SOUTH ATLANTIC COASTAL STUDY (SACS)

North Carolina Appendix

FINAL REPORT
AUGUST 2022

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SECTION 1
Introduction

The South Atlantic Coastal Study (SACS) Main Report examines the SACS study area at a regional scale and describes the Coastal Storm Risk Management (CSRM) Framework (the Framework). The Framework is leveraged to methodically assess risks, develop integrated strategies, and foster collaboration in managing risk. Eight SACS state and territory appendices execute the Framework, considering specific conditions for each state or territory, including problems and opportunities, risk assessment, and comprehensive CSRM strategies to provide a more tailored analysis. This Appendix provides details on the state of North Carolina.

The Framework is a three-tiered evaluation defined by different scales, objectives to address risk, and input from stakeholders. The Tier 1 and Tier 2 analyses are completed as part of the SACS while Tier 3 efforts would be accomplished as follow-on analyses, either by the U.S. Army Corps of Engineers (USACE) or other agencies and stakeholders. By finalizing a tiered analysis, assumptions and data requirements become more refined with each tier, as described:

- Tier 1 analysis presents a large-scale application of the Framework in the broad-spectrum evaluation of exposure, hazards, vulnerability, and potential risk for the study area. For consistency across state and territory boundaries, national datasets were used to complete the Tier 1 analysis. The Main Report describes Tier 1 methods and general output. North Carolina-specific Tier 1 information is provided in this North Carolina Appendix.
- The Tier 2 analysis presents additional state and regional data sources which are used to further refine potential risk areas identified in Tier 1. Focus areas are selected from the highest risk locations, and detailed Focus Area Action Strategies (FAAS) (which are attached to this appendix) are developed to serve as examples of how to develop strategies that lower risk in populated areas, areas of concentrated economic development, and areas with vulnerable environmental and cultural resources.
- Tier 3 (not completed by the SACS) would be a local-scale analysis incorporating in-depth analysis and benefit-cost evaluations of CSRM plans.

The purpose of the North Carolina Appendix is to provide North Carolina stakeholders with useful information and resources. Contents of the Appendix as well as how each section relates to the Framework is shown in **Table 1-1**.

Table 1-1: Appendix Organization and Alignment with the Coastal Storm Risk Management Framework

Report Section	Content	CSRM Framework Step
Section 1: Introduction	Objective of the document and organization of the report	Step 1: Initiate Analysis
Section 2: Agency Coordination and Collaboration	Overview of the collaborative efforts of the SACS study including stakeholder engagement, workshops, informational sessions, and federal partners	Step 1: Initiate Analysis
Section 3: Overview of Existing and Future Conditions	Provides geographic, climatic, and political context for the analysis and an overview of existing and expected future conditions	Step 2: Characterize Conditions
Section 4: Risk Assessment	Application of the Tier 1 Risk Assessment and development of the North Carolina-specific Tier 2 analysis used to identify high-risk areas	Step 3: Analyze Risk and Vulnerability
Section 5: Managing Risk	Overview of resources to support North Carolina resiliency efforts, including federal directives, resources, and funding to help communities better leverage needed resources	Step 4: Identify Possible Solutions
Section 6: Institutional and Other Barriers	Identification of institutional and other barriers impeding further risk management efforts	Step 4: Identify Possible Solutions
Section 7: Summary & Recommendations	Recommendations of actions to address the risks identified in Section 4	Step 5: Evaluate and compare solutions

SECTION 2
Agency Coordination and Collaboration

The study was conducted in coordination with stakeholders including federal, state, and local agencies, tribal entities, non-governmental organizations, and academics to ensure that all information, observations, and recommendations are consistent with other plans to be developed.

During the fall of 2019, USACE Wilmington District held in-person Field Workshops in Manteo, NC and Wilmington, NC. Participants were divided into breakout sessions focused on the following topics: (1) existing/future conditions, problems, and opportunities, (2) draft focus areas, (3) existing/planned risk management strategies and projects, and (4) institutional and other barriers to reducing risk. Stakeholders provided input via written questionnaires and facilitated discussion.

In summer and fall of 2020, USACE held a series of three virtual Focus Area Visioning Meetings for each focus area. The virtual nature of the workshop was due to the global COVID-19 pandemic and provided a unique opportunity to maximize outreach and participation through virtual platforms. Meetings were attended by representatives from federal, state, regional, and local government agencies and non-governmental organizations. Feedback received informed the FAAS. Additional coordination, pre- and post- meeting, was facilitated by USACE Wilmington District to ensure that actions and objectives were in alignment with stakeholders.

Throughout the development of the state and territory appendices and FAAS, USACE held additional virtual workshops to engage specific subgroups of stakeholders, including two SACS Environmental Webinars, a SACS Cultural Stakeholder Webinar, and a SACS Military Installation Webinar. The USACE Command Team and District Project Managers also held quarterly webinar updates for stakeholders to provide information on various SACS products and answer stakeholder questions.

The Wilmington District team engaged key federal stakeholders, including National Oceanic and Atmospheric Administration (NOAA), Bureau of Ocean Energy Management (BOEM), National Fish and Wildlife Foundation (NFWF), U.S. Fish and Wildlife Service (USFWS), and National Park Service (NPS). Several state agencies, non-governmental organizations and academic institutions were also engaged, including the North Carolina Office of State Archaeology and State Historic Preservation Office, North Carolina Department of Environmental Quality (NCDEQ), North Carolina National Estuarine Research Reserve System (NERRS), North Carolina Coastal Federation, and North Carolina Department of Public Safety (NCDPS), as well as research facilities, including the University of North Carolina Wilmington (UNCW) and North Carolina State University (NC State).

Key regional stakeholders participated in Focus Area Visioning Meetings. Given the structure and organization of coastal resilience management in the state of North Carolina, key stakeholders may have attended all strategy development webinars, such as the North Carolina Emergency Management (NCEM), NCDEQ, the North Carolina Division of Coastal Management (NCDCM), and the

Coastal Resources Commission (CRC). Other key stakeholders may have attended only those webinars relative to their own focus area. These stakeholders will play an important role in promoting resilience through regional coordinating and planning. Accordingly, this report does not seek to create a strategy separate from significant and ongoing efforts, but to support those of the region and develop initial considerations for future federal and non-federal efforts carried out in a systems context with reliance on joint responsibility. Documentation of coordination is located in **Table 2-1**.

Table 2-1: Documentation of Stakeholder Coordination

Type of Coordination	Measure/Action Type	Subtype	Description/Purpose	Focus Area or Statewide	Stakeholder(s)	Date	Result
Multiagency	Masonboro Island–Beach, Dune, and Back Barrier Marsh Restoration	Natural and Nature-Based Features (NNBF)	This topic was discussed in the Focus Area Wrap-Up Webinar, with the suggested action that a smaller group of stakeholders should have a follow-on meeting to discuss in more detail what the scope of effort might look like, and how it could be included as a recommendation in the SACS report. This meeting was facilitated to work with stakeholders specific to Masonboro Island with the goal of leveraging SACS for study recommendations to be included in the Brunswick and New Hanover Counties FAAS. Stakeholder feedback suggested a feasibility study for long-term restoration studies at Masonboro Island. SAW District wants to know from critical stakeholders if this recommendation makes sense and what would that scope look like. If not, what recommendations could the SACS make that would be in line with the current trajectory? The desired outcome would be to identify if there is a recommendation for Masonboro Island that would fall within the SACS scope.	Brunswick and New Hanover	USACE, NCDCM, North Carolina NERRS, NC Wildlife, North Carolina Wildlife Resources Commission (WRC), North Carolina Division of Water Resources (NCDWR), USFWS, BOEM, UNCW	22-Jan-21	Team preparation for stakeholder follow-up
Multiagency	Albemarle Pamlico Estuarine System–Back Bay Erosion and/or Wetland Restoration	Back Bay Erosion Research	A suggestion was brought up during the SACS stakeholder workshop for the northern focus areas concerning a possible effort involving an erosion assessment and wetland restoration in the back bay areas of the Albemarle-Pamlico Estuary. Interested stakeholders were identified and follow-on coordination was facilitated.	Dare County, Ocracoke, Carteret, and Craven	USACE, NCDCM, USFWS, NOAA, NCWRC, NC Marine Fisheries, NC Coastal Federation, Nature Conservancy, NCDWR	8-Feb-21	Final preparation for stakeholder follow-up coordination
Multiagency	Outreach meeting	Cultural resources-focused	Before this coordination action, only six vulnerable cultural resources were identified in North Carolina's three focus areas although coastal storms and sea level rise have the potential to adversely affect many hundreds of North Carolina's archaeological sites and historic properties/districts. This meeting was held to discuss and identify inclusion of additional archaeological sites and historic properties/districts in North Carolina that are vulnerable to the effects of coastal storms and sea level rise.	Statewide	North Carolina Office of State Archaeology, North Carolina State Historic Preservation Office (SHPO)	10-Sep-20	Identification of additional vulnerable archaeological sites and historic properties/districts not previously identified in Tier 1 analyses; Identification of North Carolina partnerships aimed at preservation and protection of vulnerable cultural resources.
Stakeholder-led	Down East Council–Community Interest Night	USACE Outreach–Silver Jackets Proposal	–	Carteret and Craven	Down East Council	28-Jan-21	Internal team preparation for presentation to council
Stakeholder-Requested Workshop	Down East Broadband Initiative	USACE Outreach	Ideas were discussed to evaluate whether to leverage risk and vulnerability data from the SACS for the asset mapping effort by the Down East Broadband Initiative. If so, an approach to leverage the data will be identified and any other SACS questions from the stakeholder will be answered.	Carteret and Craven	Michelle Nolin	23-Nov-20	–
Stakeholder-Requested Workshop	Enhanced Building Level Risk Assessment	Nonstructural Risk Assessment	–	Statewide	NCEM (Tom Langan), North Carolina Office of Recovery and Resiliency (NCORR), Carteret and Craven Counties, Dare County	9-Oct-20	Discussed analysis, benefits, and potential stakeholders for this effort within the SACS database.
Stakeholder-Requested Workshop	CAP-204 South Wanchese Harbor	Green Infrastructure	–	Dare County and Ocracoke	Dare County	–	–

Type of Coordination	Measure/Action Type	Subtype	Description/Purpose	Focus Area or Statewide	Stakeholder(s)	Date	Result
USACE	CSRM-Beneficial Use (BU) Leadership Recommendation Coordination	USACE Coordination	Within the SACS, three key products address sediment management activities: South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report), 2020 Regional Sediment Management Optimization Update (2020 RSM Optimization Update), and Dredged Material Management Area (DMMA) Offloading & Sediment Exchange. These products contain evaluations and recommendations that were used in conjunction with leadership coordination to develop actionable sediment management strategies within the North Carolina focus areas.	Statewide	USACE, BOEM, State	11-Jan-21	Initial Request for Briefing
Stakeholder-Requested Workshop	NCORR	USACE Coordination on Existing Resiliency Strategy	Leveraging risk in affordable housing assessments.	Statewide with Focus on Carteret and Craven	USACE	12-Nov-20	–
Stakeholder-Requested Workshop	City of New Bern	USACE Coordination on Existing Needs and Resiliency Efforts	–	Carteret and Craven	City of New Bern, Carteret County, NCORR	6-Oct-20	–
Multiagency	Living Shorelines	NNBF	–	Statewide	NOAA, NC Coastal Federation	–	–
USACE Stakeholder	In-person workshops	USACE Outreach	–	Statewide–1 per planning reach (NC_01 and NC_02)	All Local, State, Federal Agencies	–	–
USACE Stakeholder	SACS FAAS Action Strategy Workshop Webinar No. 3	USACE Outreach and Request for Coordination	–	Statewide	All Local, State, Federal Agencies	1-Dec-20	Dare County and Ocracoke Workshop
Stakeholder Briefing	SACS Quarterly Webinar	SACS Coordination	–	Statewide	All Local, State, Federal Agencies	–	–
Stakeholder-Requested Workshop	BOEM	–	–	Statewide	USACE, BOEM	7-Oct-20	Discussed suggestions from workshop and potential stakeholder coordination.
USACE Stakeholder	North Carolina Working Group	–	–	Statewide	NCDCM	16-Sep-20	Web app mapping tool for stakeholder input on existing strategies
State-led	State Resiliency Plan	–	–	Statewide	NCDCM	–	–
State-led	North Carolina BiWAYS Meeting	–	–	Statewide	State of NC	–	–
USACE	Military Installation Workshop	USACE Outreach	–	Statewide	Military Installations	8-Oct-20	Initial Coordination Meeting
USACE	Military Installation Follow-up Coordination	Follow-Up Coordination	–	Statewide	Naval Facilities Engineering Systems Command	18-Dec-20	–
–	USACE Leadership Coordination on FAAS Development	Leadership Buy-In	–	Statewide	USACE– South Atlantic Division (SAD)– Wilmington District (SAW)	9-Jul-20	–
–	SACS Focus Area Kick-off Webinar	USACE Outreach and Request for Coordination	Initial kickoff webinar for stakeholder coordination and development of focus area action strategies	Statewide	All Local, State, Federal Agencies	15-Jul-20	Dare County & Ocracoke Workshop
–	SACS Focus Area Strategy Development Webinar	USACE Outreach and Request for Coordination	–	Statewide	All Local, State, Federal Agencies	26-Aug-20	Dare County and Ocracoke Workshop
USACE – NOAA	Marsh Loss and Potential Beneficial-Use Opportunities	Existing Strategies and Barriers to Implementation	–	Statewide	All Local, State, Federal Agencies	13-Oct-20	–

SECTION 3
Overview of Existing and Future Conditions

3.1 Study Area

The expansive North Carolina coast comprises approximately 2.5 million acres of marine and estuarine waters, almost 325 miles of ocean shoreline, and roughly 10,000 miles of estuarine shoreline (Riggs 2011). The makeup of the coastline varies from densely developed to uninhabited state and national parks (FEMA 2017). The North Carolina coastal area is among the most biologically productive regions of the state and the nation (NCDEQ 1974).

3.1.1 Existing Conditions

The shoreline of North Carolina is vast, including large stretches of ocean shoreline—mostly in the form of broad sandy beaches—and extensive estuarine shoreline, consisting of bays, sand bars, islands, and river mouths (Riggs 2011).

The Coastal Plain, which makes up approximately 45 percent of the state's total land area, is divided into two major sub-areas; the Outer Coastal Plain and the Inner Coastal Plain. The Outer Coastal Plain, or Tidewater, lies closest to the ocean and is included entirely in the SACS planning reach for North Carolina. This area is extremely flat with poor drainage, and it is dominated by lagoons, sea marsh, and broad sandy beaches. Wetlands are a dominant feature, and streams are brackish and subject to tidal influence. The Inner Coastal Plain, partially included in the North Carolina SACS study area, lies west of the Tidewater, and typically consists of dryer and higher land.

