve nourishment or a terminal groin, as well as assessed tax values for properties at-risk to loss from erosion. These values should not be considered definitive and should not be used as the sole basis for choice or ranking of alternatives.

This section should not be considered a formal cost-benefit analysis; it is not an attempt to monetize all aspects of the range of market and non-market costs and benefits that are associated with the alternative actions. Costs and benefits associated with changes in aesthetic appeal, opportunities for recreation, or services provided by the affected natural environment constitute real economic costs but are not monetized as part of this report. Based on results in the published and peer-reviewed literature as described in Appendix O, these values are known to be substantial. However, the precise magnitude, distribution, and timing of these values will remain unknown. As such, the select monetary values that are provided herein should be considered general approximations and not representations of the true economic worth associated with the alternatives. Given the inherent uncertainties regarding specific performance of alternatives over a 30-year project planning horizon, providing an estimate of total costs, total benefits, or net gains is not practical. As a result, ranking of the alternatives based on their relative economic values is not performed.

In many cases, the benefits associated with alternatives that mitigate the effects of erosion can be considered costs of alternatives that do not mitigate erosion. For example, the benefits of shoreline stabilization via nourishment or hardened structures include maintaining the integrity of the Holden Beach shoreline and the associated real estate. These economic values may be partially or wholly sacrificed in the absence of active mitigation. Hence, the costs of no action or retreat should account for declinations in the economic value of associated real estate due to lost shoreline integrity as well as losses associated with effects on use and non-use values associated with recreation and tourism on Holden Beach. It is important to note, however, that inaction or retreat may have the greatest adverse effect on environmental conditions. Therefore, strategies that do not protect the shoreline from continued erosion are not expected to maintain environmental conditions in the study area.

Cost and benefit values described below include explicit and implicit values. Affected stakeholders include property owners, business owners, visitors, taxpayers of NC, and individuals who value coastal species and ecosystems and the character of Holden Beach. The incidence of costs and benefits across these stakeholder groups is expected to vary across the alternatives. As noted in Landry and Hindsley (2011), stakeholders can be expected to have different perceptions of the effectiveness of natural and man-made storm and erosion buffers and variable evaluations of beach characteristics in terms of aesthetics, recreation and leisure. Hence, the alternative actions can be expected to convey net economic gains to some user groups while conveying net economic losses to other groups.

Explicit costs associated with alternative actions include physical construction costs associated with shoreline nourishment activities, channel excavation costs, construction costs of a terminal groin and costs associated with destruction and/or removal of existing properties and infrastructure. Implicit costs include losses in economic value to coastal property and public infrastructure associated with degradation of the character of the shoreline and proximate coastal and marine ecosystems, as well as reductions in use and non-use values associated with recreation, aesthetics and changes in the quantity and quality of habitats and species.

Construction and maintenance costs detailed herein are those incurred by the Holden Beach Home Owners Association and are based on estimates provided by ATM as part of an engineering analysis of project alternatives (Appendix H).

These estimates were constructed using a 30-year time horizon beginning in year 2015. A four percent annual inflationary increase is assumed for construction costs. Discounting is applied to current dollar value expenditures in order to provide cost estimates in present value terms. Lower discount rates result in higher estimated present values for future expenditures and cause alternatives that involve higher future expenses to appear less favorable. Similarly, higher discount rates result in lower present values for future expenditures. The discount rate used in analyzing public projects should reflect the opportunity cost of public funds. Current long-term rates on US Treasury Bills are approximately 2.5 percent. Because the public is generally risk-averse with regard to spending on projects with uncertain outcomes, higher discount rates are more appropriate. For this analysis, the present value of future expenditures associated with the alternatives is examined using discount rates of 2.5 percent, 4.125 percent, and six percent. A 4.125 percent discount rate is standard practice for Civil Works projects by the USACE. Therefore, by using rates above and below 4.125 percent, we provide sensitivity analyses for this important and uncertain parameter.

Shoreline management alternatives that include the construction of a terminal groin involve large initial costs associated with construction but lower future costs associated with beach nourishment. This future cost saving is due to smaller quantities of sand that would be placed during each episode and/or decreased frequency of nourishment episodes. Because these alternatives involve larger up-front costs and lower future costs, they will appear more favorable when lower discount rates are employed. For the range of estimates provided for the present value of future expenditures associated with the project alternatives, higher estimates correspond to a two percent discount rate, and lower estimates correspond to a six percent discount rate.

To understand the relative scope of potential impacts on coastal property, the most recent (2012) assessed tax values for at-risk properties were used. Note that the current assessed tax values may not be reflective of current market values. To the extent that risk of future erosion is known or perceived by market participants, market values could be considerably lower than the assessed tax value. Given the dynamic nature of the Holden Beach shoreline in recent years, the loss of numerous homes and parcels to erosion, and the uncertainty regarding the potential for mitigating action, it seems logical that current market values for at-risk Holden Beach properties, especially those that are imminently threatened, will have capitalized a sense of future risk. Whether or not such risks are incorporated into value assessments is unknown.

Changes in the real estate market that have transpired since the most recent assessment may generally effect market values. These changes include general market trends as well as modifications to insurance rates specific to properties in the coastal zone. While the general real estate market trend since 2012 is upward, such enhancements are not homogenous across locations and may not be conferred upon properties at risk to erosion. Recent trends in insurance rates as part of the NC Beach Plan have been generally unfavorable for properties in the coastal zone. Expected or realized additional costs may decrease demand for coastal properties offsetting some of the general market improvements experienced in recent months. Moreover, it can be argued that the appropriate values to be used in understanding the possible effects of alternative shoreline management actions are the values that exist at the time of the associated environmental change. As noted above, and with the important exception of acute change due to damage from storms, anticipated changes in coastal environments are likely to be capitalized into the market value of real estate far in advance of actual change (Landry and Hindsley 2011, Landry 2011).

The assessed tax values of at-risk properties are used as a means of appreciating the relative magnitude of the management alternatives rather than the absolute value that is at risk. Even in terms of relative magnitudes, these values should be used with caution. As noted in Landry and Hindsley (2011), if active mitigation creates an expectation of improved conditions over time, value estimates should be interpreted as lower bounds on true value. In contrast, if conditions are expected to degrade, value estimates should be interpreted as upper bounds on true value.

Impending property loss due to erosion may result in some structures being demolished and some being moved farther inland. Monetizing the value of the transition losses associated with destruction or location of property or monetizing the gains in value that will be realized by currently unimproved parcels that are subsequently improved when structures are relocated was not attempted with this study. Although it is important to acknowledge that such effects are very likely to transpire in the case of some alternatives, forecasting the magnitude, timing and location of such transitions is not practical.

Stabilized shorelines may also convey additional use and non-use values associated with protecting coastal habitats and species. Such values may be conferred upon the public at large regardless of past or present experience with the study area. Existence values, option values, and bequest values may also accrue to past and potential visitors to Holden Beach who derive benefits from the maintenance of favorable conditions at the site. Descriptions of these values are included in Appendix O. Actions that involve the construction of a terminal groin (i.e., Alternatives 5 and 6) may also create economic benefits in terms of enhanced recreational fishing opportunities on the East End of Holden Beach although these gains have the potential to be offset by diminished visual appeal and/or any potential detrimental environmental effects produced by physical alteration of the shoreline.

Alternatives 1 (no action) and 2 (abandon/retreat) may produce economic benefits to a set of individuals who place economic value on unimpeded ecosystem function and change. These values are probably best described as non-use values although some use value losses would also transpire and can be expected to accrue to some portion of the general public. A critical assumption with regard to these values is that baseline environmental conditions are naturally occurring which may not be the case for Holden Beach given the lengthy history of shoreline protection projects that have taken place in the area.

4.5.2 Land Use

The existing land use in the Town is summarized in Table 4.8. The jurisdictional limits of the town encompass a total area of 1,489 ac, including 809 ac of "usable" high ground and 680 ac of "unusable" conservation areas consisting of unvegetated beaches (26 ac) and a combination of back-barrier tidal marshes and dredged material management areas (654 ac) (Imperial et al. 2009). Collectively, lands designated as residential, vacant and conservation account for 96 percent of the total municipal land area. Approximately 83 percent of the usable land area is zoned for residential land use, including 477 ac of existing residential development and 195 ac of vacant land that are zoned for residential use. Commercial land use accounts for about 1.3 percent of the usable land area, and with the exception of a few small outlying parcels, commercial land is concentrated at the foot of the Holden Beach Bridge (Imperial et al. 2009).

The Town of Oak Island contains approximately 12,752 ac including portions of the island (5,204 ac) and the mainland (7,547 ac). The island portion of the town is predominately residential with some commercial and tourist-related development. The western end of Oak Island, extending from State Road (SR) 1105 (Middleton Ave.), contains predominantly single family residences. Areas under development include the Point at the extreme western end of the island and the areas along NC 133. Commercial land use is concentrated along NC 211, NC 133, Yaupon Drive, a small

Table 4.8. Land use summary.

Land Use	Town of Holden Beach[1]		Town of Oak Island[2]	
	Acres	Percent	Acres	Percent
Residential	477	32	3,134.27	24.58
Vacant Land	265	18	--	--
State Owned	29.25	2	--	--
Common Area/Recreation	22	1.5	81.84	0.64
Commercial	10.25	0.7	83.35	0.65
Civic Club/Lodge/Hall	3	0.2	--	--
Church	1.25	0.08	--	--
Municipal/Institutional	1	0.07	19.23	0.15
Utilities Commercial	0.25	0.02	25.78	0.20
Transportation	--	--	110.00	0.86
ROW	--	--	579.80	4.55
Agriculture	--	--	0.52	0.004
Marsh/Spoil/Wetland	654	44	785.82	6.16
Forest/Wooded	--	--	553.47	4.34
Eroded/Unvegetated Beach	26	1.7	--	--

Source: [1]Imperial et al. (2009); [2]Town of Oak Island (2009)

commercially zoned area surrounding the Oak Island fishing pier and along a portion of Oak Island Drive. The existing land use in the Town of Oak Island is summarized in Table 4.8 for specific land uses classified in Town of Oak Island (2009). Note that some land uses are not specified in this document.

4.5.3 Infrastructure

Water Supply and Wastewater Treatment

Holden Beach operates its own municipal water supply system. The town's water supply is purchased from Brunswick County, which obtains its water supply from the Cape Fear River (above Lock and Dam #1) and groundwater drawn from the Castle Hayne aquifer. Water from the Cape Fear River is treated at the county's Northwest Water Treatment Plant in Leland which is capable of treating 24 million gallons per day (MGPD). Groundwater drawn from 15 wells is treated at the county's 211 Water Treatment Plant near Southport which is capable of treating seven MGPD. Water is delivered to the island via two pipelines that cross the AIWW at Seagull Drive and the Holden Beach Bridge. The town's distribution system includes approximately 20 miles of water distribution lines and a 300,000 gallon storage tank. The county has developed a water system master plan that addresses future demands on the county water supply. The county anticipates that Holden Beach will require additional water at the rate sufficient to meet the demands of an additional 50 housing units per year. At this rate, Holden

Beach will require 0.145 MGPD on an average day in 2015. Additional wholesale users of the Brunswick County water supply system will require 8.714 MGPD on an average day in 2015. The Holden Beach system is more than capable of meeting the projected future demand. The town completed construction of a wastewater collection system in March 2006. Connection to the municipal sewer system is mandatory for all residents and businesses. Based on the anticipated rate of growth, the current sewer system capacity is expected to meet the increase in demand over the next 10 to 15 years.

Transportation

As described in the Town CAMA Land Use Plan (2009), the Holden Beach Bridge is the only means of ingress or egress to the Town from the Mainland. Accordingly, traffic at the bridge during summer months is common as is traffic congestion at major intersections on and adjacent to the Island. The Holden Beach Bridge is maintained by the North Carolina Department of Transportation (NCDOT). Based upon information provided by the NCDOT Bridge Maintenance Unit, the Holden Beach Bridge was constructed of pre-stressed concrete in 1985.

The Holden Beach Bridge was designed for seven percent of traffic to be trucks, and for 40 miles per hour speeds. The 1985 average annual daily traffic (AADT) for the Holden Beach Bridge was 2,000 vehicles. The design year AADT (which was set at 2005) was estimated in 1985 at 3,300 vehicles. Based upon the AADT that was measured just a few miles north of the bridge (at Portable Traffic Count Station 900031), the 2004 AADT was 10,000. It seems that the bridge designer had underestimated the amount of traffic that the Holden Beach Bridge would receive. Although the design year AADT is set at a point 20 years from the date when the bridge was constructed, the design life for the bridge project is typically 50 years or more, depending upon budget constraints.

The Island's transportation system and its one connection to the mainland are adequate to serve current and projected populations in the event that an evacuation is ordered. However, the CAMA Land Use Plan contains other policies and recommendations pertaining to its transportation system. The Town supports federal and state road and bridge improvement programs. The plan also recommends treating stormwater using infiltration and other structural and nonstructural best management practices to ensure that future road improvements reduce nonpoint source (NPS) pollution.

4.5.4 Scenic Resources

Scenic resources include the physical, biological and cultural landscape elements that contribute to perceptions of scenic beauty. NC's barrier islands are highly valued for their natural beauty. Important natural landscape elements of these islands include marine and estuarine water resources, sandy beaches, dunes, maritime forests, salt marshes and associated wildlife. Cultural elements, such as historic coastal structures, contribute to a sense of place and the perception of barrier islands as a unique scenic resource. The scenic beauty of NC's barrier islands is reflected in their popularity as a tourist destination. Surveys of beach visitors in NC indicate that tourists and residents consider natural beauty, wide sandy beaches, visible wildlife and historical structures to be important elements of a positive beach experience (Ellis and Vogelsong 2005). The dune/beach/ocean system is a highly visible public resource that is readily accessible to the general public via numerous access points along the entire island.

4.5.5 Light

Artificial nighttime lighting has aesthetic and ecological implications for NC's barrier islands. Existing sources of artificial nighttime light on Holden Beach include residential and commercial exterior lighting, street lights, lighted signs, outdoor recreational facilities, lighted docks and piers, telecommunication towers, vehicular headlights, recreational and commercial vessel traffic and lighting associated with federal navigation maintenance dredging. Although artificial lighting has many beneficial effects related to safety, work productivity and recreational opportunities, excessive or misdirected light may lead to degradation of visual quality, alteration of scenic vistas and visual annoyance. Misdirected or unshielded light sources that emit upward or horizontal light contribute to light pollution in the form of sky glow, light trespass and/or glare. Light source properties that influence the amount of light pollution include wattage, spectral properties, height, angle, and degree of shielding (Shi 2010).

Ongoing federal navigation dredging projects and shoreline protection projects are a direct source of artificial light within marine, estuarine and ocean beach habitats. To take advantage of limited environmental construction windows and maximize the efficient use of construction equipment, operations are usually conducted during day and night. Nighttime construction lighting requirements for human safety are dictated by the USACE, US Coast Guard (USCG) and Occupational Safety and Health Administration (OSHA) regulations. Safety lighting requirements apply to staging areas, dredges and disposal sites [USACE Engineering Manual (EM) 385-1-1]. The USACE employs multiple measures to minimize the adverse ecological effects of artificial lighting: 1) lighting only the immediate construction area; 2) using the minimum amount of light required by federal regulations; 3) controlling light distribution by shielding, redirecting and/or lowering light fixtures; and 4) using lights with spectral properties that minimize disruption to sea turtles (e.g., low-pressure sodium vapor lights) (USACE 2008).

4.5.6 Water Quality

All surface waters in NC are assigned a primary surface water classification by the NCDWQ. Each classification must meet a specific set of water quality standards. All ocean waters within the study area are classified as SB waters. SB waters support primary recreation, including frequent and/or organized swimming, and must meet water quality standards for fecal coliform bacteria. All waters of the AIWW, LFI, and the Lower Lockwoods Folly River from the AIWW to SR 1200 have a primary classification of SA. SA waters support commercial shellfishing and are subject to fecal coliform bacteria standards, restrictions on domestic wastewater discharges and specific stormwater control measures. All SA waters are also classified as HQW, which have excellent water quality and/or important functions such as primary nursery areas. Waters of the Lower Lockwoods Folly River are also classified as Special Management Strategy Waters in accordance with 15A NCAC 2B .0227 (Water Quality Management Plans).

4.5.7 Air Quality

The North Carolina Division of Air Quality (NCDAQ) maintains an ambient air monitoring network for those criteria pollutants requiring monitoring by the EPA. Areas that exceed EPA national ambient air quality standards based on regional ambient air monitoring are designated as non-attainment areas. Brunswick County is included in the non-metropolitan statistical area of NC's southern coastal plain (NCDAQ 2010). The Wilmington Regional Office of the NCDENR has jurisdiction over the air quality in this location, and it has been determined that the ambient air quality for the area is in compliance with the National Ambient Air Quality Standards.

4.5.8 Noise

Numerous metrics are used to quantify the noise produced by various underwater activities, including a variety of alternative metrics for measuring both single-event noise and cumulative noise over an extended time period. Anthropogenic noise has the potential to cause behavioral disturbance and permanent injury to exposed marine mammals depending on the intensity level that individual animals experience (Southall et al. 2007). The NMFS currently uses the root-mean-square (RMS) sound pressure level (SPL) metric to evaluate potential impacts on marine mammals and federally listed species of fish. RMS SPL values represent the average sound pressure over the duration of the event and are expressed as decibels (dB) referenced to one micropascal (dB re: 1 μPa). The NMFS is in the process of developing a comprehensive acoustic policy that will provide guidelines for evaluating noise effects based on the sensitivity of individual marine mammal species to different noise frequency ranges and intensities. However, the NMFS currently uses generic noise exposure thresholds to define two levels of acoustic "take" under the MMPA. Actions that may expose marine mammals (mysticetes and odontocetes) to sequences of pulsed sounds with source levels of 180 dB re: 1 μPa constitute Level A harassment which has the potential to cause injury. The Level A harassment criterion for pinnipeds exposed to such sounds is 190 dB re: 1 μPa. Actions that may expose marine mammals to pulsed sounds with source levels of 160 dB re: 1 μPa constitute Level B harassment which may lead to behavioral disturbance and potential temporary threshold shifts in hearing.

Sources of anthropogenic underwater noise within the study area include commercial shipping operations associated with the Port of Wilmington, recreational watercraft activity and periodic maintenance dredging of federally maintained navigation channels. Clarke et al. (2002) documented noise levels ranging from 120 to 140 dB re: 1µPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. Peak spectral levels for individual commercial ships are in the frequency band of 10 to 50 Hertz (Hz) and range from 195 dB re: µPa 2/Hz @ 1 m for fast-moving (>20 knots) supertankers to 140 dB re: µPa 2/Hz @ 1 m for small fishing vessels [National Research Council (NRC) 2003]. Small boats with outboard or inboard engines produce sound that is generally highest in the mid-frequency [1 to 5 kilohertz (kHz)] range and at moderate (150 to 180 dB re: 1 µPa @ 1 m) source levels (Erbe 2002, Kipple and Gabriele 2003 and 2004). For instance, small craft with outboard motors [14 to 18 ft (4.3 to 5.5 m) in length with 25 to 40 horsepower, 19 to 30 kilowatt (kW) outboard motors and operated at a speed of from 10 to 20 knots] had maximum source levels (one-third octave band) at 160 dB re: 1 µPa @ 1 m with peak energy at 5 kHz (Kipple and Gabriele 2003). On average, noise levels were found to be higher for the larger vessels, and increased vessel speeds resulted in higher noise levels (Hildebrand 2009).

4.5.9 Hazards and Water Safety

A total of 304,658 recreational vessels were registered in NC during 2013 and include 9,264 registered vessels in Brunswick County (NCWRC 2013). Recreational vessel operations in state and federal territorial waters are subject to concurrent federal/state safety regulations promulgated under Title 46 of the US Code and the North Carolina Boating Safety Act. NC has entered into a cooperative agreement with the USCG whereby the state (acting through the NCWRC) has assumed the major role in carrying out and enforcing federal and state recreational boating safety laws and regulations. NCWRC responsibilities include boater education, assistance, law enforcement, accident investigations and other related safety initiatives. The NCWRC Division of Enforcement is the primary agency responsible for enforcing federal and state recreational boating safety regulations on concurrent jurisdictional waters. The Division of Enforcement exercises jurisdiction over recreational vessels in state territorial waters and federal waters when navigated as part of a trip to or from the shores of NC. The USCG has exclusive responsibility for the enforcement of vessel inspection and related federal statutes applicable to non-recreational vessels.

An average of 160 recreational boating accidents and 21 fatalities were reported in NC each year between 2006 and 2013 (NCWRC 2013). Annual boating accidents declined steadily from a high of 217 during 2006 to a low of 143 during 2013. During 2013, a total of ten recreational boating accidents and one fatality were recorded in Brunswick County. The vast majority of accidents throughout NC occurred between April and October with a peak during June, July, and August. Collisions with vessels have been the number one type of non-fatal boating accident in NC since 1990. The top causes of non-fatal accidents were operator inattention, fault of machinery/equipment/hull, careless and reckless operation, operator inexperience and hazardous/congested waters. The largest number of fatalities resulted from persons falling or jumping overboard. Most boaters of the fatal and non-fatal accidents had no formal boating safety education. The state recently enacted mandatory boater safety education for persons under the age of 26. As a result, the number of persons participating in state boating safety courses increased from 3,706 in 2006 to 16,877 in 2013 (NCWRC 2013).

5.0 ENVIRONMENTAL CONSEQUENCES

5.1 Impact Analysis Methodology

This section evaluates the potential environmental consequences (hereinafter referred to synonymously as effects and impacts) of the six alternatives according to the CEQ regulations for implementing the NEPA (40 CFR 1500 *et. seq.*). The analysis of each alternative considers the direct, indirect, and cumulative effects on environmental resources. As defined by CEQ regulations, direct impacts are those occurring at the same time and place as the proposed action while indirect impacts are those occurring later in time or at a greater distance from the proposed action. Cumulative impacts are those caused by the effects of the proposed action when added to other separate past, present, and reasonably foreseeable future actions regardless of the agency or person that undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. The projected direct, indirect, and cumulative impacts of the five action alternatives (Alternatives 2, 3, 4, 5, and 6) are evaluated against the projected impacts of the No-Action alternative (Alternative 1) (Table 5.1). The No-Action alternative, as defined in this EIS, represents the continuation of East End Beneficial Use Projects and, thus, would include beach nourishment and associated dredging activities similar to those that are currently being implemented by the Town and the USACE.

Table 5.1. Project alternatives.

Alternative #1	No Action (Status Quo)
Alternative #2	Abandon and Retreat
Alternative #3	Beach Nourishment
Alternative #4	Inlet Management and Beach Nourishment
Alternative #5	Short Terminal Groin and Beach Nourishment
Alternative #6	Intermediate Terminal Groin and Beach Nourishment

5.1.1 Direct and Indirect Impact Analysis

Direct impacts are defined in this EIS as those occurring during the active processes of beach fill placement, dredging, and/or groin construction and within the active project areas associated with these activities. In contrast, indirect impacts are those that are expected to occur after the completion of project activities and/or at a location away from the active project areas. Direct and indirect impacts were projected through quantitative and qualitative methods of analysis. Quantitative methods consisting of a geographic information system (GIS) and numerical modeling analyses were used primarily to determine direct and indirect impacts on the physical environment. Direct impacts on physical habitats were quantified through GIS analysis by superimposing the beach fill, dredging, and groin footprints of disturbance on the baseline (existing condition) map of habitats. Indirect impacts on physical coastal processes, shorelines, and habitats were quantified via numerical modeling analyses. Direct and indirect impacts on biological resources and public interest factors, which in most cases do not lend themselves to numerical measurements, were primarily assessed qualitatively by reviewing scientific literature, communicating with state and federal natural resource agencies via phone calls and email correspondence, and considering the quantitative physical impact projections.

Numerical Modeling

The Coastal Modeling System (CMS) developed by the USACE Coastal Inlets Research Program (CIRP) was used to project the long-term effects of the alternatives on coastal processes and morphology within the Permit Area. The CMS non-equilibrium advection-diffusion model component was used to simulate sediment transport. The CMS model simulates flow, sediment transport, morphological changes in response to local forcing conditions (e.g., waves, wind, and tides), and physical environmental modifications associated with beach nourishment, dredging, and other coastal engineering projects. Project engineers consulted with the USACE Engineer Research and Development Center (ERDC) during the model development process. ERDC ran a Holden Beach model application and conducted a review of coefficients, grid sizing, and other model elements to ensure accuracy and efficiency. The model simulations constitute the primary basis for evaluating the relative effects of the alternatives on coastal processes, shorelines, and physical habitats. The model-projected shoreline changes under Alternative 2 (Abandon and Retreat) were used as the standard of comparison or “control” for purposes of evaluating the model-projected changes under the remaining five alternatives. Whereas the modeling results for Alternatives 1, 3, 4, 5, and 6 reflect the influence of various shoreline management activities (i.e., beach filling, dredging/inlet management, groin construction); the modeling results for Alternative 2 represent the projected shoreline response to forcing conditions alone (e.g., waves, tides, ocean currents, storms). By comparing the projected morphological changes under the shoreline management alternatives to those of Alternative 2; the effects of beach filling, dredging, and groin construction can be distinguished from the effects of natural coastal processes. Accordingly, the impact analysis sections refer to the model-projected changes under Alternatives 1, 3, 4, 5, and 6 as “changes relative to Alternative 2” or simply as “relative changes.” It should be noted that the modeling results for Alternatives 1 (No Action) and 3 (nourishment only) reflect identical beach nourishment regimes. Although Alternative 3 incorporates additional supplemental borrow sites; the beach fill footprint, placement volumes, and nourishment interval would be the same as those associated with Alternative 1. Consequently, the model-projected shoreline changes under the two alternatives are also the same.

Model-projected changes in bathymetric contours (isobaths) and sediment volumes were used to quantify shoreline and habitat changes under the alternatives. For modeling purposes, the shoreline was defined as the area landward of the 0-m (NAVD) isobath which approximates Mean Sea Level (MSL). The relative effects of the alternatives on shoreline width were quantified by comparing projected changes in the 0-m isobath. Physical habitat changes were quantified by superimposing model-projected MHW/MLW isobaths on the baseline habitat map. Compartmentalized sediment volume projections were used to quantify shoreline change and beach fill performance in terms of volumetric sand losses and gains.

The overall CMS modeling effort involved an extensive suite of model simulations representing a wide range of timeframes, physical conditions, and actions within the Permit Area. Modeling runs of six months, one year, two years, and four years were conducted to assess short- to long-term morphological responses. Modeling simulations were also conducted under a wide range of local forcing conditions representing various physical data sets ranging from 2000 to 2012. In addition to the analysis of alternatives, specific modeling runs were used to assess the response of the system to separate actions such as federal navigation dredging. For impact analysis purposes, this EIS focuses on a specific suite of four-year modeling runs that are based on local physical data sets from 2008 to 2011. The results of four-year modeling runs represent the projected morphological responses of the Permit Area to the alternatives under local forcing conditions that are representative of those measured during 2008 to 2011. The four-year modeling runs begin immediately after construction (Year 0), and continue through post-construction Years 1, 2, 3, and 4.

The selection of the 2008 to 2011 period was based on a number of factors; including the condition of the starting 2008 shoreline, erosional conditions over the course of the four-year period, and the length of the period relative to proposed nourishment cycles under the various alternatives. The starting 2008 shoreline is in a highly eroded condition with no fill material from previous nourishment projects remaining on the beach. The purpose of selecting an eroded shoreline as the starting point is to exclude the potential masking effects of previous beach fill projects and establish starting conditions that are representative of those anticipated at the beginning of nourishment cycles under the various alternatives. The 2008 to 2011 period encompasses the erosional effects of Hurricanes Hanna (2008) and Irene (2011), and thus is representative of relatively severe erosional conditions and relatively high shoreline erosion rates in comparison with long-term averages. Therefore, the modeling results are conservative in terms of projecting the mitigating effects of the alternatives on shoreline erosion. Conversely, adverse shoreline effects that are accelerated under highly erosional conditions are less likely to be underestimated.

Given the dynamic nature of coastal systems and the unpredictability of factors such as the frequency and intensity of major storms, the modeling results should not be interpreted as a precise prediction of future conditions within the Permit Area. The principal objective of the modeling analyses was to determine how each of the alternatives will affect coastal processes and general patterns of morphological change in relation to natural background coastal processes. While the model incorporates rigorous and complex data sets to accurately simulate background processes and pulse events that are the principal drivers of sediment transport and morphological change, the model excludes some variables that may have localized effects within the system. Consequently, the modeling results show some localized atypical responses such as excessive shoaling in some portions of the AIWW channel. The exclusion of some minor variables that can potentially mask project-related effects is a standard engineering practice that is employed to more accurately assess the effects of a project on major processes that drive long-term system-wide change.

5.1.2 Cumulative Impact Analysis

Pursuant to CEQ regulations (40 CFR 1500 et. seq.), the analysis of cumulative effects considers the impacts of each alternative in combination with the impacts of separate past, present, and reasonably foreseeable future federal and non-federal beach and inlet management actions. The analysis focuses on separate actions that are similar to the proposed action; including beach nourishment, the construction of groins and jetties, navigation dredging, and ocean borrow site dredging activities. The timeframe of the analysis encompasses a 50-year period from 1996 through 2046. This timeframe encompasses all of the past locally-funded non-federal nourishment activities on Holden Beach, the trend of rapidly increasing beach nourishment activity along the southern NC coast that has been ongoing since the mid-1990s, and the future 30-year project life of the proposed action. The analysis considers the potential for cumulative effects on a local scale in the project area vicinity and on a regional scale along the entire southern NC coast between Cape Lookout and the NC/SC border. Cape Lookout divides the NC coast into distinct northern and southern regions that are markedly dissimilar in terms of both geological framework and beach management activity. The northern coast is characterized by long barriers with few inlets and broad open-water back-barrier estuaries, while the inlet-dominated southern coast is characterized by short barriers with numerous inlets and narrow, primarily marsh-filled back-barrier estuaries. The northern coast beaches are largely undeveloped and unmanaged, while the majority of the southern coast barriers are developed with active beach management projects.

The analysis of cumulative effects focuses on the potential for impact “crowding” on temporal and spatial scales. Temporally crowded cumulative effects can occur when the time required for resources to recover from a single impact event is greater than the time between repeated impact events. Temporally crowded effects are generally associated with frequent repeated impacts on a specific resource in the same area; for example, repeated dredging impacts may occur at a specific borrow site where the interval between dredging events is shorter than the time required for the benthic community to recover. The potential for temporally crowded effects on resources in the same area is primarily analyzed on a local scale in the immediate vicinity of the project area. Spatially crowded cumulative effects can occur when the proximity and timing of separate spatially discrete actions is such that their impacts overlap. Overlap does not necessarily mean that the physical impacts of the separate actions are contiguous; for instance, beach fill projects on separate barrier islands might affect foraging habitats that are used by the same population of shorebirds. The potential for spatially crowded effects is analyzed on both local and regional scales. The cumulative effect analyses incorporate the model-projected direct and indirect effects of the alternatives; however, potential separate actions were not included in the modeling simulations. Thus, the analyses of how separate actions may combine with the alternatives to produce cumulative effects are analytical or empirical in nature. A summary of separate actions considered on both local and regional scales is provided below.

<u>Separate Actions in the Project Area Vicinity</u>

The analysis of cumulative effects in the project area vicinity considers separate actions along Holden Beach and Oak Island; including activities associated with the Brunswick County Beaches (BCB) Coastal Storm Damage Reduction Project (BCB Project), the Holden Beach Central Reach Project, the Lockwoods Folly River Habitat Restoration Project Phase I (Eastern Channel), and AIWW and inlet navigation projects. The BCB Project encompasses nourishment projects along central Holden Beach (4.5 miles), central Oak Island (3.8 miles) and Caswell Beach on eastern Oak Island (2.9 miles) (Table 5.2). Initial construction of these three BCB segments was preliminarily planned to occur over four consecutive winter seasons beginning in 2020 with subsequent renourishment events following at intervals of approximately five, six, and eight years (Table 5.2). Based on this preliminary BCB sequence, East End Holden Beach nourishment events under the various alternatives could potentially coincide with two of the initial BCB events and one to two renourishment events per cycle. Note that as of March 2015, the BCB project status has been delayed indefinitely and therefore has not been included in the modeling analysis. In February 2015, the USACE issued the following brief regarding the status of the BCB project:

"*Corps' headquarters has determined that (1) no additional Federal expenditures are authorized for substantive GRR completion and (2) 100% non-Federal funds are to be used to complete the study pending execution of an agreement that also includes a non-Federal upfront repayment plan for the sponsors' proportionate share of sunk Federal costs which have been fully Federally funded to date. The Corps is working with the sponsors on a path forward on this project. In the meantime, no direct actions are currently being undertaken on the GRR."*

While the cumulative impact analyses in this DEIS account for the BCB project, initial project construction will not occur in 2020 as indicated in the BCB preliminary DEIS. Furthermore, the current impediments to the BCB project are likely to preclude implementation at any future date (Personal communication, David Hewett, Town of Holden Beach, February 2015).

The maximum combined linear extent of oceanfront beach impact during any given year would be 5.2 miles in the event of simultaneous nourishment of the 0.7-mile East End beach and the longest ~4.5-mile BCB segment (central Holden Beach). The Town's recently completed (2017) Central Reach Project placed ~1.31 million cy of material from an offshore borrow area along 4.1 miles of shoreline (Table 5.2).

Table 5.2. Holden Beach and Oak Island shore protection projects.

Length/Volume/ Interval	East End Holden Beach	Brunswick County Beaches Coastal Storm Damage Reduction			Holden Beach Central Reach	Lockwoods Folly River Habitat Restoration West End Oak Island
		Holden Beach	Oak Island[1]	Oak Island Caswell Beach		
Segment Length (mile)	0.7	4.5	3.8	2.9	4.1	0.83
Initial Construction Volume (mcy)[2]	0.1	4.5	3.0	2.0	1.3	0.23
Renourishment Volume (mcy)[2]	0.1	1.7	1.8	1.8	>5.0	0.18
Renourishment Interval (yrs)	2	5	6	8	7-10	N/A

[1] West end of Oak Island
[2] Volume is shown as million cubic yards (mcy)

In addition to dredging by the Town at the Central Reach offshore borrow site, other anticipated offshore dredging actions include federal dredging operations at Frying Pan Shoals in conjunction with BCB nourishment projects and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan. Anticipated separate federal navigation projects include maintenance dredging of the AIWW navigation channel behind Holden Beach and Oak Island, the LFI ebb channel, the Shallotte Inlet ebb channel and the Wilmington Harbor entrance channel. Phase 1 of the Lockwoods Folly River Habitat Restoration Project (Eastern Channel) included the dredging of a new channel within Eastern Channel and placement of compatible dredged material on the beach at the west end of Oak Island (Table 5.2). This navigation channel/nourishment project was completed during the spring of 2015 by the Town of Oak Island.

<u>Separate Actions in the Southern NC Coastal Region</u>

Beach Nourishment

Historically, most sand placement in NC has been undertaken through federally funded USACE civil works projects. The majority of the federal projects have consisted of either specifically authorized CSDR projects or discretional CAP projects involving beach placement of dredged material from federal navigation channels. Non-federal projects have historically accounted for only a small percentage of NC projects, but have been steadily increasing over the last two decades as the need for sand placement has increased. The four hurricanes that struck NC between 1996 and 1999 [Bertha (1996), Fran (1996), Bonnie (1998), and Floyd (1999)] initiated a trend of rapidly increasing federal and non-federal sand placement projects along the southern NC coast that has continued to date. The Wilmington District constructed two new

CSDR projects (Kure Beach in 1999 and Ocean Isle Beach in 2001) and Congress authorized the construction of two additional CSDR projects encompassing Surf City/North Topsail Beach and Topsail Beach. The Wilmington District has initiated studies encompassing most of the remaining developed beaches along the southern NC coast; including federal studies of proposed CSDR projects encompassing the Brunswick County Beaches and Bogue Banks. The increasing need for projects combined with a trend of declining federal funding has initiated a consistent trend of increasing non-federal projects along the southern NC coast over the last 20 years. As a result of increasing federal and non-federal projects, average annual sand placement between 1996 and 2015 along the southern coast increased over three-fold to ~8.5 miles (relative to a previous 20-year annual average of ~2.5 miles). The busiest single year occurred in 2001 when placements totaling ~24 miles of shoreline occurred in the southern region; including beach disposal of navigation dredged material along Bald Head Island, Oak Island, and Holden Beach in conjunction with the Wilmington Harbor deepening project.

Active projects and studies currently encompass approximately 85 miles (55%) of the total 154 miles of beaches along the southern NC coast. Current sand placement trends suggest that the extent of managed shoreline will continue increasing until essentially all 97 miles of developed shoreline along the southern NC coast are covered under an active management initiative. Given that management is unlikely to expand to undeveloped shorelines, the total of 97 miles represents the probable upper limit of sand placement along the southern NC coast. Historical sand placement data indicate an average nourishment interval of ~4.5 years for all current projects. Assuming that an average 4.5-year nourishment interval is maintained through additional future projects, annual sand placement upon reaching the projected 97-mile maximum would average 22 miles per year along the southern NC coast. It is assumed for purposes of impact analysis that sand placement will reach the annual average of 22 miles per year within the next 30 years.

Jetties and Groins

Existing jetties and groins along the southern NC coast are limited to just a few structures; including a 4,800-ft groin/breakwater along the western flank shoreline of Cape Lookout at Barden Inlet, a 1,250-ft terminal groin on the east end of Bogue Banks at Beaufort Inlet, a pair of ~3500-ft jetties at Masonboro Inlet, and a recently constructed terminal groin on Bald Head Island at Cape Fear Inlet. The NC terminal groin law allows for six terminal groins, of which only one (Bald Head Island) has been constructed to date. Currently, three additional terminal groin projects are being actively pursued; including the proposed action terminal groin on Holden Beach, a terminal groin on Figure 8 Island at Rich Inlet, and a terminal groin on Ocean Isle Beach at Shallotte Inlet. Although not currently associated with a site-specific project, the two additional groins that are allowed under NC law would most likely be constructed along the southern NC coast where there are numerous inlet-driven erosional hotspots along the terminal ends of the developed barrier islands. It is assumed for purposes of impact analysis that all six terminal groins will be constructed within the next 30 years.

Dredging

Of the 15 inlets that divide the southern NC barrier islands, nine have both inlet and AIWW inlet-crossing channels that are currently maintained under federal navigation projects. The federal inlet navigation projects include two deep draft navigation projects (Beaufort and Cape Fear Inlets) and seven shallow draft inlet projects (Shallotte, Lockwoods Folly, Carolina Beach, Masonboro, New River, New Topsail, and Bogue). The shallow draft channels and some portions of the deep draft channels are generally dredged at least once a year. It is assumed for purposes of impact analysis that these projects will continue over the next 30 years. While the vast majority of the sand that has been placed on NC beaches has been derived from navigation dredging, offshore ocean borrow sites have been used as a sand source at scattered locations along the southern coast. The inner shelf along the southern NC coast is characterized by a thin veneer of modern (Holocene) sand overlying older hard strata. Consequently, compatible sand deposits of sufficient quantity for nourishment projects are extremely limited on the inner shelf. Offshore borrow sites have historically encompassed a very small fraction of the nearshore unconsolidated soft bottom seafloor area along the southern NC coast. Although the use of offshore borrow sites is expected to increase over the next 30 years, it is expected that the combined area of seafloor encompassed by these projects will continue to be very small in relation to the regional extent of the resource.

5.2 Model-Projected Effects of the Alternatives on Shoreline Change

This section describes in detail the model-projected quantitative effects of the alternatives on oceanfront and inlet shorelines within the Permit Area. The model-projected shoreline changes serve as the basis for many of the analyses in the subsequent alternative-specific impact sections. The CMS model was set to simulate sediment transport and morphological change in response to local forcing conditions (e.g., waves, wind, and tides) and the physical environmental modifications associated with the alternatives. The projected effects of the alternatives on shoreline change are based on model-projected changes in bathymetry and topography. For modeling purposes, the shoreline was defined as the MSL (0-m NAVD88) bathymetric contour and beach width was defined as the cross-shore distance between the MSL contour and the toe of the primary dune. Projected losses and gains of intertidal beach and supratidal (dry) beach and dune habitats are based on model-projected changes in the MHW and MLW contours. As previously described, the projected shoreline changes under Alternative 2 are used as a standard of comparison for identifying projected changes under Alternatives 1, 3, 4, 5, and 6. Under Alternative 2, the model-simulated shoreline changes represent the projected shoreline response to forcing conditions alone without any influence from beach management activities. The projected relative changes under Alternatives 1, 3, 4, 5, and 6 represent the difference between their projected changes and the projected changes under Alternative 2. For reference, the six alternatives are outlined in Table 5.1 above.

Holden Beach East End Oceanfront Shoreline

Under Alternative 2, the simulated East End ocean shoreline (i.e., MSL contour) is recessive throughout the four-year modeling period; by the end of Year 4, the average width of the East End beach has been reduced by ~80 ft (Figure 5.1). The projected extent of shoreline recession is consistent with the chronically high erosion rates that have been observed along the East End beach over the past several decades. The simulated MHW line follows a similar recessional pattern, migrating landward of the primary dune between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) by the end of Year 4 (Figure 5.2). The projected change in the MHW line corresponds to a net loss of ~5 ac of supratidal (dry beach/dune) habitat at the end of Year 4 (Table 5.3). The majority of the MLW line (west of Station 30+00) is similarly recessive; however, as a result of shoal attachment along the inlet shoulder, the MLW line to the east of Station 30+00 grows seaward (Figure 5.3). Shoal attachment adds ~3 ac of intertidal beach habitat along the easternmost reach; however, the loss of ~10 ac along the western reach results in a projected net loss of ~7 ac at the end of Year 4 (Table 5.3).

Under Alternatives 1, 3, 4, 5, and 6; the starting (Year 0) shoreline positions correspond to the seaward-extended shoreline positions immediately following beach nourishment (Figures 5.4 - 5.7). Alternatives 1, 3, 4, and 5 have the same beach fill footprint dimensions; and consequently, these alternatives have identical starting Year 0 average beach widths that are 85 ft wider than the starting Year 0 average width under Alternative 2 (Figure 5.8, Table 5.4). Alternative 6 uses a slightly longer and wider beach fill footprint, which results in a slightly higher starting Year 0 average beach width that is 93 ft wider than the starting Year 0 average width under Alternative 2 (Figure 5.8, Table 5.4). During Year 1, all five with-project alternatives are effective at maintaining the initial post-nourishment relative increases in average beach width. At the end of Year 1, projected relative average beach widths under Alternatives 1, 3, 4, and 5 are minimally reduced to ~78 ft, ~78 ft, ~79 ft, and ~84 ft, respectively; whereas relative average beach width under Alternative 6 increases to ~98 ft. During Year 2, shoreline erosion accelerates rapidly under Alternatives 1, 3, 4, and 5; resulting in substantial reductions in relative average beach width. Under Alternatives 1 and 3, accelerating erosion reduces relative average beach width to ~57 ft at the end of Year 2. Alternatives 4 and 5 are similarly ineffective at maintaining a wider beach, with projected Year 2 ending relative beach widths of ~66 ft and ~64 ft, respectively. In contrast, relatively minor shoreline erosion under Alternative 6 reduces relative average beach width to ~93 ft, thus suggesting no net reduction average beach width through the end of Year 2. Shoreline erosion under Alternatives 1 and 3 continues to accelerate rapidly over the remaining two years of the model simulation, resulting in reduced relative average beach widths of ~19 ft at the end of Year 4. Alternatives 4 and 5 are similarly ineffective at maintaining a wider beach over the remaining two years, with projected Year 4 ending relative average beach widths of ~35 ft and ~36 ft, respectively. Under Alternative 6, shoreline erosion accelerates over the remaining two years of the model simulation, resulting in a reduced relative average beach width of ~63 ft at the end of Year 4.