The area north of Cape Lookout contains the second largest estuarine and wetlands system in the United States (the Albemarle-Pamlico Sound), serving as critical estuaries for many important species (Riggs 2011). This system is made possible by a string of barrier islands that are separated from the mainland by as much as 20 miles. These specific barrier islands are referred to as the Outer Banks. Sea level rise in combination with wind and wave energy cause these islands to slowly migrate landward (west) (Diemer 2005). Because of these conditions, many developments along the Outer Banks are highly susceptible to coastal hazards. South of Cape Lookout, embayments are much smaller with narrower estuaries, and short barrier islands that are more susceptible to erosion that experience higher tidal ranges under normal conditions (Riggs and Ames 2003).

North Carolina's developed shorelines contain man-made protective features. In back bay areas, these include various forms of bulkheads, riprap, rock sills, and dozens of constructed living shoreline projects. Many of the beaches along the oceanfront have been engineered through sand renourishment to mitigate the effects of shoreline migration in the face of coastal development. Although North Carolina has prohibited the development of hardened structures on the oceanfront

dating back to the 1980s, there are some limited hardened segments of the exposed (oceanfront) shoreline.

While the undeveloped sections of shoreline naturally adjust to the dynamic conditions presented by hurricanes and other coastal weather events, the developed coastline is less mobile. The coastal population of North Carolina is approximately 1,000,000, with the top three populated counties in the bottom half of the state (New Hanover, Onslow, and Brunswick). Between 1960 and 2008, the majority of North Carolina's coastline population grew from between 50 percent to 300+ percent, depending on the location (U.S. Department of Commerce 2010). However, seasonal populations can increase well beyond the official population, because millions of visitors vacation on North Carolina's beaches every year. For example, Dare County, which extends over much of the Outer Banks, has a listed population of 36,000 residents. During the summer months, though, its daily population grows to more than 250,000 residents. This trend also applies to the other coastal counties of North Carolina.

Many of the communities, and the infrastructure that supports them, are at low elevations along the shoreline and include industry, businesses, farms, homes, and schools, along with the economies they support. There are also numerous low-lying critical public facilities, including power systems, water treatments plants, police and fire, U.S. military bases, schools, and coastal highways and bridges, as well as two national seashores, 10 national wildlife refuges (NWRs), and historic sites.

In coastal North Carolina, there are currently 26 sand needs projects projected to require an estimated 446 million cubic yards (MCY) of beach-suitable sand over the next 50 years. Of those, five do not include authorization for federal funding or the RSM Optimization Update/BU benefit and are supported solely by local sponsorship (see Section 5.3 for a full list of North Carolina sand needs projects). Sand needs projects include CSRM projects, beach nourishment, RSM, and BU projects.

With thousands of miles of shoreline and extensive low-lying areas, nationally significant environmental and cultural resources, and a population of a million people that increases significantly during hurricane season, North Carolina has significant risk to coastal storms, which will increase with rising sea levels.

Figure 3-1 provides a snapshot of exposure along the North Carolina coast.

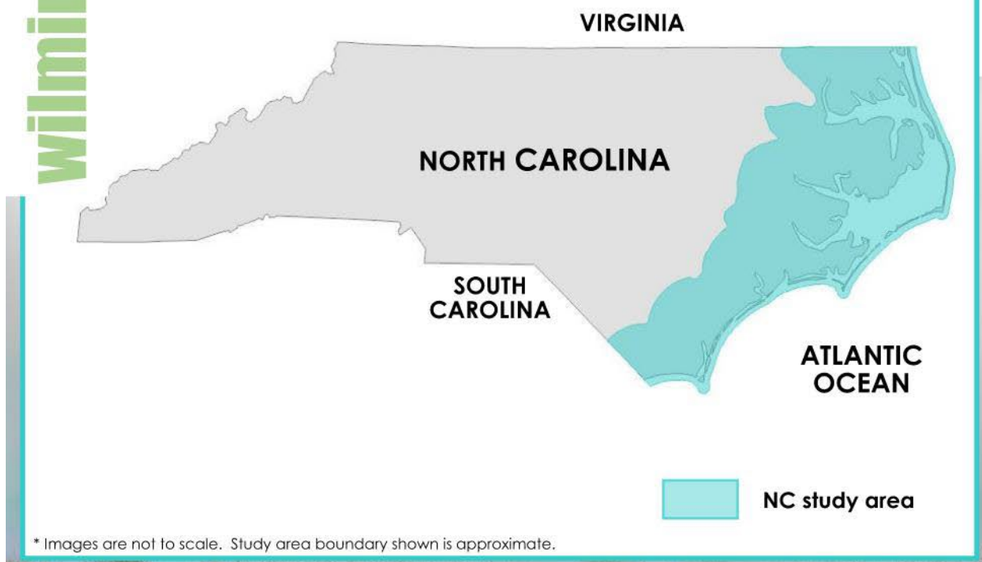
SOUTH ATLANTIC COASTAL STUDY A COASTAL MANAGEMENT STRATEGY

The study is modeled closely after the North Atlantic Coast Comprehensive Study (NACCS), a Congressional response and precedent-setting vulnerability and flood risk-reduction study completed for the north Atlantic coastline in the wake of Hurricane Sandy. The study is conducting regional analyses of coastal risk and identifying initial measures/costs that can address vulnerabilities with emphasis on regional sediment management (RSM) as an actionable strategy to sustainably maintain or enhance current levels of coastal storm risk reduction.

study area

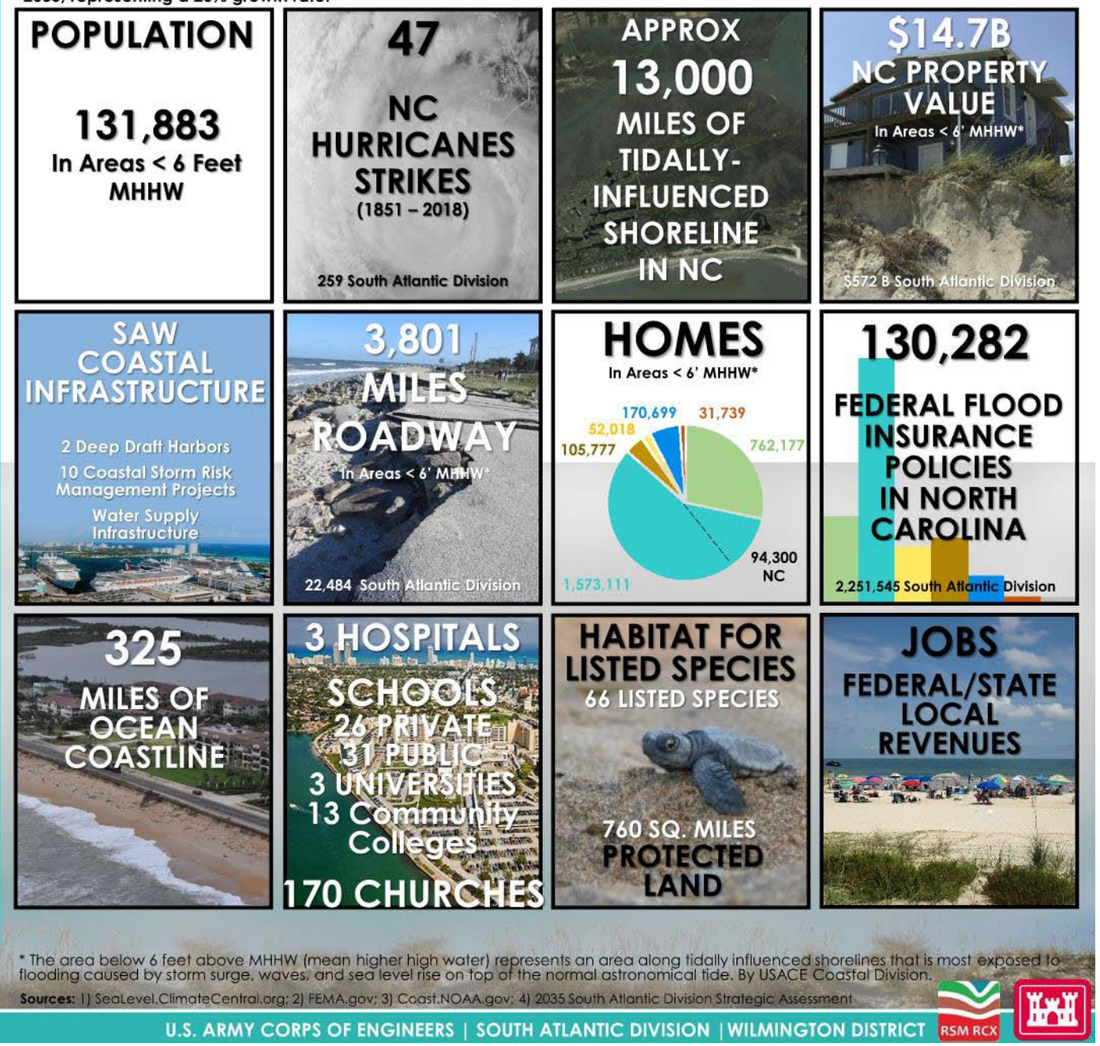
wilmington district

Reducing coastal risk is a responsibility shared by all stakeholders including coastal communities, local and state governments, tribes, Federal agencies, and others throughout the study area which covers approximately 13,000 miles of tidally influenced shorelines. Locations within the USACE South Atlantic Division Wilmington District (SAW) area of responsibility that are affected by sea level rise, and where hurricane and storm damages occur or are forecast to occur, are included within the study area.



WILMINGTON DISTRICT COASTAL EXPOSURE SNAPSHOT

The Wilmington District region is projected to experience significant growth in population and economic activity due to drivers including a favorable climate, low tax rates, availability of land for development, state and local government incentives, transportation infrastructure and networks, and proximity to international, national, and regional economic centers. The State's population is projected to grow to 12.1M by 2035, representing a 20% growth rate.



* The area below 6 feet above MHHW (mean higher high water) represents an area along tidally influenced shorelines that is most exposed to flooding caused by storm surge, waves, and sea level rise on top of the normal astronomical tide. By USACE Coastal Division.

Sources: 1) SeaLevel.ClimateCentral.org; 2) FEMA.gov; 3) Coast.NOAA.gov; 4) 2035 South Atlantic Division Strategic Assessment

U.S. ARMY CORPS OF ENGINEERS | SOUTH ATLANTIC DIVISION | WILMINGTON DISTRICT

RSM RCX

Figure 3-1: Snapshot of Resources Potentially Exposed to Coastal Hazards in North Carolina

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3.1.2 Bureaucratic and Political Context of the State

The Federal Coastal Zone Management Act (CZMA), enacted in 1972, provides a national coastal management framework that encourages states to take an active role in coastal management. Within that framework, the State of North Carolina passed the Coastal Area Management Act (CAMA) in 1974, which established "a cooperative program of coastal area management between local and State governments." As described in section A113A-101 of CAMA, "Local government shall have the initiative for planning. State government shall establish areas of environmental concern. With regard to planning, State government shall act primarily in a supportive standard-setting and review capacity, except where local governments do not elect to exercise their initiative. Enforcement shall be a concurrent State-local responsibility" (North Carolina 1974).

Balancing economic development and environmental protection is a key aspect of CAMA. Under CAMA, North Carolina established the CRC, which has the authority to develop rules and policies in the interests of coastal management. NCDM executes the plans of CAMA and operates within NCDEQ. Although other agencies play integral roles in coastal management, the NCDCM is the single centralized agency for coastal management in North Carolina. The NCDCM acts to protect, conserve, and manage the state's coastal resources through an integrated program of planning, permitting, education, and research. Using the rules and policies of the CRC, the NCDCM implements the CAMA, the Dredge and Fill Law, and the CZMA.

Within CAMA, there are currently 20 designated "coastal counties." These include Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Gates, Hertford, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington (**Figure 3-2**). CAMA requires land use plans for each of the coastal counties. The State Hazard Mitigation Officer (SHMO) provides courtesy reviews of CAMA Land Use Plan updates for the 20 coastal counties upon request from NCDEQ. The review is designed to ensure that CAMA plans are consistent with local hazard mitigation plans and the State Hazard Mitigation Plan. The State Hazard Mitigation Branch coordinates with NCDCM on work in designated CAMA counties.

Figure 3-2: Twenty Designated Coastal Counties in North Carolina within the Coastal Area Management Act

The NCDWR, a branch of NCDEQ, interacts with coastal management by administering state funding associated with shallow draft navigation channel dredging and CSRM projects. DWR also coordinates closely with NCDCM on regulatory compliance and enforcement issues within the coastal counties. In addition, DWR certifies projects on the coast that require federal authorization. To support collaboration and coordination, DWR also participates in multi-agency coordination meetings and participates in outside planning groups involved in coastal management such as the Living Shoreline Steering Committee.

In 1997, the North Carolina General Assembly passed the North Carolina Fisheries Reform Act, which resulted in the North Carolina Coastal Habitat Protection Plan (CHPP). CHPP is a guidance document that addresses habitat and water quality efforts needed to protect, enhance, and restore fish habitat in North Carolina. Development and implementation of CHPP is an NCDEQ effort, led by the Marine Fisheries, Environmental Management, Coastal Resources, and the Wildlife Resources Commission. NCDEQ staff with jurisdiction over marine fisheries, water quality, and coastal management participate in plan development. The Division of Marine Fisheries is the lead agency in drafting the plans. Other agencies, such as Albemarle-Pamlico National Estuarine Partnership; Wildlife Resource Commission; Division of Coastal Management; Division of Water Resources; Division of Energy, Mineral, and Land Resources; Division of Mitigation Services; and Soil and Water Conservation Districts have participated in the CHPP process.

The NCEM supports coastal management through administration of the following:

- Risk Management Program – This program includes the North Carolina Floodplain Mapping Program (NCFMP), which manages the implementation of FEMA's Risk MAP (Mapping, Assessment, and Planning) and provides communities with flood risk data to assist in the development of mitigation plans at the local and state levels.
- Hazard Mitigation Office – This office assists in the development of local hazard mitigation plans. For mitigation projects, NCEM staff coordinate with NCDCM to ensure that work will not conflict with an area of environmental concern according to CAMA regulations.
- NCORR – This office administers nearly $1 billion in Housing and Urban Development (HUD) disaster recovery and mitigation funding, as well as state disaster recovery funds. NCORR manages programs statewide that include homeowner recovery, infrastructure, affordable housing, resiliency, strategic buyout, and local government grants and loans.

With respect to coordination with coastal management, an array of federal agencies (NOAA, National Marine Fisheries Service [NOAA-NMFS], USFWS, BOEM, USACE, and FEMA) also form the overall makeup of coastal management efforts in the state.

3.1.3 State/Regional Government Actions Regarding Coastal Resiliency

Coastal resiliency initiatives are occurring in North Carolina at all levels of government, as well as through non-governmental entities. The following are some of the regional efforts:

1. **State Climate Risk Assessment and Resiliency Plan:** Falling under the Governor's Executive Order 80, the State Climate Risk Assessment and Resiliency Plan establishes the North Carolina Resiliency Strategy, which includes four elements: 1) North Carolina Climate Science Report, 2) State Agency Resilience Strategy, 3) Statewide Vulnerability Assessment and Resilience Strategies, and 4) North Carolina Enhanced Hazard Mitigation Plan (North Carolina 2020). The scope of the SACS ties into several critical sectors of study within the State Plan, including coastal resources, ecosystems, housing, building and support services, public safety, and transportation. Where possible, the SACS will seek to contribute to the overall State Plan.

2. **Resilient Coastal Communities Program (North Carolina Division of Coastal Management)**: This program aims to facilitate a community-driven process for setting coastal resiliency goals, assessing existing and needed local capacity, and identifying and prioritizing projects to enhance community resilience to coastal hazards. Local governments from throughout the 20 coastal counties were eligible to apply with the initial application deadline in February 2020. Funding for future iterations of this program is undetermined at the time of this report publication (NCDEQ 2020c).

3. **North Carolina Coastal Communities Resilience Guide (North Carolina Division of Coastal Management)**: An "online interactive guide designed to walk users through some of the key steps and questions required for effective community-level resiliency planning while pointing to relevant tools, resources, and examples. This online guide is the latest phase of work that has been informed by several years of resilience related planning, engagement, and investments led by the NC DCM and supported by its many partners. DCM's goal is to continue to update and adapt this tool, to incorporate lessons learned over time, and to help facilitate smart, responsible, forward-looking planning and investments for a more resilient coastal region. This guide is designed to be complementary to DCM's Coastal Adaptation and Resiliency website which hosts many of the different categories of resources referenced in the guide" (NCDEQ 2020b).

4. **North Carolina Know Your Zone (North Carolina Emergency Management and coastal counties)**: "North Carolina Know Your Zone is a tiered evacuation system that highlights areas most susceptible to hurricanes, tropical storms, and other hazards. The Know You Zone lookup tool is a color-coded interactive map resident and visitors can use to determine the evacuation zone where they live, work, or are visiting based upon a street address." When a storm is approaching, local officials will determine the zones that are most threatened and assess whether residents should evacuate (Craven County 2020).

5. **ReBuild NC (North Carolina Office of Recovery and Resiliency)**: Following Hurricane Florence in 2018, North Carolina established the NCORR, which leads the Rebuild NC initiative that assists disaster survivors and local governments with disaster recovery and improving

resiliency. The office has administered nearly $330 million in funds to homeowners, small businesses, and local governments for recovery from storm impacts, affordable housing and infrastructure, and mitigation using the Strategic Buyout Program for those in harm's way. In addition, the office administers nearly $1 billion in HUD disaster recovery and mitigation funding. NCORR has partnered with local governments, state agencies, and community organizations providing a "road map for disaster recovery planning across the state, informing policies and programs by linking key community goals with clear implementation strategies" (NCORR n.d.).

6. **SAND Report:** A component of the SACS, the SAND Report quantifies sand needs and available sand resources for all current beach nourishment projects, both federal and non-federal, in the SAD of USACE for the next 50 years. The SAND Report seeks to enhance coastal resilience by assessing the region's current and future sediment demands and resources available for nourishments and other coastal resiliency efforts. The collaborative region-wide effort of data collection and review brought together USACE technical experts in each district along with local, state, and federal stakeholders to provide input for this product and to create an extensive overview of the sand needs and availability within the study area. Products provided by this effort aid identification of areas at risk or in need of sediment and address areas with deficiencies in coastal storm protection, as well as support discovery of areas where resiliency and sustainability enhancements are possible. In addition to the SAND Report, information and key findings from this study can also be found in each of the three North Carolina FAAS.

7. **2020 Regional Sediment Management (RSM) Optimization Update**: The 2020 RSM Optimization Update was implemented as a component of SACS to support the identification and continued implementation of sustainable solutions under current authorities. The report documents RSM strategies that have been implemented throughout SAD, as well as additional RSM opportunities that have been identified by individual districts in coordination with the RSM Regional Center of Expertise (RCX). It was used to inform the BU portion of the SAND Report by incorporating federal and non-federal RSM sources such as dredging from navigational channels, inlets, flood shoals, and ebb shoals into the 50-year sediment budgets. Summary information and recommendations from this report are included in each FAAS.

8. **North Carolina Coastal Federation – Coastal Resilience Initiative**: "The Coastal Resilience Initiative takes a multi-pronged approach to strengthening our natural defenses by restoring wetland buffers and living shorelines, protecting existing wetlands from illegal destruction, and by working with farmers to convert marginal cropland back into large wetland areas. All these efforts combined will restore more than 5,000 acres of wetlands over the next three years — more than offsetting our annual losses. The initiative also includes an education and outreach component to increase awareness about the need for resiliency and what we can do at the community, local and state levels (NCCF 2020)."

3.2 Problems and Opportunities Overview

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

Stakeholders were engaged during two Field Workshops held in two regions of coastal North Carolina in 2019 to discuss existing problems related to the impact of coastal storms on people, the economy, infrastructure, and environmental and cultural resources under current and future conditions. Additional resources such as USACE and stakeholder documents, and stakeholder coordination, were used to outline broad problem statements of coastal storm risk as well as opportunities to reduce risk and increase resilience to existing and future coastal storm damages.

3.2.1 Problems

Based on stakeholder coordination and existing trends related to development, population increase, and other factors, all problems listed, though not exhaustive, are expected to increase in intensity and extent as sea level rises, depending on vulnerability and resiliency of the exposed population, infrastructure, and environmental and cultural resources.

- Coastal storms and sea level rise are adversely affecting the economy in North Carolina through negative impacts to private property, businesses, and environmental resources.
    - *Areas of potential significant impacts include Brunswick, Carteret, Dare, and New Hanover Counties*.
- Coastal storms and sea level rise have a negative impact on life safety and economics through the closure of roads, evacuation routes, and damage to critical facilities and infrastructure.
    - *Specific examples include Dare and Hyde Counties, which largely rely on NC Highway 12 for evacuations.*
    - *In the aftermath of Hurricane Florence in 2018, the City of Wilmington was largely cutoff and isolated due to flood waters inundating roads into the City.*
- Erosion and wave attack cause damages to property and infrastructure (homes, roadways, and evacuation routes) in counties with ocean-facing shorelines.
- Erosion and wave attack cause damages to property and infrastructure in counties that contain back bay shorelines.
- Erosion and inundation because of wave attack, coastal storms, and sea level rise threaten ecologically and economically beneficial habitats such as back bay salt marsh and barrier islands. As coastal areas continue to experience increases in development

as well as these natural hazards, the ability of these natural areas to provide benefits to communities is compromised.

- Storm surge inundation affects socially vulnerable and/or low-income populations within coastal floodplains, including Bertie, Beaufort, Chowan, Craven and Hyde Counties.
- Quantities of known compatible offshore sand sources do not meet projected need for coastal storm mitigation projects over the next 50 years in the following counties, as reported in the SAND Report: Onslow, Pender, New Hanover, and Brunswick.
- The effects of coastal storms and sea level rise (e.g., erosion, inundation, etc.), may affect sites and structures with significance to State-recognized Tribal nations and the Gullah Geechee community.

3.2.2 Opportunities

Opportunities to increase resiliency were identified by SACS stakeholders during workshop breakout sessions, as well as through follow-on study and coordination efforts. These opportunities include:

- Reduce impacts from storm surge, erosion, and wave attack by implementing solutions in high-risk and vulnerable areas identified in the Tier 1 Risk Assessment and Tier 2 Economic Risk Assessments.
- Increase understanding of coastal processes affecting wetland and marshland migration trends (e.g., erosion/accretion, sea level rise, etc.) and effective restoration strategies (e.g., marsh grass plantings, beneficial use of dredged material including thin-layer placement, etc.).
- Enhance environmental habitat while addressing back bay erosion.
- Improve risk communication to development groups and the public, including tribal entities.
- Identify gaps in current coastal resiliency efforts, and recommend federal, state, and local resources that can be leveraged to fill those gaps.
- Highlight and support existing resiliency efforts by federal, state, Tribal and local entities.
- Identify institutional and other barriers that limit efforts to reduce vulnerability and increase resiliency, readying the state for potential actions to reduce those barriers.
- Strengthen stakeholder involvement for collaboration on sediment management strategies, including the beneficial use of dredged material and offshore investigations, specifically in those counties with deficits in their 50-year sand budgets.

- Increase resilience and adaptive capacity to sea level rise in the coastal and back bay areas.
- Enhance public outreach and risk communication strategies regarding coastal storm damages to property, infrastructure, communities, environmental resources, and cultural resources as a result of sea level rise.
- Increase access to and utilization of existing SACS data and tools, including Coastal Hazards System (CHS) data.

3.3 Political Boundaries

The North Carolina SACS study area is divided into two planning reaches that touch on 30 counties and three congressional districts. **Figure 3-3** illustrates the SACS study area footprint and how it overlaps with the various political boundaries.

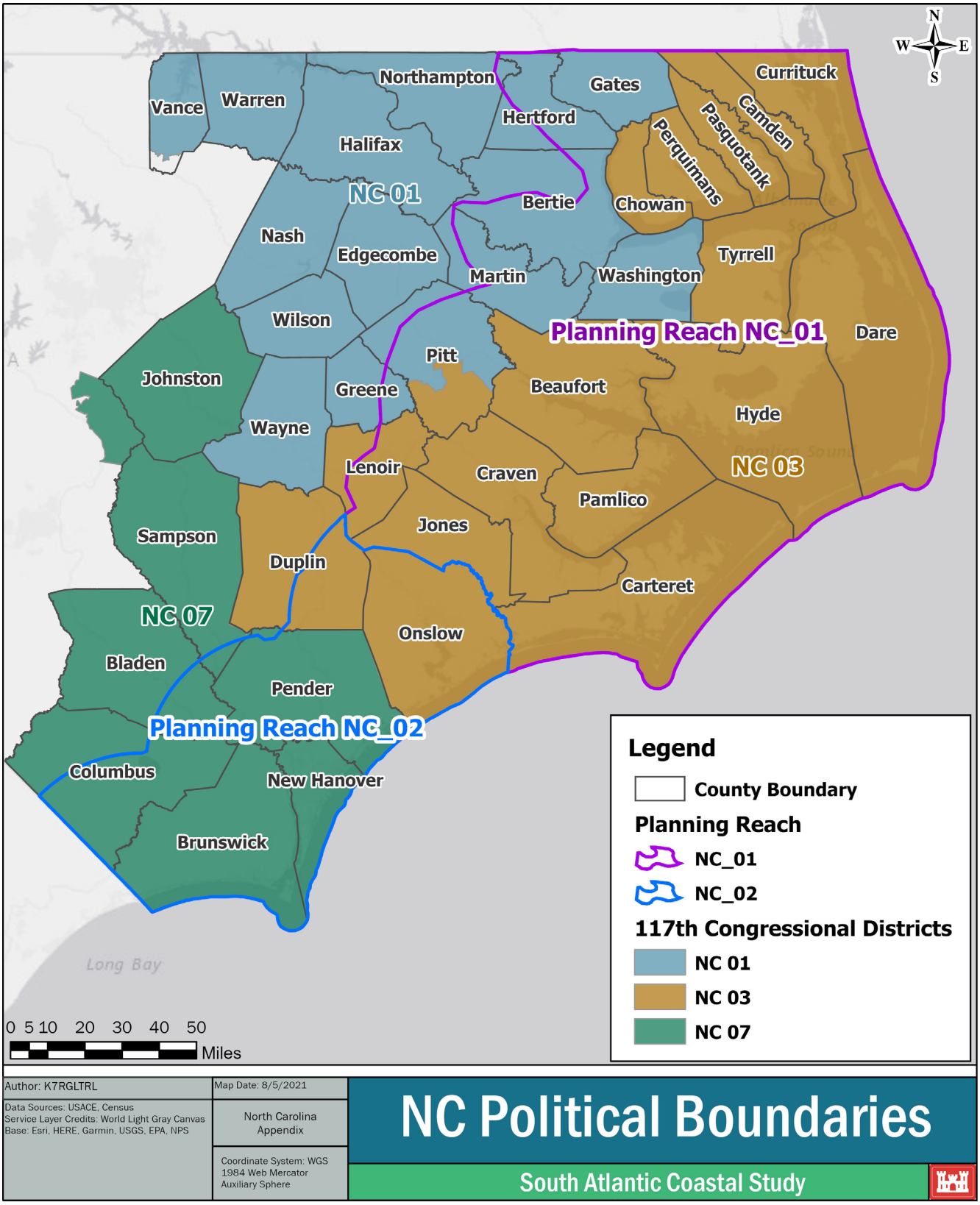


Figure 3-3: North Carolina Political Boundaries and SACS Planning Reaches

3.4 Planning Reaches

SACS planning reaches were derived from three data sets and visual edits based on coastal geomorphology and professional judgment. Data sets include state boundaries, county boundaries, the maximum inland limit of a Category 5 hurricane's storm surge inundation based on NOAA modeling, and The Nature Conservancy (TNC) Ecoregions, indicating areas that TNC has prioritized for conservation. Methodology for delineating SACS planning reaches is described in the Main Report. North Carolina planning reaches are depicted in **Figure 3-3**.

3.5 Shoreline Characteristics

Based on the NOAA Environmental Sensitivity Index (ESI) guidelines, USACE developed a grouping of generalized shoreline types. At the state level, the North Carolina Division of Coastal Management (NCDCM) identifies shoreline types similarly. Although USACE, NOAA, and NCDCM naming conventions for these types differ, the types themselves are generally analogous, as shown in **Table 3-1**. Of the 11 USACE generalized shoreline types used in the analysis for the SACS effort, eight are found in North Carolina. Regarding SACS environmental analyses, NOAA's Coastal Change Analysis Program (C-CAP) was leveraged to aid in the vulnerability assessment. C-CAP land cover classifications and naming conventions extend further inland than do the shoreline types shown in **Table 3-1**; however, shoreline types remain largely similar in function. For additional information regarding use of C-CAP classes in determining environmental vulnerability, please refer to the South Atlantic Coastal Study Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification (Environmental Technical Report) (USACE 2022b).