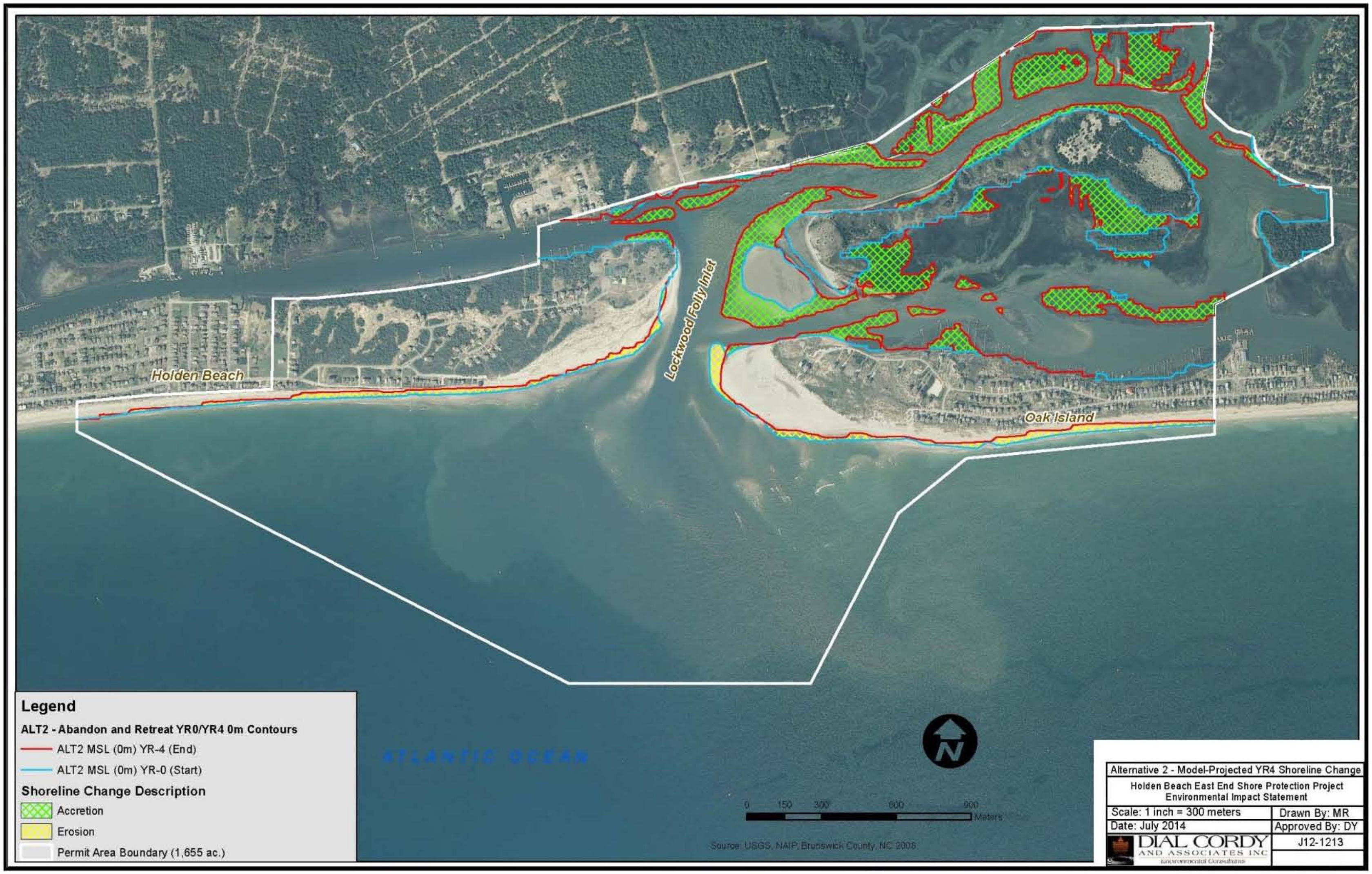


Figure 5.1. Alternative 2 – Model-Projected YR4 Shoreline Change

Figure 5.2. Holden Beach – Model-Projected YR4 MHW Lines for all Alternatives

Table 5.3. **Year 4 model-projected net habitat change (acres).**

Habitat	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6
Holden Beach Ocean Dry Beach/Dune	-3.1	-5.0	-3.1	-3.4	-1.7	-0.7
Holden Beach Ocean Intertidal Beach	-2.7	-6.9	-2.7	-8.8	-2.1	-3.1
Oak Island Ocean Dry Beach/Dune	-2.5	-2.5	-2.5	-2.5	-2.4	-2.4
Oak Island Ocean Intertidal Beach	-9.6	-9.6	-9.6	-10.4	-8.6	-8.9
Holden Beach Inlet Dry Beach/Dune	-0.5	-0.8	-0.5	-1.8	-0.8	-0.1
Holden Beach Inlet Intertidal Beach	-1.8	-1.6	-1.8	-4.4	0.4	-2.1
Oak Island Inlet Dry Beach/Dune	-0.8	-1.0	-0.8	-1.0	-1.0	-0.9
Oak Island Inlet Intertidal Beach	-6.8	-7.3	-6.8	-6.8	-6.4	-6.9
Inlet Flood Shoal Supratidal	12.4	12.5	12.4	7.3	11.4	11.5
Inlet Flood Shoal Intertidal	0.2	1.5	0.2	7.7	2.6	3.3

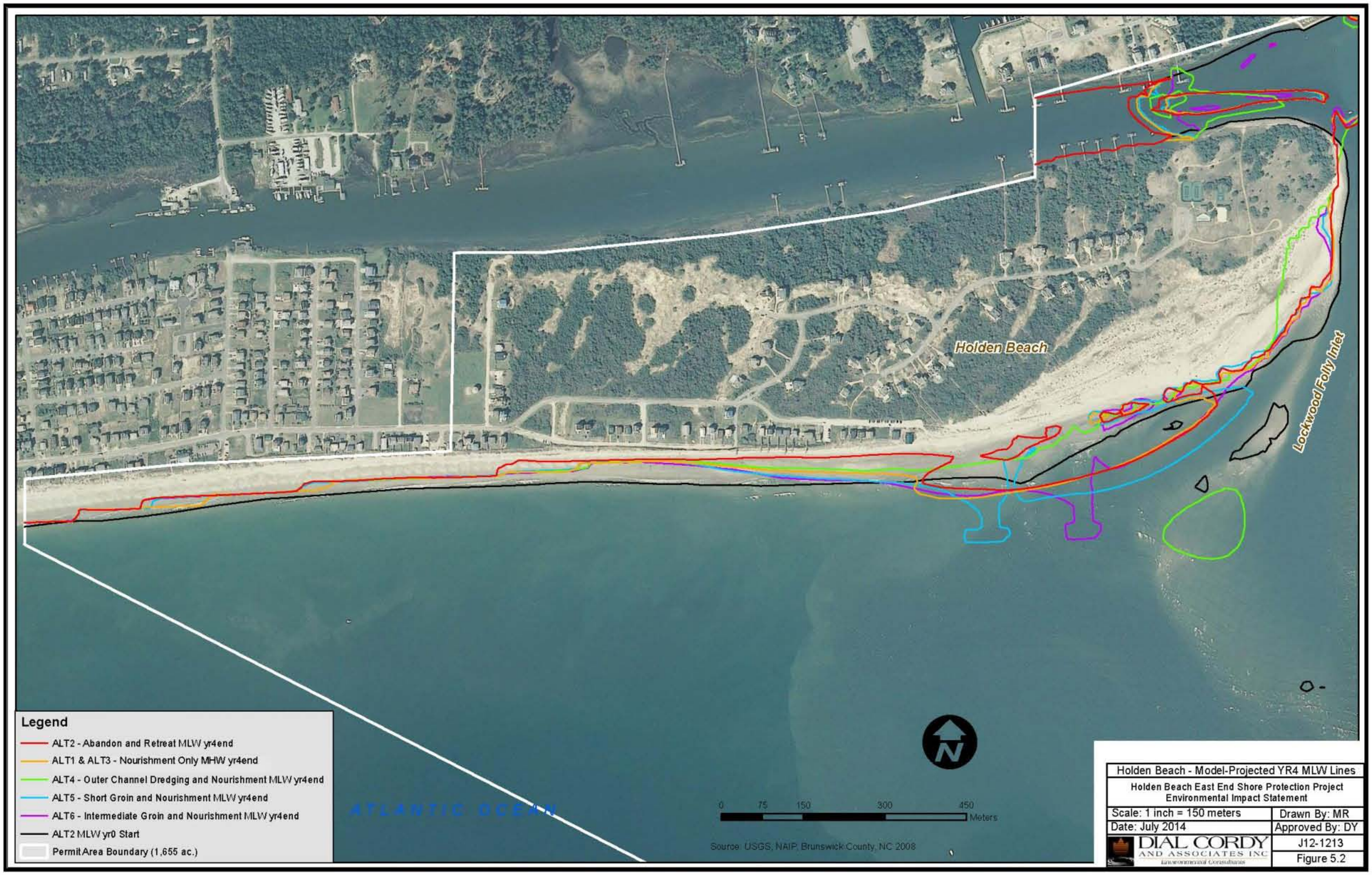


Figure 5.3. Holden Beach – Model-Projected YR4 MLW Lines for all Alternatives

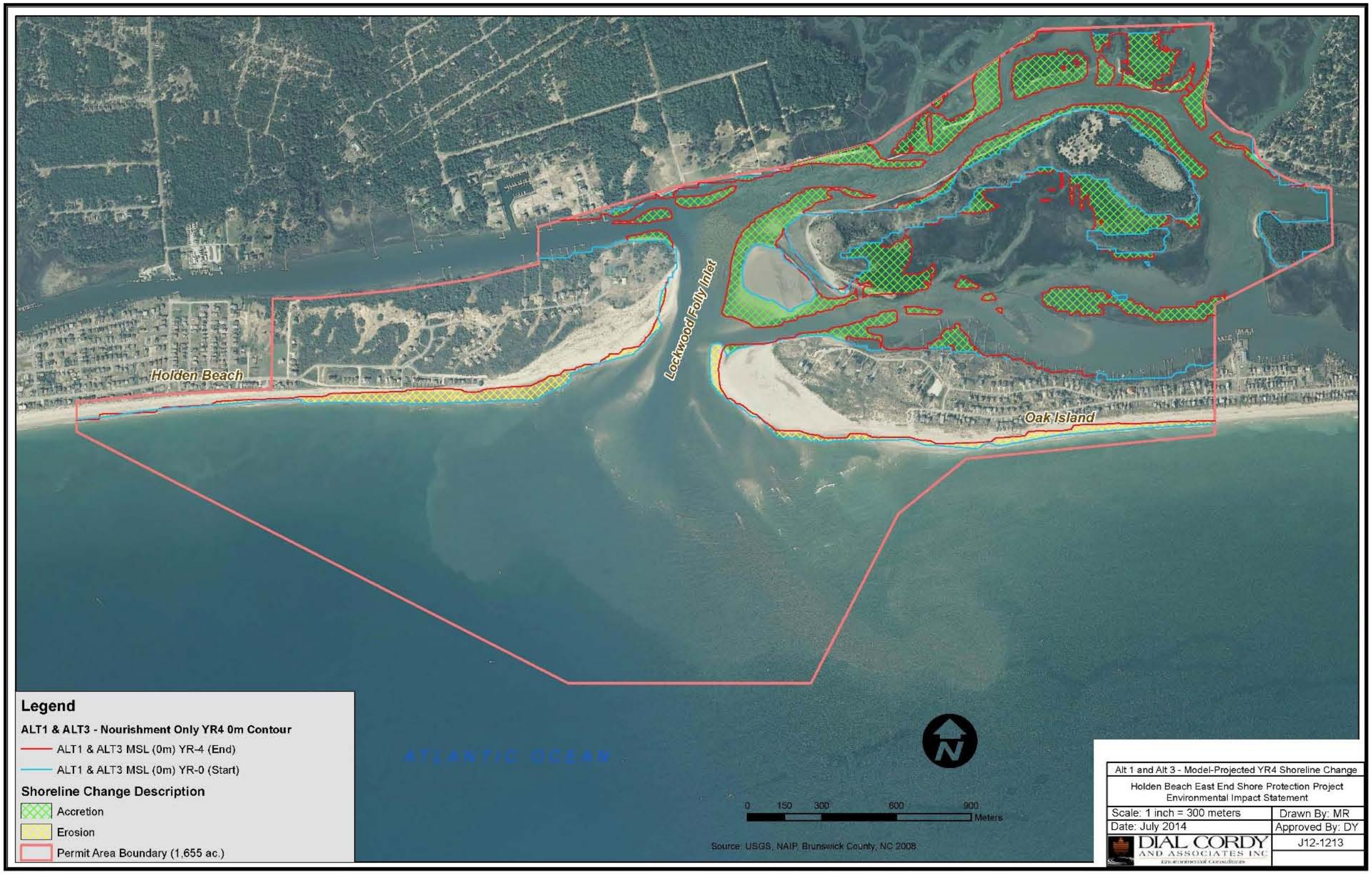


Figure 5.4. Alternative 1 and 3 – Model-Projected YR4 Shoreline Change

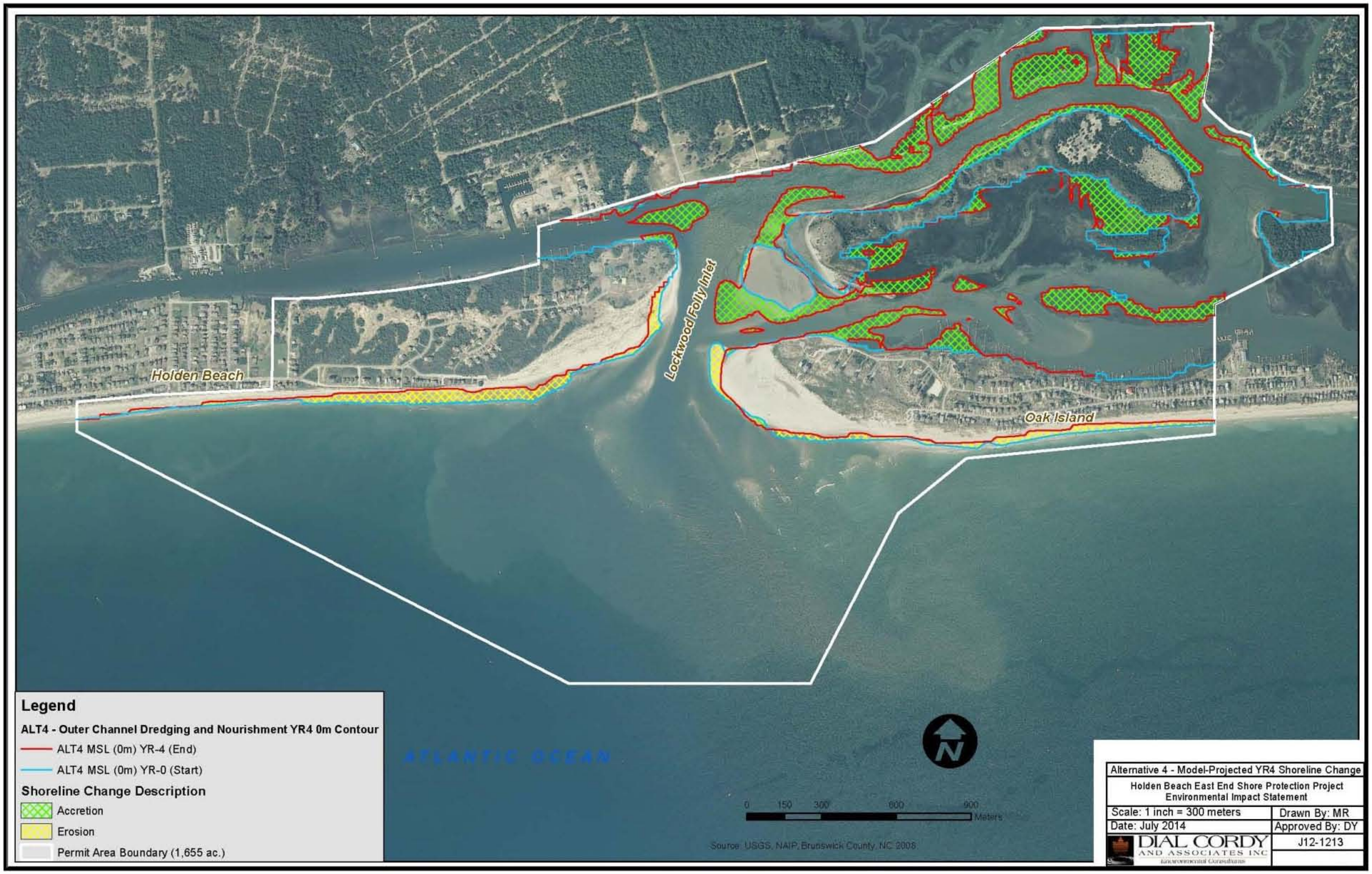


Figure 5.5. Alternative 4 – Model-Projected YR4 Shoreline Change

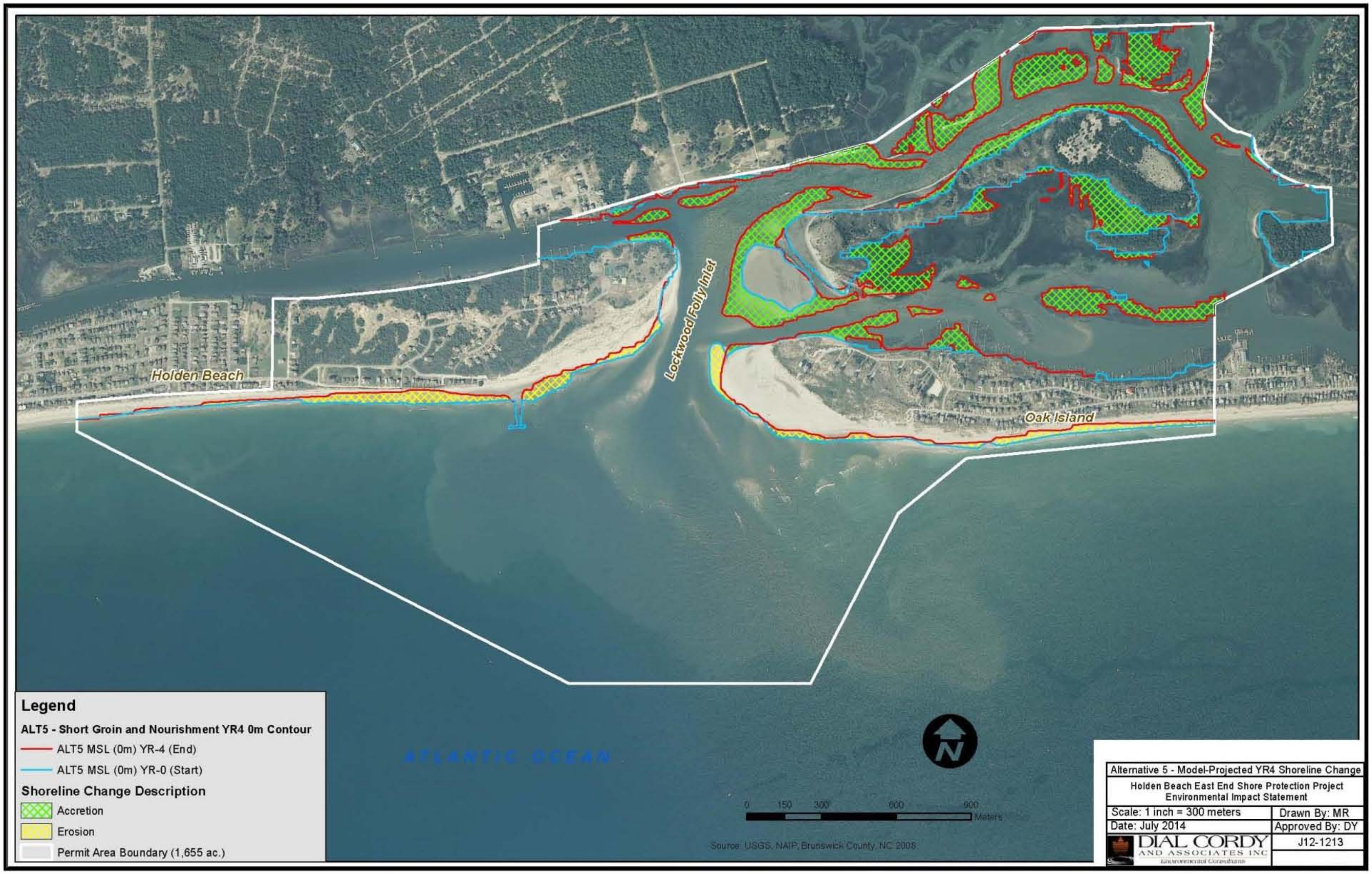


Figure 5.6. Alternative 5 – Model-Projected YR4 Shoreline Change

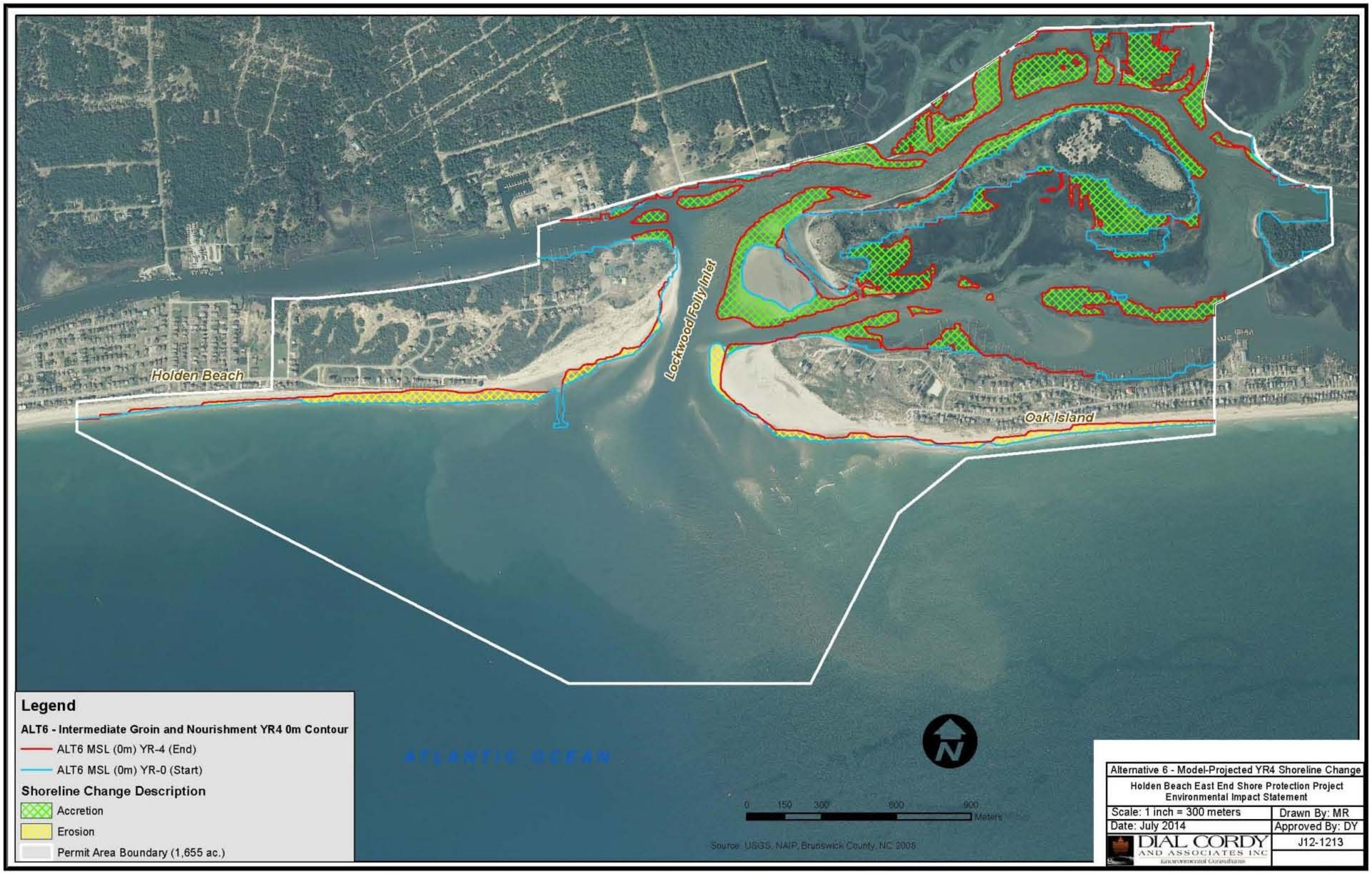


Figure 5.7. Alternative 6 – Model-Projected YR4 Shoreline Change

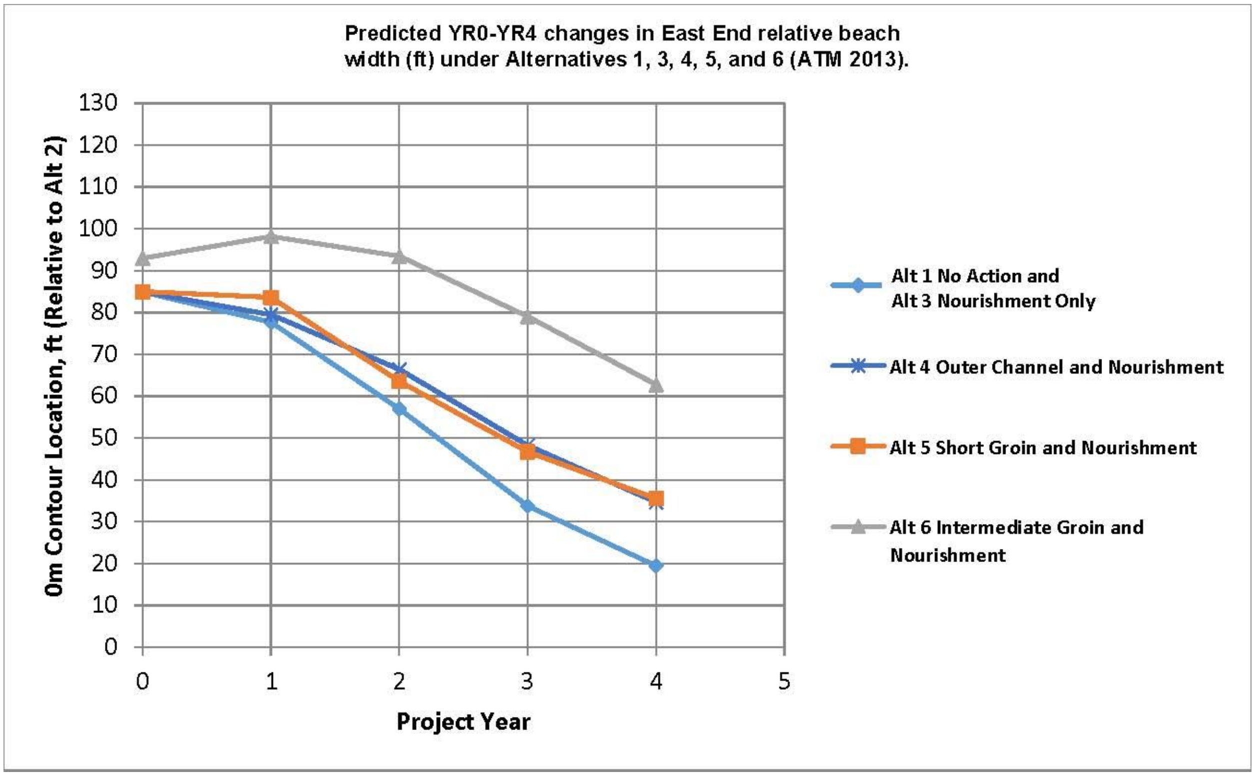


Figure 5.8. Alternatives 1, 3, 4, 5, and 6

Table 5.4. Model-projected East End relative beach widths (0 ft NAVD88).

Alternative	Year 0 (Start)	Year 1	Year 2	Year 3	Year 4
Alt 1: No Action	85	78	57	34	19
Alt 3: Nourishment Only	85	78	57	34	19
Alt 4: Nourishment and Inlet Management	85	79	66	48	35
Alt 5: Short Groin and Nourishment	85	84	64	47	36
Alt 6: Intermediate Groin and Nourishment	93	98	93	79	63

The simulated MHW line responses under Alternatives 3, 4, 5, and 6 generally mirror the respective MSL shoreline responses. Relative to Alternative 2, all four alternatives maintain a seaward extended MHW line throughout the four-year model simulations. As a result, dry beach and dune habitat losses under the five with-project alternatives are reduced by ~1 to ~4 ac in relation to Alternative 2 (Table 5.3). The projected MLW line responses under Alternatives 3, 5, and 6 are similar in pattern to the projected MLW response under Alternative 2; with shoal attachment resulting in seaward growth of the MLW line along the easternmost ~1,300-ft reach, and MLW recession occurring along the remainder of the East End shoreline to the west. Alternatives 1, 3, 5, and 6 all maintain seaward extended MLW lines in relation to Alternative 2, thereby reducing Year 4 intertidal beach habitat losses by ~4 to ~5 ac (Table 5.3). Under Alternative 4, the MLW line is similarly recessive along the western reach; however, hydrodynamic effects attributable to the relocated outer channel prevent shoal attachment along the easternmost reach, resulting in additional erosion and further recession of the MLW line. As a result, Alternative 4 increases intertidal beach habitat loss by ~2 ac in relation to Alternative 2.

As described above, all five with-project alternatives maintain a consistently wider East End beach throughout the four-year modeling simulations in relation to Alternative 2 (Table 5.4, Figure 5.8). General patterns of East End shoreline change are similar under the five with-project alternatives, with most of the erosional losses occurring along the easternmost ~2,000-ft reach where historical erosion rates have been the highest. Among the five with-project alternatives, differences between the projected relative beach widths primarily reflect different sand retaining/trapping efficiencies along the easternmost ~2,000-ft shoreline reach. Under Alternatives 1 and 3 (No Action/nourishment only), beach fill is rapidly eroded from the easternmost reach at a rate consistent with observed losses following previous beneficial use nourishment projects. Alternative 4 (outer channel relocation) maintains a substantially wider beach in relation to Alternatives 1 and 3, thus indicating that outer channel relocation would provide enhanced shore protection benefits relative to No Action or nourishment only. However, outer channel relocation has substantial negative effects on inlet hydrodynamics that increase erosion of the beach below the MSL shoreline contour. Alternative 5 maintains a relative increase in average beach width similar to that of Alternative 4; however, Alternative 5 is more effective at maintaining the MHW and MLW lines and capturing sediment below the MSL shoreline contour. Under Alternative 6, the projected relative average beach width at the end of Year 4 is nearly double that of Alternative 5. The difference between the projected beach widths under Alternatives 5 (short groin) and 6 (intermediate groin) primarily reflect different sand trapping efficiencies along the ~600-ft reach separating the two groin structures. Although the short groin is effective at retaining beach fill and trapping new sand along the adjoining western ~2,900-ft reach, it is considerably less effective at maintaining beach width along the adjoining eastern reach. Under Alternative 6, the intermediate groin has a longer effective sand trapping zone (~3,500 ft) that encompasses an additional ~600 ft of shoreline to the east of the short groin.

Lockwoods Folly Inlet

Under Alternative 2, the simulated responses of the flood shoal and the inlet shorelines of Holden Beach and Oak Island (Figure 5.1) are indicative of the absence of navigation dredging in the model simulations. The flood shoal has a natural propensity for westward accretional growth that is normally kept in check by maintenance dredging of the LFI/LFIX navigation channels. However, in the absence of federal channel dredging (due to potential loss of future federal funding), the flood shoal response is one of westward expansion. Westward accretion results in substantial new intertidal shoal habitat formation, while concurrent sediment deposition on the existing flood shoal results in substantial intertidal-to-supratidal shoal habitat conversion. The overall effect of these projected changes is a net increase in intertidal shoal habitat of ~2 ac and a net increase in supratidal shoal habitat of approximately ~13 ac at the end of Year 4 (Table 5.3). The westward-expanding flood shoal pushes the inlet throat ebb channel westward, accelerating erosion along the Holden Beach inlet shoreline. Flood shoal expansion also pushes the mouth of the Eastern Channel slightly southward, redirecting flow towards the western tip of Oak Island.

Concurrently, the southern segment of the inlet throat ebb channel adopts a straighter north-south alignment, resulting in an eastward channel shift towards the Oak Island inlet shoreline. The majority of the Holden Beach inlet shoreline is recessional throughout the model simulation period, resulting in a projected loss of ~5 ac of intertidal inlet beach habitat at the end of Year 4. However, shoal attachment along the inlet shoulder adds ~3 ac of intertidal beach habitat along the southernmost ~700-ft reach of the Holden Beach inlet shoreline, resulting in a projected net loss of ~2 ac (Table 5.3). The Oak Island inlet shoreline is recessional throughout the model simulation period, resulting in a projected loss of ~10 ac of intertidal inlet beach habitat at the end of Year 4. In the case of both the Holden Beach and Oak Island inlet shorelines, model-projected changes in the MHW lines and corresponding effects on dry inlet beach habitats are negligible under Alternative 2.

Projected flood shoal and inlet shoreline responses under Alternatives 1 and 3 (Figure 5.4) and Alternative 6 (Figure 5.7) are essentially the same as those projected under Alternative 2. Alternative 5 has a minor relative effect on the southernmost ~700-ft reach of the Holden Beach inlet shoreline that is related to the sand trapping effect of the short terminal groin. Under Alternative 5, the pattern of shoal attachment is shifted eastward (Figure 5.6), increasing accretion along the inlet shoreline and reducing the extent of projected intertidal inlet beach habitat loss by ~2 ac in relation to Alternative 2 (Table 5.3). In the case of Alternative 4 (Figure 5.5), the modeling projections indicate substantial relative effects on inlet hydrodynamics. The projected effects are related to the expanded depth and width of the relocated outer inlet channel which substantially increase the inlet tidal prism. As a result, the inlet throat ebb channel is highly unstable throughout the four-year simulation period. The principal ebb channel response is one of westward migration and associated increases in erosion along the inlet shoreline of Holden Beach. Westward migration of the ebb channel also affects shoal attachment along the inlet shoulder of Holden Beach. Similar to the other alternatives, the model projects the formation of an emergent shoal along the inlet shoulder; however, westward migration of the expanded outer channel prevents immediate shoal attachment, as outer channel infilling initially impedes shoreward shoal migration. The channel eventually fills in and the shoal resumes its natural shoreward migration pattern; however, the shoal has not yet attached at the end of the four-year modeling run. The projected inlet hydrodynamic changes also cause the LFIX ebb channel segment along the northwest corner of the flood shoal to widen, deepen, and dip southward; shifting the pattern of accretion along the flood shoal southward relative to Alternative 2. Westward channel migration under Alternative 4 also increases the extent of erosion along the remainder of the Holden Beach inlet shoreline to the north, further increasing intertidal habitat loss relative to Alternative 2. Overall, the quantity of intertidal inlet beach habitat on Holden Beach under Alternative 4 is reduced by ~3 ac relative to Alternative 2 (Table 5.3).

Oak Island West End Oceanfront Shoreline

Under Alternative 2 (abandon and retreat), the Oak Island west end oceanfront shoreline is recessional throughout the four-year model simulation (Figure 5.1). The MLW line follows a similar recessional pattern, resulting in the loss of ~10 ac of intertidal beach habitat at the end of Year 4 (Figure 5.9). The model results show a relatively minor and irregular landward shift in the MHW line which results in the loss of ~3 ac of dry beach habitat at the end of Year 4 (Figure 5.10, Table 5.3). Under Alternatives 1, 3, 4, 5, and 6, projected shoreline changes (Figures 5.4 – 5.7) and corresponding habitat effects (Table 5.3) are essentially the same as those projected under Alternative 2; thus indicating that the with-project alternatives would not have any significant project-related effects on the Oak Island west end ocean shoreline. Under Alternative 4, the model projects a slight increase in erosion along the extreme western reach of the shoreline which is related to the hydrodynamic effects of outer channel relocation. As a result, Alternative 4 increases intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). Minor reductions in erosion under Alternatives 5 and 6 slightly reduce intertidal beach habitat loss by ~1 ac in relation to Alternative 2.

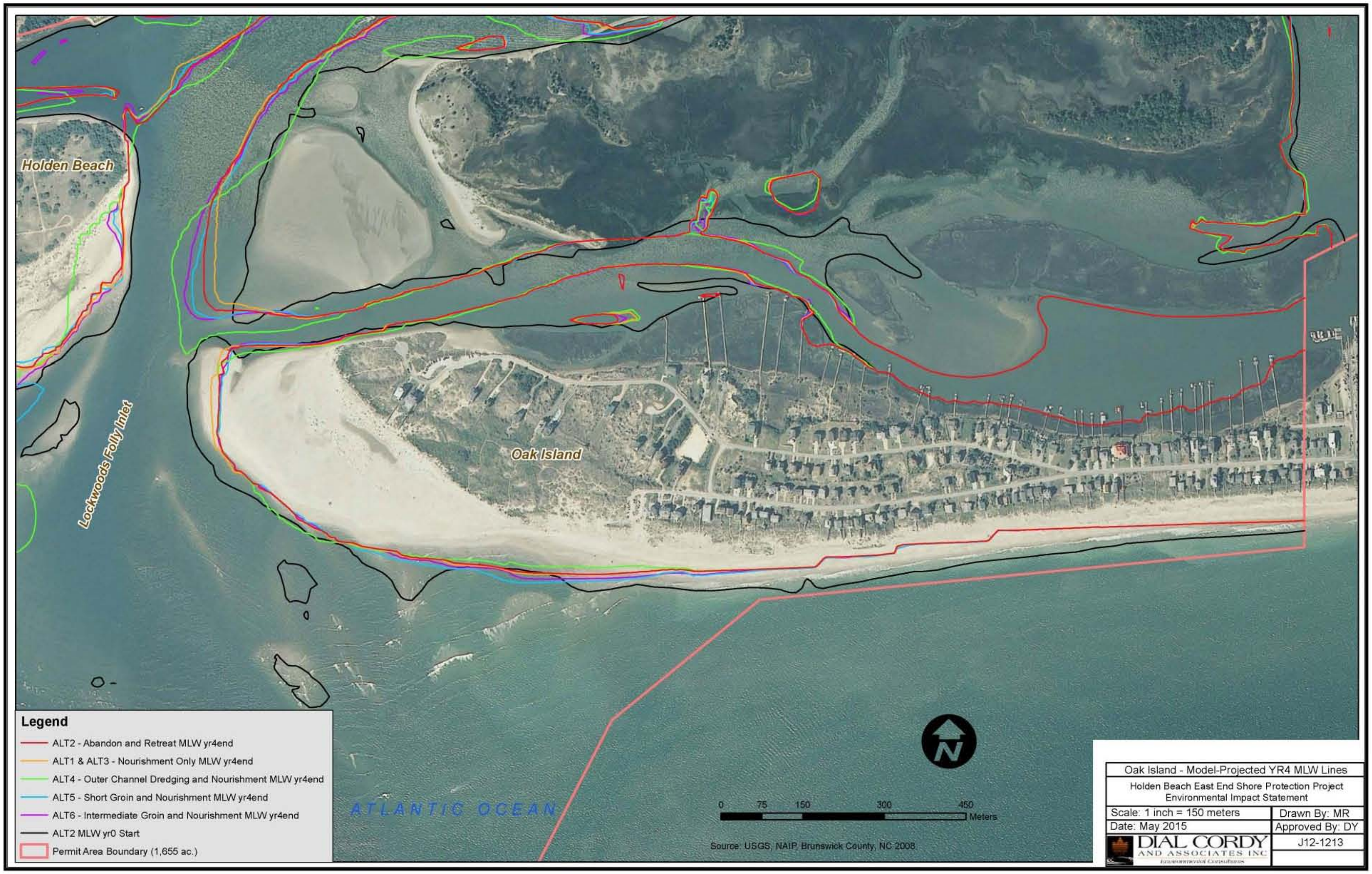


Figure 5.9. Oak Island – Model-Projected YR4 MLW Lines

Figure 5.10. Oak Island – Model-Projected YR4 MHW Lines for all Alternatives

5.3 Alternative Economic Comparison

In response to numerous public comments on the DEIS, this section provides a comparative summary of the economic factors associated with each of the alternatives (Table 5.5). The economic effects of each alternative are described in detail in the subsequent alternative-specific impact sections. Factors considered in the economic analyses include construction and maintenance costs (e.g., beach nourishment, borrow site dredging, groin construction), risk to properties and infrastructure, recreational and aesthetic values, and public non-use values associated with the natural environment. The term “non-use value” is applied to goods and services such as clean beaches and healthy habitats that are not explicitly traded in markets. Non-use values may include benefits not directly associated with use such as the benefits resulting from the knowledge that particular species or ecosystems exist (“existence values”), are available for potential future use (“option values”), or are available for future generations (“bequest values”). The erosional impacts of the alternatives on properties and infrastructure were projected based on model-projected shoreline changes described in the preceding section. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. The economic effects associated with the various alternatives are described and contrasted in the alternative-specific impact analysis sections that follow. Additional details regarding the analyses of alternative economic factors can be found in the economic analysis report in Appendix O.

Table 5.5. Comparison of alternative economic factors.

	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Costs (Relative to Status Quo)						
Construction and Maintenance[1]	$46.21 M	$0	$55.50 M	$55.50 M	$34.41 M	$34.41 M
Parcels at-risk[2]	19	28	19	19	11	16
Assessed tax value of at-risk parcels	$3.01 M	5.18 M	3.01 M	3.01 M	$994,480	$2.10 M
Structures at-risk[3]	14	19	10	10	0	3
Infrastructure replacement costs[1]	$190,699	$617,782	$190,699	$176,321	$0	$101,572
Reduction in tax base	High	Highest	Intermediate	Intermediate	Low	Low
Transition costs	High	Highest	Intermediate	Intermediate	Low	Low
Diminished recreation value	High	Highest	Intermediate	High	Intermediate	Lowest
Diminished aesthetic value	Intermediate	High	Intermediate	High	Intermediate	Intermediate
Public non-use[4] value losses (Nature)	Low	Low	Intermediate	High	High	High
Public non-use value losses (Holden Beach)	High	Highest	Intermediate	Intermediate	Low	Low
Benefits (Relative to Status Quo)						
Reduction in future nourishment expense	Intermediate	N/A	Intermediate	Low	High	High
Enhanced property value	None	None	Intermediate	Intermediate	High	High
Enhanced Recreation value	Low	Lowest	Intermediate	Intermediate	Intermediate	Highest
Public non-use value gains (Nature)	Intermediate	Highest	Intermediate	Low	Low	Low
Public non-use value gains (Holden Beach)	Low	None	Intermediate	Intermediate	High	High

[1] Based on a 4% annual increase in beach fill cost. Present value costs are provided in the alternative-specific impact analysis sections.
[2] Parcels are considered to be “at-risk” when the MHW line is within 25 ft of the seaward parcel boundary
[3] Structures within 25 ft of the MHW are considered to be “at-risk”
[4] Non-use values are goods and services such as clean beaches and healthy habitats that are not explicitly traded in markets.

5.4 Projected Environmental Impacts of the Alternatives

General environmental consequences are summarized for each alternative below. An alternatives matrix is provided to depict these general findings (refer to Appendix P). Note that more detailed information is provided in the following subsections for specific resource categories located within and adjacent to the identified project area. In addition, economic benefits and costs are evaluated in further detail in the below discussion.

5.4.1 Alternative 1: No Action

Under the No-Action alternative, the Town would continue to rely solely on the USACE's beneficial use projects for shore protection of the East End of Holden Beach. For impact analyses, the East End Beneficial Use Projects under Alternative 1 are assumed to continue at an average frequency of every two years. Beach fill placement volumes would vary according to channel shoaling rates and the availability of local funding for inclusion of the 400-ft bend widener. Based on past East End sand placement volumes, projects using only material from the main channel would presumably place ~100,000 cy of material on the East End whereas projects using sand from both the main channel and the bend widener would place ~150,000 cy of material. Based on past projects, it is assumed that the linear extent of placement would average ~0.5 mile. Dredging and beach fill placement methods would be similar to those associated with current operations. Sand would be extracted from the LFIX/bend widener channel by cutterhead pipeline dredges and pumped directly to the east end beach via submerged pipelines. Temporary containment berms would be constructed at the beach discharge points to allow for dewatering and suspended sediment redeposition, and bulldozers operating on the beach would distribute and grade the dewatered fill according to the beach profile design specifications. Front-end loaders would be used to transport and position emergent sections of the discharge pipeline on the beach. As nourishment activities progress, the emergent pipeline would be extended along the beach through the addition of extra sections of pipe.

5.4.1.1 Geology and Sediments

Under Alternative 1, dredging operations would consist of continuing federal maintenance dredging of the main LFIX navigation channel every two years. As described above, it is anticipated that some dredging events would also include the 400-ft-wide bend widener depending on the availability of funding from the Town. Assuming inclusion of the 400-ft-wide bend widener, individual dredging events would excavate ~20 ac of the subtidal inlet bottom. Excavation would not exceed the current authorized depth of the federal channel, and it is expected that a vertical buffer of compatible sand would be retained. Thus, dredging would not be expected to directly alter sediment composition within the channel. The LFIX and bend-widener channels are subject to rapid infilling by sand from the adjacent beaches; thus it is unlikely that fine sediments would accumulate and alter sediment composition in the post-extraction dredged channel. As in the case of many inlets along the southern NC coast, there is a localized reversal in longshore sediment transport along the East End beach from predominantly westward regional longshore transport to predominantly eastward longshore transport. Thus, placement on the East End beach would retain the material within the inlet-dominated littoral system, with the majority of the material being transported back into LFI. Therefore, adverse effects on the inlet sediment budget would not be expected. The sediments in LFI consist of highly compatible sand that is derived from the adjacent beaches. Therefore, placement would not be expected to have any adverse effects on the composition of East End beach sediments. Based on these considerations, it is expected that any direct, indirect, and cumulative effects on geology and sediments under Alternative 1 would be minor and short-term.

5.4.1.2 Marine Benthic Communities

<u>Soft Bottom</u>

Dredging

Direct Impacts

Under Alternative 1, project-related dredging operations would involve federal maintenance dredging of the main LFIX navigation channel every two years. As described above, it is anticipated that some dredging events would also include the 400-ft-wide bend widener depending on the availability of funding from the Town. Assuming inclusion of the 400-ft-wide bend widener, individual dredging events would directly impact ~20 ac of soft bottom habitat. Sand extraction would remove the majority of the associated soft bottom benthic invertebrate infauna and epifauna, resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the dredged channels. Soft bottom habitats in dredged channels experience frequent disturbance from waves and currents; therefore, the associated benthic communities are typically dominated by opportunistic taxa that recover rapidly from high-frequency disturbances (Wilber and Clarke 2007). Stickney (1974) reported minor, short-term impacts on benthic communities in a dredged AIWW channel in GA with full recovery occurring in one to two months. In a subsequent study, Stickney and Perlmutter (1975) reported complete removal of the benthic community in a dredged GA AIWW channel; however, full recovery was observed in only two months. Van Dolah et al. (1979) observed minor, isolated effects on the benthic community in a dredged estuarine channel in SC; recovery occurred within two months. In another SC study of benthic community response in a dredged AIWW channel, recovery occurred within six months (Van Dolah et al. 1984). In both the GA and SC channels, the rapid rates of recovery were attributed in part to recolonization via slumping of adjacent undisturbed sediments into the dredged channel. Van Dolah et al. (1984) also attributed rapid recovery to infilling by sediments that were similar in composition to the extracted sediment and avoidance of spring benthic invertebrate recruitment periods. The LFIX channel is subject to rapid infilling by similar medium sand substrate as evidenced by its repeated use as a source of fill for the east end beach. In addition, the established environmental nourishment window (16 November – 30 April) would necessitate the completion of dredging operations prior to the onset of spring benthic invertebrate recruitment periods. Therefore, it is anticipated that benthic community recovery periods in the LFIX and bend widener channels would be within two to six months based on these previous studies.

Indirect Impacts

In addition to the direct impacts of dredging on benthic communities within the actively dredged channels, dredging operations may also have indirect impacts on these communities from increased sedimentation and deposition of fine sediments that are temporarily suspended during dredging operations and can be dispersed and redeposited outside of the active dredging footprint. These sediments may potentially impact adjacent soft bottom benthic communities through burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic organisms. The spatial extent of sediment dispersal is influenced by sediment composition, dredging methods, and hydrodynamic conditions (Wilber et al. 2005). Dredging-induced sediment dispersal is primarily associated with the suspension of fine silt/clay particles which have relatively slow settling velocities compared to sand and gravel which make up the coarse-grained sediment fraction and resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009).

Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). Furthermore, hopper dredges are generally associated with higher rates of suspension and dispersal than cutterhead dredges primarily due to the surface discharge associated with overflow hopper dredging. In the case of cutterhead dredging, sediment suspension is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Field data collected during cutterhead navigation dredging projects has shown average sediment resuspension rates ranging from 0.003 to 0.135 percent of the fine silt/clay fraction and a maximum fine sediment resuspension rate of 0.51 percent (Hayes et al. 2000, Hayes and Wu 2001).

Under Alternative 1, dredging operations in the LFIX/bend widener channel would be conducted by cutterhead pipeline dredges. Sediments associated with this channel are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction. In addition, there can be isolated pockets of clay. This usually only occurs if the dredge contractor unintentionally dredges too deep or outside of the permitted footprint (Personal communication, Fran Way, Holden Beach engineer, March 19, 2015). Therefore, it is anticipated that indirect, dredging-induced sediment dispersal and redeposition effects under Alternative 1 would be localized and minor.

Direct, dredging-induced loss of benthic invertebrates would constitute a temporary reduction in the availability of prey for predatory demersal fishes. Potential indirect prey-loss effects on demersal fishes could include reduced foraging efficiency within the dredging footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. A slight increase of fine sediments in the water column can reduce the ability of visually oriented demersal fishes to capture benthic prey (Manning et al. 2013). The potential for longer-term indirect prey-loss effects on demersal fishes at the community and/or population level is difficult to assess. However, based on the anticipated rapid rates of benthic community recovery and considering that dredging would impact only 20 ac out of the 900 total ac of soft bottom habitat within the Permit Area, it is anticipated that the indirect effects of prey loss on demersal fishes would be localized and short term.

Cumulative Impacts

<u>Project Area</u>

The potential for temporally crowded cumulative effects on soft bottom communities under Alternative 1 would depend on the frequency of dredging on soft bottom communities within the same area. Specifically, effects would be considered likely if the intervals between repeated LFIX/bend widener dredging events were insufficient to allow for full recovery of benthic communities. Although the No-Action alternative includes only one LFIX dredging event every two years, interim federal maintenance dredging events would continue the current annual cycle of dredging (exclusive of the 400-ft bend widener). Additional separate actions affecting the LFIX and/or bend widener channels would not be anticipated during the 30-year project period. As described above, benthic communities associated with the dredged channels are expected to recover from dredging events in less than one year, and, therefore, based on the anticipated one-year interval between LFIX dredging events, temporally crowded cumulative impacts would not be expected under Alternative 1. The potential for spatially crowded cumulative impacts under Alternative 1 would depend on the proximity of separate dredging actions to the bend widener and the potential for overlapping effects on soft bottom communities. Dredging of other federal navigation channels, including segments of the AIWW behind Holden Beach and Oak Island and/or the LFI navigation channel, would likely coincide with project-related LFIX/bend widener dredging events. Combined losses of benthic invertebrate prey in the LFIX/bend widener channels and other dredged channels could potentially have cumulative effects on predatory demersal fishes. However, the combined area of temporary habitat/prey loss would constitute a small fraction of the available inlet/estuarine soft bottom habitat in the vicinity of Holden Beach and Oak Island, and any cumulative effects would be limited to the period of benthic community recovery. Therefore, it is anticipated that spatially crowded cumulative effects on soft bottom communities would be localized and short term.