Table 3-1: List of USACE Generalized Shoreline Types

USACE Generalized Shoreline Type	NOAA ESI Shoreline Types	NCDCM Shoreline Types	Found in North Carolina?
Wetlands/Marshes/Swamps (Sheltered)	Vegetated Low Banks, Hypersaline Tidal Flats, Salt and Brackish Water Marshes, Freshwater Marshes, Swamps, and Scrub/Shrub Wetlands	Swamp Forest (Wetland Vegetation); Marsh (Wetland Vegetation); Shorelines with Submerged Aquatic Vegetation (SAV), Mudflats, Oysters, and/or Woody Debris	Yes
Wetland/Marshes/Swamps (Exposed)	Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay) and Exposed Scarps and Steep Slopes (Clay)	Swamp Forest (Wetland Vegetation); Marsh (Wetland Vegetation); Shorelines with SAV, Mudflats, Oysters, and/or Woody Debris	Yes
Mangroves	Mangroves	-	No
Coral Reefs and Hardbottoms	Not an ESI Shoreline Type, but included as a sensitive shoreline Geographic Information System (GIS) Layer	Shorelines with SAV, Mudflats, Oysters, and/or Woody Debris	Yes
Bluffs and Steep Slopes	Scarps and Steep Slopes (Sand)	Sediment Bank	Yes
Rocky Shores (Exposed)	Exposed, Rocky Shores, Gravel Beaches, and Boulder Rubble	-	Yes

USACE Generalized Shoreline Type	NOAA ESI Shoreline Types	NCDCM Shoreline Types	Found in North Carolina?
Rocky Shores (Sheltered)	Sheltered Scarps (Bedrock/Mud/Clay) and Sheltered, Rocky, Rubble Shores	-	Yes
Man-made Structures (Exposed)	Exposed, Solid Man-made Structures and Riprap	Modified with Engineered Structure	Yes
Man-made Structures (Sheltered)	Sheltered, Permeable, Rocky Shores and Sheltered Riprap	Modified with Engineered Structure	Yes
Sandy Beaches (Exposed)	Fine-to-Medium-Grained Sand Beaches, Coarse-Grained Sand Beaches, Mixed Sand and Gravel Beaches, and Exposed Tidal Flats	Sediment Bank	Yes
Sandy Beaches (Sheltered)	Sheltered Tidal Flats	Sediment Bank	Yes

3.6 Overview of Storm History and Sea Level Rise Projections

North Carolina has experienced many historic storms and has been affected by sea level change. This section summarizes significant historical storms, hurricanes, storm surge, and sea level rise that have shaped North Carolina's coastal conditions.

3.6.1 Storm History

North Carolina is in an area of significant tropical and extratropical cyclone activity. **Figure 3-4** shows historic tracks of hurricanes and tropical storms from 2000 -2020, as recorded by the National Hurricane Center (NHC) and is available from the NOAA Historical Hurricane Tracks tool (NOAA n.d.). The circle in **Figure 3-4** indicates a 120-nautical mile radius drawn from Beaufort, NC, which is roughly the center of the state's coast. Based on NHC records, 217 hurricanes and tropical storms have passed within the 120-nautical mile state radius over the full record from 1851-2020, with an additional 67 tropical depressions and extratropical storms. Since the year 2000, 45 hurricanes, tropical storms, tropical depressions, and extratropical storms have passed within the 120-nautical mile radius. While storms passing near the coast have the most direct impact, strong storms passing at greater distances are still capable of producing damage.

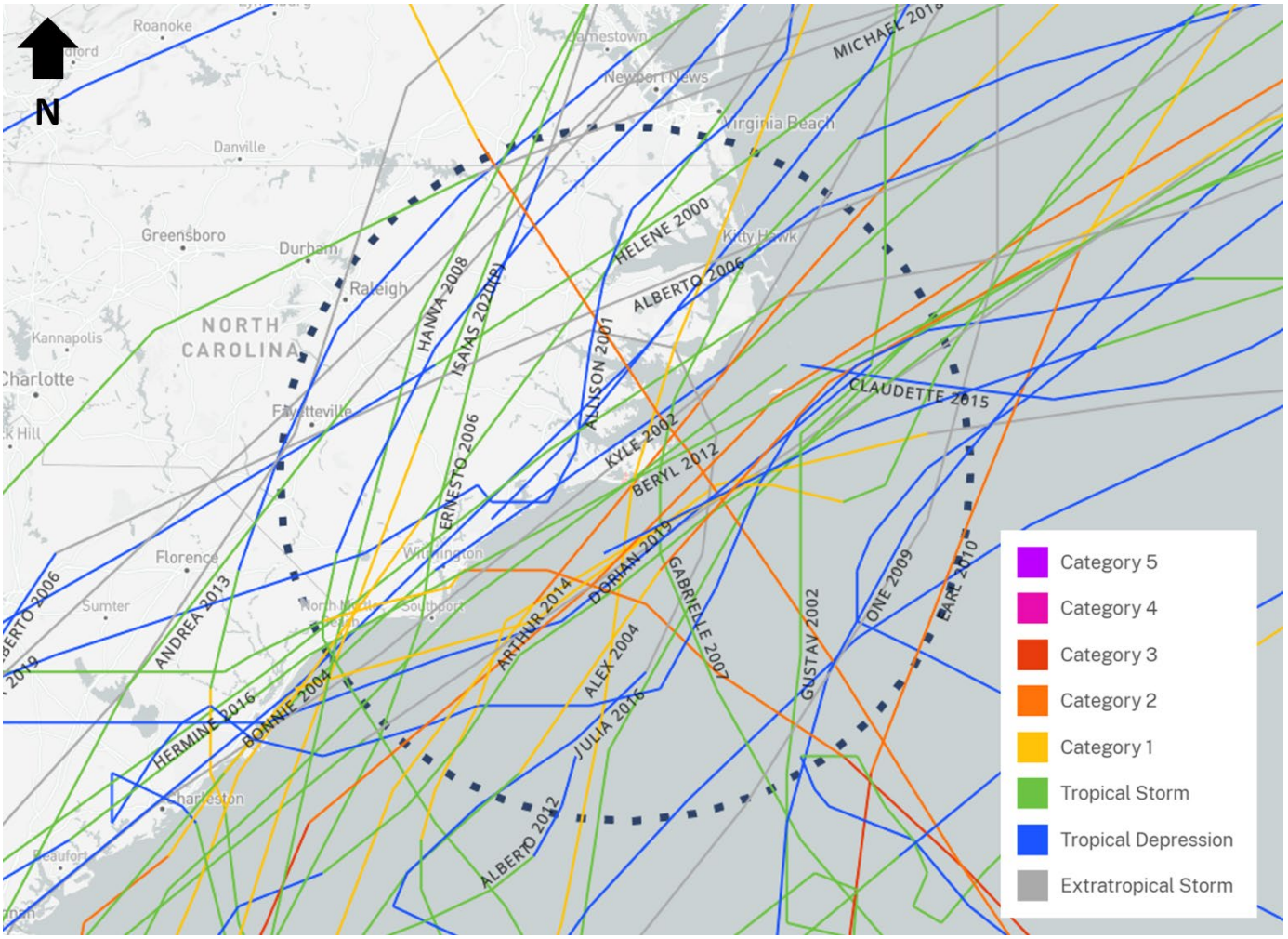


Figure 3-4: Historic Coastal Storm Tracks for North Carolina since 2000 (120-Nautical Mile Radius) (NOAA n.d.)

During intense storm activity, the factors such as storm surge, intense wave action, high winds, and heavy precipitation have potential to create massive amounts of damage to infrastructure, property, and livelihoods of North Carolinians. Storm surge and heavy precipitation lead to coastal and inland flooding, while strong winds and tornadoes tear apart buildings and waves wear down and destroy coastal infrastructure. Storms also cause the erosion of sediment from shorelines, beaches, and dune systems that are the first line of defense for coastal communities, leading to road closures for major evacuation routes such as NC Highway 12. Damages caused by storms in North Carolina since 2000 are shown in **Table 3-2**. Storms presented in the table consist of those that produced at least $1 billion in damage throughout the U.S., adjusted to the 2021 United States Dollar (USD) value.

Table 3-2: Historical Coastal North Carolina Storms Since 2000 (NOAA 2021b)

Name	Month, Year	Total U.S. Damages (in Billions, 2021 USD)	Effect on North Carolina
Hurricane Isabel	Sept. 2003	8.0	Made landfall in North Carolina Considerable storm surge damage Extra flooding due to 4- to 12-inch rains
Hurricane Charley	Aug. 2004	22.7	Some storm surge damage
Hurricane Frances	Sept. 2004	13.9	Considerable flood damage due to storm surge and 5- to 15-inch rains
Hurricane Ivan	Sept. 2004	29.1	Wind and flood damage
Hurricane Jeanne	Sept. 2004	10.6	Flood damage
Hurricane Irene	Aug. 2011	16.1	Made landfall in North Carolina Torrential rainfall and flooding Moderate wind damage Inlet opening/breach near Rodanthe Tornadoes added to damage
Hurricane Sandy	Oct. 2012	75.4	Damage from wind, rain, and heavy snow Interruption to critical water/electrical services
Hurricane Matthew	Oct. 2016	11.1	Made landfall in North Carolina Widespread damage from wind, storm surge, and inland flooding Historic levels of flooding in eastern North Carolina damaged 100,000 homes, businesses, and other structures
Hurricane Irma	Sept. 2017	53.5	Storm surge and inland flooding
Central and Eastern Winter Storm	Jan. 2018	1.1	Nor'easter Winter weather
Northeast Winter Storm	Mar. 2018	2.3	Powerful Nor'easter Combination of high winds, heavy snow, and heavy coastal erosion
Hurricane Florence	Sept. 2018	25.0	Made landfall in North Carolina Extreme rainfall (35.93 inches) Wind gusts over 100 miles per hour (mph) Most damage due to rainfall inland, which caused many rivers to surpass previous record flood heights Extensive damage to U.S. Marine Corps Base Camp Lejeune
Hurricane Michael	Oct. 2018	26.0	High winds, rain, and flooding
Hurricane Dorian	Sept. 2019	1.7	Made landfall in North Carolina Destructive sound-side surge inundated many coastal properties and isolated residents who did not evacuate Significant flood, severe storm, and tornado damage to many homes and businesses on the Outer Banks

Name	Month, Year	Total U.S. Damages (in Billions, 2021 USD)	Effect on North Carolina
Hurricane Isaias	Aug. 2020	4.8	Made landfall in North Carolina Considerable inland flooding Numerous tornadoes spotted, including several EF-2 and one EF-3
Hurricane Delta	Oct. 2020	2.9	Heavy rainfall, high winds, and some storm surge
Hurricane Zeta	Oct. 2020	4.4	High winds
Tropical Storm Eta	Nov. 2020	1.5	Extreme rainfall leading to significant flooding that damaged homes, businesses, and infrastructure

3.6.2 Storm Surge

Storm surge is the rise of the ocean surface above its astronomical tide level due to storm forces, driven primarily by atmospheric pressure gradients and water being forced toward the shore by wind. Extremely high wind velocities coupled with low barometric pressures (such as those experienced in tropical storms, hurricanes, and very strong Northeasters) can produce very high, damaging water levels. In addition to wind speed, angle of approach, and duration, storm surge is also influenced by water depth, length of fetch (distance over water), frictional characteristics of the nearshore sea bottom, and width and slope of the continental shelf.

An estimate of storm surge is required for the design of many CSRM measures. An increase in water depth may increase the potential for coastal flooding and allow larger storm waves to attack the shore.

It is possible to classify and predict storm surge elevations for various storms using historical information and theoretical models. FEMA has conducted a Flood Insurance Study (FIS) for each coastal county, resulting in storm surge elevations for storms with 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (AEPs).

Table 3-3 provides surge elevations at different AEPs for each coastal county based on the analysis generated by FEMA's Hazus Flood Model (Hazus). Water levels from Hazus are generated by interpolating AEP values from each FEMA FIS location to fit AEP values used in Hazus. AEP values at each location were then tabulated based on individual points that were representative of each area. To remain consistent throughout the state, points along the oceanfront and sound-side were each chosen with consistent depths. The storm surge elevations presented include the effects of astronomical high tide and wave setup.

Table 3-3: North Carolina Storm Tide Elevations

Shorelines	10% Annual Exceedance Probability (AEP) (feet-North American Vertical Datum of 1988 [NAVD88])	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Currituck-Coastal	4.5	6.2	7	8.6
Currituck - Interior	2.2	3	3.4	4.2
Camden	2.4	3.3	3.7	4.6
Pasquotank	2.4	3.3	3.7	4.6
Perquimans	2.4	3.3	3.7	4.6
Chowan	2.8	3.8	4.3	5.3
Hertford	4.4	6.0	6.8	8.4
Bertie	4.4	6.0	6.8	8.4
Washington	3.6	4.9	5.6	6.9
Tyrrell	2.7	3.7	4.2	5.2
Dare-North Outer Banks	5.1	7.0	7.9	9.7
Dare-South Outer Banks	5.9	8.1	9.2	11.3
Dare-Roanoke Island	5.2	7.2	8.2	10.1
Dare-Inland Mainland	2.9	4.0	4.6	5.7
Hyde	3.3	4.5	5.1	6.3
Beaufort	4.1	5.6	6.4	7.9
Pamlico	4.1	5.6	6.4	7.9
Craven	5.0	6.9	7.8	9.6
Carteret-Bogue Banks & Main	5.1	7.0	7.9	9.7
Carteret-Cape Lookout	3.8	5.3	6.0	7.4
Carteret-North Barrier	3.3	4.6	5.2	6.4
Onslow	6.3	8.6	9.8	12.1
Pender	7.6	10.4	11.8	14.5
New Hanover	7.1	9.8	11.1	13.7
Brunswick	6.6	9.1	10.3	12.7

With 1-percent AEP storm surge values ranging from 3.4 to 11.8 feet, it is evident that there is a large variation in water levels throughout North Carolina. This is likely because of the state's system of complex features, such as barrier islands broken apart by a series of inlets, large back bay, and estuarine portions where the bathtub effect often occurs, a wide continental shelf, and coastal rivers traveling through miles of low-lying coastal plains.

Additional coastal flood modeling was conducted as part of the CHS to evaluate coastal flood risks to existing and future conditions. CHS modeling efforts are discussed further in Section 4.1.4. **Table 3-4** and **Table 3-5** display the SACS CHS maximum inundation depths in North Carolina for a range of AEP storms based on existing conditions (USACE 2020). Flood depth AEP values are estimated at points representative of each tabulated location. Values presented in the tables are purely for the reader's reference and do not inform other quantitative analyses done within the SACS studies. For more information, please seek out CHS data via a point of contact or online CHS data portals.

Table 3-4: Existing Conditions Coastal Hazards System Maximum Flood Depths Relative to Mean Sea Level for Planning Reach NC_01 (USACE 2020)

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Corolla	4.73	5.22	5.75	6.08	6.89
Currituck Sound	1.63	1.77	1.94	2.09	2.44
Duck FRF	4.60	5.08	5.59	5.91	6.58
Albemarle Sound	2.06	2.46	2.84	3.09	3.48
North Pamlico Sound	2.96	3.33	3.80	4.09	4.75
Rodanthe	3.87	4.13	4.39	4.56	5.34
Pamlico River - Bath	5.20	6.41	7.61	8.39	9.90
South Pamlico Sound	5.18	6.56	7.94	8.70	10.26
Neuse River - New Bern	6.06	7.51	8.98	9.96	11.59
Ocracoke	3.81	4.08	4.50	4.84	5.51
MCAS Cherry Point	5.30	6.63	8.10	9.08	10.89
Core Sound - Davis	4.15	5.35	6.62	7.67	8.85
Newport River	5.22	6.18	7.38	8.18	10.22
White Oak River	5.81	6.92	8.21	9.23	10.62
Cape Lookout National Seashore	4.19	4.53	5.13	5.69	6.82
Bogue Sound	5.52	6.62	7.86	8.93	11.32
Emerald Isle	5.61	5.95	6.64	7.30	9.16

Table 3-5: Existing Conditions Coastal Hazards System Maximum Flood Depths Relative to Mean Sea Level for Planning Reach NC_02 (USACE 2020)

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
White Oak River	5.81	6.92	8.21	9.23	10.62
New River	4.76	5.60	6.67	7.43	8.72
North Topsail Beach	6.18	6.54	7.25	7.97	9.72
Wrightsville Beach - Back Bay	7.57	9.08	11.03	12.25	14.87
Wrightsville Beach - Ocean	6.70	7.21	8.37	9.37	11.56
Cape Fear River - MOTSU	5.96	6.51	7.59	8.39	9.83
Kure Beach	6.63	7.14	8.12	9.01	10.92
Holden Beach - Back Bay	8.38	9.09	10.54	11.60	13.72
Southport	6.78	7.52	8.60	9.40	10.88
Oak Island	7.90	8.27	8.92	9.53	10.96
Ocean Isle	8.43	8.83	9.60	10.40	12.35

3.6.3 Sea Level Rise

SACS addresses sea level change in accordance with the guidance document USACE Engineering Regulation (ER) 1100-2-8162, *Incorporating Sea Level Change in Civil Works Programs* (USACE 2019c). This document refers to "sea level change" (rather than sea level rise) because of its applicability throughout the nation, including locations where sea levels are falling as a result of land uplift. Sea levels are rising at every compliant gauge within the SACS study area. Therefore, SACS products refer to "sea level rise" to clearly communicate the upward sea level change trend occurring throughout the SACS study area.