Regional

On a regional scale, LFIX/LFI dredging events would be expected to coincide with other inlet navigation dredging projects along the southern NC coast. Of the 15 inlets that divide the southern NC barrier islands, nine have both inlet and AIWW inlet-crossing channels that are currently maintained under federal navigation projects. The federal inlet navigation projects include two deep draft navigation projects (Beaufort and Cape Fear Inlets) and seven shallow draft inlet projects (Shallotte, Lockwoods Folly, Carolina Beach, Masonboro, New River, New Topsail, and Bogue). The shallow draft channels and some portions of the deep draft channels are generally dredged at least once a year. Simultaneous impacts on soft bottom habitats and benthic invertebrate communities at separate inlets could potentially have combined effects on the foraging activities of migratory demersal fishes. However, benthic communities in dredged channels typically recover in a matter of months, and the combined extent of habitat disturbance would constitute a small fraction of the available soft bottom habitat along the southern NC coast. Therefore, it is expected that any cumulative effects would be minor and short-term.

Beach Fill Placement

Direct Impacts

Alternative 1 would continue the ongoing two-year cycle of East End nourishment via beneficial use of material from the LFIX channel and the 400-ft bend widener. Beach fill placement volumes would vary according to sediment volume availability in the LFIX channel and bend widener and the availability of local funding for inclusion of the 400-ft bend widener. It is anticipated that nourishment events using only material from the main LFIX channel would place ~100,000 cy on the East End beach whereas a combined LFIX/bend widener borrow site would provide ~150,000 cy of compatible material for the beach. Alternative 1 does not have a defined beach fill footprint; however, based on similar placement volumes under the action alternatives, a 100,000 cy nourishment event would directly impact ~8 ac of soft bottom habitat on the subtidal shoreface. Beach fill placement would cause mortality of associated benthic invertebrate infauna and epifauna by temporary burial under the deposited sand (Oliver et al. 1977, McCall 1977, and Bolam et al. 2006). The addition of fill would extend the MLW seaward, converting some of the impacted subtidal habitat to intertidal beach habitat. Benthic communities associated with the remaining subtidal portion of the beach fill footprint would experience an initial sharp decline in abundance, diversity, and biomass but would be expected to recover relatively rapidly. The delivery of dredged sand to the beach would involve the placement of pipelines on the subtidal seafloor, resulting in additional direct impacts on soft bottom communities; however, it is anticipated that pipeline impacts would be negligible since the impacts would be confined primarily to a narrow strip of substrate underlying the pipelines, and the extent of physical habitat disturbance would be minimal once the pipelines are removed.

Shallow soft bottom habitats along the beach experience frequent wave and current disturbance, and consequently, the associated benthic assemblages are dominated by opportunistic taxa that recover rapidly from high-frequency disturbance (Wilber and Clarke 2007). According to Burlas et al. (2001), the responses of nearshore soft bottom benthic communities to a beach nourishment project in NJ were limited to short-term (≤6.5 months) reductions in abundance, biomass, and taxa richness. Rakocinski et al. (1996) also reported relatively rapid recovery (≤1 year) of nearshore benthic communities following a beach nourishment project in FL. The principal project-related factors that influence recovery rates include the composition of the beach fill sediments relative to those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009). Reported rates of recovery have been rapid when highly compatible beach fill sediments were used and spring larval recruitment periods were avoided. Conversely, longer recovery periods have been associated with the use of incompatible fill and/or the execution of nourishment projects during larval recruitment periods. The LFIX navigation channel has been a consistent source of compatible beach fill for many years, and the existing environmental nourishment window (16 November - 30 April) would avoid the peak benthic invertebrate recruitment periods in NC [May through September (Hackney et al. 1996, Diaz 1980, and Reilly and Bellis 1978)]. Therefore, benthic communities would be expected to recover relatively rapidly from beach nourishment activities.

Indirect Impacts

In addition to the direct burial of benthic organisms in the beach fill footprint, beach fill placement may also indirectly impact soft bottom benthic communities via increased turbidity and siltation (Michel et al. 2013). Increased turbidity from resuspension of fine sediments during deposition and subsequent rehandling may reduce growth and have adverse effects on suspension feeders. Since dispersion and redeposition may occur outside the beach fill footprint, these potential impacts may occur in adjacent soft bottom benthic communities. Siltation arising from settlement of these fine particles may also induce mortality by smothering benthic organisms (Michel et al. 2013). The sediments associated with the LFIX channel are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction; therefore, it is anticipated that sediment dispersal and redeposition would be confined to the immediate vicinity of the beach fill footprint. The direct removal of benthic invertebrates by sand placement would constitute a reduction in potential prey for soft bottom demersal fishes (e.g., flounders, rays, spots, and croakers). Potential indirect effects on demersal fishes may include reduced foraging efficiency within the beach fill footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. Alternative soft bottom foraging habitats cover vast areas of the nearshore ocean seafloor along Holden Beach and Oak Island relative to the anticipated habitat impact area (~8 ac), and rapid recolonization of the disturbed area by early successional benthic invertebrate taxa would provide substantial food resources within a relatively short period of time. Therefore, it is expected that any effects on demersal fishes would be negligible.

Cumulative Impacts

Project Area

The potential for temporally crowded cumulative effects on nearshore soft bottom communities would depend on the frequency of repeated beach fill placement activities and their potential impacts on soft bottom communities within and adjacent to the footprint. Specifically, temporally crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of benthic communities. Based on the studies and project parameters described above, soft bottom communities within the beach fill footprint would be expected to fully recover during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project are not anticipated; therefore, temporally crowded cumulative effects on nearshore soft bottom communities would not be expected under Alternative 1.

The potential for spatially crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill actions to the east end beach and the potential for overlapping effects on nearshore soft bottom communities. Spatially separate nourishment projects that are expected to occur along Holden Beach and/or Oak Island during the 30-year project period include the Holden Beach Central Reach Project, the federal BCB Project, and the Lockwoods Folly River Habitat Restoration Project, Phase 1 – Eastern Channel. These projects are described in more detail in Section 5.3. This latter project involves dredging of the Eastern Channel and subsequent nourishment of the west end of Oak Island and occurred in the spring of 2015. The Town's recently completed (2017) Central Reach Project was a one-time nourishment event that placed ~1.31 million cy of material from an offshore borrow area along 4.1 miles of shoreline. The BCB project encompasses nourishment projects along central Holden Beach (4.5 miles), central Oak Island (3.8 miles), and eastern Oak Island/Caswell Beach (2.9 miles). Initial construction of the three BCB segments is anticipated to occur over four consecutive winter seasons beginning in 2020 with subsequent renourishment events following at intervals of approximately five, six, and eight years. East End nourishment events could potentially coincide with BCB nourishment projects. Based on this preliminary BCB sequence, East end nourishment events could potentially coincide with two of the initial BCB events and one to two renourishment events per cycle. In the event of concurrent East End Holden Beach - BCB nourishment projects, East End nourishment would increase the total area of soft bottom habitat impact by only ~8 ac. The addition of ~8 ac of impact would not be expected to affect benthic infaunal recovery rates along either reach; therefore, spatially crowded cumulative impacts on soft bottom communities would not be expected under Alternative 1.

Regional

On a regional scale, East End nourishment events would coincide with separate nourishment projects along various reaches of the southern NC coast. As described in Section 5.1.2, it is assumed that all of the 97 miles of developed barrier island beaches along the southern NC coast will eventually be managed under a recurring nourishment project. As a result of periodic nourishment, subtidal nearshore benthic communities along the developed beaches will experience recurring cycles of impact, recovery, and full productivity. Based on an average 4.5-year nourishment cycle, annual impacts could encompass nearshore communities along an average ~22 miles or ~14 percent of the total beach miles along the southern NC coast. Simultaneous reductions in soft bottom benthic prey availability along 14 percent of the southern coast beaches could increase the potential for adverse effects on the foraging activities of migratory surf zone fishes. However, considering the short-term duration of the impacts on benthic communities and the availability of vast areas of undisturbed nearshore soft bottom habitat along the southern coast during any given year, it is anticipated that any cumulative prey-loss effects would not significantly degrade surf zone fish populations.

Hardbottom

Direct, Indirect and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf which are located well seaward of the beach fill footprint, dredging area, and pipeline placement areas. Therefore, Alternative 1 is not expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.1.3 Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

The LFIX/bend widener dredging regime under Alternative 1 would be similar to the ongoing dredging regime; therefore, no dredging-induced impacts on hydrodynamic conditions would be expected. Alternative 1 would continue the ongoing two-year cycle of East End nourishment. Beneficial Use East End Nourishment Projects have been ongoing for many years and have not resulted in adverse effects on hydrodynamic conditions. Therefore, no adverse effects on hydrodynamics would be expected under Alternative 1. Based on the absence of direct and indirect impacts, cumulative impacts on hydrodynamic conditions would not be expected.

Sediment Suspension and Turbidity

Dredging activities may indirectly impact pelagic organisms via temporary sediment suspension and associated increases in turbidity. Increased sedimentation and turbidity during the dredging process can potentially affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms. The extent and duration of these impacts are influenced by sediment composition at the borrow site, the type of dredge employed and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities whereas, sands and gravels, which make up the coarse-grained sediment fraction, resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In reporting the results of turbidity monitoring during navigation dredging in Delaware Bay, Miller et al. (2002) described the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments as being confined to the dredged channel footprint with suspended sediment concentrations returning to ambient levels within one hour of the passing of the dredge. Miller et al. (2002) also noted that observed turbidity levels remained within the range of pre-project ambient turbidities throughout the period of dredging in coarse-grained sediments. Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic, hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). In comparison to cutterhead dredges, hopper dredges are generally associated with higher rates of suspension and dispersal primarily due to the surface discharge associated with overflow dredging. With cutterhead dredging, sediment suspension is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Based on sediment resuspension data collected during multiple cutterhead navigation dredging projects, Hayes et al. (2000) and Hayes and Wu (2001) reported average sediment resuspension rates ranging from 0.003 to 0.135 percent of the fine silt/clay fraction. Dredging operations under Alternative 1 would be carried out by cutterhead dredges, and sediments associated with LFIX channel and bend widener are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction. Therefore, it is anticipated that any effects of dredging-induced sediment suspension in the water column under Alternative 1 would be localized and short term.

Sediment suspension and turbidity effects would be limited to periods of active dredging; therefore, temporally crowded cumulative impacts would not be expected. Sediment suspension and turbidity effects would be localized to the immediate vicinity of the active dredging area and, therefore, overlapping spatially crowded cumulative impacts are not expected.

Beach Fill Placement

Direct and Indirect Impacts

Fine sediment suspension and increased turbidity would also occur during beach fill placement operations in the nearshore ocean zone. However, similar to the extraction process, the small fine sediment fraction suggests that sediment suspension effects related to beach fill placement under Alternative 1 would be localized and short term.

Cumulative Impacts

Sediment suspension and turbidity effects would be limited to periods of active beach nourishment and, therefore, temporally crowded cumulative impacts would not be expected. Sediment suspension and turbidity effects would be localized to the immediate vicinity of the beach fill placement areas. Therefore, overlapping spatially crowded cumulative impacts would not be expected.

<u>Entrainment</u>

Direct and Indirect Impacts

Cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of small numbers of pelagic fishes (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the available information on entrainment rates, larger demersal and pelagic juvenile and adult finfishes are likely to avoid dredging areas during operations (Michel et al. 2013). Therefore, it is expected that entrainment-related effects on adult and juvenile fishes would be minor.

Many of the common marine fishes and invertebrates in NC are estuarine-dependent species that spawn offshore as adults and reside in estuarine nursery areas during juvenile development. The recruitment of ocean-spawned planktonic larvae to estuarine nursery areas is dependent on passive ocean-to-sound transport through tidal inlets. Recruitment studies indicate that larvae accumulate along the beaches in the nearshore ocean zone where they are carried by alongshore currents to laterally adjacent tidal inlets (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet, NC, indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990).

The results of larval entrainment modeling studies conducted at Beaufort Inlet indicate that dredge entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Based on the maximum intake rate of the largest hydraulic dredge that could potentially be employed, the maximum volume of water taken in and discharged during a 24-hr dredging period would constitute 0.004 percent of the daily spring tidal flow and 0.006 percent of the daily neap tidal flow through the inlet (Table 5.6). In addition, the existing environmental nourishment window (16 November - 30 April) would avoid the peak inlet larval ingress periods. Based on all of these considerations, it is anticipated that the effects of larval entrainment on estuarine-dependent fish and invertebrate populations under Alternative 1 would be negligible. It is anticipated that the direct and indirect impacts of entrainment on pelagic communities would be minor, localized, and short term. Therefore, cumulative impacts related to entrainment would not be expected under Alternative 1.

Table 5.6. Maximum percentage of daily (24-hr) inlet flow volume entrained during dredging.

Tide Condition	Tidal Prism[1] (Ft^3)	Daily (24-hr) Flow[1] (Tidal Prism x 2)	Daily Dredge Intake Rate (CFS x 1 day)	Percent of Daily Flow Entrained (Dredge Intake/Daily Flow)
Spring	791,830,000	1,583,660,000	6,123,570	0.004
Neap	533,590,000	1,067,180,000	6,123,570	0.006

[1]Source: ATM 2013

Underwater Noise

Increased anthropogenic noise from the dredging activities may impact fishes in the water column. The effects of dredging sounds on fishes have not been fully assessed, and there are currently no specific criteria for evaluating the potential impacts of continuous dredging noise on marine fishes. Limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g., temporary or permanent loss of hearing) changes in fishes (Popper and Hastings 2009). Dredging noise may also mask biologically important signals, thereby interfering with fish communication and predator/prey interactions [Normandeau Associates, Inc. (NAI) 2012]. Although the potential effects of dredging noise on fishes are not fully known, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013). According to a study by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms with rapid attenuation occurring at short distances from the dredge and sound levels becoming essentially inaudible at a distance of approximately 500 m. Dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990); and therefore, considering that cutterhead dredges are anchored during active dredging, it is likely that most fish would move away from the dredge long before they are exposed to potentially injurious noise levels. Based on currently available information, it is expected that any non-injurious effects on fishes would be temporary and localized. In the absence of significant direct and indirect impacts, noise-related cumulative impacts would not be anticipated.

5.4.1.4 Oceanfront Beach and Dune Communities

Intertidal Beach

Direct Impacts

Alternative 1 would continue the ongoing two-year cycle of East End nourishment via beneficial use of material from the LFIX channel and 400-ft bend widener. Beach fill placement volumes would vary according to sediment volume availability in the LFIX and bend widener channels and the availability of local funding for inclusion of the 400-ft bend widener. It is anticipated that nourishment events using only material from the main LFIX channel would place ~100,000 cy on the East End beach, whereas combined LFIX/bend widener nourishment events would place ~150,000 cy. Alternative 1 does not have a defined beach fill footprint; however, based on similar placement volumes under the action alternatives, a 100,000 cy nourishment event would directly impact ~13 ac of intertidal beach habitat. Beach fill placement would eliminate the majority of the intertidal benthic invertebrate infauna through direct burial; and construction of the berm would shift the intertidal zone seaward, where the process of benthic infaunal recovery would begin upon the cessation of beach placement operations. The direct impacts of beach construction activities would include the disturbance and displacement of shorebirds from intertidal beach foraging habitats in the vicinity of the active construction zone. Although the duration of disturbance along any given segment of the nourishment beach would be short term, the indirect effects of benthic infaunal prey removal (described below) would likely preclude the immediate return of shorebirds.

The principal project-related factors that influence benthic community recovery rates are the compatibility of the beach fill sediments with those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009). Most benthic recovery studies have reported rapid recovery within seven months of the initial impact when highly compatible beach fill sediments were used and larval recruitment periods were avoided (Jutte et al. 1999a, Burlas et al. 2001, Van Dolah et al. 1994, Van Dolah et al. 1992, Gorzelany and Nelson 1987, Salomon and Naughton 1984, Parr et al. 1978, Hayden and Dolan 1974). Conversely, longer recovery periods of up to 15 months (Rakocinski et al. 1996) have generally been associated with the use of incompatible beach fill sediments containing excessively large quantities of fine silt and clay material. In an effort to minimize the biological impacts of beach nourishment projects, NC has enacted regulatory technical standards for the compatibility of beach fill sediments with those of the native beach (15A NCAC 07H.0312). Approvals of state CAMA permits for nourishment projects are contingent on the results of quantitative comparative analyses demonstrating sediment compatibility between proposed borrow areas and corresponding beach fill sites. The LFIX channel and bend widener have been a consistent source of compatible beach fill for many years, and the existing environmental nourishment window (16 November - 30 April) would necessitate avoidance of spring benthic invertebrate recruitment periods. Therefore, benthic communities would be expected to recover relatively rapidly from beach nourishment events under Alternative 1.

Indirect Impacts

Direct losses of intertidal benthic infauna within the beach fill footprint would constitute a temporary reduction in the availability of potential prey for shorebirds and predatory surf zone fishes. A two-year investigation of the effects of beach nourishment on shorebird and waterbird communities at Holden Beach and Oak Island detected no significant effects on shorebird or waterbird abundances (Grippo et al. 2007). However, the authors noted the possibility that abundances on nourished beaches could have been maintained by a continuous flux of arriving and departing migratory birds as opposed to extended residency by the same individuals. In terms of behavioral effects, Grippo et al. (2007) detected a significant reduction in waterbird feeding activity on nourished beaches; however, the feeding activities of shorebirds that are heavily dependent on intertidal beach foraging habitats (e.g., willet and sanderling) were not affected. Peterson et al. (2006) reported a 70 to 90 percent decline in shorebird feeding activity on a nourished beach at Bogue Banks. The decline in shorebird activity was attributed primarily to depressed infaunal communities; however, the use of incompatible fill containing large quantities of shell hash may have contributed to the decline by impeding shorebird foraging. Following the winter nourishment event, feeding activity remained severely depressed through July, but increased substantially between July and September and returned to normal between September and November. According to Wilber et al. (2003), the effects of a beach nourishment project in NJ on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. Under Alternative 1, potential indirect prey-loss effects on shorebirds and surf zone fishes could include a temporary reduction in foraging efficiency along the East End beach and/or temporary displacement to adjacent undisturbed intertidal foraging habitats. However, based on the anticipated rapid rates of benthic community recovery, the minimal intertidal habitat impacts, and the availability of adjacent undisturbed intertidal foraging habitat, it is anticipated that indirect impacts on shorebirds and surf zone fishes would be localized and short term under Alternative 1.

Cumulative Impacts

<u>Project Area</u>

The potential for temporally-crowded cumulative effects on intertidal beach communities would depend on the frequency of repeated beach fill placement impacts within the beach fill footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of benthic infaunal communities. As indicated above, intertidal beach communities within the beach fill footprint would be expected to fully recover during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project would not be anticipated; therefore, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 1.

The potential for spatially-crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill actions to the East End beach and the potential for overlapping effects on intertidal beach communities. Spatially-separate nourishment projects that would be expected to occur along Holden Beach and/or Oak Island during the 30-year project period would include the planned 2016/2017 Holden Beach Central Reach nourishment project as well as maintenance of the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel. There is no known schedule of maintenance for the Eastern Channel as it was permitted as a one-time project. The 2016/2017 Central Reach project would be a one-time nourishment event, and the initial East End nourishment event would not be expected to occur until at least 2017/2018. Therefore, no overlapping effects with the Central Reach project would be expected. Simultaneous nourishment of both reaches would reduce the pool of potential infaunal invertebrate recruits for recolonization of the East End beach; thus potentially extending the infaunal community recovery period. However, full recovery would still be expected during the two-year intervals between East End nourishment events; therefore, spatially-crowded cumulative impacts on intertidal benthic infaunal communities would not be expected under Alternative 1. Simultaneous losses of intertidal benthic infauna along both reaches may have minor adverse effects on surf zone fishes and shorebirds; however, such effects would be confined to the benthic community recovery period and would not carry over to subsequent nourishment events. Therefore, any spatially-crowded cumulative impacts on surf zone fishes and shorebirds under Alternative 1 would be short term and localized.

<u>Regional</u>

On a regional scale, East End nourishment events would coincide with separate nourishment projects along various reaches of the southern NC coast over the 30-year life of the project. As described in Section 5.1.2, it is assumed that all of the 97 miles of developed barrier island beaches along the southern NC coast will eventually be managed under a recurring nourishment project. As a result of periodic nourishment, intertidal benthic communities along the developed beaches will experience recurring cycles of impact, recovery, and full productivity. Based on an average 4.5-year nourishment cycle and a one-year benthic community recovery period, the extent of intertidal beach habitat in recovery on an annual basis could average ~22 miles or ~14 percent of the total beach miles along the southern NC coast. Although impacts on benthic infaunal communities would generally be short-term, simultaneous reductions in benthic prey availability along 14 percent of the southern coast beaches could increase the potential for adverse effects on the foraging activities of migratory shorebirds and surf zone fishes as they move along the southern NC coast. There are no known thresholds for determining the extent of intertidal beach impacts that would result in significant degradation of intertidal beach communities. However, considering the short-term duration of the impacts on benthic communities and the availability of fully productive benthic communities along the majority of the southern NC coast during any given year, it is anticipated that any cumulative prey-loss effects would not significantly degrade shorebird or surf zone fish populations.

<u>Dry Beach and Dune</u>

Direct Impacts

Beach fill placement would be limited to areas seaward of the primary dune toe, thus avoiding direct impacts on dunes and associated dune grass communities. The placement of beach fill on the upper dry beach would impact ghost crabs and other burrowing invertebrate macrofauna through direct burial. The reported effects of beach nourishment and beach scraping on ghost crabs range from no significant response (Bergquist et al. 2008) to significant long-term effects lasting >1 year (Dixon 2007). The results of ghost crab recovery studies indicate that influential project-related factors are similar to those associated with intertidal benthic infaunal recovery rates; including sediment compatibility, the timing of operations relative to recruitment periods, and the frequency of repeated impacts. Bergquist et al. (2008) attributed the absence of any clear response to a nourishment project at Folly Beach, SC, to the use of highly compatible beach fill; however, Lindquist and Manning (2001) and Peterson et al. (2000) attributed significant reductions in ghost crab abundances lasting six to eight months to changes in sediment composition on newly constructed dune faces at Bogue Banks. In contrast to the minimal effects of (winter) nourishment reported by Bergquist et al. (2008), a separate investigation of a summer nourishment project at Folly Beach reported significant long-term (>1 year) effects on local population structure, including the loss of entire cohorts (Dixon 2007). Lindquist and Manning (2001) detected no response to an initial beach nourishment project at Topsail Beach; however, repeated annual nourishment projects resulted in significant reductions in ghost crab abundances. Based on the results of these studies, it is anticipated that the use of compatible sediments in accordance with the state technical standards for beach fill and avoidance of recruitment periods in accordance with the established environmental nourishment window (16 November - 30 April) would minimize the potential for significant long-term effects on ghost crabs and other beach-dwelling invertebrate macrofauna. The established nourishment window would necessitate avoidance of sea turtle and shorebird/waterbird nesting seasons; therefore, no direct impacts on nesting activity or success would be expected. Construction activities would result in short-term displacement of shorebirds and waterbirds from upper beach loafing and/or roosting habitats; however, the spatial extent of displacement at any given time would amount to a relatively small segment of the beach in the immediate vicinity of the active construction zone.

Indirect Impacts

Beach nourishment has the potential for both beneficial and detrimental indirect effects on dry beach communities. In the case of severely eroded beaches, the restoration of a wider and higher dry beach can improve the quality of potential nesting habitats for sea turtles (Davis et al. 1999, Byrd 2004) and potential loafing, roosting, and nesting habitats for shorebirds and waterbirds (Melvin et al. 1991). Conversely, nourishment can modify the physical characteristics of dry beach and dune habitats in ways that reduce habitat quality. Potential detrimental effects on the quality of dry beach and dune habitats are primarily related to changes in sediment composition and the modification of other physical substrate characteristics and/or changes in beach profile morphology. As indicated by ongoing federal disposal actions, the LFIX channel and bend widener have been a consistent source of compatible east end beach fill for many years. Much of the LFIX source material is derived from the adjacent beaches of Holden Beach and Oak Island. Prior to the use of any sand source by the Town, minimum state sediment compatibility standards must be met. Available sediment data from the borrow sites indicate the presence of beach-compatible sand in sufficient volumes for nourishment. Each of the sites consists of sediments characterized by a high percentage of sand by percent weight and low percentage of fines (see Appendix H – Engineering Analysis).

The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation. Sediment compaction and changes in sediment composition can also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988, Crain et al. 1995). The initial post-construction dry beach (aka berm) profile is generally flatter than the natural beach profile, and consequently, is subject to a period of adjustment during which sediments are sorted and redistributed by wave and wind driven transport processes. This adjustment process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The potential effects of beach nourishment and other project-related activities on sea turtles and sea turtle nesting habitat are evaluated in detail along with other threatened and endangered species in Section 5.4.1.6.

Changes in sediment composition can also potentially affect the suitability of dry beach habitats for nesting shorebirds (Melvin et al. 1991). However, in the case of the developed East End oceanfront beach, nourishment is unlikely to have any beneficial or detrimental impact on the suitability of potential dry beach shorebird/waterbird nesting habitats. Although shorebird/waterbird nesting attempts along the oceanfront beach cannot be entirely ruled out, traditional oceanfront dry beach and dune breeding sites on NC's stabilized developed barrier islands have essentially been abandoned in favor of more isolated inlet spit/shoal habitats and estuarine spoil islands. The anticipated effects of nourishment on East End oceanfront beach habitats would be negligible in comparison to the overriding long-term exclusionary effects of development, stabilization, and chronic human disturbance. Therefore, Alternative 1 would not be expected to have any indirect effects on the suitability of oceanfront beach shorebird/waterbird nesting habitats. The maintenance of a wider oceanfront dry beach under Alternative 1 would be expected to improve the quality of potential shorebird/waterbird loafing and roosting habitats.

Cumulative Impacts

Project Area

The potential for temporally-crowded cumulative effects on dry beach and dune communities would depend on the frequency of repeated beach fill placement impacts within the beach fill footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of macrofaunal invertebrate communities and physical habitat characteristics. As indicated above, dry beach macrofaunal invertebrate communities within the beach fill footprint would be expected to fully recover from beach fill placement impacts during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project would not be anticipated; therefore, temporally-crowded cumulative effects on dry beach communities would not be expected under Alternative 1. The potential for spatially-crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill projects to the East End beach and the potential for overlapping effects on dry beach and dune communities. The maximum combined linear extent of oceanfront beach impact during any given year would be 5.2 miles in the event of simultaneous nourishment of the ~0.7-mile East End beach and the longest ~4.5-mile Central Reach Project on Holden Beach. Simultaneous nourishment of both reaches would reduce the pool of potential macrofaunal invertebrate recruits for recolonization of the East End beach, thus potentially extending the macrofaunal community recovery period. However, full recovery would still be expected during the two-year intervals between East End nourishment events; therefore, spatially-crowded cumulative impacts on dry beach communities would not be expected under Alternative 1.

Regional

As in the case of the intertidal beach, it is assumed that all of the 97 miles of developed beaches along the southern NC coast will eventually receive periodic nourishment at an average interval of 4.5 years. As a result of periodic nourishment, dry beach habitats and macrofaunal invertebrate communities along the developed beaches will experience recurring cycles of impact, recovery, and full productivity. Based on an average 4.5-year nourishment interval, the extent of dry beach habitat in recovery on an annual basis could average ~22 miles or ~14 percent of the total beach miles along the southern NC coast. Although effects on macrofaunal invertebrates and physical habitat characteristics would be short-term, simultaneous reductions in the quality of dry beach habitats along 14 percent of the southern coast beaches could increase the potential for adverse effects on nesting sea turtles and/or migratory shorebirds. There are no known thresholds for determining the extent of beach impacts that would result in significant degradation of dry beach communities. However, considering the short-term duration of the effects on physical habitat characteristics and the availability of recovered and undisturbed habitats along the majority of the southern NC coast during any given year, it is anticipated that any cumulative habitat modification effects would not significantly degrade sea turtle or shorebird populations.

5.4.1.5 Inlet Resources

Intertidal Flats and Shoals

Direct Impacts

Although small short-lived emergent shoals occasionally form along the margins of the ebb channel at the mouth of the inlet throat, the interior Flood Shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. Nourishment-related dredging operations would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, direct dredging-induced impacts on intertidal flats and shoals would not be expected under Alternative 1. The eastern extent of beach fill placement may approach the inlet shoulder where small shoals originating along the western margin of the ebb channel have attached in the past; however, chronic erosion generally precludes the formation of any persistent intertidal flat or shoal-like features along the Holden Beach inlet shoulder. Therefore, direct nourishment-related impacts on intertidal flats and shoals would not be expected under Alternative 1.

Indirect Impacts

The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on flats and shoals would not be expected. Net sediment transport along the East End beach is eastward towards the inlet, and the inlet itself is flood-dominant in terms of sediment transport. Consequently, sand extracted from the LFIX/bend widener channels for East End nourishment purposes would be retained within the inlet system. Therefore, indirect impacts on the Flood Shoal via modification of the inlet sediment budget would not be expected under Alternative 1.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on intertidal flats and shoals would not be expected under Alternative 1.

Inlet Dry Beach and Dune

Direct Impacts

Due to the chronically eroded nature of the East End shoreline, the demarcation between the oceanfront beach and the inlet beach is poorly defined on Holden Beach. The eastern extent of beach fill placement may encompass short reaches of the transitional southeast-facing oceanfront/inlet shoreline. Beach fill placement would be limited to areas seaward of the dune toe, thus avoiding direct impacts on dunes and associated dune grass communities. Beach fill placement would result in minor direct impacts on inlet dry beach communities.

Indirect Impacts

The potential indirect impacts of beach fill placement on inlet dry beach communities would be similar to those described above for the oceanfront beach. Based on the limited spatial extent of beach fill placement along the southeast-facing shoreline, it is anticipated that associated indirect effects would not add measurably to those already described for the oceanfront beach.

Cumulative Impacts

The potential cumulative impacts of beach fill placement on inlet dry beach communities would be similar to those described above for the oceanfront beach. Based on the limited extent of direct and indirect impacts, it is anticipated that any associated cumulative impacts would not add measurably to those already described for the oceanfront beach.

5.4.1.6 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on shellfish beds. The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on shellfish beds would not be expected. As described in Section 5.4.1.2, it is anticipated that dredging-induced sediment suspension and dispersal would be short term and highly localized, thus indicating that the potential for redeposition effects on shellfish beds would also be minimal. In the absence of anticipated direct and indirect effects, cumulative impacts on shellfish beds would not be expected under Alternative 1.

SAV

Direct, Indirect, and Cumulative Impacts

Distribution maps developed by the SAV Cooperative Habitat Mapping Program depict a few small SAV patches along the Eastern Channel between Oak Island and Sheep Island; however, according to the NCDMF, SAV does not occur in the Eastern Channel (Personal communication, NCDMF, Anne Deaton, 22 May 2014). The absence of SAV in the Eastern Channel was confirmed via ground-truthing by Dial Cordy and Associates Inc. in September 2014. Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on SAV. As stated above, indirect dredging-induced hydrodynamic and redeposition effects would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on SAV would not be expected under Alternative 1.

Tidal Marshes

Direct, Indirect, and Cumulative Impacts

Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on tidal marshes. As stated above, indirect dredging-induced hydrodynamic effects would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on tidal marshes would not be expected under Alternative 1.

5.4.1.7 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Under Alternative 1 dredging operations in the LFIX and bend widener channels would coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. The potential impacts of dredging on large whales include vessel collisions and acoustic disturbance. Although right and humpback whales routinely swim close to shore during winter migration periods along the NC coast, dredging activities under Alternative 1 would be confined to the inshore LFIX and bend widener channels, thus precluding any risk of vessel collisions. NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to root mean square sound pressure levels ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. As described by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms. Sound levels are rapidly reduced at short distances from the dredge and are essentially inaudible at a distance of ~500 m. Therefore, dredging operations under Alternative 1 would not be expected to produce noise levels at or above the thresholds described above for injurious or behavioral effects on marine mammals. Furthermore, the LFIX and bend widener channels are located ~700 m inland of the International Regulations for Preventing Collisions at Sea (COLREGS) line across the mouth of the inlet throat, thus indicating that any dredging noise that does reach the open ocean would be inaudible. Therefore, dredging noise would not be expected to have any direct or indirect effect on right or humpback whales. The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 1 would not affect any of these essential features, nor would they preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on critical habitat would be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on right and humpback whales or proposed right whale critical habitat would not be expected under Alternative 1.

West Indian Manatee

Direct, Indirect and Cumulative Impacts

The principal project-related threat to manatees would be the potential for vessel collisions related to dredging operations in the LFIX and bend widener channels. Cutterhead dredges operate from anchored barges; therefore, any potential risk of collisions would be limited to relatively brief periods of barge repositioning. Furthermore, the established environmental nourishment window (16 November - 30 April) would limit operations to the colder months when manatees are unlikely to be present in NC waters. Of the 53 live manatee sightings that were reported in NC between 1994 and 2011, nearly all (94 percent) occurred between June and October when water temperatures were above 20^{o}C (Cummings et al. 2011). Nonetheless, conservation measures would include implementation of *Guidelines for Avoiding Impacts to the West Indian Manatee: Precautionary Measures for Construction Activities In North Carolina Waters* (USFWS 2003). Based on the minimal collision risk associated with cutterhead dredges, the timing of project activities, and adherence to USFWS manatee guidelines; no direct, indirect, or cumulative impacts on manatees would be expected under Alternative 1.

Piping Plover

Direct Impacts

Sand flat and emergent shoal habitats associated with the Oak Island sand spit and the flood shoal are designated critical habitat for the Atlantic Coast wintering population of piping plovers; however, these areas are located on the opposite (eastern) side of the LFI channel at a minimum distance of ~0.5 mile from the eastern terminus of the beach fill placement area on Holden Beach. Wintering plovers are very rarely seen on developed oceanfront beaches in NC; consequently, such beaches are not considered to be suitable wintering habitat (Cameron 2009). Therefore, East End beach fill placement operations under Alternative 1 would not be expected to have any direct impacts on wintering plovers. Similarly, piping plover breeding sites on NC's developed barrier islands are restricted to inlet habitats associated with the accreting ends of the islands (USFWS 2009); therefore, direct beach fill placement impacts on breeding and nesting activity would not be expected. Dredging activities would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, no direct dredging-related impacts on piping plovers or critical habitat would be expected under Alternative 1.

Indirect Impacts

Although the restoration of a wider beach can theoretically improve the quality of oceanfront beach habitats for piping plovers, the anticipated beneficial effects of nourishment on the East End beach under Alternative 1 would not be expected to reverse the long-term exclusionary effects of development, stabilization, human disturbance, and chronic high rates of background erosion. Therefore, Alternative 1 would not be expected to have any indirect beneficial or detrimental effects on the suitability of East End beach habitats for piping plovers. The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced impacts on inlet habitats would not be expected.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on piping plovers would not be expected under Alternative 1.

<u>Red Knot</u>

The rufa red knot (hereinafter referred to as "red knot") was listed as threatened under the ESA on 12 January 2015 (79 FR 73705 73748). The red knot is a non-breeding, migratory species in NC; therefore, Alternative 1 would not have any direct effect on breeding activity or reproductive success. Migrating red knots forage along sandy beaches in NC during spring (mid-April - May) and fall (July - mid-October) migrations. Red knots appear to be most abundant in May during spring migration (Personal communication, S. Schweitzer, NCWRC, 17 October 2014). Adherence to the proposed environmental window (15 November – 30 April) would avoid migratory periods when red knots are most likely to occur within the Permit Area, thus limiting the potential for direct impacts on red knots. Direct losses of intertidal benthic infauna within the beach fill footprint would constitute a temporary reduction in the availability of potential prey for red knots. Potential indirect prey-loss effects on red knots could include a temporary reduction in foraging efficiency along the East End beach and/or temporary displacement to adjacent undisturbed intertidal foraging habitats. Conversely, nourishment would increase the quantity of available intertidal foraging habitat along the East End beach, potentially resulting in beneficial indirect effects on red knots. Based on the anticipated rapid rates of benthic community recovery, the limited spatial extent of intertidal habitat impacts, the availability of adjacent undisturbed foraging habitat, and the potential for beneficial effects through foraging habitat expansion; it is anticipated that any adverse indirect impacts on red knots would be localized and short term. In the absence of significant direct and indirect effects, cumulative impacts on red knots would not be expected under Alternative 1.

Wood Stork

Alternative 1 would not be expected to have any effect on nesting sites or estuarine foraging habitats. Therefore, no direct, indirect, or cumulative impacts on wood storks would be expected under Alternative 1.

Sea Turtles

Direct Impacts

The established environmental nourishment window (16 November - 30 April) would preclude the occurrence of East End nourishment activities during the 1 May - 15 November sea turtle nesting and hatching season; therefore, direct beach fill placement impacts on sea turtles would not be expected under Alternative 1. Cutterhead pipeline dredges, the type of dredge typically used for navigation maintenance in the AIWW crossing, are not historically known to take sea turtles, and the established nourishment window would limit dredging to periods when most sea turtles are confined to warmer offshore waters. Therefore, direct dredging impacts on sea turtles would not be expected under Alternative 1.

Indirect Impacts

Beach nourishment has the potential for both beneficial and detrimental indirect effects on sea turtle nesting habitat. In the case of severely eroded beaches, such as the East End beach, the restoration of a wider and higher dry beach can improve the quality of potential nesting habitats for sea turtles (Davis et al. 1999, Byrd 2004). Conversely, nourishment can modify the physical characteristics of dry beach habitats in ways that reduce habitat quality. Potential detrimental effects on the quality of potential sea turtle nesting habitats are primarily related to the modification of beach profile morphology and/or changes in sediment composition and other physical substrate properties. The initial post-construction dry beach (aka berm) profile is generally flatter than the natural beach profile; consequently, it is subject to a period of adjustment during which sediments are sorted and redistributed by wave and wind driven transport processes. This adjustment process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation.

Sediment compaction and changes in sediment composition can also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988, Crain et al. 1995). Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment; leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995, Ehrhart 1995, and Ackerman 1996). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996); and uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures (Hays et al. 2001). Dark sediments that increase nest temperatures may prevent successful embryonic development (Matsuzawa et al. 2002) or increase the incidence of late-stage embryonic mortality by reducing incubation periods (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2003), thus indicating that the use of uncharacteristically dark beach fill sediments could potentially alter hatchling sex ratios.

Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. This five year study (2002-2007) included monitoring of nesting activity, hatching success, substrate compaction, and nest temperature. No significant beach nourishment effects on nesting success (i.e., nest/false crawl ratios) were detected, and there was no indication that nourishment adversely affected egg development or hatching success, with the exception of one nest that apparently failed due to poor gas exchange. Nourishment had no significant effect on compaction; however, nests in nourished areas were on average 1.9°C warmer than nests laid at the same time on undisturbed beaches. Although sex ratios were not determined, Holloman and Godfrey concluded that the increase in nest temperature on nourished beaches probably increased the number of females produced. Studies documenting declines in nesting success on nourished beaches have generally reported a return to normal nesting activity by the second or third post-nourishment nesting season (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). These studies attributed the observed declines in nesting primarily to substrate compaction, escarpment formation, and/or modification of the natural beach profile. In contrast, studies have also reported immediate increases in nesting success following nourishment projects on chronically eroded beaches (Davis et al. 1999 and Byrd 2004). Studies of hatching success on nourished beaches have reported positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000, and Ehrhart and Roberts 2001), negative effects (Ehrhart 1995, Ecological Associates Inc. 1999), and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, and Brock et al. 2009). The variation in responses has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009).

It is anticipated that the use of compatible sediments in accordance with the state technical standards for beach fill would minimize the potential for long-term effects on sea turtle nesting habitat. Conservation measures would include escarpment and sediment compaction monitoring with appropriate remediation as needed (see further discussion of Conservation Measures in Section 6). Therefore, it is anticipated that physical habitat recovery would occur relatively rapidly, thus minimizing the duration of any adverse indirect habitat-modification effects on sea turtles. Nourishment would improve the quality of potential East End nesting habitat through the maintenance a wider dry beach. In the absence of nourishment, the potential for sea turtle nesting along the chronically eroded East End beach would be very low; therefore, it is anticipated that Alternative 1 would have a net beneficial indirect impact on the quality of East End nesting habitat.

Cumulative Impacts

Beach fill placement and associated dredging activities under Alternative 1 would not be expected to have any direct impacts on sea turtles, and it is anticipated that Alternative 1 would have a net beneficial indirect impact on habitat quality. Therefore, adverse cumulative impacts on sea turtles would not be expected under Alternative 1.

<u>Atlantic and Shortnose Sturgeons</u>

Direct, Indirect, and Cumulative Impacts

Dredging operations can potentially impact Atlantic and shortnose sturgeons directly through entrainment in the dredge intake pipe and/or indirectly through sediment suspension and soft bottom habitat modification. Between 1990 and 2007, federal navigation dredging operations along the Atlantic Coast resulted in the take of 11 Atlantic sturgeons and 11 shortnose sturgeons (USACE 2008). All of the shortnose sturgeon takes occurred along the North Atlantic Coast in the Delaware and Kennebec Rivers, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor included one by a hopper dredge and one by a clamshell dredge. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; therefore, its presence in the LFIX and bend widener channels during dredging operations would not be expected. Based on its low probability of occurrence and the absence of reported dredge interactions along the South Atlantic Coast, direct and indirect impacts on shortnose sturgeon would not be expected under Alternative 1. As indicated above, cutterhead dredges are not historically known to take Atlantic sturgeon; therefore, direct dredging-induced impacts on Atlantic sturgeon would not be expected. Dredging operations would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, indirect impacts related to foraging habitat modification would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on shortnose and Atlantic sturgeons would not be expected under Alternative 1.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

The USACE has conducted comprehensive annual surveys for seabeach amaranth on Holden Beach since 1992. Small numbers of plants were recorded on the East End beach during each of the annual surveys conducted from 1992 through 2006; however, seabeach amaranth was not found on the East End during surveys conducted from 2007 – 2011. Beach nourishment has the potential for both beneficial and detrimental indirect effects on seabeach amaranth. In the case of severely eroded beaches, the restoration of a wider vegetation-free dry beach can improve the quality of potential habitat; whereas projects conducted during the growing season can have adverse effects through the burial of living plants (USFWS 2005). Seabeach amaranth is an annual, meaning that the presence of plants in any given year is dependent on seed production and dispersal during previous years. Seeds that are redistributed by sand placement and grading operations may be deposited in unsuitable habitats; whereas seeds that are banked in borrow site sediments may be transferred to suitable beach habitats. Little is known of the relationship between nourishment, seed burial, and germination; however, increases in seabeach amaranth numbers have been observed following nourishment projects on Bogue Banks, possibly due to the creation of new habitat and/or the redistribution of seeds along with the beach fill (Personal communication, D. Suitor, USFWS Raleigh Ecological Services Field Office, 2011). Although the full effects of beach nourishment are not known, the USFWS generally believes that nourishment projects completed during the winter are not detrimental to seabeach amaranth (USFWS 2005). Under Alternative 1, the established environmental nourishment window (16 November - 30 April) would avoid the majority of the seabeach amaranth growing season; however, nourishment towards the end of the window in April could result in the burial of some early seedlings. Nourishment would be expected to improve habitat quality by increasing the width of the dry beach. The absence of plants along the East End in recent years is likely the result of long-term chronic erosion, thus indicating that future occurrences may be unlikely without nourishment. Therefore, it is anticipated that the net effect of East End nourishment on seabeach amaranth would be beneficial.

5.4.1.8 Cultural Resources

Direct, Indirect, and Cumulative Impacts

The remains of four Civil War vessels at LFI are listed in the National Register of Historic Places (NRHP) under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (Ranger) is located ~1 mile west of the inlet (Tidewater Atlantic Research 2011). All of the Civil War shipwrecks are located seaward of the COLREGS line that extends across the mouth of the inlet throat; whereas the LFIX and bend widener channels are associated with the AIWW on the soundside of the inlet. Alternative 1 would involve the continuation of current dredging practices within the existing federally authorized LFIX/bend widener navigation channels; and therefore, no direct, indirect, or cumulative impacts on cultural resources would be expected.

5.4.1.9 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Beach Construction

Beach construction would involve the use of bulldozers and possibly backhoes to redistribute beach fill as it is discharged onto the nourishment beach. In order to take advantage of the limited nourishment window and maximize the efficient use of manpower and machinery, beach nourishment operations would be conducted around-the-clock. As with any construction project involving the use of heavy machinery, beach construction would present a minor short-term risk to public safety. However, adherence to the established environmental nourishment window (16 November - 30 April) would limit beach construction to the colder months when recreational use is at its lowest point, thus limiting public exposure to construction activities. In order to maintain separation between the public and potentially hazardous operations, the active construction area, consisting of a ~500-ft zone on either side of the beach fill discharge point, would be fenced. During nighttime operations, appropriate lighting would be provided in accordance with USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones. Regulations also require front and back lighting on all transport vehicles and bulldozers during nighttime operations. Considering these safety measures, as well as the anticipated low level of recreational activity during the period of construction and the short-term duration of potential effects; it is anticipated that any direct, indirect, and cumulative impacts on public safety under Alternative 1 would be negligible.

Dredging

As indicated above, the limited nourishment window and the high costs associated with dredging would necessitate around-the-clock operations in the LFIX/bend widener channels. Dredges and associated pump and pipeline systems would present a minor short-term collision risk to recreational boaters. However, adherence to the established environmental nourishment window (16 November – 30 April) would limit operations to the colder months when recreational boating activity is at its lowest point, thus limiting the potential for interactions between dredges and recreational vessels. During nighttime operations, appropriate on-board lighting would be provided in accordance with USACE and OSHA safety regulations. The USACE Safety and

Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of 30 lumens per square foot on dredges. Dredges would be subject to vessel inspections and other federal safety regulations that are enforced by the USCG. As necessary to ensure the safety of recreational boating activities, the USCG would establish temporary safety zones around dredging operations. Considering these safety measures, as well as the anticipated low level of recreational boating activity during the period of construction and the short-term duration of potential effects, it is anticipated that any direct, indirect, and cumulative impacts on public safety under Alternative 1 would be negligible.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

During beach nourishment events, the presence of pipelines and construction equipment on the beach, as well as the associated emissions of noise and light, would temporarily diminish the aesthetic quality of the East End beach. Temporary construction safety zones would restrict public beach access within a ~500-ft zone on either side of the beach fill discharge point, thus potentially impacting recreational activities such as beach-combing, fishing, and surfing. Similarly, the presence of dredges and support vessels/barges within the LFIX/bend widener channels would temporarily degrade scenic vistas and could slow recreational boating traffic. Public exposure to aesthetic and recreational impacts would be limited, as the proposed environmental nourishment window (16 November – 30 April) would limit beach fill and dredging operations to the colder months when recreational beach use is at its lowest point. Conversely, beach nourishment projects under Alternative 1 would maintain a wider beach, thus resulting in long-term beneficial effects on recreation and aesthetic quality. Furthermore, the additional storm protection provided by nourishment would reduce the need for emergency measures (sandbags, beach/dune scraping) that would be detrimental to recreation and the aesthetic quality of the beach. Considering the short-term nature of the adverse impacts and the low level of public exposure to these impacts, the long-term beneficial effects would be expected to outweigh any adverse effects, thus resulting in a net beneficial effect on aesthetics and recreation. Therefore, adverse direct, indirect, or cumulative impacts on aesthetics and recreation would not be expected under Alternative 1.

<u>Navigation</u>

Direct, Indirect, and Cumulative Impacts

Alternative 1 would involve the continuation of current dredging operations within the existing federally authorized LFIX and bend widener channels. Therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 1.