Rates of sea level rise were calculated at compliant gauges (greater than 40 years of data) within North Carolina and the adjacent South Carolina coast using the USACE Sea Level Change Curve Calculator Version 2021.12 (USACE 2021). This calculator uses the methodology described in Engineer Regulation (ER) 1100-2-8162, *Incorporating Sea Level Changes in Civil Works Programs* (USACE 2019c).

North Carolina has three National Ocean Service (NOS)-compliant gauges (**Figure 3-5**). **Table 3-6** summarizes the historical (NOAA mean sea level [MSL] trend through 2020) and projected 2120 (USACE Low, Intermediate, and High Scenarios) sea level trends at these four gauges. The observed rates vary between 0.0084 feet/year (2.56 mm/year) at Wilmington, NC, and North Carolina, and 0.0157 feet/year (4.79 mm/year) at Duck, North Carolina. These rates suggest that, while the sea level is rising and expected to continue rising at each gauge, the relative rates of sea level rise are different depending on the location.

Output from the USACE Sea Level Change Curve Calculator for Wilmington, the gauge with the lowest expected sea level rise in the state, and Duck, with the highest expected sea level rise, are shown in **Figure 3-6** and **Figure 3-7**. Estimates for 2120 at Wilmington, are 0.92, 2.37, and 6.99 feet NAVD88 under the USACE Low, Intermediate, and High Scenarios (**Figure 3-6**). For the same scenarios, the estimates at Duck, are 1.59, 3.05, and 7.67 feet NAVD88, demonstrating some of the variation in estimates across the state (**Figure 3-7**).

Figure 3-8 and **Figure 3-9** show tidal datums and extreme water levels for Wilmington and Duck, respectively. Included in these figures are return period estimates based on an extreme value analysis of observed water levels at the gauge location calculated by NOAA.

Table 3-6: USACE Sea Level Calculator Summary for Compliant North Carolina Area Gauges

Gauge Number	Location	Period of Record	NOAA 2020 RSL Trend (ft/year)	NOAA 2020 95% Confidence Interval (ft/year)	Equivalent Change over 100 years (ft)	USACE Low Scenario 2120 (ft, NAVD88)	USACE Intermediate Scenario 2120 (ft, NAVD88)	USACE High Scenario 2120 (ft, NAVD88)	Conversion NAVD88 ft to 1992 MSL ft
8651370	Duck	1978 - 2020	0.0157	0.00203	1.57	1.59	3.05	7.67	0.42
8656483	Beaufort	1953 - 2020	0.0108	0.00115	1.08	1.01	2.47	7.09	0.37
8658120	Wilmington	1935 - 2020	0.0084	0.00115	0.84	0.92	2.37	6.99	0.16
8661070	Springmaid Pier, SC	1957 - 2020	0.0131	0.00164	1.31	1.23	2.69	7.30	0.45

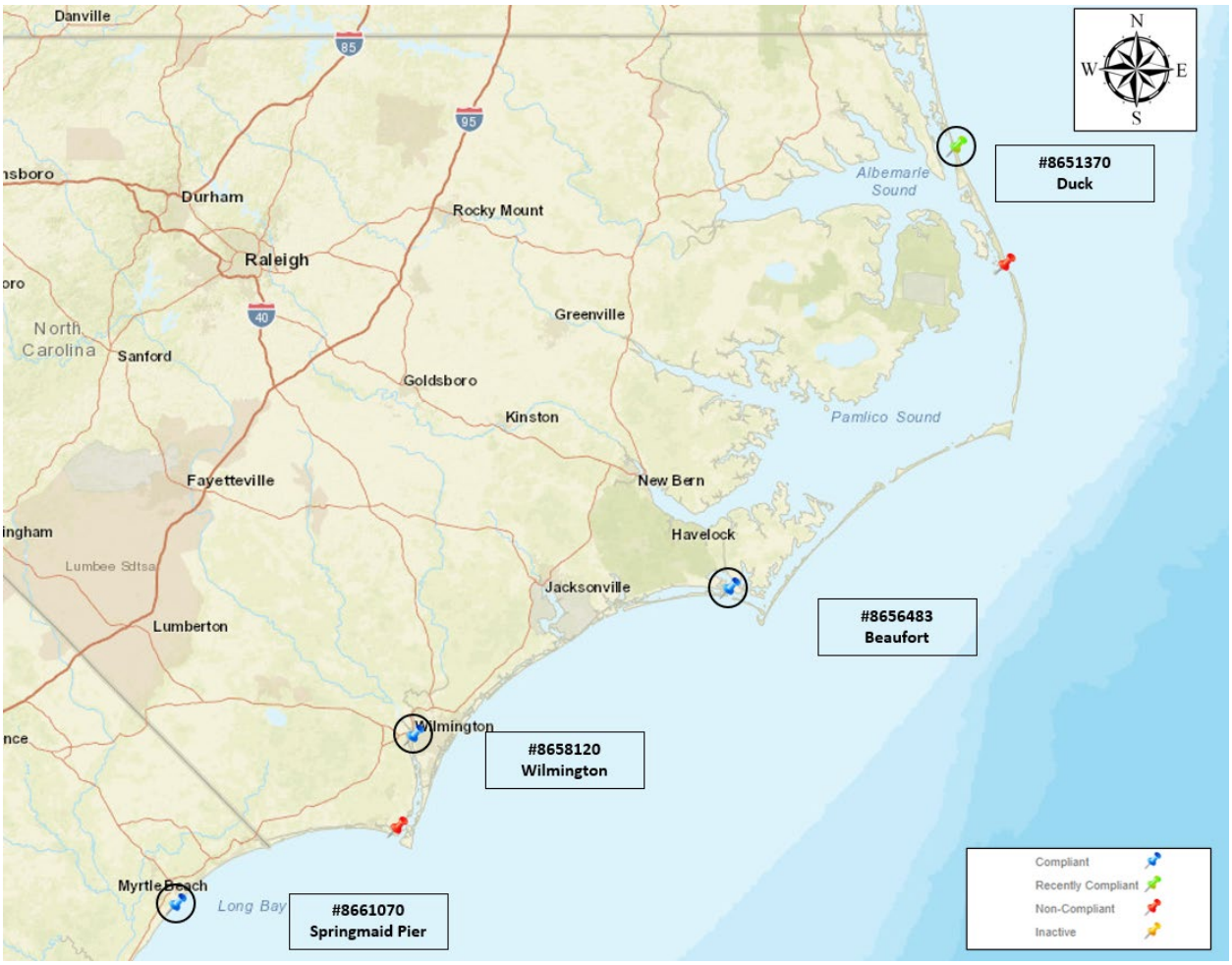


Figure 3-5: North Carolina National Ocean Service Gauges (NOAA 2021)

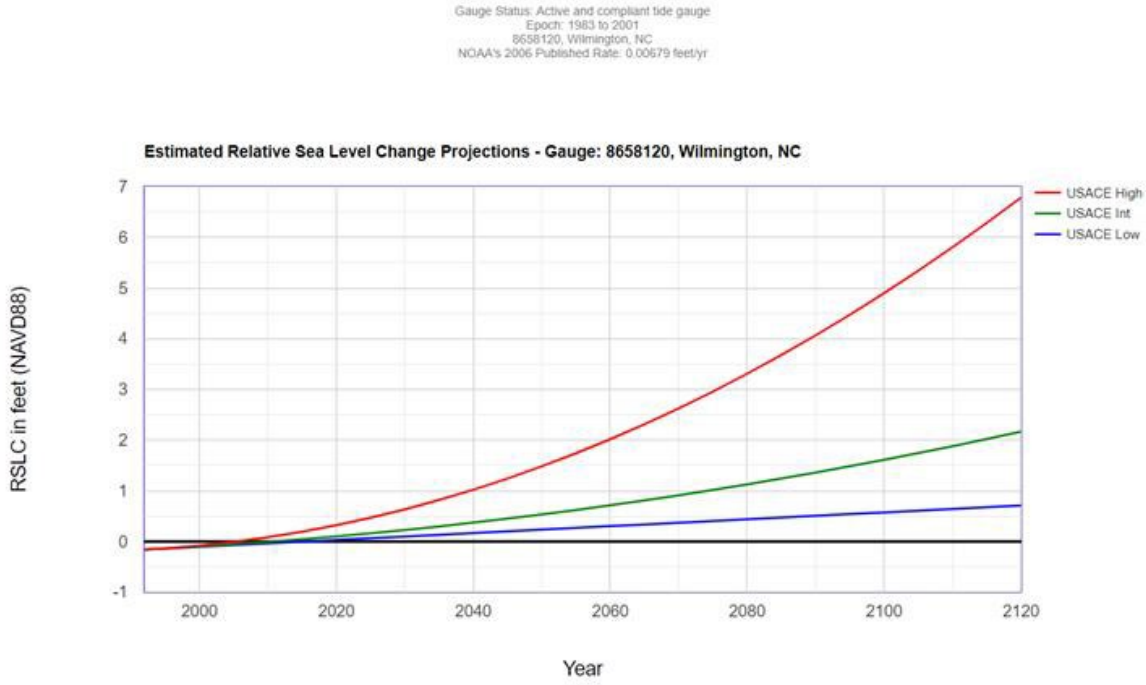


Figure 3-6: Sea Level Change Curve Calculator Output for Wilmington, North Carolina Showing Three USACE Sea Level Change curves (USACE 2017b)

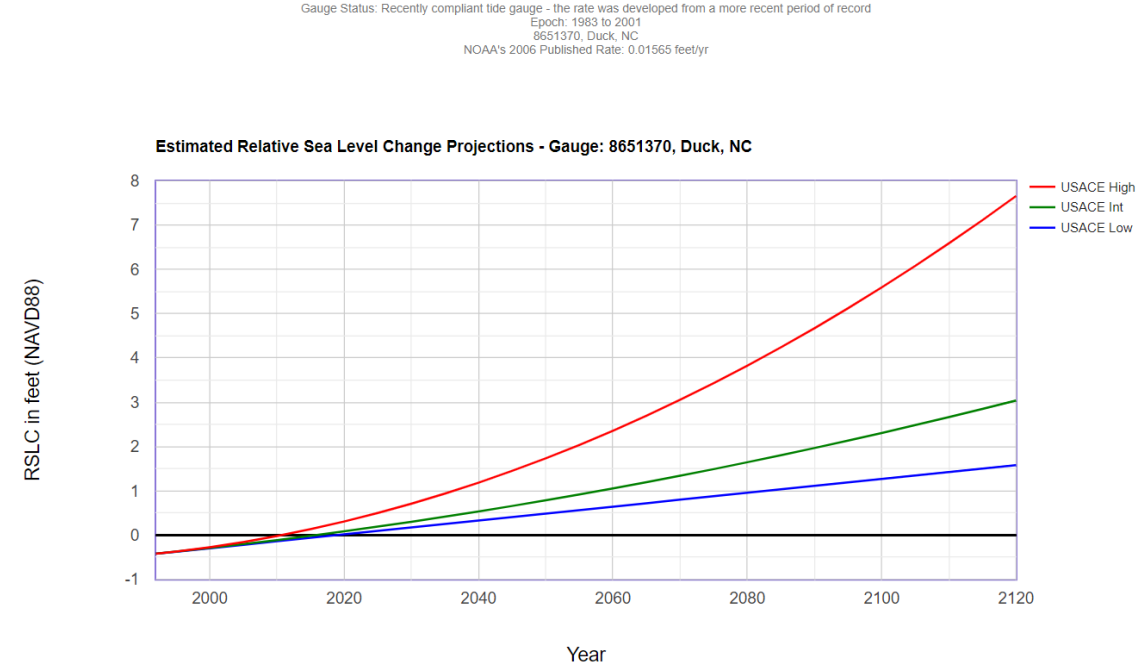
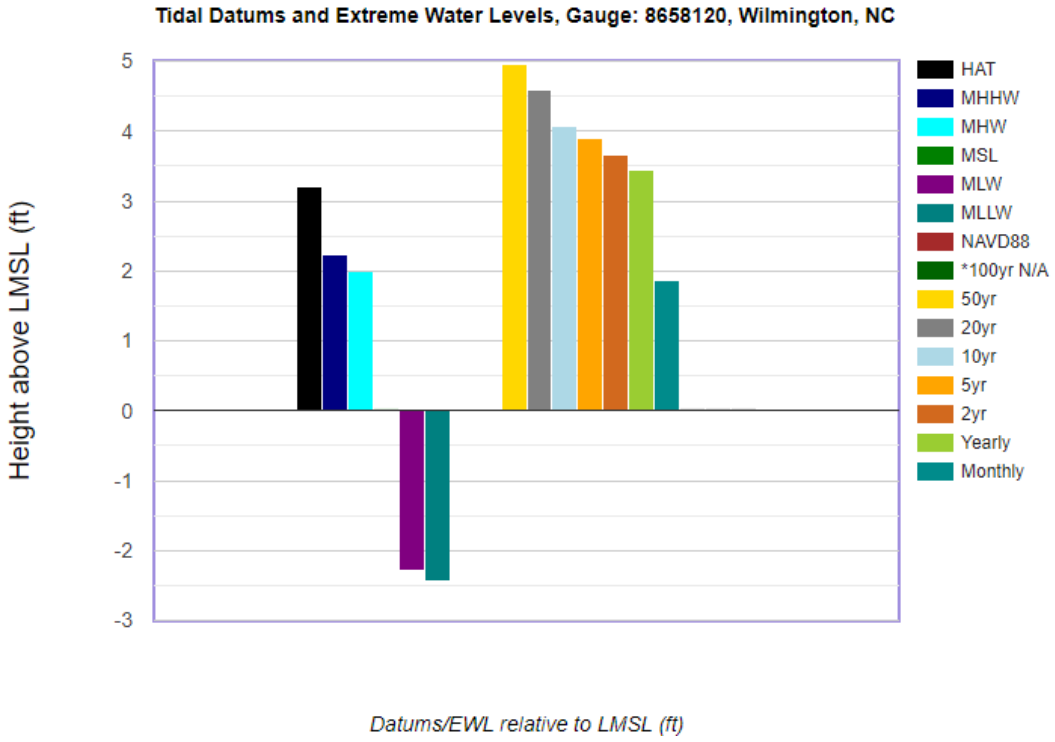


Figure 3-7: Sea Level Change Curve Calculator Output for Duck, North Carolina Showing Three USACE Sea Level Change Curves (USACE 2017b)



EWL – Extreme Water Level
HAT – Highest Astronomical Tide
LMSL – Local Mean Sea Level
MHHW – Mean Higher High Water
MHW – Mean High Water
MSL – Mean Sea Level
MLW – Mean Low Water
MLLW – Mean Lower Low Water

Figure 3-8: Sea Level Change Curve Calculator Output for Wilmington, North Carolina Showing Tidal Datums and Extreme Water Levels (USACE 2017b)

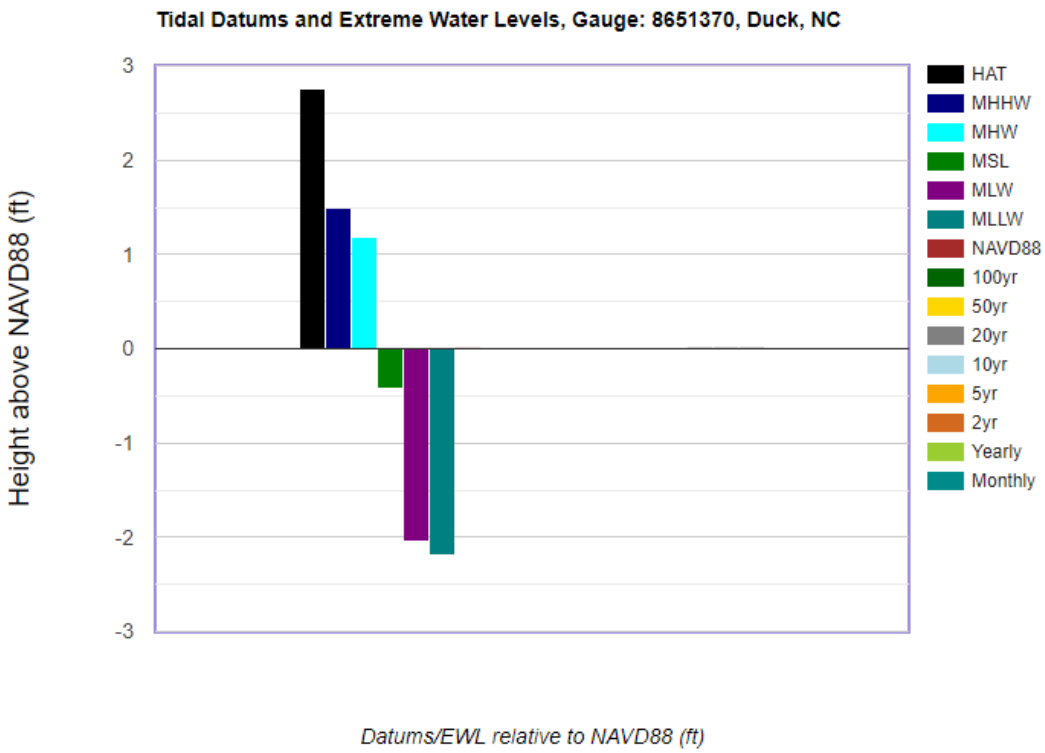
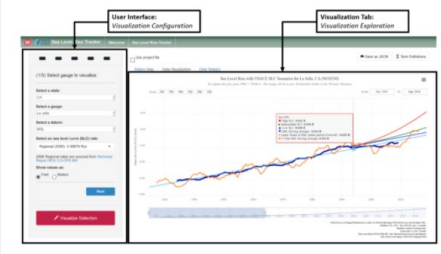


Figure 3-9: Sea Level Change Curve Calculator Output for Duck, North Carolina Showing Tidal Datums and Extreme Water Levels (USACE 2017b)

3.6.3.1 Sea Level Tracker

The USACE Sea Level Tracker tool provides visualization of historic sea level trends at compliant gauges, and compares those trends with the USACE Low, Intermediate, and High Scenarios projected from 1992 (USACE n.d.). The Sea Level Tracker plots for the Wilmington and Duck, North Carolina, gauge locations are shown in **Figure 3-10** and **Figure 3-11**. For the Wilmington location, the 19-year moving average (dark blue) is tracking between the USACE Intermediate and High Scenarios. The shorter, 5-year moving average (light blue) is tracking above the High Scenario. At Duck, North Carolina, both the 19- and 5-year moving averages are below the USACE Low Scenario but trending toward it. USACE guidance considers all sea level change scenarios equally probable.

USACE Sea Level Tracker: https://climate.sec.usace.army.mil/slr_app/



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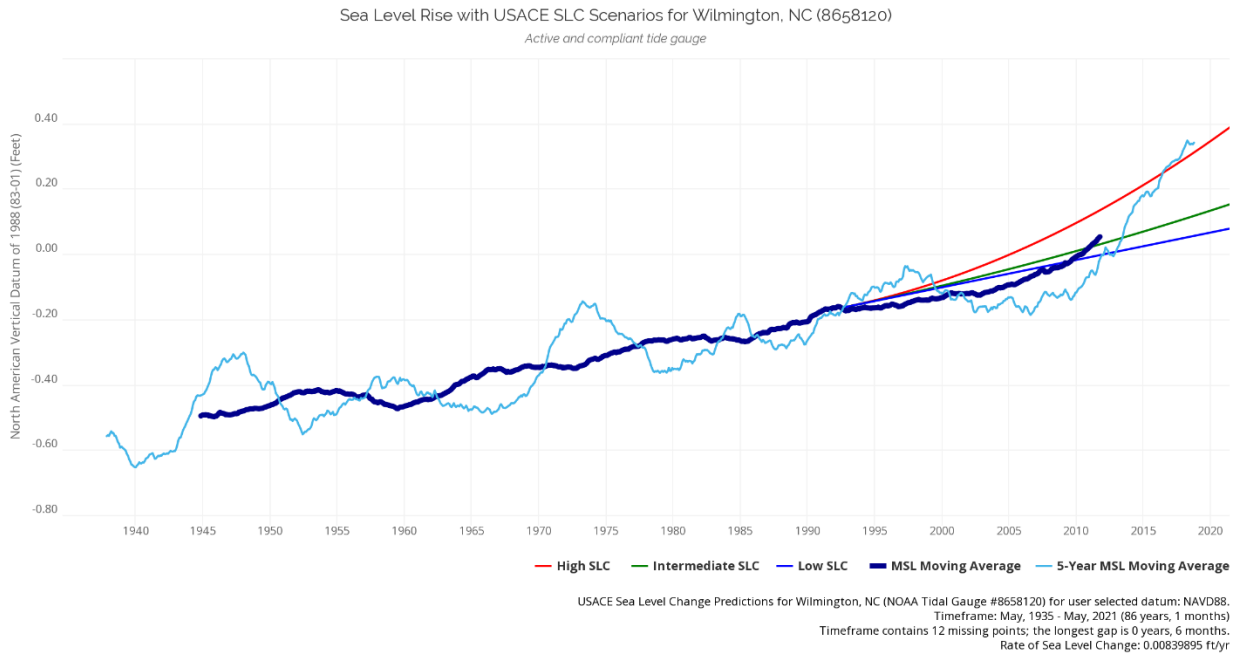


Figure 3-10: Sea Level Tracker for Wilmington, North Carolina (USACE n.d.)

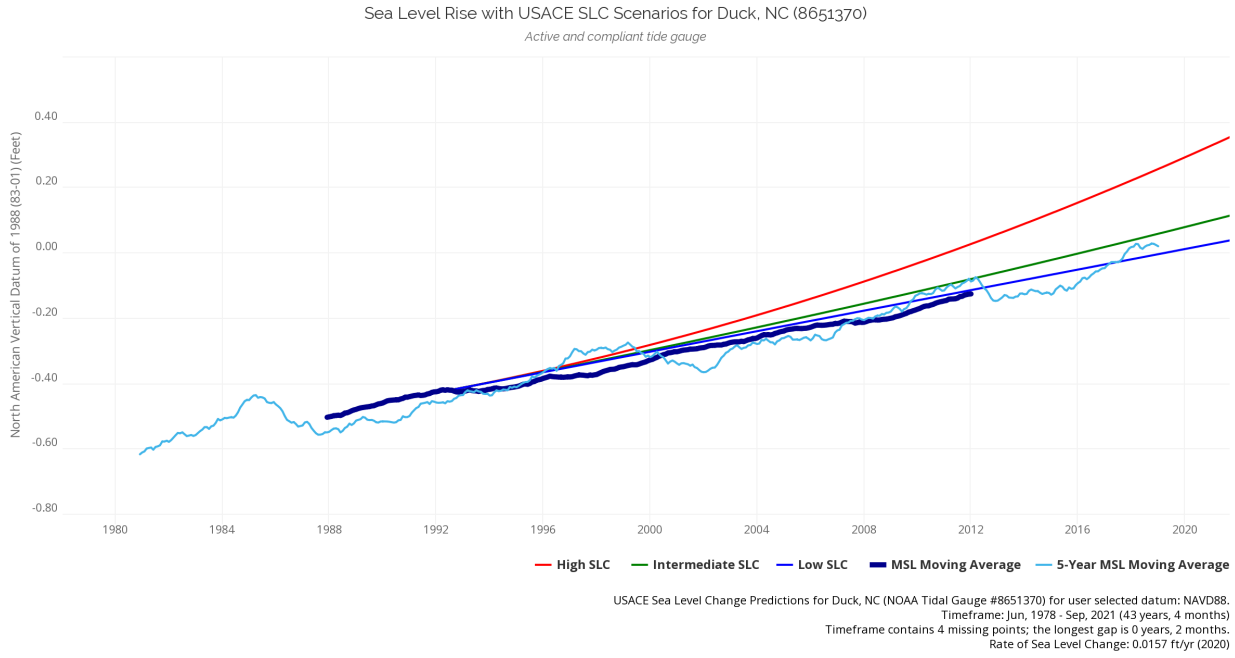
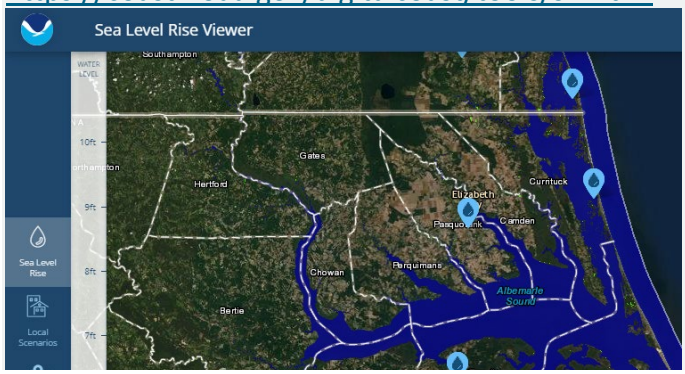


Figure 3-11: Sea level tracker for Duck, North Carolina (USACE n.d.)

3.6.3.2 NOAA Sea Level Rise Viewer

The NOAA Sea Level Rise Viewer simulates the mean higher high water (MHHW) inundation footprint with sea level rise (NOAA 2020i). Based on the USACE Sea Level Change Curve Calculator, the expected sea level rise using the USACE High Scenario is approximately 7 feet in 2120 for coastal North Carolina (**Table 3-6**). The results along the northern portion of Dare County, the southern portion of Dare County, the southern portion of the Outer Banks, Core and Bogue Banks area, and the southern coast including Wilmington are provided as examples in **Figure 3-12**. This figure shows that the USACE High Scenario would result in variable inundation footprints across coastal North Carolina, but the inundation would cover many highly populated areas as well as cultural and environmental resources. Notably, large-scale inundation of many of the barrier islands with future sea level rise may leave the entire coast more susceptible to other hazards, such as storm surge and wave attack.

NOAA Sea Level Rise Viewer: https://coast.noaa.gov/digitalcoast/tools/slr.html



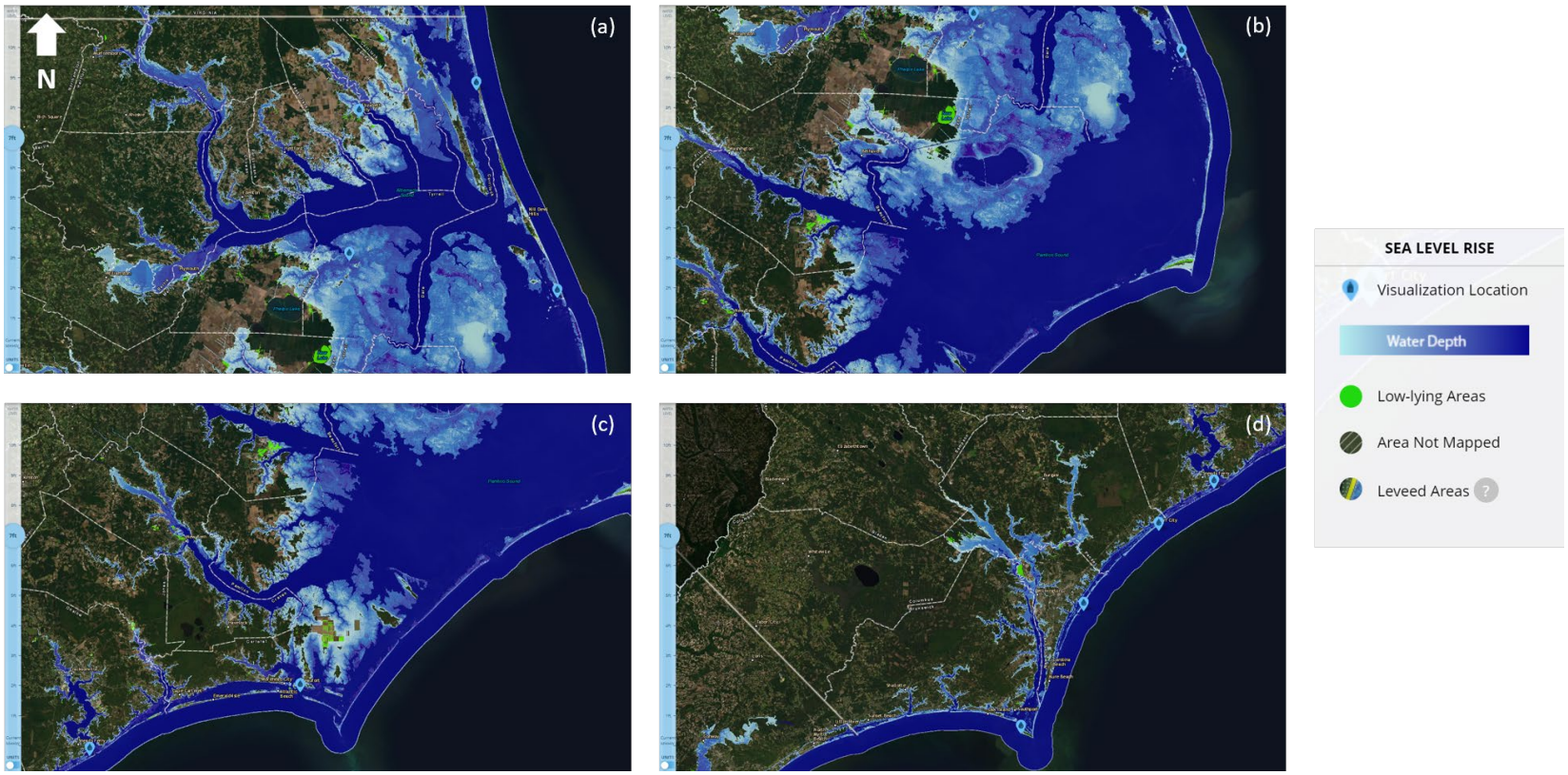


Figure 3-12: National Oceanic Atmospheric Administration Sea Level Rise Viewer Shown for the Northern Portion of Dare County (a), the Southern Portion of Dare County (b), the Southern Portion of the Outer Banks, Core and Bogue Banks Area (c), and the Southern Coast Including Wilmington (d), with an Estimation of 7 Feet Sea Level Rise Relative to Mean Higher High Water (NOAA 2020i)

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SECTION 4
Risk Assessment

This section describes the North Carolina-specific results from: (1) the Tier 1 Risk Assessment conducted consistently across the entire SACS study area and (2) the Tier 2 Risk Assessment, which represents a second pass through the Framework at a more refined analysis level. An overview of the methodology for each analysis is provided first, followed by the results organized by planning reach and a summary of the determined highest-risk locations.