Infrastructure

Under Alternative 1, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, placing 19 oceanfront properties and ~250 ft of roads and associated linear utilities at risk of erosional damage.

Economics

Under Alternative 1, construction and maintenance costs would include those associated with periodic beach nourishment, including the costs of beach fill, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with periodic nourishment and borrow site dredging activities. Over a 30-year planning horizon, assuming nourishment of the East End Beach with approximately 100,000 cy of sand every two years, and an annual four percent increase in fill costs, Alternative 1 is expected to involve total construction costs of approximately $46.21 million. In present value terms, construction costs range from $18.45 million (6% discount rate) to approximately $30.34 million (2.5% discount rate).

The erosional impacts of the alternatives on properties and infrastructure were projected based on model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix O). As described above, Alternative 1 would be expected to impact 19 properties (13 improved) and ~250 linear ft of roads and associated water, sewer, and power lines. The total assessed value of all properties projected to be newly impacted under Alternative 1 is roughly $3.01 million. The 250 linear ft of anticipated infrastructure replacement cost is valued at approximately $191,000, with a present value ranging from approximately $151,000 (6% discount rate) to $173,000 (2.5% discount rate). Under Alternative 1, use and non-use values associated with recreation, aesthetics, and the natural environment (Table 5.7) are generally expected to be enhanced relative to Alternative 2 and diminished relative to Alternatives 3, 4, 5, and 6. Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. The principle benefit of Alternative 1 would be maintenance of the current stock and flow of market and non-market goods and services.

Table 5.7. Alternative 1 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$46.21 M
Construction and Maintenance (Present Value)	$18.45 M – $30.34 M
Parcels at risk	19
Assessed Tax Value of Affected Parcels	$3.01 M
Infrastructure Replacement Costs	$190,699
Infrastructure Replacement Costs (Present Value)	$151,052 - $172,764
Reduction in tax base	High
Transition costs	High
Diminished recreation value	High
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	High
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Intermediate
Enhanced property value	None
Enhanced Recreation value	Low
Environmental Improvement	
Public non-use value (nature)	Intermediate
Public non-use value (Holden Beach)	Low

5.4.2 Alternative 2: Abandon and Retreat

Under Alternative 2, the Town would not pursue a long-term management plan, and there would not be any federally-implemented or federally-permitted actions undertaken to mitigate erosion along the East End beach. The USACE would not conduct any East End beneficial use projects; and the Town would not conduct any actions that require a federal dredge and fill permit; including beach nourishment, beach scraping, dune restoration, temporary sandbag placement, and inlet dredging. Instead, the town would develop and implement a 30-year managed retreat plan; under which structures that are threatened with erosional damage would be either relocated to unimproved interior lots or demolished. As structures become threatened by erosional damage, it is assumed that individual homeowners may implement temporary protective measures such as the placement of sandbags and/or beach scraping above the MHW line.

5.4.2.1 Geology and Sediments

Actions taken under Alternative 2 would be limited to shore-based activities; and therefore, no project-related effects on seafloor geology or sediments would be expected. The demolition and relocation of structures would potentially include operations by heavy machinery on the beach; potentially resulting in minor mechanical substrate disturbance. Demolition and relocation projects would occur individually; and therefore, the extent of sediment disturbance at any given time would be negligible.

5.4.2.2 Marine Benthic Communities

<u>Soft Bottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no project-related direct, indirect, or cumulative impacts on soft bottom communities would be expected. Federal maintenance dredging of the main LFIX navigation channel would continue under a regime similar to that of the No Action alternative; however, in the absence of beneficial use projects, the 400-ft bend widener would not be dredged under Alternative 2. Therefore, relative to the No Action alternative; dredging-induced direct, indirect, and cumulative impacts on soft bottom benthic invertebrate communities and predatory demersal fishes would be slightly reduced under Alternative 2.

<u>Hardbottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no direct, indirect, or cumulative impacts on hardbottom communities would be expected.

5.4.2.3 Water Column

<u>Hydrodynamics</u>

Direct and Indirect Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no project-related direct or indirect impacts on hydrodynamics would be expected. Hydrodynamic changes under Alternative 2 were modeled to establish a baseline for analyzing the relative impacts of the remaining action alternatives (Alternatives 1, 3, 4, 5, and 6). In the absence of project-related effects, the model-projected hydrodynamic changes under Alternative 2 primarily reflect the influence of natural coastal processes.

Modeling was conducted on the outer channel and resulted in insignificant effects on the shoreline and sediment transport processes (Personal communication, F. Way, ATM, Engineer on record, July 2015). Shoaling and/or migration of the LFI channel occurred within a few months in the modeling (agreement with analysis of past USACE surveys). The LFI channel is narrow and shallow and follows deep water, thereby it wouldn't be expected to remain navigable. Additionally, the side-cast dredgers work the outer channel and their movement of material is negligible from a sediment transport perspective. Federal channel dredging has been absent for up to a year in recent history. For example, in 2012 the inlet buoys were pulled for 36 weeks due to lack of federal dredging (the channel remained navigable for 3 - 4 months prior to the last LFI dredging event, therefore 36 weeks + ~3.5 months = a year). Similar long-term events have also occurred where the Coast Guard has needed to pull the buoys from the inlet. Due to the lack of consistent federal funding and the fact that several model runs of different channel alignments showed no significant effect on the shoreline and sediment transport processes, the four-year Alternative 2 model run did not include the LFI maintenance dredging. Additionally, all long-term four-year modeled runs were run under similar conditions in order to compare "apples to apples." Stopping the different model runs to "dredge" a 150-ft wide channel following deep water every 3 months would be impractical to implement for every single run, especially considering that sidecasting this small channel was modeled for several 1-yr simulations and shown to be insignificant on shoreline and sediment transport processes.

Sediment deposition in the Permit Area AIWW/LFIX navigation channels rapidly reduces their water volume capacity, thereby restricting tidal flow and reducing the inlet tidal prism (the “tidal prism” refers to the combined total volume of water that flows in and out of the inlet during a single ebb/flood tidal cycle). Model-simulated tidal prism volumes across transects located in the inlet throat, Eastern Channel, AIWW East channel, and AIWW West channel are steadily reduced over the course of the four-year model simulation period (Table 5.8). By the end of Year 4, the projected volumes are reduced 20 to 90 percent relative to the starting Year-0 condition. The reduction of tidal flow is most extreme in the AIWW West channel, where the extent of model-projected shoaling at the end of Year 4 is

Table 5.8. Alternative 2 model-simulated tidal prism volumes (100 mcf).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	4.24	3.68	0.52	0.13	2.19	2.14	0.54	0.69
1	4.02	3.74	0.33	0.27	2.07	1.96	0.55	0.64
2	3.68	3.69	0.22	0.22	1.95	1.83	0.56	0.65
3	3.28	3.05	0.16	0.15	1.84	1.74	0.52	0.49
4	2.79	2.88	0.12	0.14	1.75	1.64	0.31	0.46
Neap Tide								
0	2.90	2.43	0.40	0.16	1.57	1.47	0.34	0.38
1	2.73	2.33	0.25	0.20	1.47	1.34	0.36	0.34
2	2.39	2.19	0.11	0.10	1.37	1.23	0.35	0.35
3	2.07	1.83	0.07	0.08	1.36	1.21	0.25	0.24
4	1.71	1.62	0.04	0.04	1.18	1.06	0.18	0.22

such that flow is essentially completely restricted at low tide. As flow is reduced through the navigation channels, extensive shoaling occurs in the adjacent estuarine waters bordering the AIWW West channel and the Eastern Channel. By the end of Year 4, shoaling across the mouth of the Lockwoods Folly River has reached the extent that tidal flow between the river and the AIWW is almost completely restricted at low tide. Most of the outer LFI navigation channel has filled in by the end of Year 4, and the inlet throat ebb channel has shifted westward in response to westward expansion of the Flood Shoal. The Flood Shoal has a natural propensity for westward expansion; a characteristic that is normally kept in check by maintenance dredging of the LFIX and LFI navigation channels. However, in the absence of navigation dredging, the Flood Shoal reverts to its natural accretional pattern.

Cumulative Impacts

In the absence of anticipated project-related direct and indirect effects, no project-related cumulative effects on hydrodynamics would be expected under Alternative 2. Federal maintenance dredging of the Permit Area navigation channels would be expected to continue under a regime similar to that of current operations, thus slowing the projected Flood Shoal/ebb channel response described above. However, the federally authorized LFI navigation project stipulates that dredging must follow the path of the deep-water ebb channel as it exists at the time of maintenance events. Unimpeded erosion of the East End shoreline would lead to an accelerated rate of westward channel migration during the interim periods between maintenance events, thus potentially resulting in a gradual incremental westward shift in the channel position towards Holden Beach. Therefore, it is anticipated that hydrodynamic conditions could eventually approximate those projected by the model.

Sediment Suspension, Underwater Noise, and Entrainment

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities; and therefore, no direct, indirect, or cumulative impacts related to sediment suspension, underwater noise, or entrainment would be expected.

5.4.2.4 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

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

Indirect Impacts

Under Alternative 2, the CMS model-projected oceanfront shoreline responses along the east end of Holden Beach and the west end of Oak Island primarily reflect the influence of natural background processes of erosion and accretion. On Holden Beach, the projected shoreline and intertidal beach habitat changes along the easternmost ~1,000-ft section of the oceanfront beach are dominated by shoal attachment along the inlet shoulder. As a result of shoal attachment, the eastern 1,000-ft reach is net accretional at the end of four-year model simulation period, resulting in a net gain of ~2 ac of intertidal beach habitat (Figure 5.11). The remainder of the East End oceanfront shoreline to the west (~5,500-ft) is erosional throughout the model simulation period, resulting in a net loss of ~14 ac of intertidal beach habitat at the end of Year 4. Additionally, ~5 ac of intertidal beach habitat are added to the western reach through erosional dry beach-to-intertidal beach habitat conversion. Thus, the overall projected intertidal beach habitat change on Holden Beach is a net loss of ~7 ac at the end of Year 4. On Oak Island, the entire Permit Area west-end oceanfront beach is erosional throughout the model simulation period, resulting in a net loss of ~10 ac of intertidal beach habitat at the end of Year 4. Under the No Action alternative, the modeling results show a loss of ~3 ac of East End intertidal beach habitat at the end of Year 4. Thus, the modeling results suggest that the extent

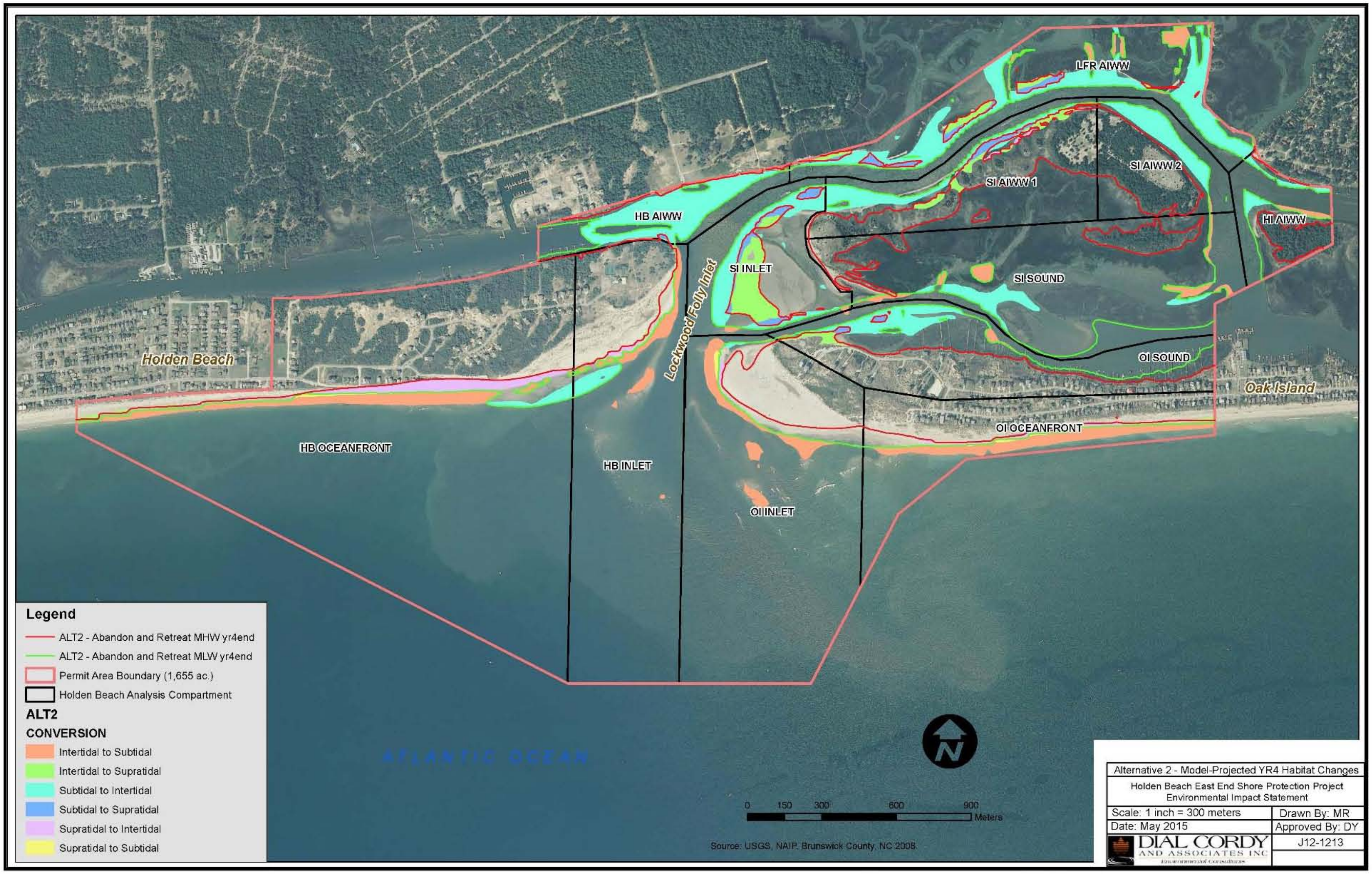


Figure 5.11. Alternative 2 – Model-Projected YR4 Habitat Changes

of East End intertidal beach habitat loss under Alternative 2 (~7 ac) would exceed that of the No Action alternative by ~4 ac.

Cumulative Impacts

In the absence of beach management, cumulative effects on the East End beach would be driven by natural erosional processes and sea level rise. As the receding shoreline begins to threaten oceanfront structures, it is assumed that the response of most property owners would include the placement of sandbags. The placement of sandbags would temporarily impede shoreline recession; however, continued shoreface erosion would cause the intertidal beach to gradually steepen and narrow. This process would be expected to accelerate as sea level continues to rise, leading to the failure of existing oceanfront sandbags and the stepwise placement of new sandbags along landward properties. Under a scenario of continued shoreface erosion without island migration, it is expected that most of the intertidal beach would eventually be converted to subtidal soft bottom habitat. Thus, Alternative 2 would be expected to have adverse cumulative effects on intertidal beach communities via habitat loss.

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

Direct Impacts

As indicated above, the demolition and/or relocation of structures would potentially include operations by heavy machinery on the beach; potentially resulting in minor direct impacts on dry beach and dune communities. Construction contracts would specify avoidance of dunes and dune vegetation to the maximum extent practicable, and any unavoidable or accidental damage to dunes or dune vegetation would require restabilization via replanting with native dune vegetation. Demolition and relocation projects would occur individually; resulting in minor localized disturbance to unvegetated beach sediments that would not be expected to have significant adverse erosional effects. Relocations may have minor direct impacts on dune communities associated with the recipient lots. The dune system along the vast majority of Holden Beach is limited to a single narrow constructed frontal dune that separates the oceanfront beach from the improved island interior. Recipient lots would include a combination of oceanfront and interior parcels. In the case of oceanfront recipient parcels, NC CAMA ocean setback rules would limit frontal dune impacts to the construction of beach access walkways. Natural secondary dunes and interior dune ridges are absent from the vast majority of the improved island interior; including the areas containing available vacant lots. Therefore, it is anticipated that the extent of direct impacts would be minor.

Indirect Impacts

Under Alternative 2, the CMS modeling results indicate erosional losses of ~5 ac of dry beach and dune habitat along the easternmost ~4,000-ft reach of the Holden Beach oceanfront shoreline (Figure 5.11). To the west along the remaining ~2,500-ft of the East End beach, there is no change in the MHW line position, and thus no projected loss or gain of dry beach habitat. In the case of Oak Island, the modeling results show a relatively minor and irregular landward shift in the MHW line, resulting in erosional losses of ~3 ac of dry beach habitat at the end of Year 4. Under the No Action alternative (Alternative 1) the modeling results show a loss of ~3 ac of East End dry beach and dune habitat at the end of Year 4. Thus, the modeling results suggest that the extent of East End dry beach and dune habitat loss under Alternative 2 (~5 ac) would exceed that of the No Action alternative by ~2 ac.

Cumulative Impacts

Potential cumulative effects on dry beach and dune communities would be similar to those described above for the intertidal beach. Under a scenario of continued shoreface erosion with island migration, it is expected that most of the dry beach and dune system would eventually be converted to subtidal soft bottom habitat. Thus, Alternative 2 would be expected to have adverse cumulative effects on dry beach and dune communities via habitat loss.

5.4.2.5 Inlet Complex

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Under Alternative 2, demolition and/or relocation activities would be shore-based and limited to the oceanfront beach. Therefore, direct impacts on intertidal flats and shoals would not be expected under Alternative 2.

Indirect Impacts

Although small, short-lived, emergent shoals occasionally form along the margins of the ebb channel near the mouth of the inlet throat, the interior Flood Shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. The CMS model-projected Flood Shoal response under Alternative 2 is characterized by westward accretional growth, resulting in the creation of ~11 ac of new intertidal shoal habitat (Figure 5.11). In addition, large volumes of sediment are deposited on the existing intertidal flood shoal, resulting in ~9 ac of intertidal-to-supratidal shoal habitat conversion. Thus, the modeling results suggest a net increase in intertidal flood shoal habitat of ~2 ac at the end of Year 4.

The majority of the Holden Beach inlet shoreline is erosional throughout the model simulation period, resulting in a loss of ~7 ac of intertidal inlet beach habitat at the end of Year 4; however, shoal attachment along the inlet shoulder adds ~3 ac of intertidal inlet beach habitat along the southernmost ~700-ft inlet shoreline reach (Figure 5.11). The entirety of the Oak Island inlet shoreline is erosional throughout the model simulation period, resulting in a projected loss of ~7 ac of intertidal inlet beach habitat at the end of Year 4. Much of the projected intertidal inlet beach habitat loss on Holden Beach and Oak Island is related to the process of westward flood shoal expansion and related effects on the alignment of the inlet throat ebb tidal channel. The westward-expanding flood shoal pushes the inlet throat ebb channel westward, accelerating erosion and habitat loss on Holden Beach. Flood shoal expansion also pushes the mouth of the Eastern Channel slightly southward, redirecting flow towards the western tip of Oak Island; while at the same time the southern segment of the inlet throat ebb channel adopts a straighter north-south alignment, resulting in an eastward channel shift towards the Oak Island inlet shoreline.

Cumulative Impacts

Long-term unmitigated erosion of the East End shoreline in combination with sea level rise could affect inlet hydrodynamics and ebb channel migration. Changes in ebb channel alignment could in turn alter patterns of erosion, accretion, and shoaling within the inlet; thereby leading to the reconfiguration of intertidal habitats. However, continued federal navigation dredging of the inlet ebb channel would limit the potential for rapid ebb channel changes, and it is anticipated that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on intertidal flats and shoals would not be expected under Alternative 2.

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

Direct Impacts

Under Alternative 2, demolition and relocation activities would be limited to the oceanfront beach; therefore, direct impacts on inlet dry beach and dune communities would not be expected. Construction contracts would specify avoidance of dunes and dune vegetation to the maximum extent practicable, and any unavoidable or accidental damage to dunes or dune vegetation would require restabilization via replanting with native dune vegetation. Demolition and relocation projects would occur individually; resulting in minor localized disturbance to unvegetated beach sediments that would not be expected to have significant adverse erosional effects.

Indirect Impacts

The modeling results show little change in the MHW line positions associated with the Holden Beach and Oak Island inlet shorelines. In the case of both Holden Beach and Oak Island, relatively minor recession of the MHW line results in a loss of ~1 ac of dry inlet beach habitat at the end of the four-year model simulation period (Figure 5.11). As described above, sediment deposition on the existing intertidal flood shoal results in ~9 ac of intertidal-to-supratidal shoal habitat conversion. An additional ~4 ac of supratidal shoal habitat is added to the flood shoal through the process of westward accretion described above, resulting in an overall projected supratidal shoal habitat increase of ~13 ac at the end of Year 4.

Cumulative Impacts

Potential cumulative effects on inlet dry beach and dune communities would be similar to those described above for the intertidal flats and shoals. Unmitigated East End erosion and sea level rise could affect inlet hydrodynamics, thereby leading to the reconfiguration of inlet dry beach and dune habitats. However, continued federal navigation dredging of the inlet ebb channel would be expected to limit the potential for rapid ebb channel changes, and it is anticipated that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on inlet dry beach and dune communities would not be expected under Alternative 2.

5.4.2.6 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities; and therefore, would not be expected to have any direct, indirect, or cumulative impacts on shellfish.

SAV

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities, and therefore, would not be expected to have any direct, indirect, or cumulative impacts on SAV.

Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities, and therefore, would not be expected to have any direct, indirect, or cumulative impacts on tidal marshes.

5.4.2.7 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would generate underwater noise or vessel traffic; and therefore, Alternative 2 would not have any direct, indirect, or cumulative impacts on right or humpback whales or proposed right whale critical habitat.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would generate vessel traffic or affect potential manatee foraging habitats; therefore, Alternative 2 would not have any direct, indirect, or cumulative impacts on the West Indian manatee.

Piping Plover

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, demolition and relocation activities could include operations by heavy machinery on the East End oceanfront beach; temporarily displacing shorebirds and potentially resulting in minor short-term habitat disturbance. However, wintering piping plovers are very rarely seen on developed oceanfront beaches in NC (Cameron 2009). Similarly, piping plover breeding sites on NC's developed barrier islands are restricted to inlet habitats associated with the accreting ends of the islands (USFWS 2009). Sand flat and emergent shoal habitats associated with the Oak Island sand spit and the flood shoal are designated critical habitat for the Atlantic Coast wintering population of piping plovers; however, these areas are located on the opposite (eastern) side of the LFI channel at a minimum distance of ~0.5 mile from the eastern terminus of the Holden Beach oceanfront shoreline. Therefore, East End relocation and demolition activities under Alternative 2 would not be expected to have any direct, indirect, or cumulative impacts on piping plovers or potential habitat. In the absence of efforts to mitigate East End erosion, unimpeded shoreline recession would be expected to initially reduce the quality and quantity of potential piping plover habitats associated with the Holden Beach inlet shoreline. If all residential structures were removed from the East End of the island, and if ocean-to-sound overwash (barrier island migration or rollover) was allowed to occur unimpeded, the quality and quantity of potential piping plover habitat could eventually improve. However, this scenario would be considered unlikely during the foreseeable future, as the extent of erosion would not be sufficient to warrant the removal of all houses on the East End. The CMS modeling analysis is limited to a four-year period; and furthermore, the model simulations do not account for federal navigation dredging. Thus, the ability to evaluate potential long-term cumulative effects that might result from unmitigated East End erosion is limited. However, continued federal navigation dredging of the inlet ebb channel would limit the potential for rapid ebb channel changes, and it is anticipated that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on piping plovers would not be expected under Alternative 2.

Red Knot

Under Alternative 2, demolition and relocation activities could result in short-term displacement of red knots from East End intertidal beach foraging habitats. Unmitigated erosion under Alternative 2 may affect red knots indirectly via a reduction in available beach foraging and roosting habitats. The CMS modeling results show a reduction in intertidal beach habitat of ~7 ac and a reduction in dry beach habitat of ~5 ac along the East End shoreline at the end of Year 4. As described in Section 5.4.2.3, under a long-term scenario of continued shoreface erosion without island migration, it is expected that most of the intertidal and dry beach habitats along the East End would eventually be converted to subtidal soft bottom habitat. Thus, adverse cumulative effects would be expected via loss of potential foraging and roosting habitat.

Wood Stork

Alternative 2 would not be expected to have any effect on nesting sites or estuarine foraging habitats. Therefore, no direct, indirect, or cumulative impacts on wood storks would be expected under Alternative 2.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

The CMS modeling results show a reduction in dry beach habitat of ~5 ac along the East End shoreline at the end of Year 4. The reduction in dry beach habitat, as a result of natural island roll over, would be expected to have adverse indirect effects on sea turtles via a reduction in available nesting habitat. The Permit Area encompasses portions of two designated terrestrial critical habitat units for nesting loggerheads (79 FR 39756). The Oak Island unit (LOGG–T–NC–07) extends from the mouth of the Cape Fear River to LFI and includes lands from the MHW line to the toe of the secondary dune or developed structures. The Holden Beach unit (LOGG–T–NC–08) extends from LFI to Shallotte Inlet and includes lands from the MHW line to the toe of the secondary dune or developed structures. Critical nesting habitat Primary Constituent Elements include: 1) unimpeded ocean-to-beach access for adult females and unimpeded nest-to-ocean access for hatchlings, 2) substrates that are suitable for nest construction and embryonic development, 3) a sufficiently dark nighttime environment to ensure that adult females are not deterred from nesting and that hatchlings are not disoriented and delayed or prevented from reaching the ocean, and 4) natural coastal processes that maintain suitable nesting habitat or artificially maintained habitats that mimic those associated with natural processes. As described in Section 5.4.2.3, under a long-term scenario of continued shoreface erosion without island migration, it is expected that most of the East End dry beach would eventually be converted to subtidal soft bottom habitat. Thus, adverse cumulative effects would be expected via loss of potential nesting habitat.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would present a risk of direct physical injury to sturgeon or affect potential benthic foraging habitats; and therefore, no direct, indirect, or cumulative impacts on Atlantic or shortnose sturgeons would be expected.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, the potential direct, indirect, and cumulative impacts on seabeach amaranth would be similar to those described above for the red knot and sea turtles. Short- and long-term reductions in available dry beach habitat along the East End would be expected to have adverse indirect and cumulative effects on seabeach amaranth.

5.4.2.8 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would potentially affect underwater archaeological resources; therefore, no direct, indirect, or cumulative impacts on cultural resources would be expected.

5.4.2.9 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

The managed retreat plan would establish an erosional threshold that would trigger preemptive relocations or demolitions of threatened structures prior to the point of imminent structural failure. As with any construction activity involving the use of heavy machinery, operations would present a minor short-term risk to public safety. However, operations would be confined to the winter months to the extent possible, thus limiting public exposure to construction activities. Therefore, no direct, indirect, or cumulative impacts on public safety would be expected under Alternative 2.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

During relocation and demolition activities, the presence of construction equipment and demolition debris on or adjacent to the beach, as well as the associated emissions of noise, would temporarily diminish the aesthetic quality of the East End beach. However, operations would be confined to the winter months to the extent possible, thus limiting the extent of public exposure to adverse effects. Furthermore, demolition and relocation projects would occur individually; therefore, the extent and duration of direct impacts at any given time would be negligible. Unimpeded erosion would result in a narrow chronically-eroded East End beach, thus diminishing the aesthetic quality of the beach and reducing recreational opportunities. As the receding shoreline begins to threaten oceanfront structures, it is assumed that the response of most property owners would include the placement of individual sandbags. The placement of sandbags would temporarily impede shoreline recession; however, continued shoreface erosion would cause the intertidal beach to gradually steepen and narrow. Under a scenario of continued shoreface erosion without island migration, it is expected that most of the beach would eventually be converted to subtidal bottom. Thus, Alternative 2 would be expected to have adverse cumulative effects on aesthetics and recreation via the placement of sandbags and loss of the recreational beach.

Navigation

Direct, Indirect, and Cumulative Impacts

Federal maintenance dredging of the Permit Area navigation channels would be expected to continue under a regime similar to that of current operations (does not include bend widener). Therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 2.

Infrastructure

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and associated linear utilities (Figure 5.12).

Figure 5.12. Alternative 2 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

Economics

The costs associated with Alternative 2 would pertain to loss of property and infrastructure, risk to property owners, and the costs associated with the relocation/demolition of homes and infrastructure. Additional costs would be associated with loss of recreational opportunities, loss of habitat and effects on species. Potential erosional impacts to properties and infrastructure were projected based on the model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix O). Under Alternative 2, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 28 properties (19 improved) and ~800 linear ft of roads and associated water, sewer, and power lines (Figure 5.12). The total assessed value of all properties projected to be newly at risk under Alternative 2 is roughly $5.2 million. The 800 linear feet of anticipated infrastructure replacement cost is valued at approximately $617,782, with a present value ranging from approximately $489,341 (6% discount rate) to $559,680 (2.5% discount rate). As the market capitalizes the expectation of continued shoreline erosion into the value of at-risk properties, market values may be driven toward zero (Landry 2011). Inland relocation of structures may offset some of these losses, but would involve nontrivial transition costs. A portion of the lost market value may transfer to properties located farther inland; however, a strategy of retreat is likely to convey an expectation of risk to newly beachfront properties, thereby offsetting most of the gains in amenity value. While proximity benefits associated with recreation and aesthetics will likely accrue to some property owners in the near term, it is unlikely that such values would be permanently capitalized into market values due to long term uncertainty and risk of future losses.

As a result of extensive shoreline erosion and associated losses of recreational beach area and natural habitats under Alternative 2, use and non-use values associated with recreation, aesthetics, and the natural environment are expected to be diminished relative to all other alternatives (Table 5.9). In addition, nontrivial losses of aesthetic appeal due to noise, equipment, and congestion would occur during the transition process, which would be expected to persist for the duration of the landward shift of the shoreline. Conversely, as noted by Judge et al. (1995), some individuals have a preference for non-intervention approaches that allow unimpeded erosion to take place. These individuals may derive real economic value from the existence of unfettered coastal ecosystems and natural processes. The timing, nature, and extent of these potential future benefits are difficult to characterize; however, in a sample of NC beachgoers, a majority favored beach nourishment as a means of maintaining beach width while 18 percent felt that beach width should not be altered by people (Whitehead et al. 2008).

Table 5.9. Alternative 2 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$0
Construction and Maintenance (Present Value)	$0
Parcels at risk	28
Assessed Tax Value of Affected Parcels	5.2 M
Infrastructure Replacement Costs	$617,782
Infrastructure Replacement Costs (Present Value)	$489,341 - $559,680
Reduction in tax base	Highest
Transition costs	Highest
Diminished recreation value	Highest
Diminished aesthetic value	High
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	Highest
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	N/A
Enhanced property value	None
Enhanced Recreation value	Lowest
Environmental Improvement	
Public non-use value (nature)	Highest
Public non-use value (Holden Beach)	None

5.4.3 Alternative 3: Beach Nourishment

Under Alternative 3, an approximately 0.7-mile section of the East End beach would be nourished with ~100,000 – 150,000 cy of sand every two years. The conceptual beach profile at the completion of nourishment events would consist of a +9 ft NAVD high dune with a 50-ft-wide crest, a +7 ft NAVD high, 200-ft-wide berm, and a 90- to 170-ft-wide transition with a slope of ~15 percent. The corresponding borrow site dredging regime would involve the extraction of ~120,000 – 180,000 cy of sand from the LFIX and 400-ft bend widener navigation channels every two years. In the event of a shortfall in available sand volume in the LFIX/bend widener channels, supplemental beach fill would be acquired firstly from the inland segment of the LFI navigation channel and secondarily from the Central Reach offshore borrow site. Sand extraction from the LFIX, bend widener, and inland LFI channels would be conducted by cutterhead pipeline dredges; whereas operations at the Central Reach offshore borrow site would involve the use of a trailing suction hopper dredge.

5.4.3.1 Geology and Sediments

Under Alternative 3, LFIX/LFI dredging activities and associated effects on geology and sediments would be similar to those described under the No Action alternative. Supplemental dredging at the Central Reach offshore borrow site would only be expected in the case of a shortfall in the combined available sand volume in the LFIX, bend widener, and LFI channels. Therefore, it is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited. Dredging operations at the Central Reach borrow site would involve thin layer (~3.5 ft) sediment removal by a hopper dredge. The shallow cuts would retain a minimum 2-ft buffer of compatible sand on top of the underlying fine sediment layers; thus effects on sediment composition would not be expected. Seismic surveys of the borrow site and a 500-meter buffer zone found no exposed hardbottom (ATM 2011). Therefore, Alternative 3 would not be expected to have any effects on hardbottom features.

5.4.3.2 Marine Benthic Resources

<u>Soft Bottom Communities</u>

Dredging Impacts

Direct Impacts

The anticipated borrow site dredging regime under Alternative 3 would involve the extraction of ~120,000 – 180,000 cy of sand from the LFIX and bend widener channels every two years. The direct impacts of dredging on soft bottom benthic communities in the LFIX and bend widener channels would be similar to those described under the No Action alternative. However, the bend widener would be dredged more frequently under Alternative 3, thus increasing the frequency of repeated dredging impacts on the associated benthic communities relative to the No Action alternative. LFIX/bend widener dredging events under Alternative 3 could include the adjoining inland LFI navigation channel as a supplemental sand source, resulting in additional direct impacts on soft bottom communities. In the case of the inland LFI channel, the overall frequency of project-related and interim federal navigation dredging under Alternative 3 would be similar to that of current operations; therefore, direct impacts on the associated benthic communities would not increase relative to the No Action alternative.

Supplemental dredging at the Central Reach offshore borrow site would only be expected in the case of a shortfall in the combined available sand volume in the LFIX, bend widener, and inland LFI channels. Therefore, it is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited. Dredging operations at the Central Reach borrow site would involve thin layer (~3.5 ft) sediment removal by a hopper dredge. At a dredge cut depth of 3.5 ft, extraction of ~120,000 – 180,000 cy of sand would directly impact ~30 ac of soft bottom habitat. Dredging would remove most of the associated benthic invertebrate infauna and epifauna; resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the active dredging footprint. Offshore soft bottom benthic communities are also generally dominated by opportunistic taxa that recover relatively rapidly from disturbance (Posey and Alphin 2002). However, in comparison to shallow nearshore and inshore soft bottom habitats, which are subject to frequent natural disturbance, offshore soft bottom habitats occur at much greater depths and are generally more stable. Consequently, offshore benthic assemblages generally include additional longer-lived invertebrate taxa that require longer recovery periods to reach pre-impact biomass levels. Reported rates of recovery at offshore borrow sites range from a few months to three years (Wilber and Clarke 2007). Generally, reports of relatively long recovery periods (>1 year) have been associated with fine silt/clay sediment deposition in relatively deep borrow pits; whereas relatively short recovery periods (<1 year) have generally been associated with shallow borrow pits that were rapidly infilled by sandy sediments of similar composition to the extracted material (Burlas et al. 2001). Posey and Alphin (2002) attributed relatively rapid (<9 months) recovery at ocean borrow sites along Kure Beach to rapid infilling of relatively shallow dredge cuts and avoidance of spring benthic invertebrate larval recruitment periods. Jutte et al. (1999b) attributed rapid benthic community recovery (6-9 months) in relatively shallow (~3 ft) hopper dredge furrows to the retention of benthic invertebrates on undisturbed intervening ridges, which provided an immediate source of potential recruits that likely contributed to rapid recolonization. In the case of potential hopper dredging at the Central Reach offshore borrow site, the relatively shallow (~3.5 ft) cut depths would be expected to facilitate rapid infilling of the furrows by compatible sandy sediments. Furthermore, the proposed hopper dredging environmental window (16 November - 31 March) would necessitate avoidance of spring benthic invertebrate larval recruitment periods, thus increasing the chances of relatively rapid recolonization via larval recruitment. Therefore, it is expected that offshore benthic communities would recover relatively rapidly from dredging.

Indirect Impacts

Under Alternative 3, the indirect impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative. However, each of the additional bend widener dredging events under Alternative 3 would result in an additional period of suppressed benthic infaunal prey densities; thus increasing the overall temporal extent of indirect prey-loss effects on demersal fishes. In the event of supplemental dredging at the Central Reach offshore borrow site, indirect impacts on soft bottom communities would be similar to those associated with dredging in the inshore channels; including potential indirect effects related to the redeposition of suspended sediments and losses of benthic infaunal prey. Prolonged sediment suspension and widespread dispersal are associated with fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). Sediments associated with the Central Reach borrow site are composed of medium sand (mean grain size = 0.35 mm) with a very small (~5 percent) fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension and redeposition would be localized and relatively minor.

Dredging operations at the Central Reach borrow site would employ hopper dredges, which have relatively high sediment suspension rates, primarily due to the discharge of sediments at the surface during overflow dredging (LaSalle et al. 1991). However, even during overflow hopper dredging, sediment suspension is localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction. A turbidity monitoring study by Miller et al. (2002) found that the turbidity plume associated with overflow hopper dredging in coarse-grained sediments (97 percent sand) was confined to the dredged navigation channel. Furthermore, suspended sediment concentrations in the channel returned to ambient levels within one hour of the passing of the dredge, and the range of observed turbidity levels during the project fell within the range of pre-project ambient turbidities. Based on the composition of sediments at the Central Reach borrow site and the reported characteristics of sediment suspension during overflow hopper dredging, it is anticipated that the indirect effects of dredging-induced sediment suspension and redeposition on soft bottom communities would be localized and minor. Potential indirect prey-loss effects on demersal fishes at the Central Reach borrow site would be similar to those associated with dredging in the LFIX, bend widener, and inland LFI channels. Based on the relatively small dredging footprint (~30 ac), the limited overall extent of anticipated dredging over the 30-year project life, and the expansive distribution of ocean soft bottom habitats along Holden Beach and Oak Island; it is anticipated that any indirect impacts on demersal fishes would be localized and minor.

Cumulative Impacts

Project Area

Under Alternative 3, the potential for temporally-crowded cumulative effects would be related to the frequency of repeated dredging impacts on soft bottom communities within the project-related dredging areas. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated dredging events at a specific borrow site were insufficient in length to allow for full recovery of benthic communities. In the case of the LFIX and inland LFI channels, the overall frequency of project-related and interim federal navigation dredging would be similar to that of current operations; therefore, temporally-crowded cumulative impacts would be similar to those described under the No Action alternative. Project-related bend widener dredging events under Alternative 3 would occur every two years, whereas benthic communities in dredged channels typically recover in a matter of months. Separate dredge and fill actions affecting benthic communities at the bend widener would not be expected during the 30-year project; therefore, temporally-crowded cumulative effects would not be expected under Alternative 3. The frequency and extent of dredging operations at the Central Reach offshore borrow site over the course of the 30-year project would be very limited; furthermore, the relatively thin compatible sand layer would not be expected to support multiple extractions from the same dredging footprint. Separate actions affecting benthic communities at the Central Reach borrow site would not be expected during the 30-year project; therefore, temporally-crowded cumulative effects would not be expected under Alternative 3.

Spatially-crowded cumulative effects would be related to the overall combined effect of multiple individual dredging-induced soft bottom community impacts in spatially-separate dredging areas; including the project-related borrow areas and dredging areas associated with separate actions. Dredging operations in separate federal navigation channels, including segments of the AIWW behind Holden Beach and Oak Island and the outer LFI navigation channel, could occur in close temporal proximity to project-related and interim federal dredging activities in the LFIX/bend widener and inland LFI channels. Concurrent reductions in benthic invertebrate densities within the LFIX/bend widener, inland LFI, and separate federal channels could potentially result in spatially-crowded cumulative effects on predatory demersal fishes. However, considering the anticipated rapid rates (≤6 months) of benthic community recovery, it is expected that spatially-crowded cumulative effects on demersal fishes at the community and/or population level would be localized and short term. In the event of supplemental dredging at the Central Reach offshore borrow site, potential separate actions affecting spatially-separate areas of soft bottom habitat would include dredging associated with the 2016/2017 Central Reach nourishment project, the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan. Dredging associated with the Central Reach nourishment project would likely occur at least one year prior to the initiation of project-related dredging activities under Alternative 3, thus indicating that impacted soft bottom communities would be substantially recovered at the time of any project-related impacts at the

Central Reach borrow site. In the event of concurrent East End/Bald Head Island dredging projects, the relatively small area (~30 ac) of East End project-related dredging impact and the distance (~15 miles) between the Central Reach borrow site and Frying Pan Shoals/Jay Bird Shoals suggest that any spatially-crowded cumulative effects would be negligible.

Regional

On a regional scale, LFIX/LFI dredging events would be expected to coincide with other inlet navigation dredging projects along the southern NC coast over the 30-year life of the project. Of the 15 inlets that divide the southern NC barrier islands, nine have both inlet and AIWW inlet-crossing channels that are currently maintained under federal navigation projects; including two deep draft inlet navigation projects (Beaufort and Cape Fear Inlets) and seven shallow draft inlet projects (Shallotte, Lockwoods Folly, Carolina Beach, Masonboro, New River, New Topsail, and Bogue). The shallow draft channels and some portions of the deep draft channels are generally dredged at least once a year. Simultaneous impacts on soft bottom habitats and benthic invertebrate communities at separate inlets could potentially have combined effects on the foraging activities of migratory demersal fishes. However, benthic communities in dredged channels typically recover in a matter of months, and the combined extent of habitat disturbance would constitute a small fraction of the available soft bottom habitat along the southern NC coast. Therefore, it is expected that any cumulative effects resulting from LFIX/LFI dredging would be minor and short-term. Based on the limited extent of potential supplemental dredging at the Central Reach offshore borrow site, and considering that soft bottom habitats cover vast areas of the seafloor along the southern NC coast, any ocean borrow site dredging activities under Alternative 3 would not be expected to have any regional scale cumulative effects.

Beach Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, the direct, indirect, and cumulative impacts of beach fill placement on soft bottom communities would be similar to those described under the No Action alternative.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

State coastal management regulations prohibit borrow sites within 500 m of hardbottom areas (15A NCAC 07H.0208). The 500-m rule is designed to prevent both direct physical impacts from dredging, as well as indirect impacts related to the dispersal and redeposition of suspended sediments. Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf, which are located well seaward of the beach fill footprint and the LFIX/LFI navigation channels. In the case of the Central Reach offshore borrow site, compliance with the 500-m rule was confirmed through remote sensing surveys conducted in 2011 (Tidewater Atlantic Research 2011). The Central Reach borrow site was subsequently approved and permitted for the Holden Beach Central Reach nourishment project (Appendix Q). Potential sand delivery pipeline routes for East End projects have yet to be identified; however, approvals of proposed East End projects would be contingent on pre-project surveys demonstrating avoidance of hardbottom features. Based on the demonstrated absence of hardbottom features within 500 m of the Central Reach offshore borrow site; and the commitment to avoid hardbottom sites during pipeline placement; Alternative 3 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.3.3 Water Column

Hydrodynamics

Direct and Indirect Impacts

Under Alternative 3, the potential direct and indirect impacts of dredging operations in the LFIX/bend widener and LFI channels on hydrodynamics would be similar to those described under the No Action alternative. The CMS modeling results suggest that bend widener dredging tends to shift the corresponding LFI ebb channel segment slightly eastward to a more centralized position between Holden Beach and the flood shoal, thus reducing erosion along the northern inlet shoreline of Holden Beach. The projected shift is temporary, with the channel returning to its westward position against the inlet shoreline as rapid shoaling fills in the bend widener. Under Alternative 3, the bend widener would be dredged more frequently; thus generally maintaining a more eastward alignment and reducing the average rate of erosion over the course of the 30-year project relative to the No Action alternative. Ocean depths at the Central Reach offshore borrow site range from ~30 to 35 ft MSL; and therefore, in the case of supplemental dredging, the relatively shallow (~3.5 ft) furrows created by hopper dredging would not be expected to have any effect on wave conditions or wave-driven currents.

The CMS model-projected inlet and estuarine hydrodynamic responses to beach nourishment under Alternative 3 are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities across transects located in the inlet throat, Eastern Channel, and AIWW east/west channels are consistently within +/-5 percent of the corresponding Alternative 2 values throughout the four-year model simulation period (Table 5.10). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all four of the inlet/estuarine transects. Corresponding model-projected changes in channel morphology under Alternative 3 are similarly nearly identical to those associated with Alternative 2. The similarity of the responses suggests that the model-projected hydrological and morphological responses under Alternative 3 are primarily the result of natural background coastal processes; thus indicating that beach nourishment would have little effect on hydrodynamics.

Table 5.10. Alternative 3 - relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	100%	100%	99%	97%	100%	100%	100%	100%
1	97%	97%	96%	96%	100%	100%	100%	100%
2	97%	96%	96%	79%	100%	100%	99%	100%
3	100%	98%	94%	98%	101%	97%	97%	100%
4	107%	100%	88%	100%	98%	99%	153%	103%
Neap Tide								
0	100%	100%	100%	98%	100%	100%	100%	100%
1	96%	97%	92%	89%	100%	100%	100%	100%
2	97%	92%	94%	97%	100%	101%	99%	75%
3	98%	99%	90%	67%	97%	101%	97%	101%
4	104%	101%	117%	105%	99%	102%	124%	104%

Cumulative Impacts

Under Alternative 3, the CMS modeling results indicate that direct and indirect impacts on hydrodynamic conditions would be limited to short-term, localized effects on the ebb channel in the immediate vicinity of the bend widener. Furthermore, federal navigation dredging practices within the Permit Area and adjacent federal channels would be expected to continue under the current dredging regime. Therefore, cumulative hydrodynamic impacts would not be expected Under Alternative 3.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Under Alternative 3 the direct, indirect, and cumulative impacts of dredging operations in the LFIX/bend widener and inland LFI channels would be comparable to those described under the

No Action alternative. In the event of supplemental dredging at the Central Reach offshore borrow site, the impacts of dredging-induced sediment suspension would be of a similar nature to the impacts of dredging in the inshore channels. Sediments associated with the Central Reach borrow site are similarly composed of medium sand (mean grain size = 0.35 mm) with a very small (~5 percent) fine sediment fraction. Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In contrast to the use of cutterhead dredges in the inshore channels, operations at the Central Reach borrow site would employ hopper dredges. Hopper dredges are generally associated with higher rates of sediment suspension, primarily due to the discharge of sediments at the surface during overflow dredging (LaSalle et al. 1991). However, even in the case of overflow hopper dredging, sediment suspension is characteristically localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction. According to Miller et al. (2002), the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments was confined to the dredged navigation channel. Suspended sediment concentrations in the channel returned to ambient levels within one hour of the passing of the dredge, and the observed range of turbidity levels during dredging operations remained within the range of pre-project ambient turbidities. Therefore, it is anticipated that the extent and duration of dredging-induced sediment suspension at the Central Reach borrow site would be localized and short term; thus indicating that direct and indirect impacts on water quality and pelagic communities would be relatively minor. Based on the short-term, localized nature of the direct and indirect impacts, cumulative impacts would not be expected under Alternative 3.

Beach Fill Placement

Under Alternative 3, beach fill placement operations and the associated direct, indirect, and cumulative effects of sediment suspension on water quality and pelagic communities would be similar to those described under the No Action alternative.

<u>Underwater Noise</u>

Direct and Indirect Impacts

Under Alternative 3, the direct and indirect impacts of underwater dredging noise associated with operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative. Dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1µPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS (2010b) has cited the study by Clarke et al. (2002) as an appropriate basis for evaluating hopper dredge noise at sand borrow sites, as it involved similar substrate (i.e., sand) and metrics that are consistent (i.e., SPL rms values) with established

NMFS marine mammal and sea turtle noise impact thresholds. The NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to SPL rms noise levels ≥180 dB re 1µPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1µPa rms or continuous noise levels ≥120 dB re 1µPa constitute Level B harassment with the potential to cause behavioral disruption. The NMFS has used similar criteria to assess the impacts of dredging noise on sea turtles, specifically ≥180 dB re 1µPa rms for injurious effects, and based on a study by McCauley (2000), ≥166 dB re 1µPa rms for behavioral disruption (NMFS 2010b). Using the Clarke et al. (2002) study as the basis for its noise impact analysis, the NMFS determined that marine mammals within a 794-m radius of the dredge at an offshore borrow site in VA could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1µPa rms). In addition, the highest predicted noise level was 164 dB re 1µPa rms at a distance of one meter from the dredge. Current noise exposure thresholds for fishes are limited to interim criteria developed by the Fisheries Hydroacoustic Working Group (FHWG) for impulsive pile-driving noise; consequently, there are no specific criteria for evaluating the potential impacts of continuous dredging noise on marine fishes.