4.1 Overview

The SACS refers to risk and vulnerability as defined in Engineering Regulation (ER) 1105-2-101. The ER clearly states that flood risk can be conceptualized as a function of the hazard, performance, exposure, vulnerability, and consequences, as depicted in **Figure 4-1**. As such, risk can be reduced by modifying these components (i.e., by reducing vulnerability or exposure).

The ER broadly defines risk as a situation or event in which something of value is at stake, and its gain or loss is uncertain. Risk is typically expressed as a combination of the likelihood and consequence of an event. Consequences are measured in terms of harm to people, cost, time, environment, property, and other metrics.

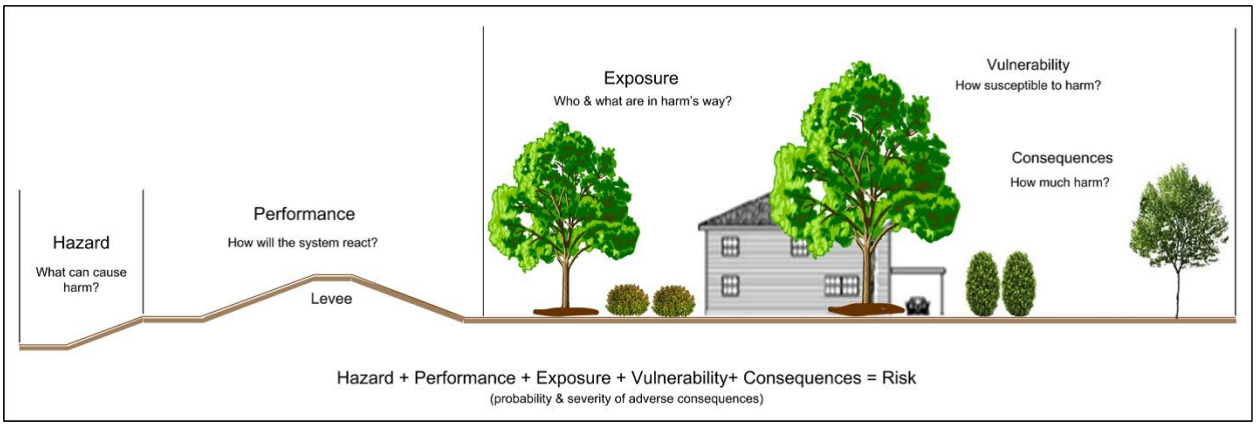


Figure 4-1: Conceptualization of Risk (USACE 2019)

Definitions of risk components as utilized in the SACS include:

Hazard – In a general sense, hazard is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014).

Performance – System's reaction to the hazard, and its features and the capability to contain or manage the hazard for the full range of possible events. In the context of the SACS, performance can include multiple built or natural environments that contribute to how well the system reacts to a hazard.

Exposure – Describes who and what may be harmed by the flood hazard. Exposure incorporates a description of where the flooding occurs at a given frequency, and what assets exist in that area.

Vulnerability – Susceptibility of harm to human beings, property, and the environment when exposed to a hazard. Depth-damage functions, depth-mortality functions, and other similar relationships can be used to describe vulnerability.

Consequence – Harm that results from a single occurrence of the hazard. Consequences are measured in metrics such as economic damage, acreage of habitat lost, value of crops damaged, and lives lost.

Risk – Combination of likelihood and harm to people, property, infrastructure, and other assets.

This icon will serve as a guide through the Risk Assessment sub-sections. A red color indicates the risk component currently being assessed for a given Planning Reach.

4.1.1 Tier 1 Hazards

In a general sense, a "hazard" is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014a). The Tier 1 Risk Assessment provides a consistent regional assessment of coastal flood risk caused by storm surge and sea level rise for the SACS study area scale. This is because, of all coastal storm hazards, storm surge inundation has the

greatest potential to negatively impact populations and infrastructure. FEMA states that, “Floods are the most common and costly national disasters in the United States.” (FEMA 2019a).

Tier 1 flood hazards include the following list of water levels. Additional descriptions are provided in the Geospatial Appendix.

- 10-percent AEP water levels from the U.S. Army Engineer Research and Development Center Coastal and Hydraulics Laboratory (ERDC/CHL).
- 1-percent AEP water levels imported from the FEMA National Flood Hazard Layer (NFHL).
- Category 5 Hurricane Maximum of Maximum (MOM) hazard from NOAA’s Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model (Zachry et al. 2015; Jelesnianski et al. 1992).

In Tier 1, 3 feet of sea level rise was added to the 1-percent and 10-percent AEP flood hazard layers to simulate future flooding events. Three feet of sea level rise was not added to the Category 5 MOM due to the uncertainty of SLOSH modeling for such major events, as well as the extremely low probability of occurrence. The spatial extent of the 1-percent and 10-percent AEP events plus 3 feet of sea level rise fall within the bounds of spatial extent of the Category 5 MOM.

The timeframe of when 3 feet of sea level rise is projected to occur is dependent on the projection scenario and specific location within the SACS study area. **Figure 4-2** shows projected sea level change relative to a start year of 2020. The average of all active and compliant gauges (record lengths of greater than 40 years) throughout the SACS study area is plotted as the solid-colored line for each scenario. The shaded areas around each line show the variability range across the SACS study area.

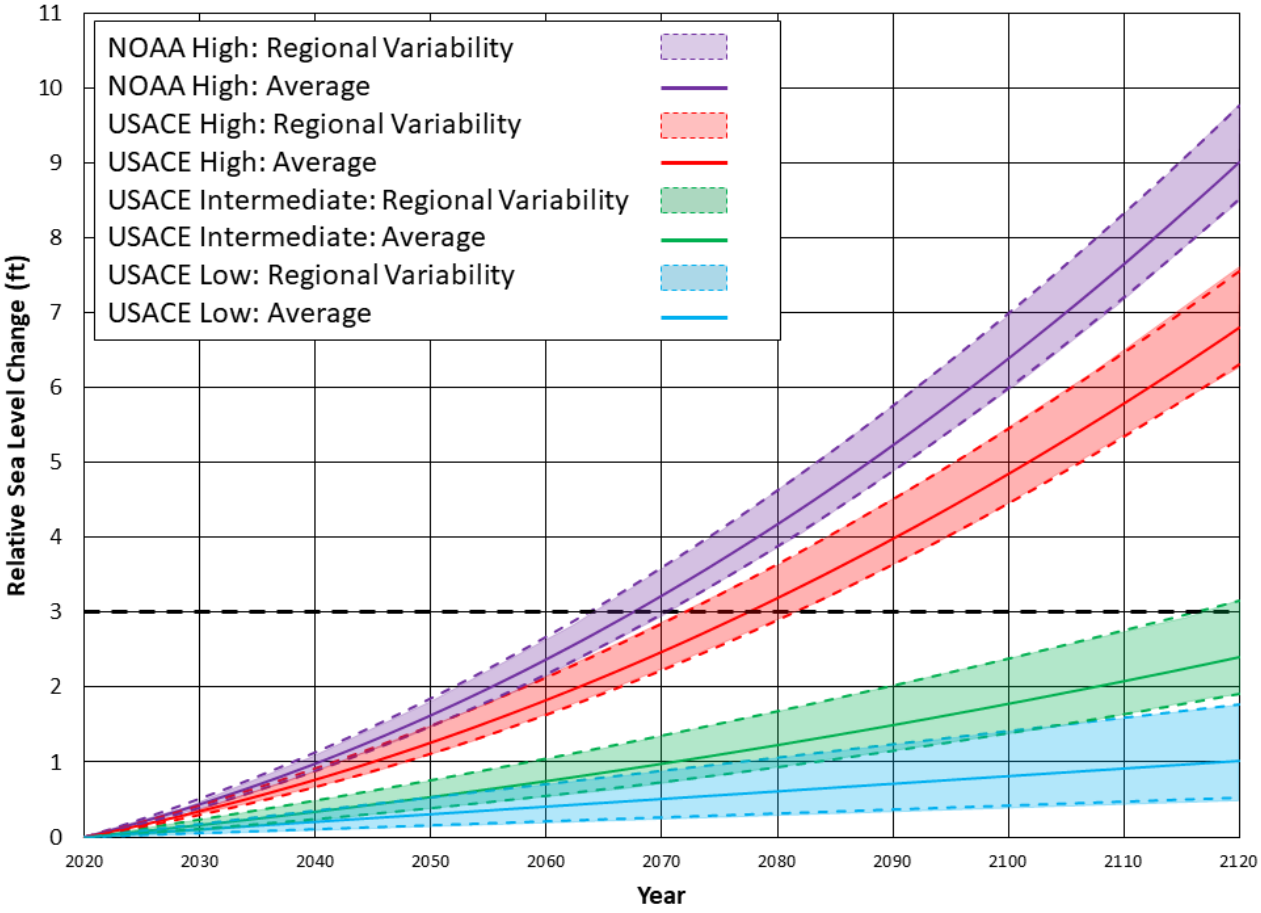


Figure 4-2: Mean Regional Sea Level Rise Projections for All Compliant Gauges Relative to 2020 Throughout the SACS Study Area

4.1.2 Tier 1 Exposure

The term exposure describes who/what may be impacted by the flood hazard. Exposure incorporates a description of where the flooding occurs at a given frequency, and what exists in that area. At the broad Tier 1 scale, exposure was defined by the study area and not by individual hazard footprints. Although a myriad of criteria can be used to identify exposure, the Tier 1 analysis focused on the following categories and criteria to define exposure indices:

- **Population and Infrastructure Exposure Index:** Population density includes the number of persons within an aerial extent across the study area. Infrastructure includes critical assets that support the population and communities. These factors were combined to reflect overall exposure of the built environment.
- **Environmental and Cultural Resources Exposure Index:** This exposure index captures unique natural resources, important habitat areas, and selected cultural resources that would be affected by storm surge.

- **Social Vulnerability Exposure Index:** Social vulnerability characterization includes certain segments of the population that may have more difficulty preparing for and responding to coastal flood events. Although this category is related to the vulnerability of the population within the study area, rather than actual "exposure" given the definition, this category was maintained as an "exposure index" to maintain consistency with the North Atlantic Coast Comprehensive Study (NACCS).

The methodology and data used are described in the Main Report, the Geoportal Tier 1 Risk Assessment Viewer Overview tab, and the Engineering Appendix.

As described in the Main Report, the three independent exposure indices were weighted and summed to develop one Composite Exposure Index (CEI) to convey overall exposure. Weighting used in the NACCS methodology was 80/10/10 (80 percent population and infrastructure; 10 percent environmental, cultural, and habitat; 10 percent social vulnerability). Rather than mirror the NACCS weighting, the SACS weighting was modified to 60/30/10 (60 percent population and infrastructure; 30 percent environmental, cultural, and habitat; 10 percent social vulnerability). This revised weighting better reflects the study authority and conditions in the study area for the following reasons:

- Decreasing the weight of the Infrastructure and Population Exposure Index to 60 percent more accurately reflects demographic differences in the coastal zone from the northeast (lower urban densities regionally/overall).
- Increasing the weight of the Environmental, Cultural, Habitat Exposure Index to 30 percent is consistent with authorizing language and better reflects the potential risk to vulnerable environmental resources that provide significant coastal storm risk management.

4.1.3 Tier 1 Vulnerability

Because the Tier 1 Risk Assessment relies on national-level data sets and a consistent approach, the broad assumption made regarding vulnerability is that any exposed resources impacted by the flood hazard are vulnerable. Essentially, if a resource becomes inundated (submerged) from one of the hazards, it is vulnerable. While this is a broad assumption, it is relevant to the Tier 1 purpose, which is to broadly identify where coastal storm flood risk is likely and where the likelihood may increase with sea level rise. The Social Vulnerability Exposure Index provides an additional refinement of vulnerability specific to populations within the study area.

4.1.4 Tier 2 Hazards

The Tier 2 analysis refines the Tier 1 analysis through the consideration of additional hazards and more localized hazard data relevant to North Carolina. Tier 2 hazards considered in this study include shoreline erosion, wave attack, and storm surge inundation, and their increased impact as a result of sea level rise. Evaluating the impact of these hazards will be the focus of North Carolina's Tier 2 analysis. Additional hazards will include wind, compound flooding from rainfall combined with storm

surge, and saltwater inundation and intrusion. **Table 4-1** outlines the hazards considered in Tier 1 and Tier 2 analyses.

Table 4-1: Summary of Tier 2 Hazards

Primary Hazards	Description of Hazard	Tier 1	Tier 2
Inundation	Inundation was assessed in Tier 1 but was re-examined using FEMA's Hazus Flood Model data and preliminary Flood Insurance Rate Maps in Tier 2.	X	X
Wave Attack	Impact of waves on shorelines can be hazardous to both natural shorelines and engineered structures.		X
Erosion	Coastal erosion is hazardous to natural shorelines such as marshes and sandy beaches. Erosion can lead to increased vulnerability of cultural and environmental resources, and infrastructure.		X
Secondary Hazards	**Description of Hazard**	**Tier 1**	**Tier 2**
Wind	High winds during hurricanes can cause damage to both infrastructure and environmental resources.		X
Compound Flooding	Individual hazards may be amplified when they occur concurrently. Compound flooding is a combination of inundation, precipitation, nuisance flooding, and/or high groundwater table elevations which can create greater flooding than each individual hazard alone.		X
Saltwater Inundation and Intrusion	Saltwater inundation and intrusion can damage and destroy environmental and agricultural resources, and freshwater sources.		X

The following sub-sections briefly overview the hazards assessed in Tier 2. Sections 4.2 and 4.3 provide additional details of each hazard by planning reach.