Based on the studies conducted by Clarke et al. (2002) and the NMFS (2010b), hopper dredging at the Central Reach offshore borrow site would not be expected to produce noise levels ≥180 dB re 1µPa rms (i.e., Level A harassment); therefore, dredging would not be expected to result in direct injury to marine mammals or sea turtles. Marine mammals could be exposed to noise levels ≥120 dB re 1µPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. Marine mammals that may be present in the vicinity of the Central Reach borrow site during dredging operations would include Atlantic spotted and bottlenose dolphins, humpback whales, and North Atlantic right whales. The rapid swimming capabilities of dolphins would most likely limit their exposure to noise levels ≥120 dB to very brief periods. The potential effects of dredging noise on the behavior of large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, no significant adverse behavioral effects would be expected. A detailed evaluation of the potential impacts to humpback and right whales under Alternative 3 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.3.6.

Dredging noise levels would not be expected to reach 166 db re 1µPa rms; therefore, based on the noise thresholds described above, adverse behavioral effects on sea turtles would not be expected. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, it is likely that most fish would move away from the slow-moving (~3 knots) dredge long before they are exposed to potentially injurious noise levels.

Cumulative Impacts

The anticipated effects of underwater dredging noise on marine organisms would be non-injurious, localized, and short term. Therefore, noise-related cumulative impacts would not be expected under Alternative 3.

<u>Entrainment</u>

Direct and Indirect Impacts

Hopper and cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the results of these studies, it is assumed that most juvenile and adult finfish would avoid the active dredging zone in response to elevated levels of noise and turbidity, thus avoiding entrainment in the dredge intake pipe. Hopper dredges also have the potential to entrain sea turtles; consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges. Navigation channel and sand borrow site dredging projects are also generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. A detailed evaluation of the potential dredging-related impacts to sea turtles under Alternative 3 is included in Section 5.5.3.5.

Many of the common marine fishes and invertebrates in NC are estuarine-dependent species that spawn offshore as adults and reside in estuarine nursery areas during juvenile development. The recruitment of ocean-spawned planktonic larvae to estuarine nursery areas is dependent on passive ocean-to-sound transport through tidal inlets. Recruitment studies indicate that larvae accumulate along the beaches in the nearshore ocean zone where they are carried by alongshore currents to laterally adjacent tidal inlets (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990). Under Alternative 3, dredging operations at the LFIX/LFI and/or offshore borrow sites would be completed within the proposed dredging window (16 November - 30 April), thus avoiding peak periods of larval ingress through LFI. As described under Alternative 1 (see Section 5.4.1.2), the anticipated maximum volume of water entrained per 24-hr period would equate to 0.0008 percent of the daily (24-hour) spring tidal flow and 0.0012 percent of the daily (24-hour) neap tidal flow through LFI. The results of larval entrainment modeling based on simulated dredging at Beaufort Inlet indicate that entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Considering the relatively small volume of water that would be entrained, the low model-projected rates of larval entrainment, and the timing of dredging operations relative to peak larval ingress periods; it is anticipated that the effect of larval entrainment on estuarine-dependent fish and invertebrate populations under Alternative 3 would be negligible.

Cumulative Impacts

It is anticipated that entrainment-related impacts on marine organisms at the community and/or population level would be negligible. Therefore, cumulative impacts related to entrainment would not be expected under Alternative 3.

5.4.3.4 Oceanfront Beach and Dune Communities

<u>Intertidal Beach Communities</u>

Direct Impacts

Under Alternative 3, individual beach fill placement events would directly impact ~13 ac of intertidal oceanfront beach habitat. The nourishment regime and associated direct impacts on physical habitat characteristics and benthic invertebrate infaunal communities would be similar to those described under the No Action alternative.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 3, indirect impacts associated with the initial placement of beach fill; including temporary sediment suspension and benthic infaunal prey-loss effects; would be similar to those described under the No Action alternative.

Long-Term Model-Projected Effects

Under Alternative 3, the CMS model-projected shoreline and intertidal habitat changes along the Oak Island west-end oceanfront beach (Figure 5.13) are the same as the projected future without project changes under Alternative 2 (Figure 5.11). Under both alternatives, shoreline erosion over the course of the four-year model simulation period results in projected intertidal beach habitat losses of ~10 ac (Table 5.3). The similarity of the responses indicates that the projected shoreline changes and intertidal beach habitat losses under Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would not

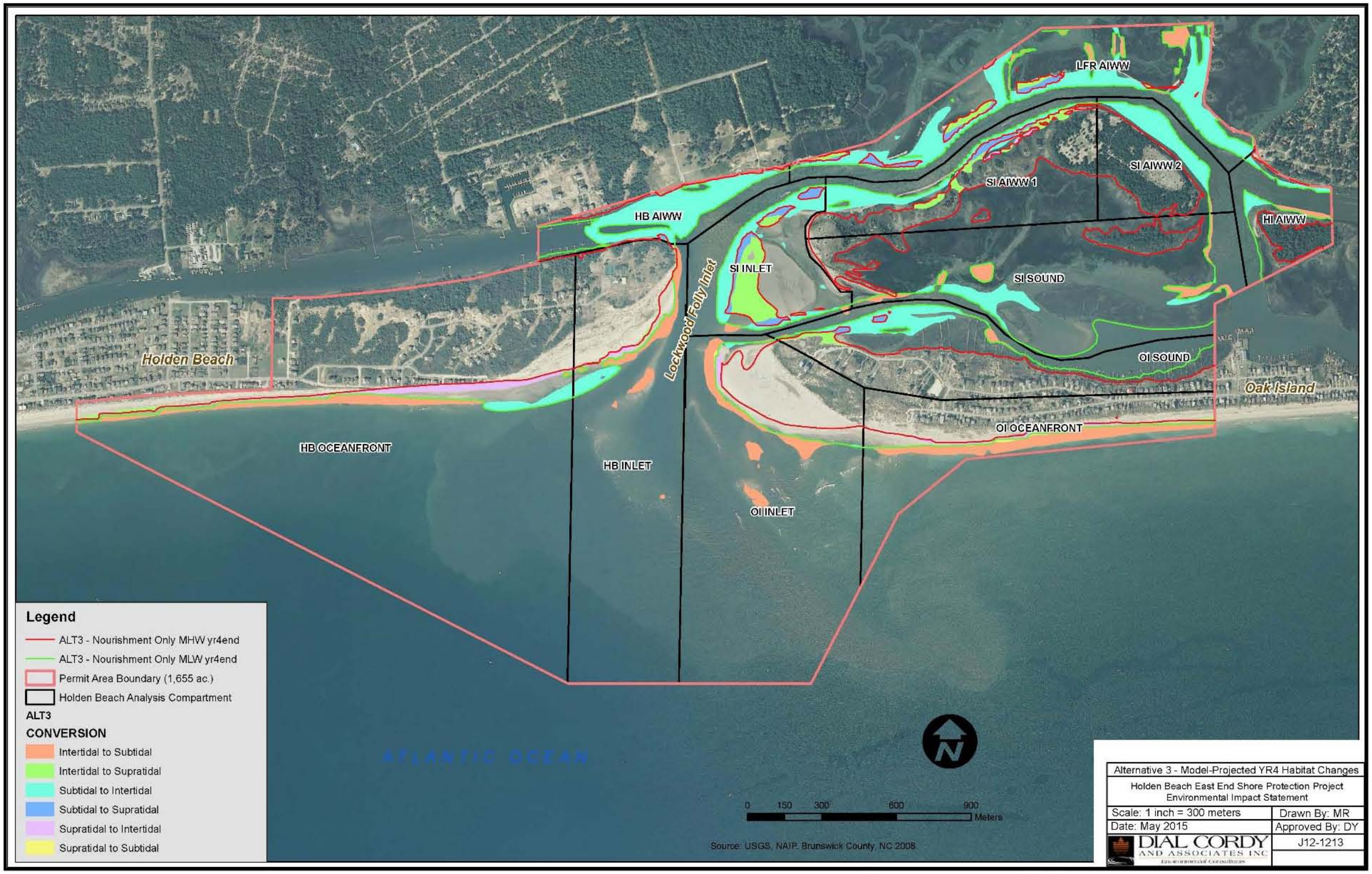


Figure 5.13. Alternative 3 – Model-Projected YR4 Habitat Changes

affect intertidal beach habitat on Oak Island. The projected response of the East End oceanfront shoreline on Holden Beach under Alternative 3 is similar in pattern to the projected response under Alternative 2; however, under Alternative 3, the performance of the beach fill is reflected in a wider East End beach. On average, the nourished East End beach at the end of Year 4 is ~19 ft wider than the corresponding East End beach under Alternative 2 (Table 5.4). The corresponding effect on the quantity of intertidal beach under Alternative 3 is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 3, the East End nourishment regime and associated potential cumulative impacts on intertidal beach habitats and communities would be similar to those described under the No Action alternative.

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

Direct Impacts

Under Alternative 3, individual beach fill placement events would directly impact ~4 ac of dry oceanfront beach habitat. Direct impacts on physical habitat characteristics and associated dry beach communities would be the same as those described under the No Action alternative. Unlike the No Action alternative, beach nourishment under Alternative 3 would include the reconstruction of eroded dunes. Reconstruction could directly impact up to an additional ~6 ac of dune habitat. The existing dune system consists of a narrow (~75-ft-wide), artificially-constructed, continuous berm. Thus, impacts related to morphological alteration and/or loss of habitat heterogeneity would not be expected. Dune reconstruction would result in temporary losses of dune vegetation and ghost crabs through direct burial and/or mechanical disturbance. Reconstructed dunes would be immediately replanted with native species that are characteristic of natural dune plant communities, thereby facilitating habitat recovery. As in the case of impacts to the dry beach, avoidance of infaunal recruitment periods and the use of compatible sediments would be expected to facilitate relatively rapid recovery of dune communities.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 3, the potential indirect effects of physical habitat modification, including changes in beach profile morphology and sediment composition, would be similar to those described under the No Action alternative.

Long-Term Model-Projected Effects

As described above, the CMS model-projected responses of the Oak Island west end oceanfront shoreline under Alternatives 3 and 2 are the same. Corresponding dry beach/dune habitat changes on Oak Island under Alternatives 3 (Figure 5.13) and 2 (Figure 5.11) are also the same, with both alternatives resulting in projected losses of ~3 ac (Table 5.3). In the case of Holden Beach, the projected relative increase in beach width under Alternative 3 corresponds to an increase in dry beach/dune habitat of ~2 ac relative to Alternative 2. Thus, the modeling results suggest that Alternative 3 would not affect dry beach/dune habitat on Oak Island, whereas the projected effect of Alternative 3 on Holden Beach is a relative increase of ~2 ac.

Cumulative Impacts

Under Alternative 3, the East End nourishment regime and associated potential cumulative impacts on dry beach and dune communities would be similar to those described under the No Action alternative.

5.4.3.5 Inlet Complex

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Although small short-lived emergent shoals occasionally form along the margins of the ebb channel at the mouth of the inlet throat, the interior flood shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. Nourishment-related dredging operations would be confined to the existing federally authorized LFIX/bend widener and LFI navigation channels; therefore, direct dredging impacts on intertidal flats and shoals would not be expected under Alternative 3. The eastern extent of beach fill placement may approach the inlet shoulder where small shoals originating along the western margin of the ebb channel have attached in the past; however, chronic erosion generally precludes the formation of any persistent intertidal flat or shoal-like features along the Holden Beach inlet shoulder. Therefore, direct beach fill placement impacts on intertidal flats and shoals would not be expected under Alternative 3.

Indirect Impacts

Under Alternative 3, the LFIX/bend widener and LFI dredging regimes would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on flats and shoals would not be expected. Net sediment transport along the East End beach is eastward towards the inlet, and the inlet itself is flood-dominant in terms of sediment transport. Consequently, sand extracted from the LFIX/bend widener channels for East End nourishment purposes would be retained within the inlet system. Therefore, indirect impacts on the flood shoal via modification of the inlet sediment budget would not be expected under Alternative 3.

The CMS model-projected inlet response under Alternative 3 (Figure 5.13) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.11). The only difference between the projected responses is a minor reduction in accretion along the western margin of the flood shoal under Alternative 3, which reduces new intertidal habitat creation by ~1 ac relative to Alternative 2 (Table 5.3). The similarity in responses indicates that the projected inlet changes under Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would have little effect on intertidal inlet habitats.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on intertidal flats and shoals would not be expected under Alternative 3.

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

Direct Impacts

Due to the chronically eroded nature of the East End shoreline, the demarcation between the oceanfront beach and the inlet shoreline is poorly defined on Holden Beach. The eastern extent of beach fill placement may encompass short reaches of the transitional southeast-facing oceanfront/inlet shoreline. Under Alternative 3, beach fill placement would result in minor direct impacts on inlet dry beach and dune communities. Direct effects on physical habitat characteristics and dry inlet beach and dune communities would be similar in nature to those described for the oceanfront beach.

Indirect

The potential indirect impacts of beach fill placement on inlet dry beach and dune communities would be similar in nature to those described for the oceanfront beach. Based on the limited spatial extent of beach fill placement along the southeast-facing shoreline, it is anticipated that associated indirect effects would not add measurably to those already described for the oceanfront beach.

As described above, the CMS model-projected inlet response under Alternative 3 (Figure 5.13) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.11). Corresponding inlet dry beach/dune and supratidal shoal habitat changes are also essentially the same, with similar projected gains occurring under Alternatives 3 and 2 (Table 5.3). The similarity of the responses indicates that the projected inlet changes under

Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would have little effect on inlet dry beach and dune habitats.

Cumulative Impacts

The potential cumulative impacts of beach fill placement on transitional dry beach and dune communities would be similar to those described for the oceanfront beach. Based on the limited extent of direct and indirect impacts, it is anticipated that any associated cumulative impacts would not add measurably to those already described for the oceanfront beach.

5.4.3.6 Estuarine Resources

<u>Shellfish</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on shellfish beds would be the same as those described under the No Action alternative.

<u>SAV</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on SAV would be the same as those described under the No Action alternative.

<u>Tidal Marsh Communities</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on tidal marshes would be the same as those described under the No Action alternative.

5.4.3.7 Threatened and Endangered Species

<u>North Atlantic Right Whale and Humpback Whale</u>

Direct, Indirect, and Cumulative Impacts

Sand extraction dredging operations would potentially coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. Right and humpback whales routinely swim close to shore during winter migration periods along the NC coast; therefore, both species could be present in offshore waters of the Permit Area during potential East End borrow site dredging operations. Dredging can potentially impact large whales through acoustic disturbance and vessel collisions. NMFS currently uses generic noise exposure thresholds to define two levels of acoustic "take" under the MMPA. Actions that may expose marine mammals to root mean square sound pressure levels ≥180 dB re 1µPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1µPa rms or continuous noise levels ≥120 dB re 1µPa constitute Level B harassment with the potential to cause behavioral disruption.

Under Alternative 3; the potential direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels would be the same as those described under the No Action alternative. Dredging activities under Alternative 3 could also include limited supplemental hopper dredging at the Central Reach borrow site. Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1µPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS has used the data collected by Clarke et al. (2002) as the basis for evaluating hopper dredging noise impacts at ocean sand borrow sites, citing the similarity in substrate (i.e., sand) and the use of metrics that are consistent (i.e., SPL rms values) with established marine mammal noise impact thresholds (NMFS 2010b). Based on the results of a noise impact analysis for dredging at an offshore sand borrow site in VA, the NMFS determined that marine mammals within a 794-m radius of the dredge could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1µPa rms). The highest predicted sound level was 164 dB re 1µPa rms at a distance of one meter from the dredge, thus indicating that marine mammals would not be exposed to injurious noise levels. Based on these studies, hopper dredging at the Central Reach offshore borrow site would not be expected to produce noise levels ≥180 dB re 1µPa rms (i.e., Level A harassment); and therefore, dredging would not be expected to result in direct injury to right or humpback whales. Right and humpback whales could be exposed to noise levels ≥120 dB re 1µPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. The potential behavioral effects of dredging noise on large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, it is anticipated that behavioral effects would be minor. Considering that the anticipated effects of underwater dredging noise on right and humpback whales would be limited to localized, short-term, behavioral responses; cumulative noise-related impacts would not be expected under Alternative 3.

Instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented; however, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent North Atlantic right whale along the GA coast near the Brunswick Harbor entrance channel (NMFS 2012a). The risk of collisions between dredges and large whales during sand extraction at the Central Reach borrow site would be low, as hopper dredges travel at slow speeds (~3 knots) during the active dredging process. The maximum unloaded transit speed of a hopper dredge is ~17 knots; and therefore, the risk of collisions would increase during transit between the borrow site and nearshore pump-out stations. Offshore borrow site dredging contracts would incorporate standard conservation measures to minimize the risk of marine mammal collisions; including speed limits (≤10 knots), 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience, and compliance with federal regulations [50 CFR 224.103(c)] prohibiting the approach of any vessel within 500 yards of a right whale. It is anticipated that supplemental dredging at the Central Reach borrow site would be minimal; and considering the relatively small East End beach fill volume requirements, the number of transits between the borrow site and pump-out stations would be low. Considering the anticipated limited extent of offshore dredging, it is expected that the proposed conservation measures would reduce the risk of collisions to negligible levels.

The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 3 would not affect any of these essential features; and furthermore, based on the proposed conservation measures described above, supplemental dredging at the Central Reach offshore borrow site would not preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on proposed critical habitat would be expected under Alternative 3.

<u>West Indian Manatee</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, direct; indirect; and cumulative impacts on the West Indian manatee would be the same as those described under the No Action alternative.

<u>Piping Plover</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, direct; indirect; and cumulative impacts on piping plovers would be similar to those described under the No Action alternative.

<u>Red Knot</u>

Under Alternative 3, direct; indirect; and cumulative impacts on the red knot would be similar to those described under the No Action alternative.

Wood Stork

Under Alternative 3, direct; indirect; and cumulative impacts on the wood stork would be similar to those described under the No Action alternative.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

Beach Nourishment

Under Alternative 3, the direct; indirect; and cumulative impacts of beach fill placement on sea turtles would be similar to those described under the No Action alternative.

Dredging

Under Alternative 3; the direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels would be the same as those described under the No Action alternative. Supplemental dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Sea turtles are vulnerable to direct injury by hopper dredges as a result of being entrained in the dredge intake pipe during the sediment extraction process. Consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges, and hopper dredging projects are generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a V-shaped sand ridge in front of the draghead as it is drawn along the seafloor, thus providing for the deflection of sea turtles while avoiding direct contact with draghead. The distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that inshore and nearshore sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April to 20 November for inshore waters and a range of 23 April to 27 November for nearshore ocean waters.

Supplemental dredging at the Central Reach offshore borrow site would only be expected in the case of a shortfall in the combined available sand volume in the LFIX, bend widener, and inland LFI channels. Therefore, it is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited. Rigid deflector dragheads would be required on all hopper dredges, thus reducing the potential for sea turtle entrainment. The proposed environmental hopper dredging window (16 November to 31 March) would limit dredging to periods when most sea turtles have moved to warmer offshore waters, thus further reducing the potential for sea turtle entrainment. Based on the use of rigid deflector dragheads, the proposed environmental hopper dredging window, and the anticipated limited extent of offshore dredging; it is anticipated that the risk of sea turtle entrainment under Alternative 3 would be very low.

Atlantic and Shortnose Sturgeons

Under Alternative 3; the direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels on Atlantic and shortnose sturgeon would be similar to those described under the No Action alternative. The frequency of bend widener dredging events under Alternative 3 would relatively be the same as the No Action alternative, thus maintaining the frequency (approximately a two-year cycle) of repeated impacts on benthic foraging habitats and the overall temporal extent of potential indirect benthic infaunal prey-loss effects.

Supplemental dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Hopper dredging can potentially impact sturgeons directly through entrainment in the dredge intake pipe and/or indirectly through impacts to soft bottom benthic foraging habitats. Between 1990 and 2007, 11 shortnose sturgeons and 11 Atlantic sturgeons were taken during federal dredging operations along the Atlantic Coast (USACE 2008). All shortnose sturgeon takes occurred along the North Atlantic Coast, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor during this period included one during hopper dredging and one during clamshell dredging. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; and therefore, its presence in the vicinity of the Central Reach offshore borrow site during dredging operations would not be expected. Therefore, based on its low probability of occurrence in the Permit Area and the absence of reported dredge interactions along the South Atlantic Coast, direct, indirect, and cumulative impacts on the shortnose sturgeon would not be expected under Alternative 3. Atlantic sturgeons could potentially be present in the vicinity of the Central Reach offshore borrow site during dredging operations. The use of rigid deflector dragheads on hopper dredges would be expected to reduce the risk of Atlantic sturgeon entrainment. It is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited; and based on the relatively small East End beach fill volume requirements (~100,000 – 150,000 cy), the extent and duration of individual dredging events would also be limited. Therefore, it is anticipated that the risk of entrainment to Atlantic sturgeon would be very low under Alternative 3.

Seabeach Amaranth

Direct, indirect, and cumulative impacts on seabeach amaranth under Alternative 3 would be similar to those described under the No Action alternative.

5.4.3.8 Cultural Resources

Direct, Indirect, and Cumulative Impacts

The remains of four Civil War vessels at LFI are listed in the NRHP under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (*Ranger*) is located approximately one mile west of the inlet (Tidewater Atlantic Research 2011). All of the Civil War shipwrecks are located seaward of the COLREGS line, whereas the LFIX/bend widener and inland LFI channels are located landward of the COLREGS line. Therefore, direct and indirect impacts on NRHP-listed vessels would not be expected under Alternative 3. LFIX/bend widener and inland LFI channel dredging would be confined to the existing federally authorized navigation channels; and therefore, impacts on undocumented shipwrecks would not be expected. In the case of the Central Reach offshore borrow site, a remote sensing survey for potential cultural resources was conducted as part of the environmental review process for the Holden Beach Central Reach nourishment project (Tidewater Atlantic Research 2011). The results of the remote sensing survey identified a single magnetic anomaly and no acoustic targets. Data analysis indicated that the magnetic anomaly was a single isolated object most likely consisting of modern debris. Therefore, potential supplemental dredging operations at the Central Reach borrow site would not be expected to have any direct or indirect impacts on cultural resources. Based on the absence of anticipated direct and indirect impacts, cumulative effects on cultural resources would not be expected under Alternative 3.

5.4.3.9 Public Interest Factors

<u>Public Safety</u>

Direct, Indirect, and Cumulative Impacts

Beach Construction

Beach construction would involve the use of bulldozers and possibly backhoes to redistribute beach fill as it is discharged onto the nourishment beach. In order to take advantage of the limited environmental dredging window and maximize the efficient use of expensive construction equipment, beach nourishment operations would be conducted around-the-clock. As with any construction project involving the use of heavy machinery, beach construction would present a minor, short-term risk to public safety. In order to maintain separation between the public and potentially hazardous operations; the active construction area, consisting of a ~500-ft zone on either side of the beach fill discharge point, would be fenced. During nighttime operations, appropriate lighting would be provided in accordance with the USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones.

Regulations also require front and back lighting on all transport vehicles and bulldozers during nighttime operations. Adherence to the proposed environmental dredging window (16 November - 30 April) would restrict beach construction activities to the colder months when recreational use is at its lowest point, thus limiting public exposure to potential construction-related risks. Considering the safety measures that would be implemented and the anticipated low level of recreational activity during the period of construction; no direct, indirect, or cumulative impacts to public safety would be expected under Alternative 3.

Dredging

Dredging operations within the LFIX/LFI channels would employ a cutterhead pipeline dredge, whereas operations at the offshore borrow site would most likely employ a hopper dredge. As indicated above, the limited dredging window and the high costs associated with dredging would necessitate around-the-clock operations. Dredges and associated pump and pipeline systems would present a minor short-term collision risk to recreational boaters. Adherence to the proposed environmental dredging window (16 November - 30 April) would limit operations to the colder months when recreational boating activity is at its lowest point, thus limiting the potential for dredge/recreational vessel interactions. During nighttime operations, appropriate on-board lighting would be provided in accordance with the USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of 30 lumens per square foot on dredges. Dredges would be subject to vessel inspections and other federal safety regulations that are enforced by the USCG. As deemed necessary to ensure the safety of recreational boating activities, the USCG would establish temporary safety zones around dredging operations. Considering these safety measures and the anticipated low level of recreational boating activity during the period of construction; no direct, indirect, or cumulative impacts to public safety would be expected under Alternative 3.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

During beach nourishment events, the presence of pipelines and construction equipment on the beach and associated noise emissions and artificial nighttime lighting would temporarily diminish the aesthetic quality of the East End beach. Temporary construction safety zones would restrict public beach access within a ~500-ft zone on either side of the beach fill discharge point, thus potentially impacting recreational activities such as beach-combing, fishing, and surfing. Similarly, the presence of dredges and support vessels/barges within the LFIX/LFI borrow site channels would temporarily degrade scenic vistas and could slow recreational boating traffic. Public exposure to aesthetic and recreational impacts would be limited, as the proposed environmental dredging window (16 November - 30 April) would limit beach fill and dredging operations to the colder months when recreational beach use is at its lowest point. Beach nourishment projects under Alternative 3 would maintain a wider beach, thus resulting in long-term beneficial effects on recreation and the aesthetic quality of the beach.

Furthermore, the additional storm protection provided by nourishment would reduce the need for emergency measures (sandbags, beach/dune scraping) that would be detrimental to recreation and the aesthetic quality of the beach. Considering the low level of public exposure and the short-term nature of the adverse impacts, it is anticipated that the long-term beneficial effects of a wider beach would result in net beneficial effects on aesthetics and recreation.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, the direct, indirect, and cumulative impacts of dredging operations in the LFIX/bend widener and inland LFI channels on navigation would be the same as those described under the No Action alternative. The Central Reach offshore borrow site is not located in the vicinity of any navigation channels; and therefore, supplemental dredging at the Central Reach borrow site would not be expected to have any direct, indirect, or cumulative impacts on navigation.

Infrastructure

Under Alternative 3, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 19 oceanfront properties and ~250 ft of roads and associated linear utilities (Figure 5.14). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 3 by an average ~19 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.12). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 3.

Economics

Under Alternative 3, construction and maintenance costs would include those associated with periodic beach nourishment; including the costs of beach fill, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with periodic nourishment and borrow site dredging activities. Over a 30-year planning horizon, assuming nourishment of the East End Beach with approximately 150,000 CY of sand every two years, and an annual four percent increase in fill costs, Alternative 3 is expected to involve total construction costs of approximately $55.50 million. In present value terms, construction costs range from $21.97 million (6% discount rate)

Figure 5.14. Alternative 3 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

to approximately $36.32 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 3, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 19 properties (13 improved) and ~250 linear ft of roads and associated water, sewer, and power lines (Figure 5.14). The total assessed value of all properties protected to be newly impacted under Alternative 3 is roughly $3.01 million. The 250 linear feet of anticipated infrastructure replacement cost is valued at approximately $191,000, with a present value ranging from approximately $151,000 (6% discount rate) to $173,000 (2.5% discount rate).

Under Alternative 3, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 2 and 4 and diminished relative to Alternatives 5 and 6 (Table 5.11). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. The principle benefit of Alternative 3 would be the addition of beach width relative to baseline conditions. It is expected that maintenance of a wider beach would confer benefits in the form of improved property values in the immediate vicinity of the project. Improvements in property values can be expected for properties that would otherwise be imminently threatened. As a result, the Holden Beach tax base would be expected to improve.

Table 5.11. Alternative 3 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$55.50 M
Construction and Maintenance (Present Value)	$21.97 - $36.32 M
Parcels at risk	19
Assessed Tax Value of Affected Parcels	3.01 M
Infrastructure Replacement Costs	$190,699
Infrastructure Replacement Costs (Present Value)	$151,052 - $172,764
Reduction in tax base	Intermediate
Transition costs	Intermediate
Diminished recreation value	Intermediate

Table 5.11. (concluded).

Costs (Relative to Status Quo)	
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Intermediate
Public non-use value losses (Holden Beach)	Intermediate
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Intermediate
Enhanced property value	Intermediate
Environmental Improvement	
Enhanced Recreation value	Moderate
Public non-use value (nature)	Intermediate
Public non-use value (Holden Beach)	Intermediate

5.4.4 Alternative 4: Outer Inlet Channel Management and Beach Nourishment

Under Alternative 4, the Town would mitigate East End erosion through relocations of the LFI outer ebb channel and concurrent nourishments of the East End beach with ~100,000 – 150,000 cy of sand every two years. Outer inlet channel relocation events would involve the construction of a new wider and deeper outer channel with a more westerly alignment towards the inlet shoulder of Holden Beach. The new 0.5-mile-long channel would extend seaward from the inlet throat across the LFI ebb tidal delta to the ocean 14-ft (MLW) depth contour. The new channel would be excavated to a uniform depth of 14 ft (MLW), and would have a variable width ranging from ~350 ft at the inlet throat to ~850 ft at the outer 14-ft (MLW) ocean depth contour. Excavation of the new outer channel would require the extraction of ~500,000 cy of sediment from the ebb tidal delta by a cutterhead or hopper dredge. Approximately 100,000 – 150,000 cy of the extracted material would be placed on an approximately 0.7-mile section of the East End beach, and the remaining ~350,000 – 400,000 cy would be removed by a side-cast dredge and returned to the adjacent ebb tidal delta via open water disposal. Dredging and associated beach placement operations would adhere to a 16 November - 31 March environmental window. It is anticipated that sand derived from outer inlet channel relocation events would meet all of the East End beach fill requirements under Alternative 4. The beach nourishment footprint, beach profile design, and beach construction methods would be the same as those described under Alternative 3.

5.4.4.1 Geology and Sediments

Outer inlet channel dredging events would excavate ~36 acres of seafloor in the vicinity of the ebb tidal delta. A vertical buffer of compatible sand would be retained, thus dredging would not be expected to directly alter sediment composition within the channel. The ebb tidal delta and outer ebb channel are continuously exposed to strong tidal currents; and consequently, as evidenced by the quarterly USACE maintenance dredging cycle, the outer channel is subject to rapid infilling by sand from the adjacent beaches. Furthermore, as indicated by the very small (≤1 percent) fine sediment fraction associated with the ebb tidal delta, silt and clay particles are rapidly dispersed by currents before significant settlement and accumulation can occur. Thus, it is unlikely that fine sediments would accumulate and alter sediment composition in the dredged channel. As described below in Section 5.4.4.2, the CMS modeling results for Alternative 4 show a substantial project-related increase in the inlet tidal prism, which in turn has a destabilizing effect on the ebb tidal delta. However, the modeling results do not indicate any significant change in the ebb tidal delta sediment volume relative to the future without project condition under Alternative 2 (Table 5.12). As in the case of many inlets along the southern NC coast, there is a localized reversal in longshore sediment transport along the East End beach from predominantly westward regional longshore transport to predominantly eastward longshore transport. Thus, placement on the East End beach would retain the material within the inlet-dominated littoral system, with the majority of the material being transported back into LFI. Therefore, adverse effects on the inlet sediment budget would not be expected. Sediments associated with the LFI channel and ebb tidal delta consist of highly compatible sand that is derived from the adjacent beaches. Therefore, placement would not be expected to have any adverse effects on the composition of East End beach sediments. Based on these considerations, it is expected that any direct, indirect, and cumulative effects on geology and sediments under Alternative 4 would be minor and short-term.

Table 5.12. LFI Model-projected ebb shoal sediment volume change (cubic yards).

Alternative	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4
2	14,346,167	13,728,537	13,341,543	13,033,153	12,959,610
3	14,346,167	13,735,874	13,362,521	13,051,699	13,005,674
4	14,175,015	13,548,282	13,244,169	13,066,701	13,030,132
5	14,346,167	13,726,379	13,362,731	13,050,836	12,966,947
6	14,356,826	13,727,674	13,361,240	13,030,027	12,956,458

5.4.4.2 Marine Benthic Resources

Soft Bottom Communities

Dredging

Direct Impacts

Excavation of the new outer inlet channel would directly impact ~36 ac of soft bottom habitat associated with the ebb tidal delta. Sand extraction would remove the majority of the associated benthic invertebrate infauna and epifauna; resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the dredged channel. However, benthic communities would be expected to recover rapidly from the impacts of dredging. Shallow unstable soft bottom habitats such as those associated with the ebb tidal delta are typically dominated by opportunistic benthic invertebrate taxa that recover rapidly from high frequency disturbance (Wilber and Clarke 2007). Furthermore, studies of benthic community recovery in dredged navigation channels along the southeastern coast have reported rapid recovery within two to six months (Van Dolah et al. 1984, 1979; Stickney and Perlmutter 1975; Stickney 1974). These studies indicate that recolonization via slumping of adjacent undisturbed sediments into the dredged channel is an important recovery mechanism. In addition, Van Dolah et al. (1984) attributed quick recovery to rapid infilling of the channel by sediments that were similar in composition to the extracted material and avoidance of spring benthic invertebrate recruitment periods. Relatively rapid rates of recovery (<1 year) at offshore borrow sites have been attributed to similar factors; including relatively rapid infilling by similar sediments (Burlas et al. 2001; Posey and Alphin 2002), recruitment via slumping of material into dredge cuts (Jutte et al. 1999b), and avoidance of spring infaunal recruitment periods (Posey and Alphin 2002).

The ebb tidal delta and outer ebb channel are continuously exposed to strong tidal currents; consequently, as evidenced by the quarterly USACE maintenance dredging cycle, the outer channel is subject to rapid infilling. Furthermore, as indicated by the very small (≤1 percent) fine sediment fraction associated with the ebb tidal delta, silt and clay particles are rapidly dispersed by currents before significant settlement and accumulation can occur. Thus, relatively rapid infilling of the excavated channel by sandy sediments that are similar in composition to the excavated material would be expected. Additionally, the proposed environmental nourishment window (16 November – 31 March) would necessitate the completion of dredging operations prior to the onset of peak spring benthic invertebrate recruitment periods. Therefore, it is anticipated that outer channel relocation events would be followed by relatively rapid benthic community recovery.

Additional direct impacts on soft bottom benthic communities adjacent to the channel would occur through the redeposition of sediments discharged by sidecast dredges. Sediment redeposition can impact soft bottom benthic invertebrates through direct burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic organisms. However, the absence of a significant fine sediment fraction would likely preclude extensive gill/filter-clogging effects. Reported rates of benthic community recovery from burial at dredged material placement sites along the Atlantic and Gulf coasts range from one month to one year (Wilbur and Clarke 2007). Bishop et al. (2005) studied the impacts of two sediment disposal events on ebb-tidal delta soft bottom communities at Beaufort Inlet. The smaller of the two disposal events (150,000 cy) had no apparent impact on benthic communities; however, the larger disposal event (860,000 cy) was followed by a substantial reduction in Spionid polychaete abundance. The reduction in polychaete abundance at the large disposal site was attributed to a change in substrate composition from fine to coarse sediment. Reductions in abundance were greatest in areas that experienced direct deposition, with impacts attributable to subsequent transport of the material being much reduced. Given the linear nature of the outer channel dredging footprint, the redeposited sediment layer would be potentially thinly spread over a relatively large seafloor area; thus anticipating a limited extent of direct burial impacts. Therefore, it is expected that benthic communities would recover relatively rapidly from redeposition impacts.

Indirect Impacts

As described in detail under Section 5.4.4.2, the CMS modeling results for Alternative 4 show a substantial project-related increase in the inlet tidal prism, which in turn has substantial effects on flow and sediment transport dynamics throughout the inlet and estuarine channels of the Permit Area. As expected, the modeling results at the end of Year 1 show a destabilized ebb tidal delta and a corresponding westward shift in sediment distribution towards the seaward terminus of the new outer channel. However, the new outer ebb channel fails to stabilize and subsequently undertakes an eastward migration that characterizes the remainder of the four-year simulation period. In response to outer channel migration, the ebb tidal delta is continually in a destabilized state of corresponding eastward migration. The projected pattern of ebb delta sediment redistribution would elicit corresponding adjustments in soft bottom benthic community composition. However, based on the opportunistic nature of the dominant benthic taxa and gradual pace of sediment redistribution, it is expected that benthic community adjustments would occur rapidly with only minor, short-term reductions in community levels of abundance, diversity, and/or biomass. The modeling results do not indicate any significant change in the ebb tidal delta sediment volume relative to the future without project condition under Alternative 2 (Table 5.12); therefore, indirect losses of ebb shoal habitat would not be expected.

Direct dredging-induced losses of benthic invertebrates within the new outer channel would constitute a temporary reduction in the availability of prey for predatory demersal fishes. Potential indirect prey-loss effects on demersal fishes could include reduced foraging efficiency within the dredging footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. The potential for longer-term indirect prey-loss effects on demersal fishes at the community and/or population level is difficult to assess; however, based on the anticipated rapid rates of benthic community recovery, it is anticipated that the indirect effects of prey loss on demersal fishes would be localized and short term. Sandy shoals of capes and offshore bars are designated EFH for Coastal Migratory Pelagics (CMPs). As indicated above, the modeling results do not show any significant change in the ebb tidal delta sediment volume; and therefore, no indirect losses of shoal habitat would be expected. Destabilization would be expected to increase shoal habitat heterogeneity, potentially resulting in beneficial effects on CMPs.

Cumulative Impacts

Project Area

The potential for temporally-crowded cumulative effects on soft bottom communities under Alternative 4 would depend on the frequency of repeated dredging impacts on soft bottom communities within the outer inlet channel dredging footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated outer channel dredging events were insufficient to allow for full recovery of benthic communities. The excavation of a wider and deeper outer channel would initially reduce the need for interim federal maintenance dredging, thus initially reducing the frequency of repeated impacts on benthic invertebrate communities relative to the current quarterly federal maintenance dredging regime. However, rapid infilling of the new channel (see Section 5.4.4.2) would likely necessitate the resumption of interim federal dredging during the latter half of the two-year intervals between relocation events. The overall frequency of combined project-related and interim federal dredging events could approach the current quarterly federal dredging cycle, potentially resulting in repeated impacts on benthic communities prior to full recovery from previous events. As a result, benthic invertebrate communities in the outer channel could be held in an early successional stage and/or could experience long-term reductions in levels of infaunal/epifaunal abundance and biomass.

The potential for spatially-crowded cumulative effects on soft bottom communities would depend on the proximity of spatially-separate dredging actions to the LFI outer ebb channel and the extent of overlap between the project-related and separate action impacts. Spatially-separate dredging actions potentially affecting soft bottom communities along Holden Beach and Oak Island would include federal dredging of the inland LFI channel, Shallotte Inlet channel, and Wilmington Harbor entrance channel. Additional potential borrow site dredging actions would include dredging associated with the Central Reach nourishment project, Lockwoods Folly River Habitat Restoration Phase I – Eastern Channel project, and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan (see Section 5.2.2). Dredging associated with the Central Reach nourishment project would likely occur at least one year prior to the initiation of project-related dredging activities under Alternative 4, thus allowing for substantial benthic invertebrate community recovery prior to the initiation of project-related dredging activities. In the event of concurrent outer channel/ Bald Head Island dredging projects; the relatively small area (~36 ac) of project-related dredging impact and the distance (~15 miles) between LFI and Frying Pan Shoals/Jay Bird Shoals suggest that any spatially-crowded cumulative effects would be negligible. Concurrent reductions in benthic invertebrate prey densities within the outer and inland LFI navigation channels could potentially have cumulative effects on predatory demersal fishes. However, the combined area of temporary habitat/prey loss (~45 ac) would constitute a small fraction of the available inlet/ocean soft bottom habitat in the vicinity of Holden Beach and Oak Island.

<u>Regional</u>

On a regional scale, LFI outer channel dredging events would be expected to coincide with other inlet navigation dredging projects along the southern NC coast. Of the 15 inlets that divide the southern NC barrier islands, nine have both inlet and AIWW inlet-crossing channels that are currently maintained under federal navigation projects. The federal inlet navigation projects include two deep draft navigation projects (Beaufort and Cape Fear Inlets) and seven shallow draft inlet projects (Shallotte, Lockwoods Folly, Carolina Beach, Masonboro, New River, New Topsail, and Bogue). The shallow draft channels and some portions of the deep draft channels are generally dredged at least once a year. Simultaneous impacts on soft bottom habitats and benthic invertebrate communities at separate inlets could potentially have combined effects on the foraging activities of migratory demersal fishes. However, benthic communities in dredged channels typically recover in a matter of months, and the combined extent of habitat disturbance would constitute a small fraction of the available soft bottom habitat along the southern NC coast. Therefore, it is expected that any cumulative effects would be minor and short-term.

Beach Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the direct, indirect, and cumulative impacts of beach fill placement on soft bottom communities would be the same as those described under the No Action alternative and Alternative 3.

<u>Hardbottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf; and therefore, would not be expected to occur in association with the deep sediment deposits that make up the ebb tidal delta. However, if deemed necessary through pre-project agency coordination, inlet channel relocation events would be contingent on investigations demonstrating the absence of potential hardbottom features within 500 m of the active dredging area. Similarly, beach nourishment events would be contingent on pre-construction investigations demonstrating the absence of hardbottom features within proposed corridors. Hopper dredges, the preferred dredge for this action, do not have a pipeline from the borrow area to the beach. There will be a transfer station in the nearshore in ~25 ft of water (as close to the beach as possible) where the hopper will hook up and pump to the shore. The USACE BCB conducted an extensive nearshore hardbottom survey in the area confirming no known hardbottom features have been identified along potential pipeline corridors. Therefore, Alternative 4 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.4.3 Water Column

<u>Hydrodynamics</u>

Direct and Indirect Impacts

The CMS modeling results for Alternative 4 show substantial project-related effects on flow and current dynamics throughout the inlet and estuarine channels of the Permit Area. The projected hydrodynamic effects are the result of a substantial increase in the inlet tidal prism, which in turn is related to the expanded depth and width of the realigned outer channel. The “tidal prism” refers to the combined total volume of water that flows in and out of the inlet during a single ebb/flood tidal cycle. In the case of Alternative 4, the deeper and wider outer channel has an expanded water volume capacity, which allows more water to move in and out of the inlet. The CMS model was used to project tidal prism volumes across four transects spanning the inlet throat, Eastern Channel, AIWW East channel, and AIWW West channel. As shown in Table 5.13, the majority of the projected volumes across all transects during Years 1 and 2 are on the order of 110 to 154 percent of the corresponding future without project volumes under Alternative 2. The realigned outer channel experiences high rates of infilling throughout the four-year model simulation period, and the resulting loss of water volume capacity is reflected in declining tidal prism volumes during Years 3 and 4. By the end of Year 4, the majority of model-projected tidal prism volumes across the inlet throat, Eastern Channel, and AIWW East transects are comparable to the corresponding volumes under Alternative 2.

The hydrodynamic response of the inlet has substantial corresponding morphological effects throughout the outer ebb channel/delta complex and the inlet throat complex. As expected, model-simulated bathymetry at the end of Year 1 shows a destabilized ebb tidal delta and a westward shift in sediment distribution towards the seaward terminus of the new outer channel. Concurrent with the initial reorganization of the ebb tidal delta, the modeling results show rapid infilling of the new channel by the end of Year 1; including near-complete infilling of the outermost 0.25-mile channel segment. The model-simulated bathymetry at the end of Year 2 shows an eastward shift in the ebb channel concurrent with continued rapid infilling of the new outer channel. The initial westward ebb channel shift at the end of Year 2 is followed by rapid westward ebb channel migration throughout the final 2 years of the model simulation period. By the end of Year 4, the outer channel approximates its original pre-relocation position; and has taken on a similar recurved alignment towards the Oak Island inlet shoulder. As a result of eastward outer ebb channel migration, the ebb tidal delta is in a continual destabilized state of

Table 5.13. Alternative 4 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	103%	102%	111%	154%	102%	101%	101%	101%
1	115%	118%	92%	103%	113%	117%	126%	111%
2	108%	117%	90%	85%	115%	121%	107%	106%
3	100%	112%	75%	98%	109%	108%	97%	100%
4	96%	101%	33%	89%	101%	97%	138%	94%
Neap Tide								
0	104%	103%	112%	134%	102%	101%	102%	101%
1	113%	120%	89%	93%	115%	118%	112%	114%
2	108%	120%	88%	65%	115%	125%	110%	108%
3	95%	107%	59%	62%	101%	105%	96%	96%
4	85%	87%	51%	116%	97%	93%	99%	61%

westward migration during Years 3 and 4. However, the modeling results do not show any significant change in the ebb tidal delta sediment volume relative to Alternative 2. The model-projected ebb delta sediment volume at the end of Year-1 equates to a relative deficit of ~100,000 cy. The relative deficit is reduced to ~25,000 cy by the end of Year 2, and the projections for Years 3 and 4 indicate a slight relative increase in sediment volume. Thus, the modeling results do not indicate any losses of ebb shoal soft bottom habitat.

The simulated inlet throat ebb channel is also highly unstable throughout the four-year simulation period. The principal ebb channel response is one of rapid westward migration; and by the end of Year 2, the channel is beginning to erode the northern inlet shoreline of Holden Beach. Erosion of the Holden Beach inlet shoreline progresses throughout the remaining two years of the simulation period, resulting in additional losses of inlet beach habitat relative to Alternative 2. Westward migration of the ebb channel also has a relative effect on shoal attachment dynamics along the inlet shoulder of Holden Beach. The modeling results for all other action alternatives show the formation and ultimate attachment of an emergent shoal along the inlet shoulder, which increases the width of the inlet shoulder intertidal beach. The emergent shoal also forms under Alternative 4; however, as a result of westward ebb channel migration, the shoal remains detached. In addition to the projected effects of westward ebb channel migration, the LFIX ebb channel segment along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of accretion along the flood shoal southward relative to Alternative 2. The AIWW channels generally maintain their pre-project positions; however, there is considerable sediment redistribution within the channels that is not apparent under Alternative 2. As is the case for all of the action alternatives, the modeling results show extensive shoaling in the AIWW West channel and along the margins of the Eastern Channel and AIWW East channel. However, there is some additional shoaling in the AIWW West channel under Alternative 4 that exceeds the projected shoaling under Alternative 2. The additional shoaling is reflected in the AIWW West tidal prism volumes during Years 2 - 4, which are substantially reduced relative to Alternative 2 (Table 5.12). The projected response of the AIWW West channel is an exception to the overall inlet tidal prism response described above.

Cumulative Impacts

The CMS modeling analysis is limited to the four-year period following a one-time inlet channel relocation event, thus the ability to evaluate potential cumulative effects that might result from repeated relocation events and interactions with separate federal dredging activities over the 30-year project period is limited. However, the failure of the ebb channel to stabilize during the four-year simulation period suggests that repeated relocations every two years would result in chronic hydrological and morphological instability throughout the inlet complex. Projected adverse effects on the Holden Beach inlet and oceanfront shorelines (see Sections 4.4.3 and 4.4.4) could be perpetuated, resulting in cumulative erosional losses over the 30-year life of the project.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Temporary sediment suspension and associated increases in turbidity during the dredging process can potentially affect the behaviors (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms. The extent and duration of dredging-induced sediment suspension and associated increases in turbidity are influenced by sediment composition at the borrow site, the type of dredge employed, and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In reporting the results of turbidity monitoring during navigation dredging in Delaware Bay, Miller et al. (2002) described the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments as being confined to the dredged channel footprint, with suspended sediment concentrations returning to ambient levels within one hour of the passing of the dredge. Miller et al. (2002) also reported that observed turbidity levels remained within the range of pre-project ambient turbidities throughout the period of dredging in coarse-grained sediments. Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). In comparison to cutterhead dredges, hopper dredges are generally associated with higher rates of suspension and dispersal; primarily due to the surface discharge associated with overflow dredging. In the case of cutterhead dredging, sediment suspension is generally confined to the near-bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991).

Ebb tidal delta sediments at depths corresponding to the proposed outer inlet channel are composed of medium sand with a very small (≤1 percent) fine sediment fraction; thus indicating that the extent and duration of sediment suspension during outer channel dredging would be limited. Dredging operations would involve the use of a sidecast dredge in combination with either a cutterhead or hopper dredge. As indicated above, sidecast and hopper dredges are generally associated with relatively high suspension rates; however, even in the case of overflow hopper dredging, sediment suspension is characteristically localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction (Miller et al. 2002). Furthermore, the ebb tidal delta is exposed to continuous high-velocity tidal currents, thus indicating that any suspended fine particles would be rapidly dispersed. Therefore, it is anticipated that the effects of dredging-induced sediment suspension during inlet channel relocation events would be localized and short term. Sediment suspension and turbidity effects would be temporally limited to periods of active dredging and spatially localized to the immediate vicinity of the active dredging area; and therefore, cumulative impacts would not be expected.

Beach Fill Placement

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the direct, indirect, and cumulative effects of sediment suspension related to beach fill placement would be the same as those described under the No Action alternative and Alternative 3.

<u>Salinity Intrusion</u>

Existing salinities in the AIWW between LFI and the Lockwoods Folly River range from ~29 to 36 ppt (NCDWQ 2007), and thus are nearly comparable to ocean salinities. Salinity changes were not assessed in the model simulations; however, the projected tidal prism increases suggest that Alternative 4 could increase mean salinities in the AIWW and the lower Lockwoods Folly River.

Underwater Noise

Direct and Indirect Impacts

Under Alternative 4, the potential impacts of underwater dredging noise on marine organisms would be similar to those described for hopper dredging operations at the Central Reach offshore borrow site under Alternative 3. As detailed under Alternative 3, hopper dredging would not be expected to produce noise levels that would result in direct injury to marine mammals [≥180 dB re 1μPa rms (Level A Harassment)]. However, marine mammals within an approximate 800-m radius of the hopper dredge could be exposed to noise levels that would cause behavioral disruption [≥120 dB re 1μPa rms (Level B Harassment)]. Marine mammals that may be present in the vicinity of the outer inlet channel during dredging operations would include Atlantic spotted and bottlenose dolphins, humpback whales, and North Atlantic right whales. The rapid swimming capabilities of dolphins would most likely limit their exposure to noise levels ≥120 dB to very brief periods. The potential effects of dredging noise on the behavior of large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, no significant adverse behavioral effects would be expected. A detailed evaluation of the potential impacts to humpback and right whales under Alternative 4 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.4.6. Hopper dredging would not be expected to produce noise levels that would have injurious or behavioral effects on sea turtles [≥180 dB re 1μPa rms (Level A Harassment); ≥166 db re 1μPa rms (Level B Harassment)]. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, it is likely that most fish would move away from the slow-moving (~3 knots) dredge long before they are exposed to potentially injurious noise levels.

Cumulative Impacts

The anticipated effects of underwater dredging noise on marine organisms would be non-injurious, localized, and short term. Therefore, noise-related cumulative impacts would not be expected under Alternative 4.

Entrainment

Direct, Indirect, and Cumulative Impacts

Cutterhead, hopper, and sidecast dredges all have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the results of these studies, it is assumed that most juvenile and adult finfish would avoid the outer inlet channel active dredging zone in response to elevated levels of noise and turbidity, thus avoiding entrainment in the dredge intake pipe. Hopper dredges also have the potential to entrain sea turtles; and consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on all hopper dredges. Navigation channel and sand borrow site hopper dredging projects are also generally restricted to the colder months when most sea turtles have moved offshore to warmer waters. A detailed evaluation of the potential impacts to sea turtles under Alternative 4 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.4.6.

The planktonic larvae of ocean-spawning/estuarine-dependent fishes and invertebrates would not be able to avoid the dredges; and consequently, those larvae occurring in the immediate vicinity of the dredge intake pipe would be entrained and presumably permanently lost to the pelagic water column community. Ocean-spawning/estuarine-dependent fishes and invertebrates use offshore continental shelf habitats for spawning and estuarine habitats for juvenile development. Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by alongshore currents and transported to the nearest inlet (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990). The proposed environmental dredging window (16 November – 31 March) would necessitate avoidance of peak larval ingress periods. As described in section, the maximum dredge water intake rate under Alternative 4 would be 6,123,570 ft^3 per 24-hour period; which equates to 0.004 percent of the daily (24-hour) spring tidal flow and 0.006 percent of the daily neap tidal flow through LFI. Furthermore, model simulated larval entrainment rates in Beaufort Inlet indicate that entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Considering the relatively small volume of water that would be entrained, along with the low model-projected rates of larval entrainment and avoidance of the peak May to early June larval ingress period; it is expected that the direct, indirect, and cumulative effects of larval entrainment on estuarine-dependent fish and invertebrate populations would be negligible under Alternative 4.

5.4.4.4 Oceanfront Beach and Dune Communities

<u>Intertidal Beach Communities</u>

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on intertidal beach habitats and communities would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 4, indirect impacts associated with the initial placement of beach fill; including sediment suspension and benthic infaunal prey-loss effects; would be the same as those described under the No Action alternative and Alternative 3.

Long-Term Model-Projected Effects

Under Alternative 4, the CMS model-projected shoreline and habitat changes along the Oak Island oceanfront beach (Figure 5.15) are essentially the same as the projected future without project changes under Alternative 2 (Figure 5.11). Under both alternatives, the oceanfront shoreline is erosional throughout the four-year model simulation period. The corresponding effect on intertidal beach habitat under both alternatives is a projected loss of ~10 ac (Table 5.3). The similarity in responses indicates that the projected shoreline and habitat changes under Alternative 4 are primarily the result of natural background coastal processes; thus suggesting that Alternative 4 would have little to no effect on intertidal beach habitat on Oak Island. The projected oceanfront shoreline changes on Holden Beach are generally similar in pattern under the two alternatives; however, there are differences between the responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. As described in Section 5.4.4.2, the modeling results for Alternative 4 show substantial project-related effects on inlet hydrodynamics, which in turn have substantial morphological effects on the inlet shoulder shoreline. Under Alternative 2, shoal attachment adds intertidal beach habitat along the inlet shoulder; however, under Alternative 4, rapid westward migration of the inlet throat ebb channel prevents the shoal from attaching. As a result, Alternative 4 increases intertidal beach habitat loss by ~2 ac in relation to Alternative 2.

Cumulative Impacts

Under Alternative 4, potential cumulative impacts on intertidal beach communities would be similar to those described under the No Action alternative and Alternative 3.

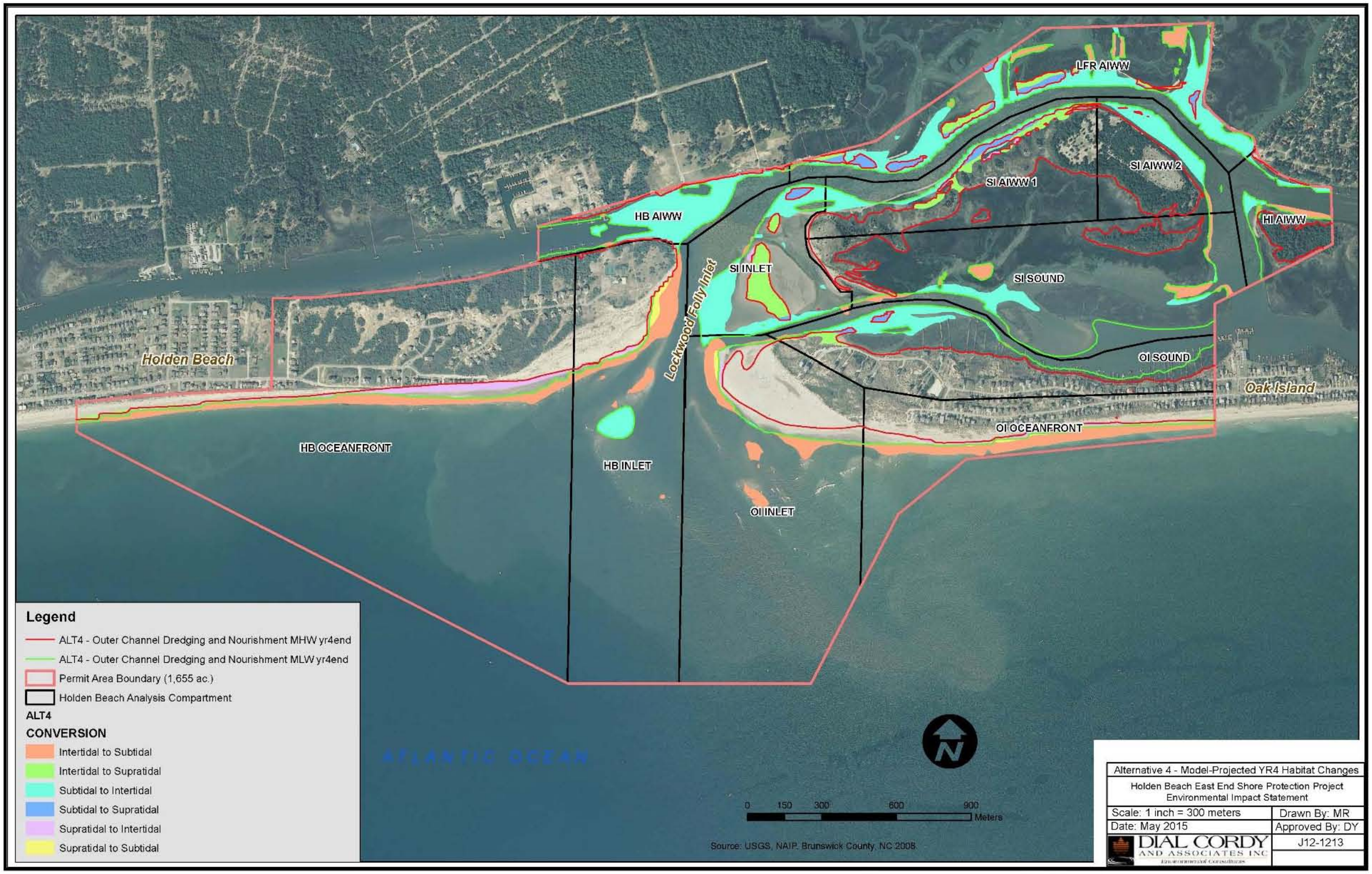


Figure 5.15. Alternative 4 – Model-Projected YR4 Habitat Changes

Dry Beach and Dune Communities

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on dry beach and dune communities would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 4, indirect habitat modification effects resulting from the placement of beach fill would be the same as those described under Alternative 3.

Long-Term Model-Projected Effects

The CMS model-projected oceanfront shoreline response on the west end of Oak Island under Alternative 4 is essentially the same as the projected future without project response under Alternative 2. Corresponding effects on dry beach and dune habitats under Alternatives 4 (Figure 5.15) and 2 (Figure 5.11) are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). On Holden Beach, the influence of beach fill placement and outer channel relocation under Alternative 4 are reflected in a wider (MSL 0-m) East End beach and a seaward extended MHW line relative to Alternative 2. The corresponding effect on the quantity of dry beach habitat at the end of Year 4 is an increase of ~2 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 4, cumulative impacts on dry beach and dune communities would be similar to those described under Alternative 3.

5.4.4.5 Inlet Complex

Intertidal Flats and Shoals

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on intertidal flats and shoals would be similar to those described under the No Action alternative and Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on intertidal flats and shoals would not be expected under Alternative 4.

Indirect Impacts

The CMS model-projected inlet response under Alternative 4 (Figure 5.15) is generally similar in pattern to the projected future without project response under Alternative 2 (Figure 5.11); however, there are a number of significant differences between the responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. The relationship between the projected hydrological and morphological inlet responses under Alternative 4 were detailed in Section 5.4.4.2. As described above in the analysis of oceanfront beach impacts, rapid westward migration of the inlet throat ebb channel under Alternative 4 prevents the process of shoal attachment along the inlet shoulder that is projected under Alternative 2. As a result, losses of intertidal inlet beach habitat on Holden Beach under Alternative 4 are increased relative to Alternative 2. Westward channel migration under Alternative 4 also increases the extent of erosion along the remainder of the Holden Beach inlet shoreline to the north, further increasing intertidal habitat loss relative to Alternative 2. Overall, the quantity of intertidal inlet beach habitat on Holden Beach under Alternative 4 is reduced by ~3 ac relative to Alternative 2 (Table 5.3).

The model-projected response of the Oak Island inlet shoreline under Alternative 4 is essentially the same as the projected response under Alternative 2. Under both alternatives, erosion of the inlet shoreline over the course the four-year model simulation period results in the loss of ~7 ac of intertidal inlet beach habitat (Table 5.3). The similarity in responses indicates that the projected shoreline and habitat changes under Alternative 4 are primarily the result of background coastal processes; thus suggesting that Alternative 4 would have little effect on the Oak Island intertidal inlet beach. The general pattern of projected flood shoal response is also similar under Alternatives 4 and 2. Under both alternatives, accretion along the western margin of the flood shoal results in substantial new intertidal habitat formation, and sediment deposition on the existing flood shoal results in substantial intertidal-to-supratidal habitat conversion. However, there are differences between the flood shoal responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. Under Alternative 4, the LFIX channel along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of westward accretion southward relative to Alternative 2. As a result, the extent of westward accretion and new intertidal habitat formation increases by ~4 ac relative to Alternative 2; whereas the extent of deposition and intertidal-to-supratidal habitat conversion decreases by ~2 ac relative to Alternative 2. The net effect of these differences on the quantity of intertidal shoal habitat under Alternative 4 is an increase of ~6 ac relative to Alternative 2. Although the relative increase under Alternative 4 is suggestive of beneficial effects on the flood shoal, there is an ~7-ac relative decrease in the quantity of supratidal shoal habitat under Alternative 4. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives is approximately the same at the end of Year 4. The projected flood shoal sediment volumes under the two alternatives at the end of Year 4 are also similar, with only a slight relative reduction in volume of ~15,000 cy under Alternative 4.

Cumulative Impacts

The CMS modeling analysis is limited to the four-year period following a one-time inlet channel relocation event; and furthermore, the model simulations do not include federal navigation dredging. Thus, the ability to evaluate potential cumulative effects that might result from repeated relocation events and interactions with separate federal dredging activities over the 30-year project period is limited. However, the failure of the ebb channel to stabilize during the four-year simulation period suggests that repeated relocations every two years would result in chronic hydrological and morphological instability throughout the inlet complex. Projected adverse effects on the Holden Beach inlet shoreline could be perpetuated, resulting in cumulative erosional losses over the 30-year life of the project. However, ongoing chronic erosion typically limits the extent of intertidal flats along the Holden Beach inlet shoreline. Thus, any additional losses would not be expected to result in cumulative effects.

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

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on inlet dry beach and dune communities would be the same as those described under Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on inlet dry beach and dune communities would not be expected under Alternative 4.

Indirect Impacts

As described above, the CMS model-projected response of the Oak Island inlet shoreline under Alternative 4 (Figure 5.15) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.11). Corresponding effects on inlet dry beach and dune habitats are also the same, with projected losses of ~1 ac occurring on Oak Island under both alternatives (Table 5.3). On Holden Beach, the projected increase in shoreline erosion under Alternative 4 has minor effects on inlet dry beach habitat, resulting in a projected decrease of ~1 ac relative to Alternative 2. As described above, there are differences between the projected flood shoal responses under the two alternatives that are related to the hydrodynamic effects of channel relocation under Alternative 4. Under Alternative 4, the extent of new supratidal shoal habitat creation via westward accretion and the extent of intertidal-to-supratidal shoal habitat conversion are both reduced relative to Alternative 2. The result is a relative decrease in supratidal shoal habitat of ~7 ac under Alternative 4. Although the relative decrease under Alternative 4 is suggestive of adverse flood shoal effects, there is an ~6-ac relative increase in the quantity of intertidal shoal habitat under Alternative 4. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives is approximately the same. Furthermore, as stated above, the overall model-projected flood shoal sediment volumes at the end of Year 4 are approximately the same under Alternatives 4 and 2.

Cumulative Impacts

The potential for cumulative effects on inlet dry beach and dune communities under Alternative 4 would be similar to that described above for inlet intertidal communities.

5.4.4.6 Estuarine Resources

Shellfish

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat, whereas shellfish beds are primarily associated with protected estuarine waters. Therefore, direct dredging-induced impacts on shellfish would not be expected under Alternative 4.

Indirect Impacts

During active dredging, suspended sediments that are dispersed and redeposited outside of the active dredging footprint can potentially impact shellfish through smothering and/or interference with filter feeding. However, shellfish beds are primarily associated with estuarine habitats that are removed from the seaward outer inlet channel. Furthermore, sediments associated with the ebb tidal delta dredging footprint have a very small fine sediment fraction (≤1 percent); thus indicating that sediment dispersal would be minimal. Therefore, indirect dredging-induced impacts on shellfish would not be expected under Alternative 4.

Cumulative Impacts

In the absence of anticipated direct and indirect impacts, cumulative effects on shellfish would not expected under Alternative 4.

SAV

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat, whereas SAV beds are confined to protected estuarine waters. Therefore, direct dredging-induced impacts on SAV would not be expected under Alternative 4.

Indirect and Cumulative Impacts

Potential indirect and cumulative effects on SAV under Alternative 4 would be the same as those described above for shellfish.

Tidal Marsh Communities

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat whereas tidal marshes are confined to interior estuarine waters. Therefore, direct dredging-induced impacts on tidal marshes would not be expected under Alternative 4.

Indirect and Cumulative Impacts

The model-projected tidal marsh response under Alternative 4 is the same as the projected future without project response under Alternative 2, with both alternatives resulting in tidal marsh losses of ~2 ac at the end of the four-year simulation period. The similarity of the responses indicates that the projected losses under Alternative 4 are primarily the result of natural background coastal processes; thus suggesting that Alternative 4 would have little effect on tidal marsh communities. In the absence of anticipated direct and indirect impacts, cumulative effects on tidal marshes would not expected under Alternative 4.

5.4.4.7 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Outer inlet channel dredging operations would potentially coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. Right and humpback whales routinely swim close to shore during winter migration periods along the NC coast; and therefore, both species could be present in offshore waters of the Permit Area during potential East End dredging operations. Dredging can potentially impact large whales through acoustic disturbance and vessel collisions. The NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to rms SPL ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. Excavation of the new outer inlet channel would employ either a cutterhead or hopper dredge in combination with a sidecast dredge. According to a study by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms, with rapid attenuation occurring at short distances from the dredge and sound levels becoming essentially inaudible at a distance of ~500 m. Therefore, dredging operations under Alternative 4 would not be expected to produce noise levels at or above the thresholds described above for injurious or behavioral effects on marine mammals or sea turtles. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, considering that cutterhead dredges are anchored during the active dredging process, it is likely that most fish would move away from the dredge long before they are exposed to potentially injurious noise levels.

Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1μPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS has used the data collected by Clarke et al. (2002) as the basis for evaluating hopper dredging noise impacts at ocean sand borrow sites, citing the similarity in substrate (i.e., sand) and the use of metrics that are consistent (i.e., SPL rms values) with established marine mammal noise impact thresholds (NMFS 2010b). Based on the results of a noise impact analysis for dredging at an offshore sand borrow site in VA, NMFS determined that marine mammals within a 794-m radius of the dredge could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1μPa rms). The highest projected sound level was 164 dB re 1μPa rms at a distance of one meter from the dredge, which is well below the ≥180 dB re 1μPa rms threshold for Level A harassment. Based on these studies, hopper dredging under Alternative 4 would not be expected to have any injurious acoustic effects on right or humpback whales. However, right and humpback whales could be exposed to noise levels ≥120 dB re 1μPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. The potential behavioral effects of dredging noise on large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, it is anticipated that behavioral effects would be minor. In comparison to hopper and cutterhead dredges, which are used for more rigorous deep draft dredging and beach nourishment projects, the dredge pumps on shallow draft sidecast dredges are substantially reduced in terms of size and horsepower (hp). The pump engines on sidecast dredges that are currently operated by the Wilmington District have a maximum output of ≤400 hp, whereas the pump engines on the cutterhead and hopper dredges that were monitored by Clarke et al. (2002) can produce up to 10,000 hp and 15,000 hp, respectively. Therefore, sidecast dredging would not be expected to have any adverse acoustic impacts on right or humpback whales.

Instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented; however, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent North Atlantic right whale along the GA coast near the Brunswick Harbor entrance channel (NMFS 2012a). The risk of collisions between dredges and large whales during operations in the outer channel would be low, as hopper and sidecast dredges travel at slow speeds (≤3 knots) during the active dredging process and cutterhead dredges are relatively stationary. In the case of hopper dredging, operations would also include transits between the outer channel and nearshore pump-out stations along the East End beach. The maximum unloaded speed of a hopper dredge is ~17 knots; and therefore, the risk of collisions would increase during transit. Dredging contracts would incorporate standard conservation measures to minimize the risk of large whale collisions; including speed limits (≤10 knots), 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience, and compliance with federal regulations [50 CFR 224.103(c)] prohibiting the approach of any vessel within 500 yards of a right whale. Considering the relatively small East End beach fill volume requirements (~100,000 – 150,000 cy) and the short distance between the outer channel and the East End beach, the number and duration of transits would be minimal. Therefore, it is expected that the proposed conservation measures would reduce the risk of collisions to negligible levels.

The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 4 would not affect any of these essential features; and furthermore, based on the proposed conservation measures described above, neither inlet relocation dredging nor supplemental dredging at the Central Reach offshore borrow site would preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on proposed critical habitat would be expected under Alternative 4.

<u>West Indian Manatee</u>

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts on manatees under Alternative 4 would be similar to those described under the No Action alternative and Alternative 3.

<u>Piping Plover</u>

Direct Impacts

Under Alternative 4, the potential direct impacts of beach fill placement operations on piping plovers would be the same as those described under the No Action alternative and Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on piping plovers would not be expected under Alternative 4.

Indirect and Cumulative Impacts

Beach Fill Placement

Under Alternative 4, the potential indirect and cumulative impacts of beach fill placement operations on piping plovers would be the same as those described under the No Action alternative and Alternative 3.

Outer Inlet Channel Relocation

Under Alternative 4, the CMS model-projected inlet morphological response to outer channel relocation (Figure 5.15) is generally similar in pattern to the projected future without project response under Alternative 2 (Figure 5.11). The previously described model-projected effects of outer channel relocation on East End inlet shoulder shoaling processes indicate a reduction in potential intertidal foraging habitat of ~3 ac relative to Alternative 2. The modeling results do not show any indication of project-related effects on the Oak Island inlet shoreline; thus indicating that Alternative 4 would not affect associated critical habitat for the piping plover. The general pattern of projected flood shoal response is similar under Alternatives 4 and 2, with accretion along the western margin of the flood shoal resulting in substantial new intertidal habitat formation, and sediment deposition on the existing flood shoal resulting in substantial intertidal-to-supratidal shoal habitat conversion. However, there are differences between the flood shoal responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. Under Alternative 4, the LFIX channel along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of westward accretion southward relative to Alternative 2. As a result, the extent of westward accretion and new intertidal habitat formation increases by ~4 ac relative to Alternative 2. Conversely, the extent of depositional intertidal-to-supratidal habitat conversion on the existing flood shoal decreases by ~2 ac relative to Alternative 2. The net effect of these differences on the quantity of intertidal shoal habitat under Alternative 4 is an increase of ~6 ac relative to Alternative 2. Although the relative increase under Alternative 4 is suggestive of beneficial effects on the quantity of shoal habitat, there is a ~7 ac increase in the quantity of supratidal shoal habitat under Alternative 2. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives are approximately the same at the end of Year 4. The projected flood shoal sediment volumes under the two alternatives at the end of Year 4 are also similar, with only a slight relative reduction in volume of ~15,000 cy under Alternative 4. Although Alternative 4 would decrease the quantity of potential flood shoal supratidal nesting habitat relative to Alternative 2, the relative increase in intertidal shoal habitat may have indirect beneficial effects on migrating and wintering plovers. Migrating plovers are dependent on large areas of intertidal foraging habitat with abundant prey resources, and such areas are an essential element of the designated critical habitat units for the wintering population.

Red Knot

Under Alternative 4, potential direct, indirect, and cumulative impacts on red knots would be similar to those described above for the piping plover.

Wood Stork

Under Alternative 4, potential direct, indirect, and cumulative impacts on wood storks would be comparable to those described under the No Action alternative and Alternative 3.

Sea Turtles

Beach Fill Placement

Direct Impacts

As described previously, critical habitat has been designated for nesting sea turtles within Unit LOGG-T-NC-08 which encompasses the dry beach habitat along Holden Beach. Should the erosion continue along the inlet beaches within the East End of Holden Beach, the critical habitat for nesting sea turtles could be impacted. Under Alternative 4, the direct impacts of beach fill placement on sea turtles would be the same as those described under the No Action alternative and Alternative 3.

Indirect Impacts

Under Alternative 4, indirect nesting habitat modification effects associated with the initial placement of beach fill would be the same as those described under the No Action alternative and Alternative 3.

As previously described, the CMS model-projected oceanfront shoreline response on the west end of Oak Island under Alternative 4 (Figure 5.15) is essentially the same as the projected response under Alternative 2 (Figure 5.11). Corresponding effects on dry beach and dune habitats are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). Thus, the modeling results for Alternative 4 suggest that East End nourishment would not affect sea turtle nesting habitat on Oak Island. In the case of Holden Beach, the performance of the beach fill under Alternative 4 is reflected in a relative increase in beach width at the end of Year 4. As a result, dry beach habitat loss under Alternative 4 is reduced by ~2 ac relative to Alternative 2 (Table 5.3). Thus, the modeling results for Alternative 4 suggest the potential for minor beneficial effects on sea turtles via an increase in available dry beach nesting habitat on Holden Beach.

Cumulative Impacts

Under Alternative 4, the cumulative impacts of beach fill placement operations on sea turtles would be similar to those described under the No Action alternative and Alternative 3.

Dredging

Direct, Indirect, and Cumulative Impacts

Excavation of the new outer inlet channel would employ either a cutterhead or hopper dredge in combination with a sidecast dredge. Cutterhead pipeline dredges are not known to entrain sea turtles; however, sea turtles are susceptible to entrainment by hopper dredges. Consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges, and hopper dredging projects are generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a V-shaped sand ridge in front of the draghead as it is drawn along the seafloor, thus providing for the deflection of sea turtles while avoiding direct contact with draghead. The distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that inshore and nearshore sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April to 20 November for inshore waters and a range of 23 April to 27 November for nearshore ocean waters. Under Alternative 4, rigid deflector dragheads would be required on all hopper dredges, thus reducing the potential for sea turtle entrainment. The proposed environmental hopper dredging window (16 November to 31 March) would limit dredging to periods when most sea turtles have moved to warmer offshore waters, thus further reducing the potential for sea turtle entrainment. Considering the relatively small East End beach fill volume requirements (~100,000 – 100,000 cy), the temporal extent of hopper dredging operations would be relatively limited. Therefore, it is expected that the use of rigid deflector dragheads and adherence to the proposed environmental hopper dredging window would reduce the risk of sea turtle entrainment to negligible levels.

In comparison to larger commercial hopper and cutterhead dredges, which are used for more rigorous deep draft dredging and beach nourishment projects, shallow draft sidecast dredges use relatively small California style dragheads and dredge pumps that are substantially reduced in terms of size and hp. As a result, the intake velocity and suction field are also substantially reduced. The draghead opening on sidecast dredges is also subdivided by a grid into smaller openings (max = 5 x 8 inches), thus further restricting the size of objects that can be drawn through the draghead (USACE 2008). During testing performed by the USACE on a dead juvenile sea turtle, the low suction velocity and small draghead openings associated with a sidecast dredge prevented the sea turtle from being retained. Furthermore, the test results indicate that turtles impinged against the draghead would soon be broken free by the motion of the draghead (NMFS 1999). Based on the limited entrainment potential, sidecast dredging under Alternative 4 would not be expected to have any direct impact on sea turtles.

The NMFS currently uses generic noise exposure thresholds to evaluate potential acoustic impacts on sea turtles. Actions that may expose sea turtles to rms SPL ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose sea turtles to continuous noise levels ≥166 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption (NMFS 2010b, McCauley 2000). As described in Section 5.4.4.2, none of the dredges that could be used in the outer channel would be expected to produce noise levels ≥166 db re 1μPa rms; and therefore, based on the noise thresholds described above, acoustic effects on sea turtles would not be expected under Alternative 4.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Dredging operations can potentially impact Atlantic and shortnose sturgeons directly through entrainment and/or indirectly through sediment suspension and soft bottom habitat modification. Between 1990 and 2007, federal navigation dredging operations along the Atlantic Coast resulted in the take of 11 Atlantic sturgeons and 11 shortnose sturgeons (USACE 2008). All of the shortnose sturgeon takes occurred along the North Atlantic Coast in the Delaware and Kennebec Rivers, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor included one by a hopper dredge and one by a clamshell dredge. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; and therefore, its presence in the outer inlet channel during dredging operations would not be expected. Based on its low probability of occurrence and the absence of reported dredge interactions along the South Atlantic Coast, direct impacts on shortnose sturgeon would not be expected under Alternative 4.

Atlantic sturgeon could potentially be present in the vicinity of the outer inlet channel during dredging operations. As indicated above, cutterhead and sidecast dredges are not known to entrain Atlantic sturgeon; and therefore, direct impacts resulting from the use of these dredge types in the outer channel would not be expected under Alternative 4. As indicated above, hopper dredges are known to entrain Atlantic sturgeon; however, all of the reported incidents along the South Atlantic Coast occurred in relatively confined rivers and harbors, where it has been suggested that restrictions on sturgeon movements may result in the highest risk of entrainment (NMFS 2012b). Therefore, considering that the outer channel is located in the open ocean, it is anticipated that the risk of entrainment would be very low. The use of rigid deflector dragheads on hopper dredges would be expected to further reduce the risk of Atlantic sturgeon entrainment; and considering the relatively small East End beach fill volume requirements (~100,000 – 100,000 cy), the duration of hopper dredging operations and the associated risk of entrainment would be of short duration. Therefore, it is anticipated that the Atlantic sturgeon entrainment risk under Alternative 4 would be negligible.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, direct, indirect, and cumulative impacts on seabeach amaranth would be similar to those described under the No Action alternative and Alternative 3.

5.4.4.8 Cultural Resources

Direct Impacts

The remains of four Civil War vessels at LFI are listed in the NRHP under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (*Ranger*) is located ~1 mile west of the inlet (Tidewater Atlantic Research 2011). Among these shipwrecks, the nearest to the proposed new outer channel is the Bendigo, located ~400 ft to the east. The *Iron Age* and the *Elizabeth* are located ~1,000 ft and ~1,700 ft east of the proposed new outer channel, respectively. Based on the distance between these shipwrecks and the proposed channel, direct impacts on NRHP-listed vessels would not be expected under Alternative 4.

Indirect and Cumulative Impacts

As described in Section 5.4.4.2, the modeling results project eastward migration of the inlet ebb channel over the majority of the four-year simulation period, thus indicating that the ebb channel could eventually intersect one or more of the known Civil War vessels at LFI. However, project-related ebb channel changes would be consistent with natural fluctuations and the dynamic nature of the inlet; and therefore, no indirect or cumulative effects on underwater archaeological resources would be expected under Alternative 4.

5.4.4.9 Public Interest Factors

<u>Public Safety</u>

Under Alternative 4, direct, indirect, and cumulative impacts on public safety would be comparable to those described under Alternative 3.

<u>Aesthetics and Recreation</u>

Under Alternative 4, direct, indirect, and cumulative impacts on aesthetics and recreation would be comparable to those described under Alternative 3.

<u>Navigation</u>

The existing federal inlet channel would be maintained during construction of the new outer channel, with the existing and new channels being joined at the end of the channel relocation process. Furthermore, USACE maintenance dredging of the ebb channel would continue during the interim periods between channel relocation events; therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 4.

Infrastructure

Under Alternative 4, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 19 oceanfront properties and ~230 ft of roads and associated linear utilities (Figure 5.16). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 4 by an average ~19 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.12). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 4.

Economics

Under Alternative 4, construction and maintenance costs would include those associated with periodic beach nourishment and outer inlet channel relocation; including the costs of beach fill, channel relocation dredging, mobilization/demobilization, monitoring, surveying, and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with outer channel excavation, inlet modification, and periodic nourishment borrow site dredging activities. Over a 30-year planning horizon, assuming outer channel relocation and nourishment of the East End Beach with approximately 150,000 cy of sand every 2 years, and an annual 4 percent increase in fill costs, Alternative 4 is expected to involve total construction costs of approximately $55.50 million. In present value terms, construction costs range from $21.97 million (6% discount rate) to approximately $36.32 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 19 properties (13 improved) and ~228 linear ft of roads and associated water, sewer, and power lines (Figure 5.16). The total assessed value of all properties projected to be newly at risk under Alternative 4 is roughly $3.01 million. The 250 linear ft of anticipated infrastructure replacement cost is valued at approximately $176,321, with a present value ranging from approximately $139,663 (6% discount rate) to $159,738 (2.5% discount rate).

To the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach, these effects may result in economic losses associated

Figure 5.16. Alternative 4 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats (Table 5.14). Additional adverse effects on use and non-use values would be expected as a result of channel relocation and inlet instability. The principle benefit of Alternative 4 would be the addition of beach width relative to baseline conditions. It is expected that maintenance of a wider beach would confer benefits in the form of improved property values in the immediate vicinity of the project. Improvements in property values can be expected for properties that would otherwise be imminently threatened. As a result, the Holden Beach tax base would be expected to improve.

Table 5.14. Alternative 4 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$55.50 M
Construction and Maintenance (Present Value)	$21.97 M - $36.32 M
Parcels at risk	19
Assessed Tax Value of Affected Parcels	3.01 M
Infrastructure Replacement Costs	$176,321
Infrastructure Replacement Costs (Present Value)	$139,663 - $159,738
Reduction in tax base	Intermediate
Transition costs	Intermediate
Diminished recreation value	High
Diminished aesthetic value	High
Environmental Damage	
Public non-use value losses (nature)	High
Public non-use value losses (Holden Beach)	Intermediate
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Low
Enhanced property value	Intermediate
Enhanced Recreation value	Moderate
Environmental Improvement	
Public non-use value (nature)	Low
Public non-use value (Holden Beach)	Intermediate

5.4.5 Alternative 5: Short Terminal Groin and Beach Nourishment

Under Alternative 5, the Town would assume responsibility for East End shore protection through the construction of an ~800-ft-long short terminal groin at the eastern end of the oceanfront beach between Stations 10+00 and 20+00 and the implementation of an independent 30-year beach nourishment plan. The main stem of the short terminal groin would include a 550-ft-long segment extending seaward from the toe of the primary dune and a ~250-ft-long anchor segment extending landward from the toe of the primary dune. The groin would also include a 250-ft-long shore-parallel T-Head segment centered on the seaward terminus of the main stem. The 250-ft anchor segment is designed to prevent flanking of the groin in the event of shoreline migration landward of the primary dune. The anchor segment would be entirely buried at the completion of groin construction, and the majority of the anchor segment is designed to remain buried based on historical shoreline analyses back to 1938. The short groin is designed to be a relatively low profile structure, both to promote sand over-passing and to minimize impacts to beach recreation and aesthetics. In addition to the 250-ft anchor segment, a portion of the adjoining groin segment across the upper dry beach would also be completely buried, thus maintaining recreational beach access across the groin. The relatively low profile of the groin would allow some sand over-passing even under eroded conditions at the end of the four-year nourishment cycle.

The short terminal groin would be constructed of 4- to 5-ft-diameter granite armor stone; and unlike conventional jetties and groins, would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for construction of the groin to the design 25 percent void ratio, thus providing the “leaky” characteristic that allows sand to pass through the structure. To prevent settlement of the stone, and if necessary to facilitate modification or removal of the groin, a base layer layer of geo-textile matting (1-ft thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the short groin would have a crest width of ~5 ft and a base width of ~40 ft, whereas the underlying geo-textile base layer would have a slightly greater width of ~45 ft. The relatively short length of the groin and the large tidal range at Holden Beach would allow for construction of the groin entirely from shore. It is anticipated that the East End public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

Nourishment events would place ~100,000 – 100,000 cy of sand on an approximately 0.7-mile section of the East End beach every four years. The beach nourishment footprint and the basic dune/berm/toe profile design would be similar to those associated with Alternatives 3 and 4; however, the initial nourishment event would also include the construction of a “groin fillet” that would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the short groin. The seaward terminus of the short groin would extend ~300 ft beyond the MHW line position associated with the eroded 2012 East End beach, which is considerably landward of the historical range of seaward shoreline positions at the eastern terminus of the oceanfront beach. Accounting for sand losses during beach construction, the projected borrow site dredging regime under Alternative 5 would involve the extraction of ~120,000 – 180,000 cy of sand from the preferred LFIX/Bend-Widener borrow site every four years, with the addition of potential supplemental sand acquisition from the inland LFI navigation channel and Central Reach offshore borrow site. The initial groin construction/nourishment event would adhere to a 15 November – 30 April environmental window. All subsequent maintenance nourishment events would adhere to a 15 November – 31 March environmental window.

5.4.5.1 Geology and Sediments

Under Alternative 5, the effects of dredging and sand placement activities on geology and sediments would be the same as those described under Alternative 3. The results of hydrodynamic and sediment transport modeling analyses indicate that groin-related effects on longshore current dynamics and sediment transport processes would be highly localized to the East End shoreline in the immediate vicinity of the groin structure. As in the case of many NC inlets, there is a localized reversal of the dominant westward regional sediment transport pattern along the inlet-influenced East End beach to locally dominant eastward sediment transport. In relation to Alternative 2, the principal model-projected effect of the short groin is a reduction in the rate of locally dominant eastward sediment transport from the East End beach into LFI, whereas the dominant westward regional transport rate in the vicinity of LFI is largely unaffected by the groin. The groin-related reduction in erosion along the East End beach in turn reduces the rate of shoaling in the LFIX and LFI channels. However, sediment volume changes throughout the remainder of the inlet complex and along Oak Island are essentially the same as those projected under Alternative 2. The response of the downdrift East End shoreline to the east of the groin under both alternatives is characterized by accretion resulting from shoal attachment. Shoal attachment adds sand to the downdrift shoreline under both alternatives; however, under Alternative 5, the groin reduces erosion along the immediately downdrift shoreline, thereby retaining more of the shoal material and resulting in a relative increase in beach width along the downdrift shoreline at the end of Year 4. The modeling results do not indicate any adverse erosional effects on the downdrift inlet shoreline, thus indicating that the effects of the short groin and associated nourishment activities under Alternative 5 on sediment transport would be minor and localized.

5.4.5.2 Marine Benthic Resources

<u>Soft Bottom Communities</u>

Dredging

Direct Impacts

The anticipated borrow site dredging regime under Alternative 5 would involve extractions of ~120,000 – 180,000 cy of sand from the LFIX channel and associated 400-ft bend widener every four years (in contrast to every two years for the No Action alternative and Alternative 3). In the case of a shortfall in sand volume, supplemental sand would be acquired firstly from the inland LFI channel and secondarily from the Central Reach offshore borrow site. Under Alternative 5, the direct impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. However, relative to the No Action alternative, Alternative 5 would increase the frequency of bend widener events, thus increasing the frequency of repeated dredging impacts on the associated benthic communities in the bend widener. Conversely, relative to Alternative 3, Alternative 5 would reduce the frequency of bend widener events, thus decreasing the frequency of repeated dredging impacts on the associated benthic communities. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, direct impacts on soft bottom communities would be the same as those described under Alternative 3. Assuming increased beach fill longevity (i.e., fewer dredging events over a 30 year timespan), reduced impacts to the Central Reach borrow area would be anticipated.

Indirect Impacts

Under Alternative 5, the indirect impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. However, relative to the No Action alternative, the additional bend widener dredging events under Alternative 5 would result in additional periods of suppressed benthic infaunal prey densities; thus increasing the overall temporal extent of indirect prey-loss effects on demersal fishes. Conversely, relative to Alternative 3, the reduction in bend widener dredging frequency under Alternative 5 would reduce the overall temporal extent of indirect prey-loss effects on demersal fishes. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, indirect impacts on soft bottom communities would be the same as those described under Alternative 3. Based on the model-projected increase in beach fill longevity (i.e., fewer dredging events over a 30 year time span), reduced impacts to the Central Reach borrow area would be anticipated.

Cumulative Impacts

Under Alternative 5, the potential cumulative impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative and Alternative 3. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, potential cumulative impacts on soft bottom communities would be the same as those described under Alternative 3. Based on the model-projected increase in beach fill longevity (i.e., fewer dredging events over a 30 year time span), reduced impacts to the Central Reach borrow area would be anticipated.

Terminal Groin and Beach Nourishment

Direct Impacts

Construction of the conceptual short terminal groin under Alternative 5 would directly impact ~0.6 ac of subtidal soft bottom habitat, resulting in the permanent loss of the associated benthic infaunal/epifaunal communities. The beach fill footprint and the direct impacts of individual East End beach fill placement events on soft bottom communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on soft bottom benthic communities.

Indirect Impacts

Under Alternative 5, the indirect impacts of individual beach fill placement events on soft bottom communities and surf zone fishes would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, under Alternative 5, the extended four-year nourishment interval and corresponding reduction in the frequency of repeated direct impact events would reduce the overall temporal extent of indirect prey-loss effects on surf zone fishes.

Cumulative Impacts

Under Alternative 5, the beach fill footprint and the potential cumulative effects of beach fill placement on soft bottom communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on soft bottom communities. Based on the minimal extent of groin-related direct impacts (~0.6 ac), cumulative effects would not be expected.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf, which are located well seaward of the beach fill and short terminal groin footprints and the LFIX/bend widener and inland LFI channels. In the case of the Central Reach offshore borrow site, compliance with the state 500-m hardbottom buffer rule was confirmed through remote sensing surveys conducted in 2011 (Tidewater Atlantic Research 2011). Therefore, Alternative 5 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities. Submerged portions of the short terminal groin would provide many of the same habitat functions that are associated with natural hardbottom habitats. The fish communities that are associated with groins and jetties in NC are typically a subset of the species found on natural ocean hardbottoms and estuarine oyster reefs (Lindquist et al. 1985; Hay and Sutherland 1988). Taxa reported from groins and jetties in NC and SC include small cryptic resident fishes (e.g., blennies and gobies), numerically dominant fishes that migrate offshore in winter (e.g., pinfish, spottail pinfish, black sea bass, and pigfish), predatory pelagic fishes (e.g., bluefish, Spanish mackerel, and king mackerel), fishes attracted to jetties during their seasonal migrations [e.g., smooth dogfish (*Mustelus canis*)], and tropical fishes occurring as strays during the summer (e.g., butterflyfishes and surgeonfishes) (Hay and Sutherland 1988). Therefore, the additional hardbottom habitat created by the short terminal groin would be expected to have beneficial effects on hardbottom communities.

5.4.5.3 Water Column

Hydrodynamics

Direct and Indirect Impacts

Dredging

Under Alternative 5, the potential direct and indirect hydrodynamic effects of dredging in the LFIX/bend widener and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. The potential direct and indirect hydrodynamic effects of dredging at the Central Reach offshore borrow site would be the same as those described under Alternative 3.

Short Terminal Groin and Nourishment

The CMS model-projected inlet and estuarine hydrodynamic responses to beach nourishment and groin construction under Alternative 5 are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities for the inlet throat, AIWW east channel, AIWW west channel, and Eastern Channel are consistently within +/-10 percent of the corresponding Alternative 2 values during the four-year model simulation period (Table 5.15). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all four of the inlet/estuarine transects. Corresponding model-projected changes in channel morphology under Alternative 5 are also essentially the same as those associated with Alternative 2. The similarity of the responses under the two alternatives suggests that the model-projected inlet and estuarine hydrodynamic responses under Alternative 5 are primarily the result of natural background coastal processes; thus indicating that the short groin and associated nourishment activities under Alternative 5 would have little effect on inlet and estuarine hydrodynamics.

The model-projected nearshore ocean hydrodynamic response along Holden Beach indicates that groin-related effects on longshore current dynamics are highly localized to the groin structure. Under flood tide conditions, the potential for any deflection of longshore currents by the groin is overridden by the large tidal push of water into the inlet; and consequently, easterly longshore currents along the Holden Beach oceanfront shoreline are driven tightly around the groin and into the inlet where they resume their normal pattern of flow (Figure 5.17). Similarly, the large tidal push of water out of the inlet during ebb tide conditions drives westerly longshore currents from the inlet tightly around the groin and along the Holden Beach oceanfront shoreline (Figure 5.18). Therefore, adverse effects on longshore currents would not be expected under Alternative 5. The filled East End beach in combination with the groin fillet would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the terminal groin, thus minimizing the potential for effects on longshore currents. Furthermore, the groin would extend the oceanfront shoreline seaward by only ~300 ft relative to the eroded 2012 MHW line position, which is considerably landward of the historical range of seaward shoreline positions associated with the eastern terminus of oceanfront beach.

Other potential hydrodynamic-effects that are generally associated with terminal groins include the potential for rip current formation along the groin structure and the potential for interference with the transport of estuarine-dependent fish and invertebrate larvae from the updrift nearshore ocean zone to the inlet. The minimal model-projected effects on longshore current dynamics indicate that larval transport is unlikely to be significantly impeded by the groin. Additional larval transport modeling analyses were conducted using the CMS hydrodynamic and sediment transport model to further evaluate potential impacts to larval transport. The CMS model was used to compare changes in particle concentrations (representing larvae) along the East End beach under Alternatives 2 and 5. The only differences between the projected particle concentration changes under the two alternatives correspond to areas of subtidal/intertidal to supratidal beach conversion within the beach fill footprint (Figure 5.19), thus indicating that the differences are related to the displacement of water by beach fill under Alternative 5. Thus, the modeling results indicate only localized groin-related effects on larval transport. The T-head feature of the groin is designed to minimize rip current formation, and the CMS current vector modeling results do not show any rip current activity along the groin structure. However, the modeling results do show a general increase in rip current activity along the adjacent East End

Table 5.15. Alternative 5 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	100%	100%	99%	97%	100%	100%	100%	100%
1	97%	97%	95%	95%	100%	100%	100%	100%
2	97%	96%	94%	78%	100%	100%	99%	100%
3	99%	97%	88%	97%	101%	97%	98%	100%
4	103%	97%	101%	100%	104%	101%	118%	96%
Neap Tide								
0	100%	100%	99%	98%	100%	100%	100%	100%
1	97%	97%	90%	88%	100%	100%	100%	100%
2	97%	92%	92%	95%	100%	101%	99%	74%
3	98%	99%	87%	66%	99%	101%	98%	100%
4	105%	101%	116%	113%	110%	106%	113%	95%

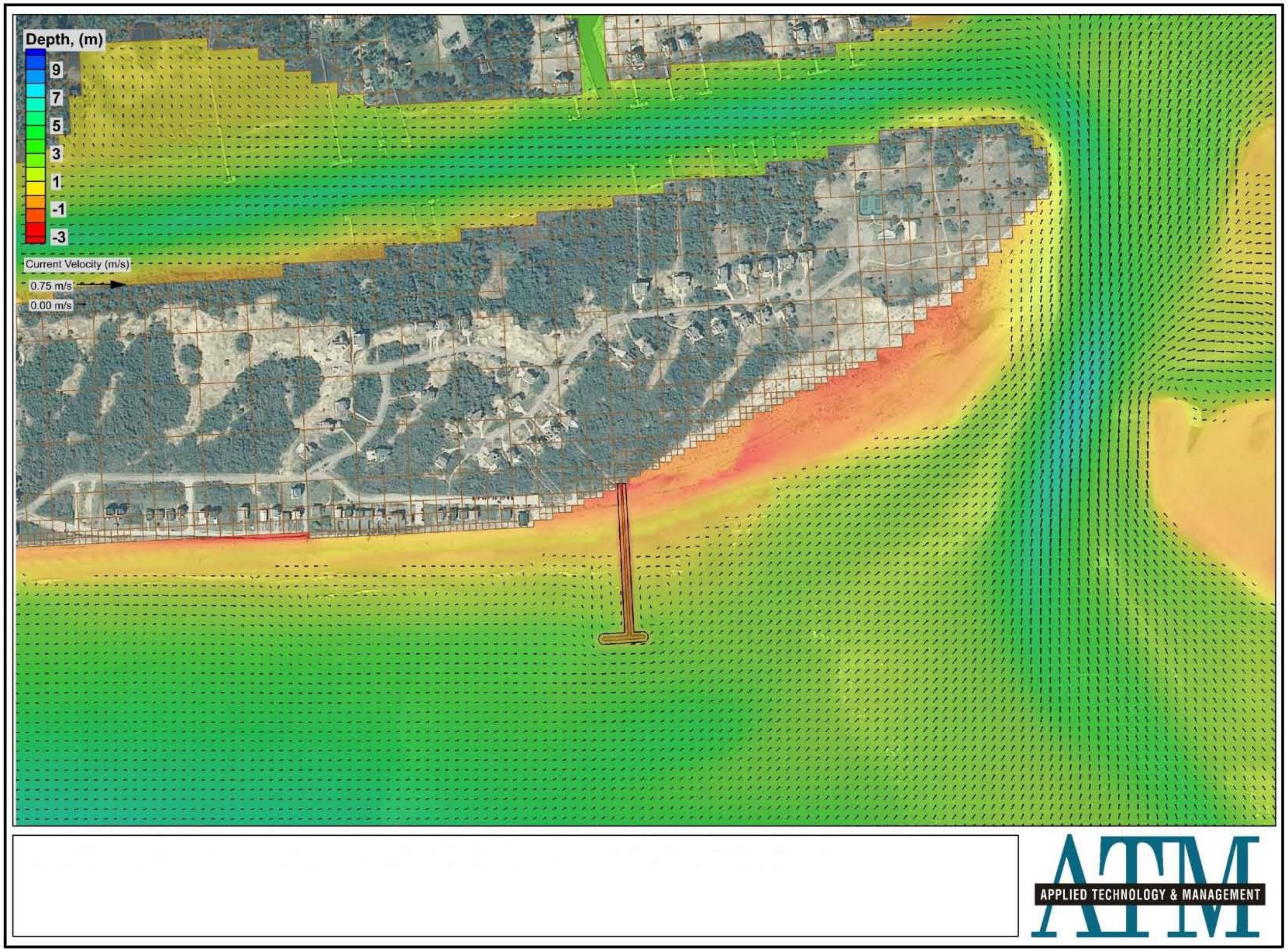


Figure 5.17. Alternative 5 - Typical Flood Tide Current Vector Diagram

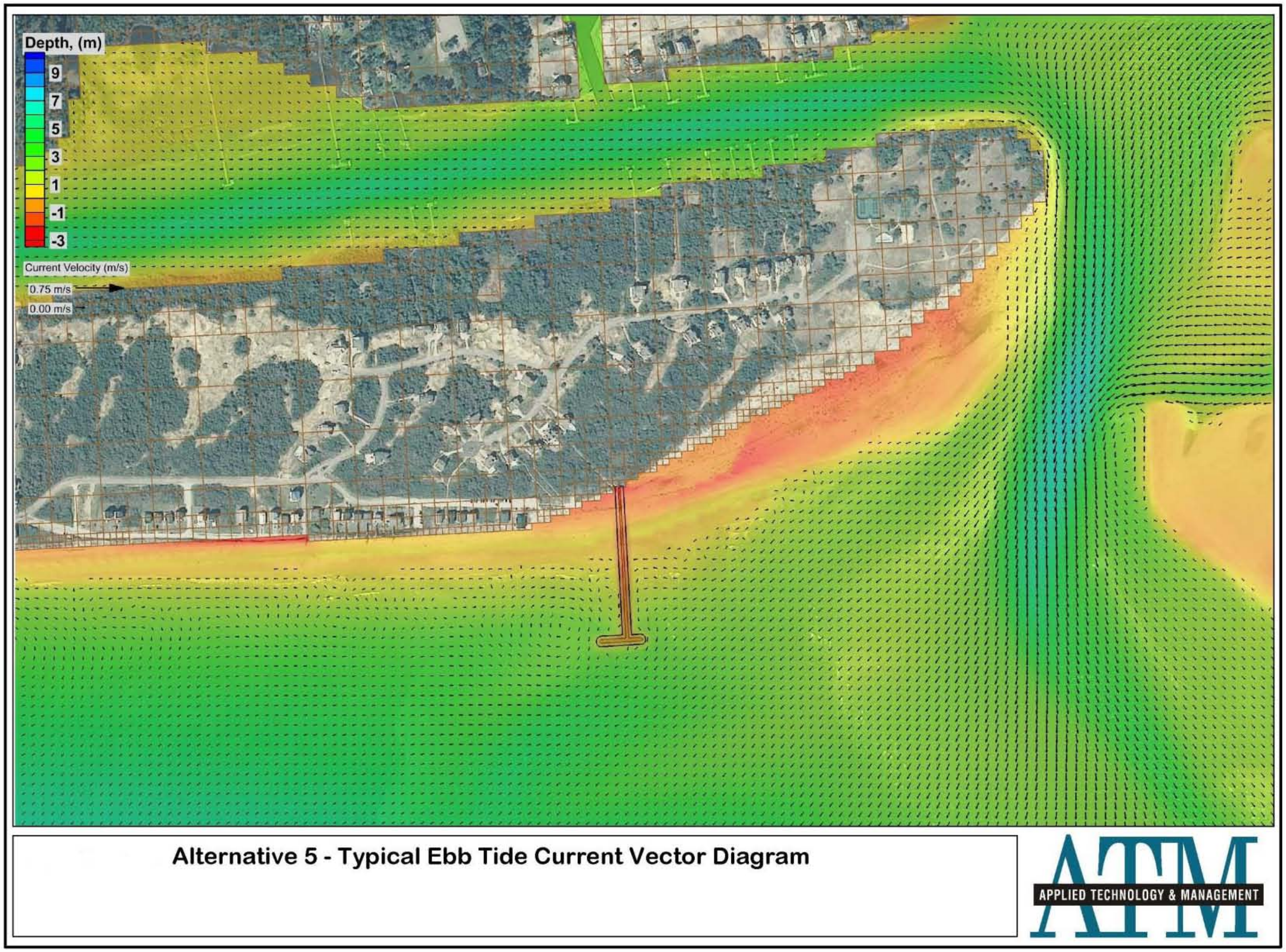


Figure 5.18. Alternative 5 - Typical Ebb Tide Current Vector Diagram

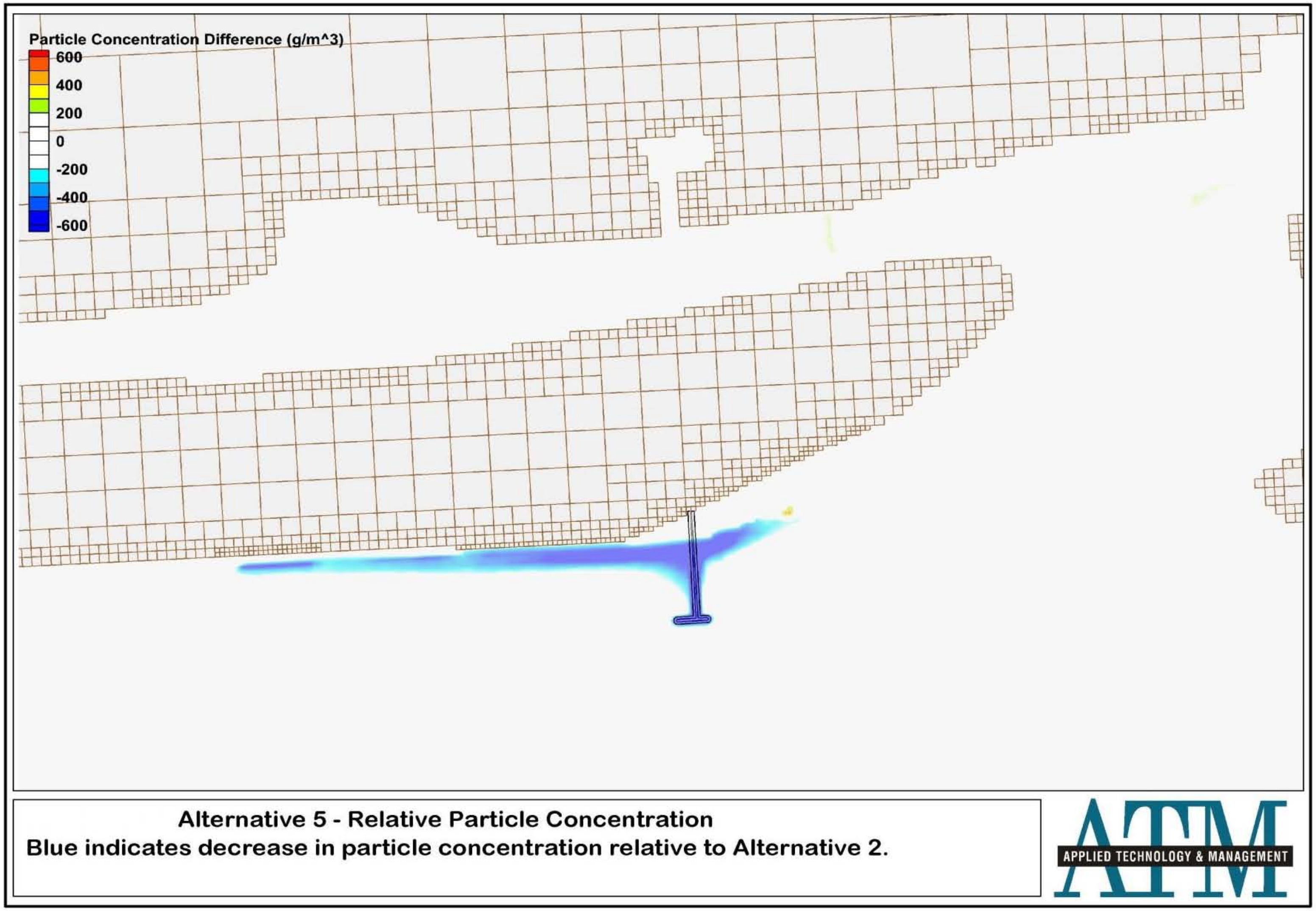


Figure 5.19. Alternative 5 - Relative Particle Concentration

beach during ebb tidal conditions, thus suggesting a greater risk of rip current formation along the East End beach under Alternative 5. However, existing hydrodynamic conditions along the East End beach are also conducive to rip current formation when inlet ebb tidal current velocities exceed 5 ft per second.

Cumulative Impacts

The CMS modeling results for Alternative 5 suggest that project-related direct and indirect effects on hydrodynamics would be minor and highly localized to the groin structure. Therefore, cumulative impacts on hydrodynamics would not be expected under Alternative 5.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Under Alternative 5; the direct, indirect, and cumulative effects of dredging-induced sediment suspension on water quality and pelagic communities would be similar to those described under the No Action alternative and Alternative 3. Although project related dredging for nourishment purposes would occur less frequently under Alternative 5, it is anticipated that continuing interim federal maintenance dredging would maintain a similar LFIX dredging regime, thereby resulting in similar sediment suspension effects within the water column.

Short Terminal Groin and Nourishment

Construction of the short groin would be conducted entirely from shore, and the extent of subtidal/intertidal substrate disturbance would be minimal (~0.3 ac). Therefore, it is expected that the direct and indirect impacts of groin-related sediment suspension would be short-term, localized, and minor. Direct and indirect sediment suspension effects associated with East End beach fill placement events would be similar to those described under the No Action alternative and Alternatives 3 and 4. Sediment suspension effects associated with groin construction and periodic nourishment would be short term and localized to the East End beach; and therefore, cumulative impacts would not be expected under Alternative 5.

<u>Underwater Noise</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the direct, indirect, and cumulative impacts of underwater noise produced by dredging operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative and Alternative 3. In the case of supplemental dredging at the Central Reach offshore borrow site; the potential direct, indirect, and cumulative impacts of underwater noise would be the same as those described under Alternative 3.

Entrainment

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the direct, indirect, and cumulative impacts of entrainment would be comparable to those described under Alternative 3.

5.4.5.4 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 5, construction of the short terminal groin would directly impact ~0.2 ac of intertidal beach habitat, resulting in the permanent loss of the associated benthic infaunal/epifaunal communities. The beach fill/fillet footprint and the direct impacts of individual East End beach fill placement events on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on intertidal benthic communities.

Indirect Impacts

Under Alternative 5, the indirect impacts of individual beach fill placement events on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of indirect benthic infaunal prey-loss effects on shorebirds and surf zone fishes. Based on the minimal area of permanent groin-related intertidal habitat loss (~0.2 ac), associated indirect effects on shorebirds and surf zone fishes would be negligible.

Under Alternative 5, the CMS model-projected response of the Oak Island west-end oceanfront shoreline (Figure 5.20) is essentially the same as the projected future without project shoreline response under Alternative 2 (Figure 5.11). Under Alternative 5, a minor reduction in shoreline erosion over the course of the four-year model simulation period slightly reduces intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). The similarity of the Oak Island responses indicates that the projected shoreline and intertidal beach habitat changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would not affect intertidal beach habitat on Oak Island. The projected responses of the East End oceanfront

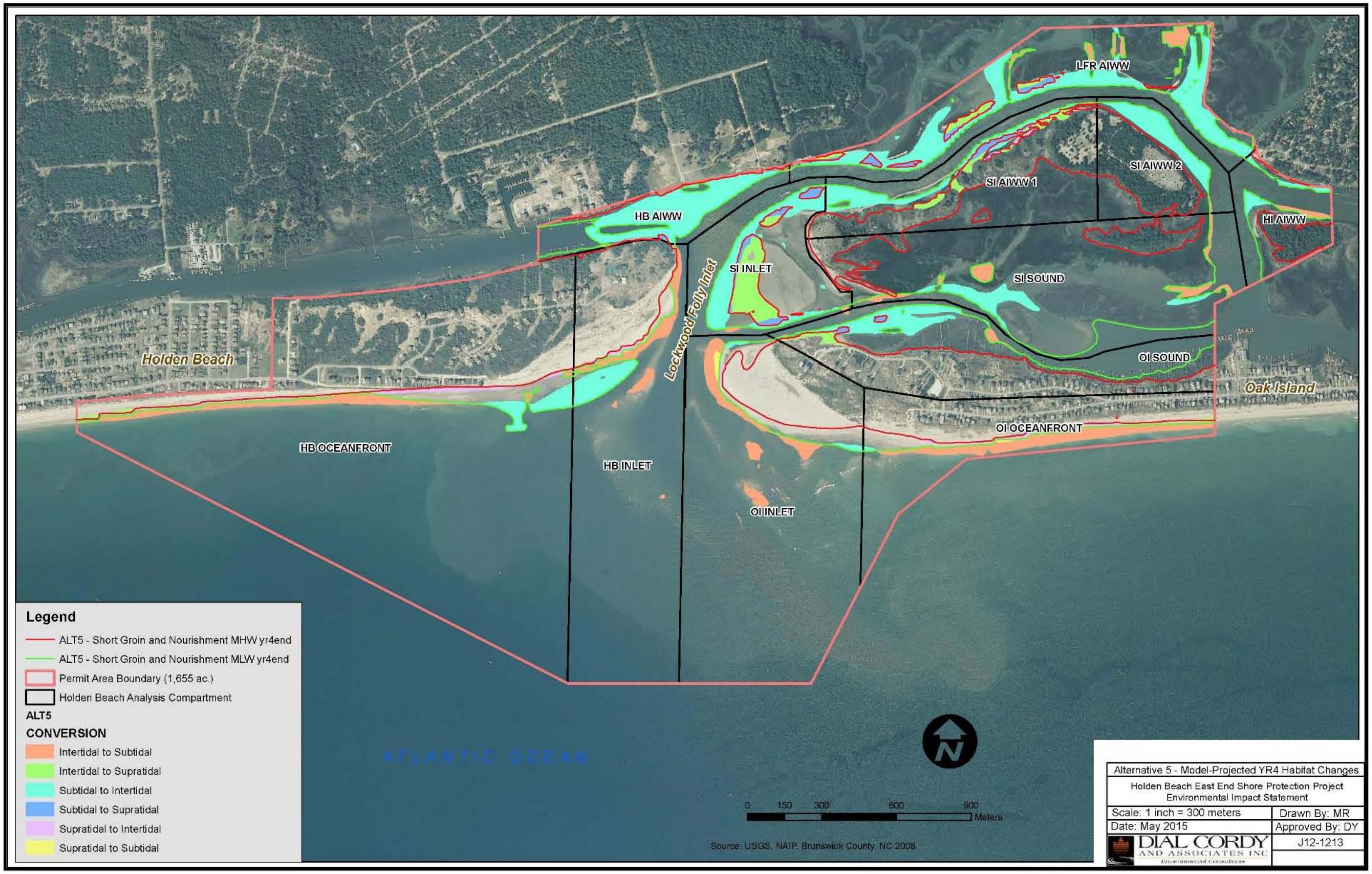


Figure 5.20. Alternative 5 – Model-Projected YR4 Habitat Changes

shoreline on Holden Beach under Alternatives 2 and 5 are similar in pattern; however, there are differences between the responses that are related to the performance of the beach fill and the sand trapping function of the groin under Alternative 5. The entire East End beach to the west of the groin is erosional under both alternatives; however, under Alternative 5, the performance of the beach fill is reflected in a relative increase in beach width at the end of Year 4. The response of the remaining downdrift East End beach to the east of the groin under both alternatives is characterized by accretion resulting from shoal attachment. Shoal attachment adds sand to the downdrift shoreline under both alternatives; however, under Alternative 5, the groin reduces erosion along the immediately downdrift shoreline, thereby retaining more of the shoal material and resulting in a relative increase in beach width along the downdrift shoreline at the end of Year 4. The modeling results do not indicate any adverse erosional effects on the downdrift inlet shoreline. As a result of beach fill performance and groin effects, the nourished East End beach under Alternative 5 is on average ~36 ft wider than the corresponding East End beach under Alternative 2 at the end of Year 4 (Table 5.4). The corresponding effect on the quantity of intertidal beach habitat under Alternative 5 is an increase of ~5 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Project Area

Under Alternative 5, the cumulative impacts of East End beach fill placement events on intertidal beach communities in the vicinity of the project area would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on intertidal beach communities. A terminal groin similar to the short groin was recently constructed on Bald Head Island at Cape Fear Inlet, and a similar terminal groin has been approved for construction on Ocean Isle Beach at Shallotte Inlet. Under Alternative 5, the CMS modeling results indicate that the influence of the short groin would be highly localized to the 0.7-mile East End beach. It is expected that the influence of the two additional terminal groins would be similarly limited to relatively short, inlet-influenced reaches of the oceanfront beach. Therefore, it is expected that the combined extent of intertidal beach affected by the three terminal groins would constitute a small percentage of the ~31 miles of beaches along Bald Head Island, Oak Island, Holden Beach, and Ocean Isle Beach. Therefore, it is expected that any groin-related cumulative effects would not significantly degrade intertidal beach communities in the vicinity of the project area.

Regional

The regional-scale cumulative effects of East End beach fill placement events on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on intertidal beach communities. Prior to the construction of a terminal groin on Bald Head Island in 2016, jetties and groins along the southern NC coast were limited to just a few structures; including a 4,800-ft groin/breakwater on the western flank shoreline of Cape Lookout at Barden Inlet, a 1,250-ft terminal groin on the east end of Bogue Banks at Beaufort Inlet, and a pair of dual ~3,500-ft jetties at Masonboro Inlet. The NC terminal groin law allows for six terminal groins, of which only one (Bald Head Island) has been constructed. Currently, three additional terminal groin projects are being actively pursued; including the proposed action terminal groin on Holden Beach, a terminal groin on Figure 8 Island at Riches Inlet, and a terminal groin on Ocean Isle Beach at Shallotte Inlet. The remaining two groins that are allowed under NC law, although not currently associated with a site-specific project, would most likely be constructed along the southern NC coast where numerous erosional hotspots are associated with inlets. Under Alternative 5, the CMS modeling results indicate that the influence of the short groin would be highly localized to the 0.7-mile East End beach. It is expected that the five additional terminal groins would be similarly designed to act on relatively short, inlet-influenced reaches of the oceanfront beach. Although the influence of the existing impermeable structures at Barden, Beaufort, and Masonboro Inlets likely extends to longer reaches, it is expected that the combined extent of intertidal beach affected by the three existing structures and the six terminal groins would constitute a small percentage of the 163 miles of beaches along the southern NC coast. There are no known thresholds for determining the extent of intertidal beach impacts that would result in significant degradation of intertidal beach communities. However, considering the limited extent of affected beach habitat in relation to the 163 miles of beach habitat along the southern NC coast, it is anticipated that any cumulative effects would not significantly degrade intertidal beach communities.

Dry Beach and Dune Communities

Direct Impacts

Under Alternative 5, construction of the short terminal groin would permanently impact ~0.2 ac of dry beach and dune habitat. The direct impacts of individual East End beach fill placement events on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated impacts on dry beach and dune communities.

Indirect Impacts

The indirect impacts of individual East End beach fill placement events on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of indirect physical habitat modification effects on dry beach and dune communities. The majority of the short groin dry beach segment and the entirety of the landward anchor segment through the dunes would be completely buried; thus minimizing the potential for indirect physical habitat modification effects. Based on the minimal area of permanent groin-related dry beach habitat loss (~0.2 ac), associated indirect effects on dry beach communities would be negligible.

As described above, the CMS model-projected responses of the Oak Island oceanfront shoreline are the same under Alternatives 5 (Figure 5.20) and 2 (Figure 5.11). Corresponding dry beach/dune habitat changes on Oak Island are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). The similarity of the Oak Island responses indicates that the projected dry beach and dune habitat changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would not affect dry beach and dune habitats on Oak Island.

In the case of Holden Beach, the projected relative increase in beach width under Alternative 5 corresponds to an increase in dry beach/dune habitat of ~3 ac relative to Alternative 2 (Table 5.3); thus suggesting a beneficial relative increase in habitat under Alternative 5.

Cumulative Impacts

Project Area

Under Alternative 5, potential cumulative impacts on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on dry beach and dune communities. The CMS modeling results indicate that the influence of the short groin would be highly localized to the 0.7-mile East End beach. As described above, it is expected that the influence of the two additional terminal groins on Bald Head Island and Ocean Isle Beach would be similarly limited to relatively short, inlet-influenced reaches of the oceanfront beach. Therefore, it is expected that the combined extent of dry beach and dune habitat affected by the three terminal groins would constitute a small percentage of the ~31 miles of beach and dune habitat along Bald Head Island, Oak Island, Holden Beach, and Ocean Isle Beach. Therefore, it is expected that any groin-related cumulative effects would not significantly degrade dry beach and dune communities in the vicinity of the project area.

Regional

The regional-scale cumulative effects of East End beach fill placement events on dry beach and dune communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on dry beach and dune communities. As in the case of the intertidal beach, it is expected that the combined extent of dry beach and dune habitat affected by jetties and groins would constitute a small percentage of the 163 miles of beaches along the southern NC coast. Considering the limited extent of affected beach habitat in relation to the total 163 miles of beach habitat, it is anticipated that any cumulative effects would not significantly degrade dry beach and dune communities.

5.4.5.5 Inlet Complex

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Direct impacts on intertidal flats and shoals under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement and Dredging

The indirect impacts of dredging and beach nourishment on intertidal flats and shoals under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Long-Term Model-Projected Effects

The CMS model-projected inlet response under Alternative 5 (Figure 5.20) is essentially the same as the projected future without project inlet response under Alternative 2 (Figure 5.11). The only dissimilarity between the projected inlet responses under the two alternatives is a minor difference in the pattern of shoal attachment along the inlet shoulder of Holden Beach. The inlet response under both alternatives includes the same general pattern of shoal formation and attachment along the inlet shoulder; resulting in net accretion along the adjoining ~500-ft segment of the inlet shoreline at the end of Year 4. However, under Alternative 5, a larger quantity of the shoal sediment volume is retained by the short groin, resulting in a relative increase in intertidal habitat of ~2 ac at the end of Year 4 (Table 5.3). Otherwise, the projected inlet response and the associated losses and gains of intertidal habitat under Alternative 5 are essentially the same as those described under Alternative 2. The similarity of the inlet responses under the two alternatives indicates that the projected changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would have little effect on inlet intertidal habitats.

Cumulative Impacts

In the absence of direct and indirect effects, potential cumulative impacts on intertidal flats and shoals would not be expected under Alternative 5.

Inlet Dry Beach and Dune Communities

Direct

Direct impacts on inlet dry beach and dune communities under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Indirect

Under Alternatives 5, the CMS model-projected changes in the distribution and quantity of inlet dry beach and dune habitats (Figure 5.20) are the same as the projected future without project changes under Alternative 2 (Figure 5.11). The similarity of the responses indicates that the projected changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that Alternative 5 would not have any effect on inlet dry beach and dune habitats.

Cumulative Impacts

In the absence of direct and indirect effects, potential cumulative impacts on inlet dry beach and dune communities would not be expected under Alternative 5.

5.4.5.6 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on shellfish would be the same as those described under the No Action alternative and Alternative 3.

SAV

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on SAV would be the same as those described under the No Action alternative and Alternative 3.

Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on tidal marshes would be the same as those described under the No Action alternative and Alternative 3.

5.4.5.7 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts of dredging and beach fill placement operations on right and humpback whales and proposed right whale critical habitat under Alternative 5 would be the same as those described under Alternative 3. The short groin structure would be confined to relatively shallow waters (<6 m). Considering that the essential features of proposed right whale critical habitat within the study area include a water depth ≥6 m, no adverse effects on critical habitat would be expected under Alternative 5.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts on the West Indian manatee would be the same as those described under the No Action alternative and Alternative 3.

Piping Plover

Direct, Indirect, and Cumulative Impacts

As described in Section 5.4.5.4, the modeling results for Alternative 5 do not show any project-related effects on the inlet habitats that are likely to be used by piping plovers. Therefore, potential direct, indirect, and cumulative impacts on piping plovers under Alternative 5 would be comparable to those described under the No Action alternative and Alternative 3.

Red Knot

Under Alternative 5; the potential direct, indirect, and cumulative impacts on red knots would be similar to those described under the No Action alternative and Alternative 3. However, Alternative 5 would maintain a consistently wider East End oceanfront beach while reducing the frequency of periodic nourishment impact events, thus suggesting the potential for additional beneficial effects on red knots via habitat enhancement.

Wood Stork

Under Alternative 5; the potential direct, indirect, and cumulative impacts on wood storks would be the same as those described under the No Action alternative and Alternatives 3 and 4.

Sea Turtles

Direct Impacts

Under Alternative 5; the potential direct impacts of beach fill placement and dredging on sea turtles would be comparable to those described under Alternative 3. The proposed window for the initial groin construction event (16 November – 30 April) would avoid the sea turtle nesting season. Therefore, direct impacts on sea turtle nesting would not be expected. Direct impacts on sea turtles in the water would not be expected, as groin construction would occur entirely from shore.

Indirect and Cumulative Impacts

Initial Beach Fill Placement, Dredging, and Groin Construction

The potential indirect impacts of beach fill placement and dredging operations on sea turtles would be comparable to those described under Alternative 3. Groin construction would result in minimal (~0.2 ac) permanent loss of potential dry beach nesting habitat; and the majority of the groin segment across the dry beach would be buried, thus minimizing the potential for indirect physical habitat modification effects. Furthermore, based on the groin's location near the eastern terminus of the oceanfront beach, and its perpendicular alignment relative to the beach, effects on sea turtle access to dry beach nesting habitats would not be expected. Therefore, the short groin would not be expected to have adverse indirect or cumulative effects on sea turtles via modification of potential nesting habitat. The groin could affect the movements of sea turtles in the water; however, the filled East End beach in combination with the groin fillet would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the terminal groin, thus minimizing the potential for effects on sea turtle movements. Furthermore, the short groin would extend the oceanfront shoreline seaward by only ~300 ft relative to the eroded 2012 MHW line position, which is considerably less than the historical range of seaward shoreline positions along the eastern terminus of the oceanfront beach. Therefore, it is expected that any groin-related effects on sea turtles in the water would be minimal. The modeling results indicate an increase in ocean dry beach habitat of ~4 acres along the East End relative to Alternative 2 at the end of Year 4, thus suggesting the potential for beneficial effects on sea turtles via enhancement of nesting habitat.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; direct, indirect, and cumulative impacts on Atlantic and shortnose sturgeons would be similar to those described under Alternative 3. However, the bend widener would be dredged less frequently under Alternative 5, thus reducing the frequency of repeated impacts on the associated benthic invertebrate communities. Thus, the overall temporal extent of potential indirect benthic infaunal prey-loss effects under Alternative 5 would be reduced relative to Alternative 3.

Seabeach Amaranth

Under Alternative 5; the direct and indirect impacts of individual beach fill placement events on seabeach amaranth would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on dry beach habitats, thus reducing the frequency and overall temporal extent of potential adverse impacts on seabeach amaranth relative to the No Action alternative and Alternatives 3 and 4. Similarly, the reduction in the frequency and temporal extent of beach fill placement impacts would lessen the potential for adverse cumulative effects. The maintenance of a wider dry beach would potentially have beneficial indirect effects on seabeach amaranth via habitat enhancement. The modeling results indicate an increase in ocean dry beach habitat of ~4 ac along the East End relative to Alternative 2 at the end of Year 4, thus suggesting the potential for beneficial effects on sea beach amaranth via habitat enhancement.

5.4.5.8 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts of beach fill placement and dredging on cultural resources would be the same as those described under Alternative 3. The short groin would extend only ~300 ft seaward of the MHW line, and the groin footprint would be evaluated for the presence of potential marine debris and archaeological resources prior to construction. Therefore, construction of the short groin would not be expected to have any direct, indirect, or cumulative effects on cultural resources.

5.4.5.9 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential direct, indirect, and cumulative impacts of beach nourishment and dredging on public safety would be the same as those described under the No Action alternative and Alternative 3. In general, groin-related public safety concerns are related to the creation of a potential hazard to navigation and the potential for an increase in rip current activity along the groin structure. The short terminal groin would not be located in a navigation channel, but would constitute a potential hazard to small recreational watercraft operating in close proximity to the shoreline. As a potential hazard to navigation, the short terminal groin would be subject to USCG approval and marking requirements in accordance with 33 CFR 64. Marking requirements would be determined by the USCG, and once established would be maintained until the groin is removed. The T-head feature of the groin is designed to minimize rip current formation, and the CMS current vector modeling results do not show any rip current activity along the groin structure. However, the modeling results do show a general increase in rip current activity along the immediately adjacent East End beach during ebb tidal conditions, thus suggesting a greater risk of rip current formation along the East End beach under Alternative 5. However, existing hydrodynamic conditions along the East End beach are also conducive to rip current formation when inlet ebb tidal current velocities exceed 5 ft per second (ATM 2013).

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts of beach fill placement and dredging on aesthetics and recreation would be similar to those described under the No Action alternative and Alternative 3. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of beach construction activities and associated adverse effects on aesthetics and recreation relative to the No Action alternative and Alternative 3. The extended nourishment interval may facilitate the removal of some existing sandbags along the East End beach, Although NCDCM issues sandbag permits to individual homeowners, and the Town has no authority over their installation or removal, sandbags are permitted on a temporary basis and must eventually be removed when a more permanent solution to the erosional hazard is implemented. The short terminal groin would not provide a natural beach aesthetic environment, and thus may detract from the aesthetic quality of the beach for some beachgoers. However, the groin is designed to be a low profile structure with minimal exposure on the recreational beach, in part to minimize aesthetic effects. However, to the extent that the terminal groin structure itself may be viewed as aesthetically unappealing, aesthetic quality may be reduced relative to that which would exist with a natural and stable shoreline. However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline may be seen as preferable.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential direct, indirect, and cumulative impacts of beach nourishment and dredging on navigation would be similar to those described under the No Action alternative and Alternative 3. The short groin would not be located in a navigation channel and would extend only ~300 ft seaward of the MHW line. As described in Section 5.2, the CMS current vector analyses do not show any hydrodynamic changes that would affect navigation. Furthermore, as described above, the potential structural hazard to small recreational watercraft operating in close proximity to the shoreline would be mitigated through adherence to the marking requirements of 33 CFR 64. Therefore, no direct, indirect, or cumulative groin-related impacts on navigation would be expected under Alternative 5.

Infrastructure

Under Alternative 5, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~800 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 10 oceanfront properties (Figure 5.21). No roads or linear utilities are affected. In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 5 by an average ~36 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.12). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 5.

Economics

Under Alternative 5, construction and maintenance costs would include those associated with construction and maintenance of the short groin and periodic beach nourishment; including the costs of beach fill and groin materials, mobilization/demobilization, monitoring, surveying, and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with the groin and periodic nourishment and dredging activities. Over a 30-year planning horizon, assuming $2.5 million for initial groin construction and nourishment of the East End Beach with approximately 150,000 cy of sand every four years, and an annual four percent increase in fill costs, Alternative 5 is expected to involve total construction costs of approximately $34.41 million. In present value terms, construction costs range from $15.24 million (6% discount rate) to approximately $23.43 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 5, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~800 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 11 properties (6 improved) (Figure 5.21). The total assessed value of all properties projected to be at risk under Alternative 5 is roughly $994,000. Projected shoreline changes under Alternative 5 do not result in any impacts to infrastructure, thus no infrastructure replacement costs are associated with Alternative 5.

Figure 5.21. Alternative 5 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

Under Alternative 5, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 2, 3, and 4 and similar to those projected under Alternative 6 (Table 5.16). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. To the extent that the terminal structure itself may be viewed as aesthetically unappealing, properties with views of the structure may have reduced amenity value relative to that which would exist with a natural and stable shoreline. However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline would likely be seen as preferable relative to the alternative condition. Furthermore, to the extent that the structure would attract recreationists (i.e. anglers) or inhibit movement along the shoreline, property owners in the vicinity of the groin could suffer economic losses due to inconvenience and crowding. The use of a hardened structure to mitigate erosion would confer economic losses on the segment of the population that values unfettered ecosystem function. Even if harmful effects are never realized, some people could remain opposed to the use of hardened structures for shoreline erosion control. In the case of the proposed terminal groin on Holden Beach, such sentiments may be partially mitigated by the understanding that the required frequency of beach nourishment events would be reduced, thereby lessening the environmental impacts of dredging and sand placement over the lifetime of the structure.

The principle benefits of Alternative 5 would be associated with enhanced shoreline stability and increased beach width relative to baseline conditions. To the extent that the public views the terminal structure as reducing the risk of future erosion, this added stability would serve to enhance property values along the Holden Beach East End shoreline. Based on the literature (see Appendix O), it is reasonable to expect that properties up to 300 m inland of the shoreline would realize improvements in market value. Associated benefits would likely include increased rental revenues and higher municipal tax revenues. As noted in Parsons and Powell (2001), active mitigation efforts such as beach armoring may also serve to encourage additional use and/or development and generate additional economic impacts relative to the status quo in the form of increased municipal tax revenues as well as temporary construction employment and spending. The terminal groin may create enhanced recreation values as a result of the projected gains in beach width and shoreline stability, especially those in the vicinity of the structure, as well as the creation of rocky bottom area that may increase species diversity and enhance the quality of recreational fishing near the structure. Because dune and beach habitats in the project area will be subject to reduced losses from erosion, indirect and non-use values may also be created, enhanced, or preserved.

Table 5.16. Alternative 5 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$34.41 M
Construction and Maintenance (Present Value)	$15.24 M – $23.43 M
Parcels at risk	11
Assessed Tax Value of Affected Parcels	$994,480
Infrastructure Replacement Costs	$0
Infrastructure Replacement Costs (Present Value)	$0
Reduction in tax base	Low
Transition costs	Low
Diminished recreation value	Low
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	High
Public non-use value losses (Holden Beach)	Low
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	High
Enhanced property value	High
Enhanced Recreation value	High
Environmental Improvement	
Public non-use value (nature)	Low
Public non-use value (Holden Beach)	High

5.4.6 Alternative 6: Intermediate Terminal Groin and Beach Nourishment

Under Alternative 6, the Town would assume responsibility for East End shore protection through the construction of an ~1,000-ft-long intermediate terminal groin at the eastern end of the oceanfront beach between Stations 00+00 and 10+00 and the implementation of an independent 30-year beach nourishment plan. The main stem of the intermediate terminal groin would include a 700-ft-long segment extending seaward from the toe of the primary dune and a ~300-ft anchor segment extending landward from the toe of the primary dune. The groin would also include a 120-ft-long shore parallel T-Head segment centered on the seaward terminus of the main stem. As previously described for the short groin, the anchor segment is designed to prevent flanking of the groin in the event of shoreline migration landward of the primary dune. The anchor segment would be entirely buried at the completion of groin construction, and the majority of the anchor segment is designed to remain buried based on historical shoreline analyses back to 1938. Similar to the short groin, the intermediate groin is designed to be a relatively low profile structure, both to allow sand over-passing and to minimize impacts to beach recreation and aesthetics. In addition to the 300-ft anchor segment, a portion of the adjoining 700-ft segment across the upper dry beach would also be completely buried, thus maintaining recreational beach access across the groin. The relatively low profile of the groin would allow some sand over-passing even under eroded conditions at the end of the four-year nourishment cycle.

Similar to the short groin, the intermediate groin would be constructed of 4- to 5-ft-diameter granite armor stone; and unlike conventional groins and jetties; would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for construction of the groin to the design 25 percent void ratio, thus providing the "leaky" characteristic that allows sand to pass through the structure. To prevent settlement of the stone, and if necessary to facilitate modification or removal of the groin, a base layer of geo-textile matting (1-ft thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the groin would have a crest width of ~10 ft and a base width of ~40 ft, whereas the underlying geo-textile base layer would have a slightly greater width of ~45 ft. The relatively short length of the intermediate groin along with the large tidal range at Holden Beach would allow for construction of the groin entirely from shore. It is anticipated that the public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

The projected beach nourishment regime would involve the placement of ~100,000 – 150,000 cy of sand on the East End beach every four years. Compared to the short groin, the intermediate groin would be located ~300 ft farther east, resulting in a corresponding 300-ft relative increase in the lengths of the berm, toe, and groin fillet components under Alternative 6. Therefore, nourishment events under Alternative 6 would encompass an approximately 0.8-mile section of the East End beach. The greater length of the intermediate groin is designed to account for the landward shift in shoreline position as the east-west oriented oceanfront beach transitions to the north-south oriented inlet shoreline. Relative to the east-west oriented oceanfront shoreline at the proposed short groin location, the intermediate groin does not extend any farther seaward. The shore-perpendicular widths of the beach fill toe and groin fillet footprints in the vicinity of the intermediate groin structure would also increase slightly to account for the shift in shoreline position. Otherwise, the beach fill profile design would be similar to that of Alternatives 3, 4, and 5; including a +9 ft NAVD high dune with a 50-ft-wide crest, a +7 ft NAVD high, ~200-ft-wide berm, and a 90- to 200-ft-wide transition with a 15 percent slope. The anticipated borrow sites and dredging regimes would be the same as those described above under Alternative 5. The initial groin construction/nourishment event would adhere to a 15 November – 30 April environmental window. All subsequent maintenance nourishment events would adhere to a 15 November – 31 March environmental window.

5.4.6.1 Geology and Sediments

Under Alternative 6, the effects of dredging, sand placement, and groin construction on geology and sediments would be similar to those described under Alternative 5.

5.4.6.2 Marine Benthic Resources

<u>Soft Bottom Communities</u>

Dredging

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; the direct, indirect, and cumulative impacts of dredging operations on soft bottom communities would be the same as those described under Alternative 5.

Intermediate Terminal Groin and Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; the direct, indirect, and cumulative impacts of the intermediate groin and periodic East End nourishment on soft bottom communities would be essentially the same as those described under Alternative 5. The relatively long intermediate groin requires a slightly larger beach fill footprint, resulting in a minor increase in the extent of direct beach fill placement impacts on soft bottom habitats.

<u>Hardbottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on hardbottom communities would be the same as those described under Alternative 5.

5.4.6.3 Water Column

<u>Hydrodynamics</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, with the exception of the AIWW West channel, the CMS model-projected inlet and estuarine hydrodynamic responses are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities for the inlet throat, AIWW East channel, and Eastern Channel are consistently within +/-10 percent of the corresponding Alternative 2 values during the four-year model simulation period (Table 5.17). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all three of these transects. In the case of the AIWW West channel, the hydrodynamic responses under Alternatives 2 and 6 are both characterized by rapid channel shoaling and rapidly declining tidal prism volumes, with the majority of the shoaling under both alternatives being related to natural background coastal processes. Also note that Alternatives 1, 3, 4, 5 and 6 include placement of sand on the beachfront and some of this material ends up in the AIWW West area after the four-year model runs, which also aids in slightly restricting the tidal prism. Under Alternative 6, the rate and extent of shoaling in the AIWW West channel is increased relative to Alternative 2, which is generally similar to the other modeled alternatives. As previously mentioned, existing flows within the AIWW West channel are significantly smaller than those to the AIWW East, therefore relative percentage changes can be expected to exhibit higher variation. As a result, the majority of the AIWW West simulated tidal prism volumes during Years 1, 2, and 3 of the model simulation period are reduced by 20 to 35 percent relative to Alternative 2. Alternatives 3, 4, and 5 exhibit some similar patterns of increased shoaling in the AIWW West channel; however, the pattern is most consistent and pronounced under Alternative 6.

The Alternative 6 beach fill footprint extends farther east than any of the other alternative beach fills. Additionally, some proposed fill is placed to the east of the intermediate groin. This material travels into the AIWW West more quickly than the other alternative fills and influences the relative tidal prism decrease exhibited in the model. As indicated above, the projected hydrodynamic response throughout the majority of the inlet/estuarine system under Alternative 6 is essentially the same as the projected response under Alternative 2. The similarity of the responses under the two alternatives suggests that the majority of the model-projected inlet and estuarine hydrodynamic changes under Alternative 6 are primarily the result of natural background coastal processes; thus indicating that the intermediate groin and associated nourishment activities under Alternative 6 would have little effect on inlet and estuarine hydrodynamics outside of localized effects within the AIWW West channel. The intermediate groin would extend ~150 ft further seaward of the MHW line than the short groin; however, under Alternative 6, the model-projected nearshore ocean hydrodynamic response along

Table 5.17. Alternative 6 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	97%	98%	97%	88%	100%	100%	99%	99%
1	92%	93%	81%	78%	100%	100%	99%	99%
2	91%	92%	79%	75%	101%	100%	99%	100%
3	96%	96%	82%	89%	101%	97%	95%	100%
4	101%	97%	80%	88%	99%	100%	139%	94%
Neap Tide								
0	98%	98%	97%	92%	100%	100%	100%	100%
1	90%	92%	69%	66%	100%	100%	97%	99%
2	92%	93%	73%	82%	101%	100%	101%	99%
3	95%	97%	72%	64%	98%	101%	96%	100%
4	102%	99%	104%	107%	107%	103%	110%	93%

Holden Beach and associated effects on longshore current dynamics (Figures 5.22 and 5.23) are the same as those described under Alternative 5. Similarly, the model-projected effects of Alternative 6 on larval transport (Figure 5.24) and rip current dynamics are the same as those described under Alternative 5. Under Alternative 6; the potential direct, indirect, and cumulative impacts of dredging operations on hydrodynamics would be comparable to those described under Alternative 5.

Sediment Suspension and Turbidity

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative sediment suspension effects would be the same as those described under Alternative 5.

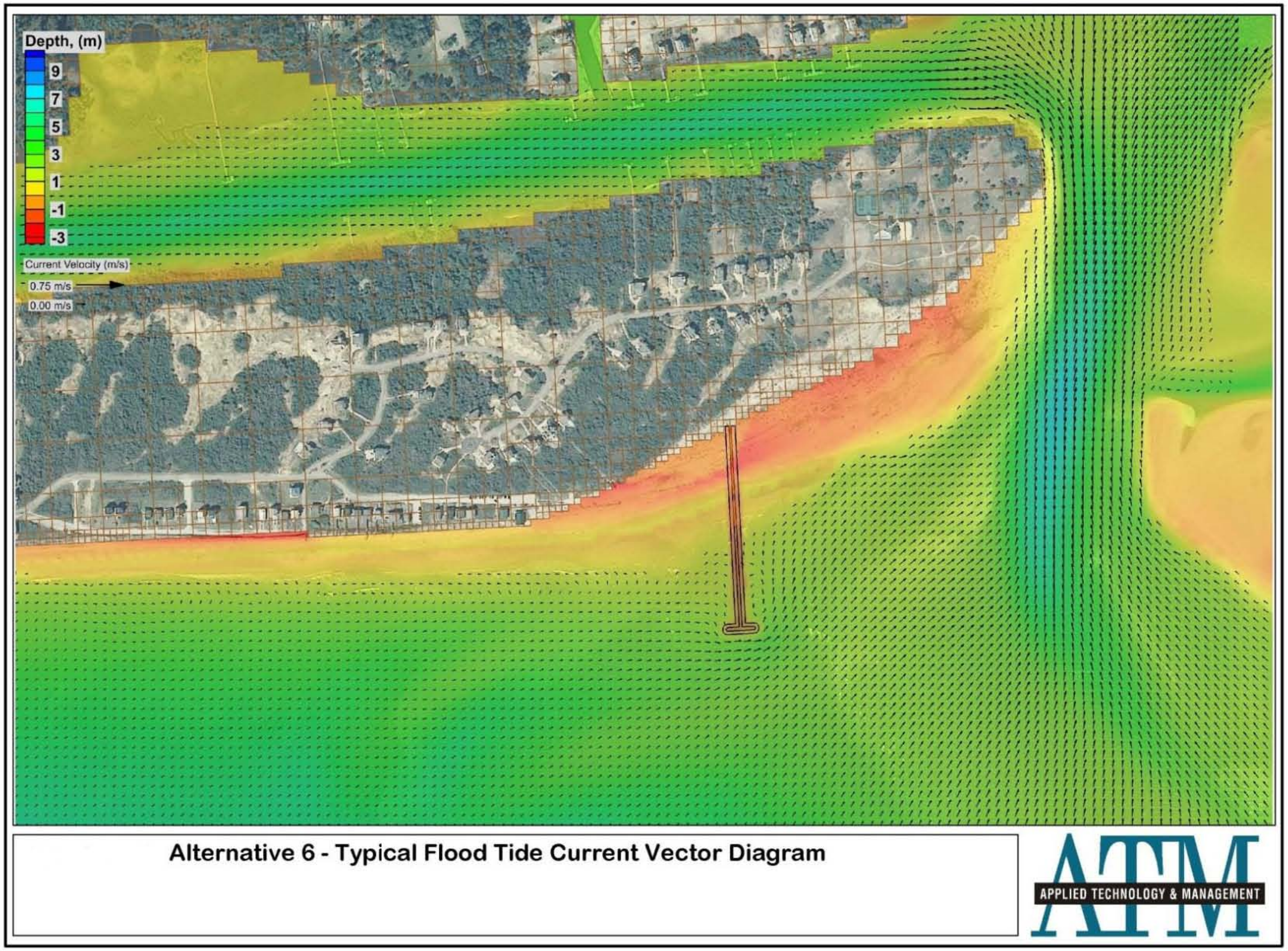


Figure 5.22. Alternative 6 - Typical Flood Tide Current Vector Diagram

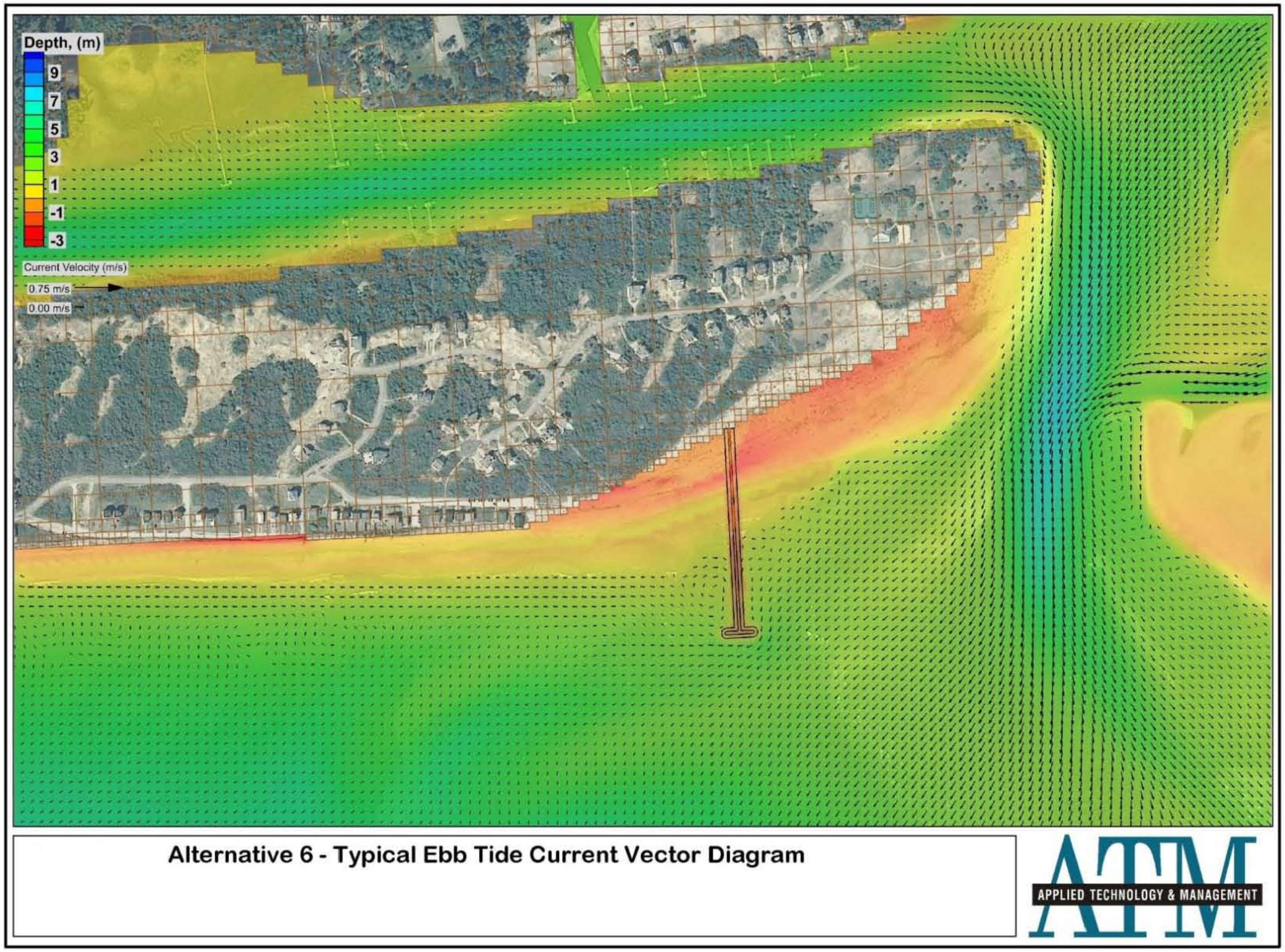


Figure 5.23. Alternative 6 – Typical Ebb Tide Current Vector Diagram

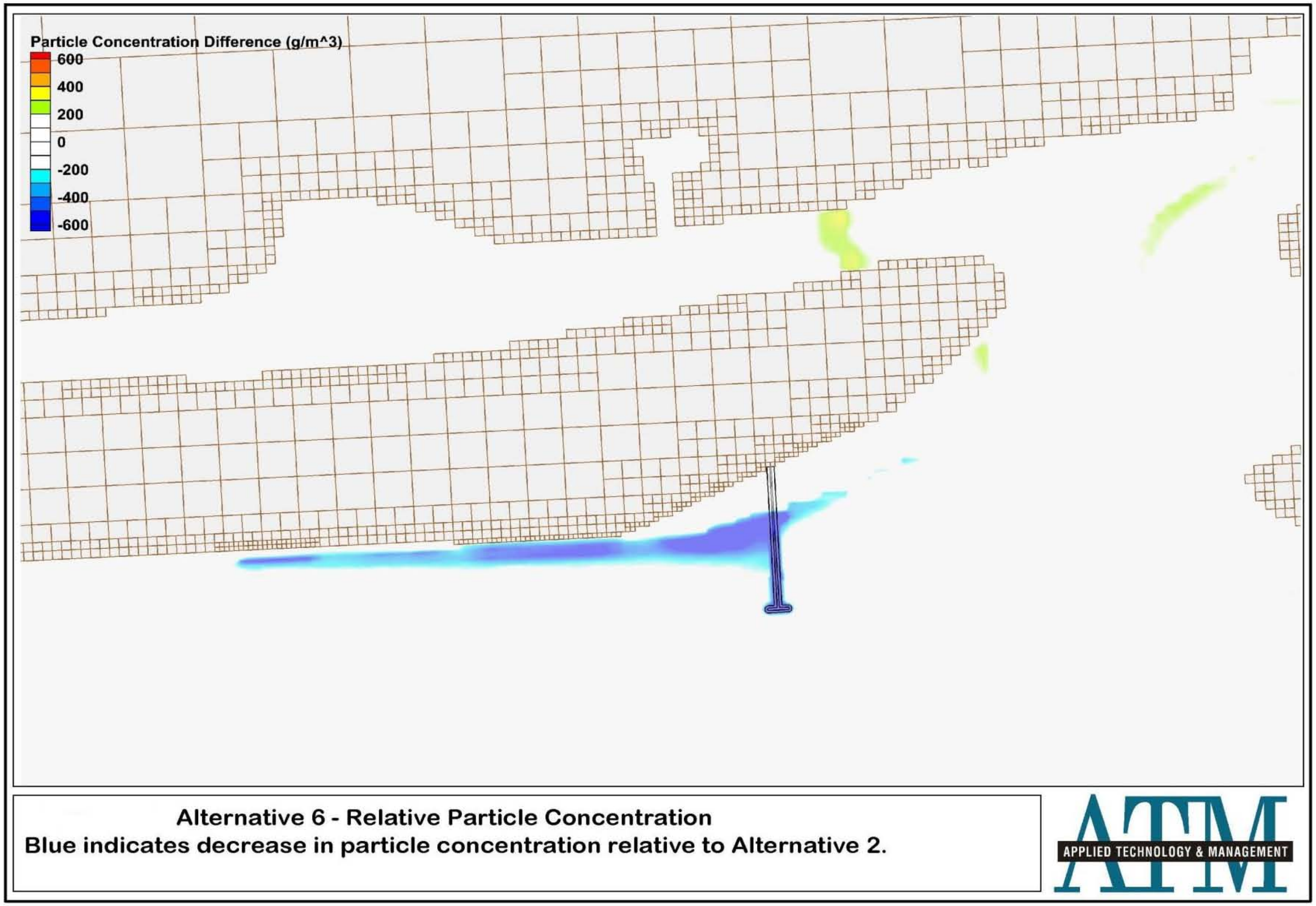


Figure 5.24. Alternative 6 - Relative Particle Concentration

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative underwater noise effects would be the same as those described under Alternative 5.

Entrainment

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts related to entrainment would be the same as those described under Alternative 5.

5.4.6.4 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 6, direct impacts on intertidal beach habitats and communities would be the same as those described under Alternative 5.

Indirect Impacts

Indirect impacts on intertidal beach communities under Alternative 6 would be the same as those described under Alternative 5.

Under Alternative 6, the CMS model-projected response of the Oak Island west-end oceanfront shoreline (Figure 5.25) is essentially the same as the projected future without project shoreline response under Alternative 2 (Figure 5.11). Under Alternative 6, a minor reduction in shoreline erosion over the course of the four-year model simulation period slightly reduces intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). The similarity of the Oak Island responses indicates that the projected shoreline and intertidal beach habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on intertidal beach habitat on Oak Island.

The projected response of the Holden Beach East End oceanfront shoreline under Alternative 6 is similar in pattern to that of Alternative 2; however, there are differences between the responses that are related to the performance of the beach fill and the sand trapping function of the groin under Alternative 6. The entire East End beach to the west of the groin is erosional under both alternatives; however, under Alternative 6, the performance of the beach fill and groin is reflected in a relative increase in beach width at the end of Year 4. Under Alternatives 1

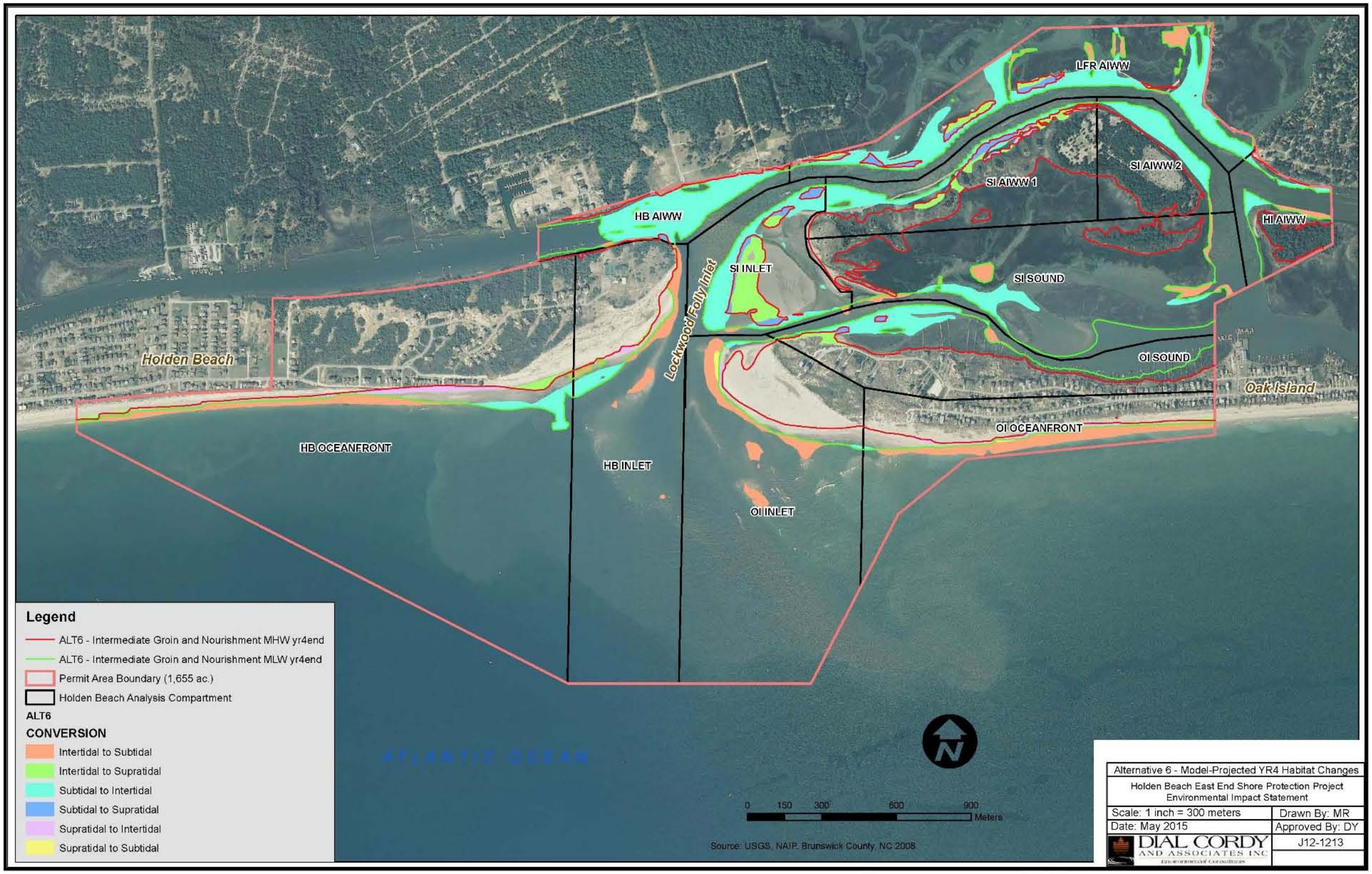


Figure 5.25. Alternative 6 – Model-Projected YR4 Habitat Change

and 2, the response of the remaining East End beach to the east of the groin is characterized by shoal attachment and corresponding net accretion at the end of Year 4; however, under Alternative 6, a larger quantity of the shoal sediment volume is retained by the groin, resulting in a relative increase in accretion at the end of Year 4. As a result of beach fill performance and groin effects, the nourished East End beach under Alternative 6 is on average ~63 ft wider than the corresponding East End beach under Alternative 2 at the end of Year 4 (Table 5.4). The corresponding effect of the wider beach on the quantity of intertidal beach habitat under Alternative 6 is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 6, cumulative impacts on intertidal beach communities would be the same as those described under Alternative 5.

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

Direct Impacts

Under Alternative 6, direct impacts on dry beach and dune habitats and communities would be the same as those described under Alternative 5.

Indirect Impacts

Initial Beach Fill Placement, Dredging, and Groin Construction

Indirect impacts on dry beach and dune communities under Alternative 6 would be the same as those described under Alternative 5.

Long-Term Model-Projected Effects

As described above, the CMS model-projected response of the Oak Island oceanfront shoreline under Alternative 5 (Figure 5.25) is the same as the projected future without project response under Alternative 2 (Figure 5.11). Corresponding dry beach and dune habitat changes on Oak Island are also the same, with both alternatives resulting in projected losses of ~3 ac at the end of Year 4 (Table 5.3). The similarity of the Oak Island responses suggests that Alternative 6 would not affect dry beach and dune communities on Oak Island.

As described above, the model-projected response of the Holden Beach East End oceanfront shoreline under Alternative 6 indicates an average increase in beach width of ~63 ft relative to Alternative 2. The corresponding effect of a wider beach on dry beach habitat is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 6, potential cumulative impacts on dry beach and dune communities would be the same as those described under Alternative 5.

5.4.6.5 *Inlet Complex*

Intertidal Flats and Shoals

Direct Impacts

Under Alternative 6, direct impacts on intertidal flats and shoals would be similar to those described under Alternative 5.

Indirect Impacts

The CMS model-projected inlet response under Alternative 6 (Figure 5.25) is essentially the same as the projected future without project inlet response under Alternative 2 (Figure 5.11). The only dissimilarity between the projected inlet responses under the two alternatives is a minor relative decrease in the extent of westward flood shoal accretion under Alternative 6. The corresponding effect on intertidal shoal habitat under Alternative 6 is an increase of ~2 ac relative to Alternative 2 (Table 5.3). Otherwise, the projected inlet response under Alternative 6 and the associated losses and gains of intertidal habitat are essentially the same as those described under Alternative 2. The similarity of the inlet responses under the two alternatives indicates that the projected inlet habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on inlet intertidal habitats.

Cumulative Impacts

Under Alternative 6, cumulative impacts on intertidal flats and shoals would be the same as those described under Alternative 5.

Inlet Dry Beach and Dune Communities

Direct Impacts

Under Alternative 6, direct impacts on dry inlet beach and dune communities would be similar to those described under Alternative 5.

Indirect Impacts

The CMS model-projected inlet response and corresponding changes in the distribution and quantity of inlet dry beach and dune habitats under Alternative 6 (Figure 5.25) are essentially the same as the projected future without project changes under Alternative 2 (Figure 5.11). Projected inlet dry beach/dune and supratidal flood shoal habitat changes at the end of Year 4 are essentially the same under both alternatives (Table 5.3). The similarity of the responses indicates that the projected inlet dry beach and dune habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on inlet dry beach and dune habitats.

Cumulative Impacts

Under Alternative 6, cumulative impacts on dry inlet beach and dune communities would be the same as those described under Alternative 5.

5.4.6.6 Estuarine Resources

<u>Shellfish</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on shellfish would be the same as those described under Alternative 5.

<u>SAV</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on SAV would be the same as those described under Alternative 5.

<u>Tidal Marsh Communities</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on tidal marshes would be the same as those described under Alternative 5.

5.4.6.7 Threatened and Endangered Species

<u>North Atlantic Right Whale and Humpback Whale</u>

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts on right and humpback whales and proposed right whale critical habitat under Alternative 6 would be the same as those described under Alternative 5.

<u>West Indian Manatee</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on the West Indian manatee would be the same as those described under Alternative 5.

<u>Piping Plover</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on piping plovers would be comparable to those described under Alternative 5.

<u>Red Knot</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on red knots would be comparable to those described under Alternative 5.

<u>Wood Stork</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on wood storks would be comparable to those described under Alternative 5.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on sea turtles would be the same as those described under Alternative 5.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on Atlantic and shortnose sturgeons would be the same as those described under Alternative 5.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on seabeach amaranth would be the same as those described under Alternative 5.

5.4.6.8 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on cultural resources would be the same as those described under Alternative 5.

5.4.6.9 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on public safety would be the same as those described under Alternative 5.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on aesthetics and recreation would be the same as those described under Alternative 5.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on navigation would be similar to those described under Alternative 5.

Infrastructure

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,100 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 16 oceanfront properties and ~130 ft of roads and associated linear utilities (Figure 5.26). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 6 by an average ~63 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.12). Thus, the modeling results suggest a relative reduction in property (12 fewer oceanfront properties impacted), road (impacts reduced by 670 linear ft), and utility (impacts reduced by 670 linear ft) impacts under Alternative 6.

Economics

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, construction and maintenance costs would include those associated with construction and maintenance of the intermediate groin and periodic beach nourishment; including the costs of beach fill and groin materials, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with the groin and periodic nourishment and dredging activities. Over a 30-year planning horizon, assuming $2.5 million for initial groin construction and nourishment of the East

Figure 5.26. Alternative 6 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

End Beach with approximately 150,000 cy of sand every four years, and an annual four percent increase in fill costs, Alternative 6 is expected to involve total construction costs of approximately $34.41 million. In present value terms, construction costs range from $15.24 million (6% discount rate) to approximately $23.43 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-projected shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix O). Under Alternative 6, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,100 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 16 properties (11 improved) and ~130 linear ft of roads and associated water, sewer, and power lines (Figure 5.26). Thus, relative to Alternative 2, the modeling results suggest a reduction in property (12 fewer oceanfront properties impacted), road (impacts reduced by 670 linear ft), and utility (impacts reduced by 670 linear ft) impacts under Alternative 6. The total assessed value of all properties protected to be newly impacted under Alternative 6 is roughly $2.1 million. The 131 linear feet of anticipated infrastructure replacement cost is valued at approximately $101,572, with a present value ranging from approximately $80,455 (6% discount rate) to $92,019 (2.5% discount rate).

Under Alternative 6, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 1, 2, 3, and 4 and similar to those projected under Alternative 5 (Table 5.18). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. To the extent that the terminal structure itself may be viewed as aesthetically unappealing, properties with views of the structure may have reduced amenity value relative to that which would exist with a natural and stable shoreline. However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline would likely be seen as preferable relative to the alternative condition.

Furthermore, to the extent that the structure would attract recreationists (i.e. anglers) or inhibit movement along the shoreline, property owners in the vicinity of the groin could suffer economic losses due to inconvenience and crowding. The use of a hardened structure to mitigate erosion would confer economic losses on the segment of the population that values unfettered ecosystem function. Even if harmful effects are never realized, some people could remain opposed to the use of hardened structures for shoreline erosion control. In the case of the proposed terminal groin on Holden Beach, such sentiments may be partially mitigated by the understanding that the required frequency of beach nourishment events would be reduced, thereby lessening the environmental impacts of dredging and sand placement over the lifetime of the structure.

Table 5.18. Alternative 6 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$34.41 M
Construction and Maintenance (Present Value)	$15.24 M – $23.43 M
Parcels at risk	16
Assessed Tax Value of Affected Parcels	$2.10 M
Infrastructure Replacement Costs	$101,572
Infrastructure Replacement Costs (Present Value)	$80,455 - $92,019
Reduction in tax base	Low
Transition costs	Low
Diminished recreation value	Low
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	High
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	High
Enhanced property value	High
Enhanced Recreation value	Moderate
Environmental Improvement	
Public non-use value (nature)	High
Public non-use value (Holden Beach)	Low

The principle benefits of Alternative 6 would be associated with enhanced shoreline stability and increased beach width relative to baseline conditions. To the extent that the public views the terminal structure as reducing the risk of future erosion, this added stability would serve to enhance property values along the Holden Beach East End shoreline. Based on the literature (see Appendix O) it is reasonable to expect that properties up to 300 m inland of the shoreline would realize improvements in market value. Associated benefits would likely include increased rental revenues and higher municipal tax revenues. As noted in Parsons and Powell (2001), active mitigation efforts such as beach armoring may also serve to encourage additional use and/or development and generate additional economic impacts relative to the status quo in the form of increased municipal tax revenues as well as temporary construction employment and spending. The terminal groin may create enhanced recreation values as a result of the projected gains in beach width and shoreline stability, especially those in the vicinity of the structure, as well as the creation of rocky bottom area that may increase species diversity and enhance the quality of recreational fishing near the structure. Because dune and beach habitats in the project area will be subject to reduced losses from erosion, indirect and non-use values may also be created, enhanced, or preserved.

5.5 Summary of Alternative Effects

Shoreline Change

All five with-project alternatives (Alternatives 1, 3, 4, 5, and 6) maintain a consistently wider East End beach throughout the four-year modeling simulations in relation to Alternative 2. General patterns of East End shoreline change are similar under the five with-project alternatives, with differences in projected relative beach widths primarily reflecting different sand retaining efficiencies along the easternmost ~2,000-ft shoreline reach where erosion rates have historically been the highest. Under Alternatives 1 and 3, beach fill is rapidly eroded from the easternmost reach at a rate consistent with historical observed losses. As a result, relative beach width at Year 4 is reduced to ~19 feet under Alternatives 1 and 3. Alternative 4 maintains an average relative beach width of ~35 ft at Year 4, thus indicating that outer channel relocation provides some enhancement of shore protection benefits relative to Alternatives 1 and 3. Alternative 5 maintains a similar average relative beach width of ~35 ft at Year 4, thus indicating that the short groin provides a level of enhanced beach fill retention and shore protection similar to that of Alternative 4. Alternative 6 maintains an average relative beach width of ~63 ft at the end of Year 4, thus indicating that the intermediate groin provides the highest level of East End shoreline protection by maintaining an oceanfront shoreline. Projected shoreline changes along the west end of Oak Island under each of the five with-project alternatives (Alternatives 1, 3, 4, 5, and 6) are essentially the same as those projected under Alternative 2, thus indicating that the projected changes are primarily the result of natural background coastal processes.

Marine Benthic Communities

Periodic LFIX/bend-widener dredging events under Alternatives 1, 3, 5, and 6 would have similar direct and indirect effects on soft bottom benthic communities within the navigation channel; including short-term direct impacts on benthic invertebrates via excavation and short-term indirect impacts on demersal fishes via temporary reductions in the benthic prey base. Under Alternative 4, periodic LFI outer channel relocation events would have similar types of direct and indirect impacts on soft bottom communities, but at a location farther seaward in the vicinity of the ebb tidal delta. The excavation of a wide outer channel under Alternative 4 would also impact a substantially larger area of soft bottom habitat in relation to LFIX/bend-widener dredging under Alternatives 1, 3, 5, and 6. Periodic East End nourishment events under Alternatives 1, 3, 4, 5, and 6 would have similar direct and indirect effects on soft bottom benthic communities within the subtidal portions of the beach fill footprints; including short-term direct impacts on benthic invertebrates via burial and short-term indirect impacts on surf zone fishes via temporary reductions in the benthic prey base. Under Alternatives 1, 3, and 4; soft bottom communities in the dredging and beach fill footprints would experience recurring impacts every two years. Under Alternatives 5 and 6; soft bottom communities in the dredging and beach fill footprints would experience recurring impacts every four years. Under Alternative 2, shore-based structure relocations and demolitions would not be expected to have any impacts on marine benthic communities.

Oceanfront Beach and Dune Communities

Periodic nourishment events under Alternatives 1, 3, 4, 5, and 6 would have similar direct and indirect effects on oceanfront beach and dune communities; including short-term direct impacts on intertidal benthic infauna and ghost crabs via direct burial and short-term indirect impacts on shorebirds, surf zone fishes, and sea turtles via temporary reductions in the benthic prey base and/or temporary physical habitat changes. Under Alternatives 1, 3, and 4; oceanfront beach and dune communities would experience recurring nourishment impacts every two years. Under Alternatives 5 and 6; oceanfront beach and dune communities would experience recurring nourishment impacts at a reduced frequency of every four years. As described above under Shoreline Change, the modeling results indicate that all five with-project alternatives (Alternatives 1, 3, 4, 5, and 6) would maintain a consistently wider East End beach in relation to Alternative 2, thus suggesting the potential for beneficial effects on beach communities via relative increases in habitat availability. As described above, the largest increase in average relative beach width of ~63 ft is projected under Alternative 6; followed by projected relative increases of ~35 ft under Alternatives 4 and 5 and ~19 ft under Alternatives 1 and 3.

Inlet and Estuarine Communities

The model-projected hydrodynamic and morphological responses of the LFI system under Alternatives 1, 3, 5, and 6 are essentially the same as those projected under Alternative 2; thus indicating that the projected changes are primarily the result of natural background coastal processes. In the case of Alternative 4, the modeling results show significant project-related effects on the inlet complex that are related to the hydrodynamic effects of outer inlet channel relocation. Rapid westward migration of the inlet throat ebb channel under Alternative 4 prevents the process of shoal attachment along the inlet shoulder that is projected under Alternative 2. As a result, losses of intertidal inlet beach habitat on Holden Beach under Alternative 4 are increased. Westward channel migration under Alternative 4 also increases the extent of erosion along the remainder of the Holden Beach inlet shoreline to the north, further increasing intertidal habitat loss and converting this habitat to subtidal habitat. Overall, the quantity of intertidal inlet beach habitat on Holden Beach under Alternative 4 is reduced by ~3 ac in relation to Alternative 2 and converted to subtidal habitat.

Economics

Under Alternatives 3 and 4, frequent nourishment and dredging events at two-year intervals result in the highest construction and maintenance costs of ~55.5 M over the 30-year life of the project. Alternative 1 would encompass a similar two-year nourishment and dredging regime; however, a lower per event placement volume reduces the 30-year construction and maintenance cost to ~46.2 M. Under Alternatives 5 and 6, although additional costs are incurred due to groin construction, the extended four-year nourishment interval reduces the overall 30-year construction and maintenance cost to ~34.4 M under both alternatives. No construction and maintenance costs are associated with Alternative 2, as no management activity would be undertaken by the Town. Based on the model-projected changes in the MHW line, the costs associated with potential erosional damage to at-risk properties and infrastructure (MHW line within 25 ft of parcel boundary) are highest under Alternative 2; intermediate under Alternatives 1, 3, and 4; and lowest under Alternatives 5 and 6. The beneficial economic impacts of increased beach width on recreational value are highest under Alternative 6, intermediate under Alternatives 4 and 5, low under Alternatives 1 and 3, and absent under Alternative 2.

6.0 AVOIDANCE, MINIMIZATION AND MITIGATIVE MEASURES

Pursuant to the CEQ regulations for implementing NEPA, environmental impact analyses must consider all relevant and reasonable measures to avoid and minimize potential adverse effects of proposed actions. The CEQ regulations require the incorporation of measures through which the impacts of a proposed action are avoided, minimized, rectified, reduced/eliminated over time, or compensated for through resource replacement. This section describes conservation measures that would be implemented to avoid, minimize, rectify, reduce and compensate for the impacts of the proposed action; including measures incorporated into the project design, measures to mitigate potential impacts during project construction, and measures to detect and rectify potential post-construction project impacts.

6.1 Terminal Groin Measures

6.1.1 Terminal Groin Design Features

As described in the Engineering Report (Appendix H), analyses of potential terminal groin designs considered functional shore protection performance as well as numerous environmental response parameters. Through several iterations of modeling analysis and adaptive redesign, functional and mitigative groin design features were refined to provide the optimal balance between functional efficiency and environmental impact avoidance and minimization. The majority of the mitigative features, which are common to both groin alternatives, are designed to minimize groin-related effects on hydrodynamic and sediment transport processes; thereby, in turn, avoiding adverse downdrift erosional effects on adjacent shorelines. The principal mitigative features are related to the permeability, profile, and length of the groin; as well as the performance of the accompanying beach fill. The groin would be constructed of 4- to 5-ft-diameter granite armor stone; and unlike traditional jetties, would not have a core component of smaller diameter stone. The exclusive use of large armor stone would allow for groin construction to the design 25 percent void ratio, thus providing the “leaky” characteristic that allows sand to pass through the structure. The groin would also have a relatively low profile; thereby allowing sand to pass over the structure. The low profile is designed to allow overpassing even under eroded conditions at the end of each four-year nourishment cycle.

The initial nourishment event would “pre-fill” the groin with sand, thereby minimizing the extent of sand capture during the initial fillet formation process. Once formed, the wedged-shaped “sand fillet” would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the terminal groin, thereby minimizing the potential for adverse effects on longshore currents and sediment transport. Furthermore, both groin designs would extend the oceanfront shoreline seaward by only ~300 ft relative to the

2012 MHW line position, which is considerably less than the historical range of seaward shoreline positions associated with the eastern terminus of the oceanfront project beach. Although the angle of the transitional shoreline would increase over time as the beach fill is eroded, erosion of the fillet would eventually subside as the sand trapping capacity of the groin and background shoreline erosion reach equilibrium, thereby maintaining a fillet through the end of each four-year nourishment interval.

6.1.2 Inlet Management Plan

Pursuant to the NC Coastal Policy Reform Act of 2013, proposals to construct terminal groins must incorporate a plan for management of the associated inlet, as well as the immediately adjacent estuarine and ocean shorelines that are under the influence of the inlet. Specifically, Inlet Management Plans (IMPs) must: 1) describe post-construction activities that will be undertaken to monitor groin-related impacts, 2) define the baseline for assessing impacts and the thresholds that will trigger mitigation, 3) provide for the implementation of mitigation measures in the event that thresholds are reached, and 4) provide for the modification or removal of the groin in the event that impacts cannot be otherwise mitigated. This section presents an overview of the Applicant's proposal to monitor and mitigate potential groin-related impacts in accordance with the Coastal Policy Reform Act. Further detail can be found in the Applicant's Final IMP (Appendix E).

As part of its ongoing beach management program, the Town has conducted annual topographic/bathymetric profile surveys of the Holden Beach oceanfront and inlet shorelines since 2000. Beginning in 2012, the inlet and adjoining oceanfront shorelines on Oak Island were added to the Town's annual monitoring program. Annual surveys consist of conventional and hydrographic survey data collection along permanent shore-perpendicular transects extending from the primary dune out to a depth of at least -25 ft NAVD88. The proposed terminal groin monitoring program would utilize 16 of the existing transects to document shoreline profile changes. An additional survey grid encompassing the flood shoal to wading depth would be established at a maximum grid spacing of 25 ft. Monitoring of the existing transects and flood shoal grid would include pre-project and immediate post-construction surveys, biannual surveys during the initial five-year post-construction period, and annual surveys thereafter. Additional bathymetric survey data covering the AIWW crossing, bend-widener, and LFI channel would be acquired from the USACE, which typically surveys these areas several times a year. However, in the event that USACE surveys have not occurred within the previous four months, annual monitoring efforts by the town will incorporate hydrographic surveys of these areas. Aerial photographs of the study area that include the survey transects will be obtained biannually during the initial two-year post-construction period and annually during years three through five. At the end of the initial five-year post-construction period, the applicant will coordinate with regulatory agencies to determine the need for additional annual aerial photography. During the initial two-year post-construction period, surficial beach sediment samples will be collected along two project area transects and three control transects located outside of the project footprint. Samples at each of these transect profiles will be collected at three cross-shore locations corresponding approximately to the +6 ft, +3 ft, and -3 ft NAVD88 elevation contours. Sediment samples will be analyzed using standard ASTM procedures for grain size distribution, percent fines, color, and visually for shell content.

Monitoring data will be analyzed to determine sediment volume and shoreline position changes within the project area. At a minimum, the following analyses will be performed:

- <u>Beach Profile Comparison Plots</u>: The current survey for each profile will be graphically compared to the previous survey(s).

- <u>Shoreline Change Analysis</u>: The shoreline (typically the mean high water line) positions between consecutive surveys will be compared, plotted, and analyzed for mean and extreme changes.

- <u>Volume Change Analysis</u>: Project placement volumes will be compared with volume remaining in the active profile at the time of each survey. Estimates of cross-shore and longshore sediment volume changes will be calculated and compared with the results of each subsequent survey, to the extent possible.

- <u>Sediment Grain Size Distribution</u>: Sediment samples will be analyzed and compared to the composite mean grain size of the native beach material.

- <u>Storm Events</u>: Any significant storm events that affect the project beach will be described based on available local meteorological data.

- <u>Performance Assessment</u>: Overall project performance will be assessed based on the design goals and current state of the project.

The Final IMP (Appendix E) establishes a volumetric shoreline erosion rate mitigation threshold based on analyses of observed annual volumetric changes from 2000 through 2012. As described in Appendix E, monitoring results indicating an exceedance of the established threshold would trigger an assessment by a Technical Advisory Committee (TAC). The TAC would consist of three NC licensed professional engineers with substantial expertise and employment experience in coastal engineering; including one engineer representing the Town of Holden Beach, one engineer representing the Town of Oak Island, and one independent engineer mutually agreed upon by both Towns. The TAC will review the monitoring data to determine if there are any threshold exceedances attributable to the terminal groin. The TAC will coordinate with the USACE and NCDCM in making such determinations. The TAC would be formally established prior to the completion of terminal groin construction.

If a majority of the TAC determines that a threshold exceedance is attributable to the terminal groin project, the Town of Holden Beach will work with the TAC and affected parties to implement appropriate mitigation measures. Mitigation measures may include renourishment of the affected beach, groin modification (reconfiguration, notching, or shortening), or complete groin removal. As previously described, a base layer of geo-textile matting installed below grade would prevent settlement of the armor stone and facilitate modification or removal of the groin. Furthermore, the relatively short length of the groin and the local tidal range would allow for modifications or removal of the groin from shore using conventional heavy construction equipment. The Town has independently maintained a consistent source of funding for beach management activities [i.e., Beach, Parks, Access and Recreation/Tourism Fund (BPART)]. The Town's BPART Fund, which has regularly financed nourishment and other beach management projects over the past 15 years, would be used to fund monitoring and any potential mitigation related to the terminal groin over the life of the project.

6.2 Dredging Measures

Environmental Window

Dredging activities would adhere to a 16 November to 30 April environmental window; thereby avoiding peak estuarine-dependent fish and invertebrate larval ingress periods, peak benthic invertebrate recruitment periods, and periods when sea turtles and manatees are most likely to occur in project area waters.

Pipeline Inspections

Dredging contracts would require routine inspections of dredging equipment and sand delivery pipelines, thereby minimizing the potential for pressurized leaks and associated turbidity effects.

Pollution Prevention

Dredging contracts would require spill control plans and waste management plans for all dredging fleet equipment.

6.3 Beach Fill Placement Measures

Sediment Compatibility

All beach fill material would comply with the State of North Carolina Technical Standards for Beach Fill Projects (15A NCAC 07H .0312), thereby minimizing the extent and duration of potential beach fill placement impacts on terrestrial and marine habitats and biological communities. The Technical Standards require comparative analyses of recipient beach and proposed borrow site sediments; including quantitative analyses of percent weight of fine-grained sediment, percent weight of granular sediment, percent weight of gravel, and percent weight of calcium carbonate. As previously described, analyses have shown that sediments associated with the preferred and potential supplemental borrow sites are compatible according to the state standards. Continuous visual monitoring of fill material would be conducted at the pipeline outfall before it is redistributed along the beach. If noticeable quantities of incompatible fill material are detected, the contractor will cease operations and immediately contact the Wilmington District Regulatory Branch and NCDCM to determine the appropriate course of corrective action.

Environmental Window

Terminal groin construction and beach fill placement activities would adhere to a 16 November to 30 April environmental window; thereby avoiding the sea turtle nesting season, the majority of the shorebird breeding season, the majority of the seabeach amaranth growing season, and peak benthic invertebrate recruitment periods.

Water Quality

Dredging contracts would require the use of spreaders on pipelines to reduce effluent discharge velocities during sand-slurry placement. Temporary shore parallel sand dikes would be used to contain and direct the horizontal flow of the discharged sand-slurry along the beach. These measures would maximize sediment retention within the designated placement area, thereby minimizing potential surf zone turbidity effects.

Shielded Lighting

Directional, shielded, and low intensity lighting would be employed during construction to minimize the potential effects of artificial nighttime lighting on marine organisms.

Staging Areas and Beach Access

The staging area and refueling location for construction equipment (bulldozers, frontend loaders, pickups, etc.) would be located off the beach at the existing East End public access parking lot. Construction equipment would access the beach via the existing public access corridor. During nighttime hours, idle construction equipment would be stored off the beach to the extent practicable. Heavy equipment would be removed from refurbished shorelines as soon as practicable, restoring unrestricted public access.

Pipeline Inspections

Beach fill placement contracts would require routine inspections of sand delivery pipelines, thereby minimizing the potential for pressurized leaks along the beachfront.

Pollution Prevention

Beach fill placement contracts would require spill control plans and waste management plans for all construction equipment.

6.4 Conservation Measures

The following measures would be implemented to reduce potential impacts on ESA-listed species and critical habitats:

Sea Turtles

1) Groin construction and beach nourishment activities would avoid the 1 May-15 November sea turtle nesting and hatching season in NC. The initial groin construction/nourishment event would be completed between 16 November and 30 April, and all subsequent renourishment events would be completed between 16 November and 31 March.

2) All material placed on the beach and in associated dune systems will consist of beach compatible sediment that is suitable for sea turtle nesting. Beach compatible material will consist of sediments that are similar in composition, grain size distribution, and color to the native sediments of the recipient beaches. All placed beach fill will meet NC Technical Standards for Beach Fill Projects (15A NCAC 07H .0312).

3) Immediately after completion of the initial groin construction/nourishment event and each subsequent renourishment event, and to the maximum extent practicable prior to 1 May, surveys for escarpments will be conducted within the limits of construction areas. Identified escarpments that that may interfere with sea turtle nesting (>18 inches in height and ≥ 100 ft in length) will be leveled to the natural beach profile. If it is determined that escarpment leveling is required during the nesting season, leveling activities would be coordinated with the USFWS or NCWRC.

4) Immediately after completion of the initial groin construction/nourishment event and each subsequent renourishment event, and to the maximum extent practicable prior to 1 May, the limits of construction areas will be evaluated for compaction in coordination with the USFWS and NCWRC. If it is determined that tilling is required for sea turtle nesting habitat suitability, the construction areas will be tilled to a depth of 36 inches. All tilling activity shall be completed prior to 1 May to the maximum extent practicable.

5) Post-construction surveys of artificial nighttime lighting visible from the East End beach will be conducted to determine if groin-related accretion has increased the extent to which sea turtles may be exposed to nighttime lighting in the vicinity of the groin. Two lighting surveys will be conducted during the first post-construction year: the first between 1 May and 15 May and the second between 15 July and 1 August. A lighting survey report will be submitted to the USFWS.

6) Three years of post-construction sea turtle nest monitoring will be conducted within the groin/sand placement areas to assess potential effects on nesting. Monitoring will include daily nest surveys from 1 May until 15 September. Established nests will be monitored through the end of hatching to determine if the groin is causing erosional nest losses or impeding hatchlings from reaching the ocean. Sea turtle monitoring will be conducted by qualified personnel of the Holden Beach Volunteer Sea Turtle Monitoring Group. Nesting and hatching data will be included in annual monitoring reports to be provided to the NCWRC and USFWS.

7) All hopper dredging operations will be completed between 16 November and 31 March; thereby reducing the risk of sea turtle entrainment by limiting dredging operations to periods of cooler water temperatures when most sea turtles have moved to warmer waters outside of the project area.

8) Rigid draghead deflectors would be required on all hopper dredges, thereby minimizing the risk of sea turtle entrainment. Dredging contracts would include specifications for the proper installation and operation of rigid dragheads to ensure effective mitigation of the entrainment risk.

9) All hopper dredges would be equipped with the DQM automated dredging quality assurance monitoring system. DQM data would be used to monitor draghead performance and contractor compliance with other hopper dredge operational requirements, thereby minimizing the potential for sea turtle interactions and other potential impacts due to operator error.

Piping Plover and Red Knot

1) Groin construction and beach nourishment activities would avoid the majority of the piping plover breeding season and the peak red knot migration period in NC. The initial groin construction/nourishment event would be completed between 16 November and 30 April, and all subsequent renourishment events would be completed between 16 November and 31 March.

2) As a means of minimizing the extent and/or duration of adverse effects on piping plover and red knot habitats and benthic prey resources, all material placed on the beach and in associated dune systems will consist of beach compatible sediment. Beach compatible material will consist of sediments that are similar in composition, grain size distribution, and color to the native sediments of the recipient beaches. All placed beach fill will meet NC Technical Standards for Beach Fill Projects (15A NCAC 07H .0312).

3) Construction staging areas and pipeline routes will be located to avoid high-value inlet complex habitats for piping plovers and red knots to the maximum extent practicable.

4) Temporary storage areas for construction equipment and pipelines will be located off the beach to the maximum extent practicable.

5) All personnel involved in groin construction and sand placement activities will be made aware of the potential presence of piping plovers and red knots. Prior to the start of work each morning, a visual survey of the daily work area will be conducted to determine if piping plovers and red knots are present.

6) Monitoring of piping plovers, red knots, and other shorebirds/colonial waterbirds within the LFI area will be conducted during the initial groin construction/nourishment event and for three full years after completion of the initial construction event. Monitoring data will be included in annual monitoring reports to be provided to the NCWRC and USFWS. Shorebird monitoring data that is currently being collected by the Town of Oak Island for the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel (Figure 6.1) will serve as a baseline for evaluating the effects of the Holden Beach East End project. The current monitoring study encompasses LFI, including the East End of Holden Beach and the west end of Oak Island. The Bird Monitoring Plan for the Lockwoods Folly River Habitat Restoration Project is provided in Appendix R.

Seabeach Amaranth

1) Groin construction and beach nourishment activities would avoid the majority of the seabeach amaranth growing season in NC. The initial groin construction/nourishment event would be completed between 16 November and 30 April, and all subsequent renourishment events would be completed between 16 November and 31 March.

2) Seabeach amaranth surveys will be conducted within the project area for three full years after completion of the initial groin construction/nourishment event. Survey data will be included in annual monitoring reports to be provided to the USFWS.

West Indian Manatee

1) All dredging operations will be completed between 16 November and 30 April; thereby avoiding periods when manatees are likely to be present in NC waters.

2) All dredging operations will adhere to USFWS Guidelines for Avoiding Impacts to the West Indian Manatee: Precautionary Measures for Construction Activities in North Carolina Waters.

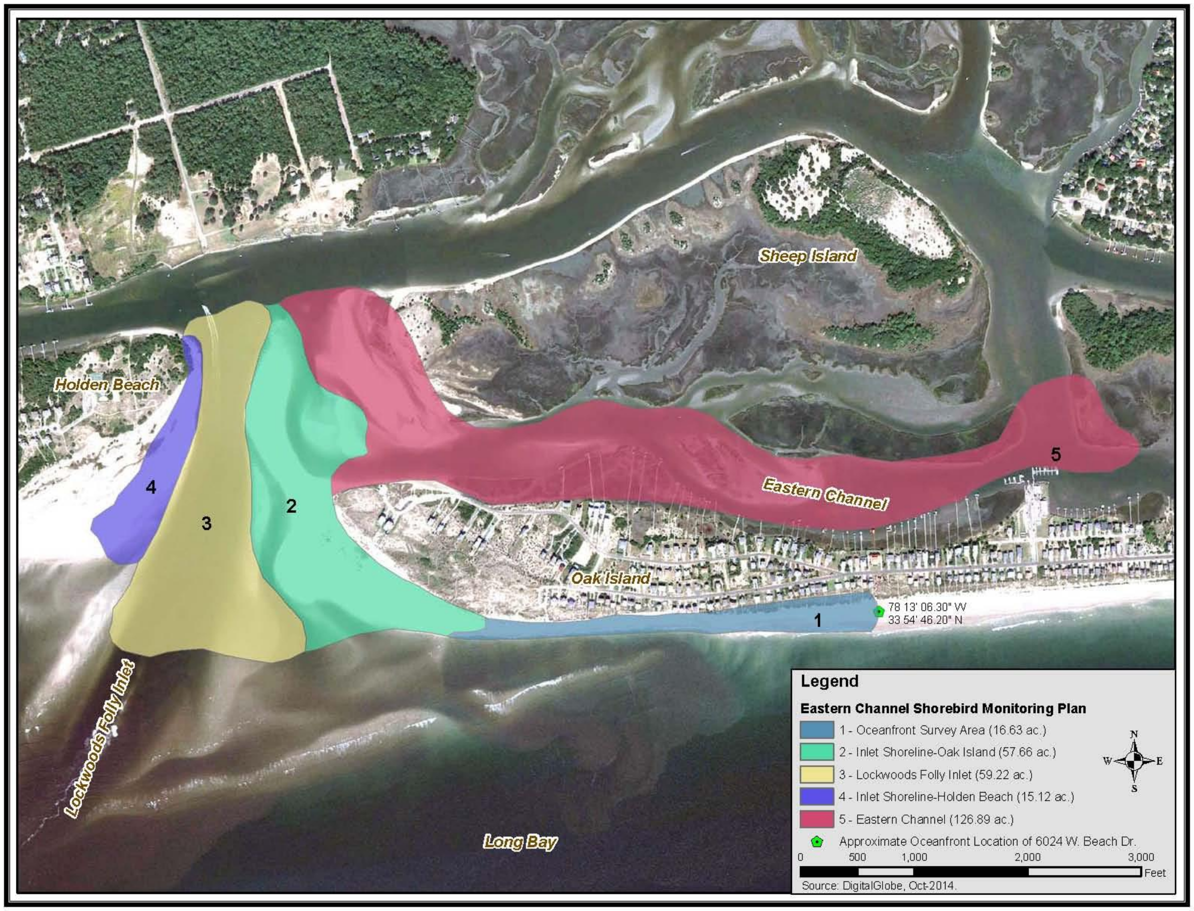


Figure 6.1. Bird Monitoring Plan for the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel

North Atlantic Right Whale

1) Hopper dredges would adhere to a speed limit of ten knots or less during transit between borrow sites and nearshore pump-out stations, thereby minimizing the risk of collisions with large whales.

2) During daylight hours (dawn to dusk), one NMFS-approved endangered species observer with at sea large whale identification experience would be onboard hopper dredges to conduct observations for large whales. If a right whale is sighted within 500 yards during active dredging, operations will cease until the observers are confident that the whale has left the area. If a whale is sighted during transit, the crew would reduce speed and alter course as necessary to maintain a distance of 500 yards between the vessel and the whale. All whale sightings would be documented and reported to the NMFS.

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