4.1.4.1 Inundation

Inundation (flood) hazard was assessed further in Tier 2 using the FEMA Hazus model to develop a more refined understanding of the potential existing and future infrastructure damages. A Level 1 analysis was completed for the SACS study area using data from FEMA's FIS. For the existing condition, infrastructure damages are based on the 10-, 2-, 1-, and 0.2-percent AEP storm events. For the future condition damages, 3 feet of sea level rise is added to these events. Effects of sea level rise were analyzed at 3 feet to remain consistent throughout the SACS study area. Sea level rise rate estimates vary throughout the state, but 3 feet is a typical intermediate-to-high estimate for the year 2120. For more information regarding the application of the Hazus model, refer to the Tier 2 Economic Risk Assessment.

Data defined at save points throughout the study area are available from the CHS web portal. At the save points, hydrodynamic and wave model results are available for all the simulated storms that make up the probabilistic storm suite for the study, along with AEP curves for water level, wave height, and wave period. While dense in spatial coverage for typical model

Coastal Hazards System data are available through the CHS web portal: **https://chs.erdc.dren.mil/**

output, the save point locations correspond with a small fraction of the overall hydrodynamic model mesh nodes. The unstructured grid model resolution varies, but it approaches a minimum of approximately 30 meters to best resolve coastal features. Timeseries output for a given storm event is typically not saved at all mesh nodes due to data limitations; however, data necessary to define the stillwater level (SWL) AEP, such as peak water level for each storm, is saved allowing AEP values to be calculated. For SACS, the AEP SWLs at the model mesh nodes were computed to allow for a higher resolution and better visualization of the values throughout the state.

The SWLs at the mesh nodes were calculated for various AEPs for existing conditions and sea level rise scenarios (2.73 feet and 7.35 feet). **Figure 4-3**, **Figure 4-4**, and **Figure 4-5** show the 1 percent AEP SWLs for existing conditions and two future sea level rise scenarios throughout North Carolina. Higher SWL exist in exposed coastlines that directly experience storm surge from the ocean, areas adjacent to inlets that undergo the effects of changes in ocean water levels, and back bay areas with fetches large enough to produce localized storm surge. There is also latitudinal variation in these SWLs – southern parts of North Carolina experience higher SWLs. Comparing the three figures, it is evident that SWLs will increase with sea level rise, but the spatial variation in SWL throughout the state will decrease.

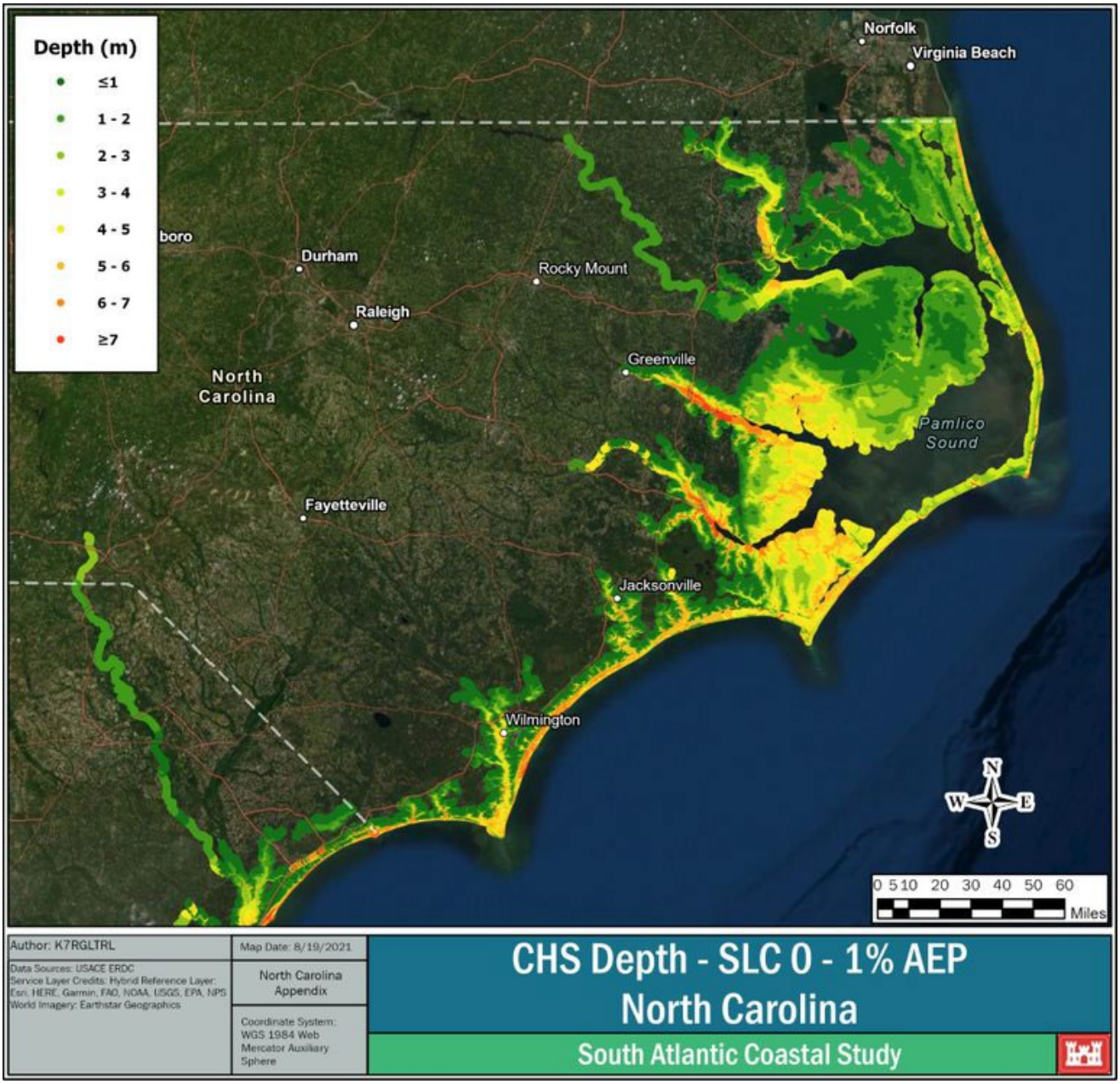


Figure 4-3: Coastal Hazards System Modeled Inundation Depth for the 1-percent Annual Exceedance Probability Event under Existing Conditions

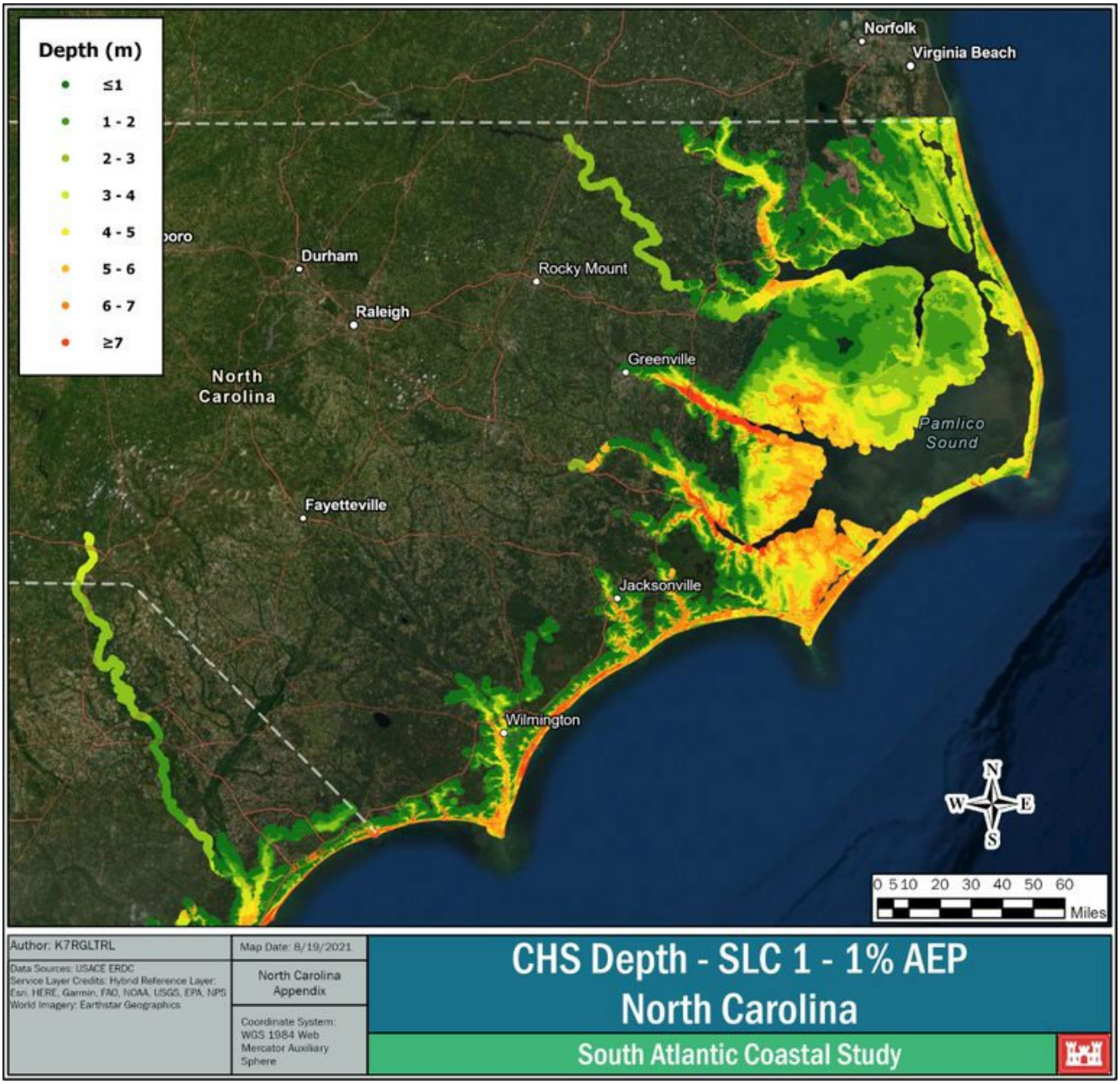


Figure 4-4: Coastal Hazards System Modeled Inundation Depth for the 1-percent Annual Exceedance Probability Event with 2.73 Feet of Sea Level Rise in North Carolina

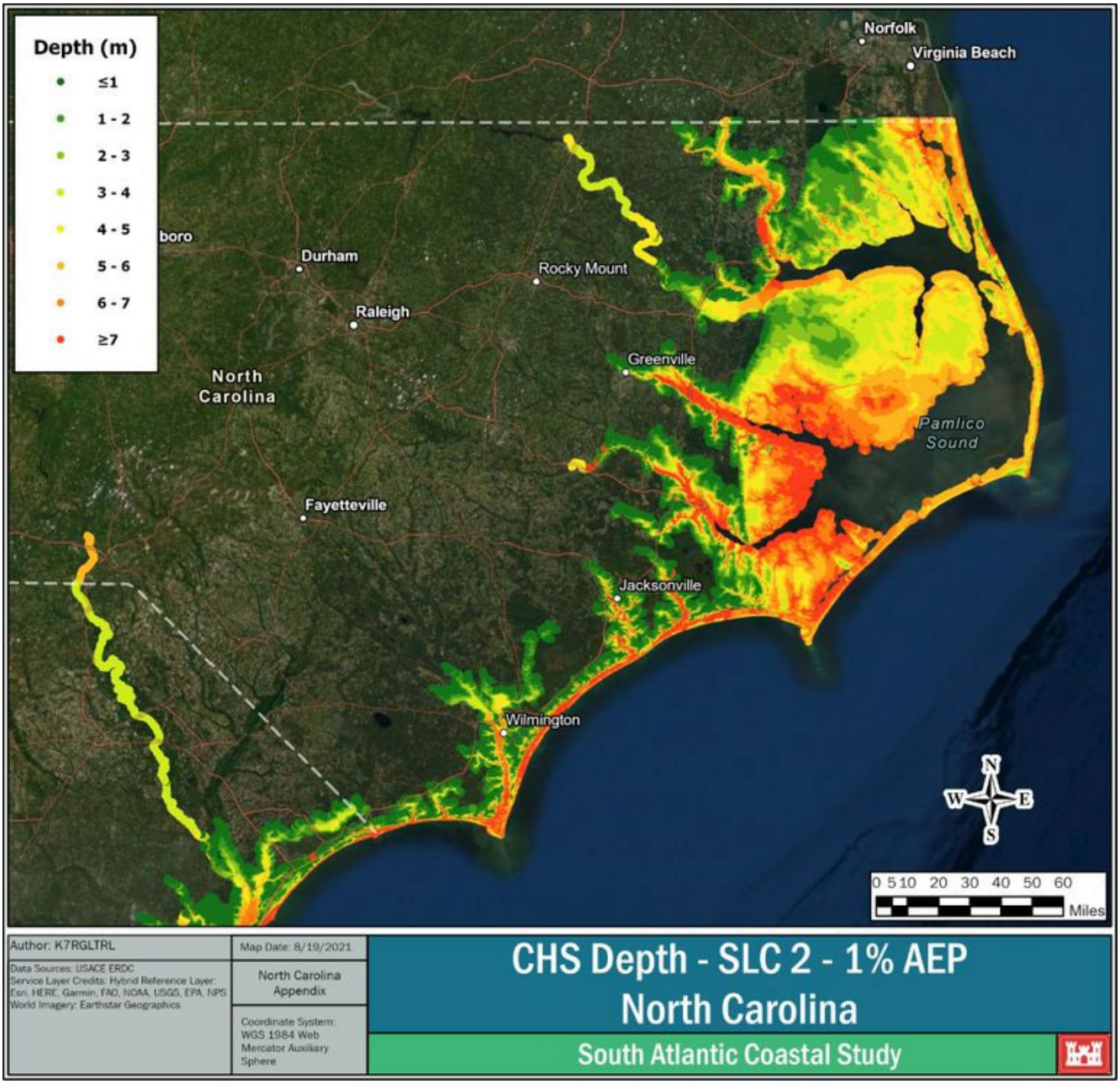


Figure 4-5: Coastal Hazards System Modeled Inundation Depth for the 1-percent Annual Exceedance Probability Event with 7.35 Feet of Sea Level Rise in North Carolina

4.1.4.2 Wave Attack

Wave attack is the impact of waves on a shoreline and is considered one of the main coastal damage mechanisms. The repeated pounding of waves can damage shorelines or structures over time under normal wave conditions, and that damage is exacerbated during storm conditions when waves become larger and more frequent. Damages from wave attack are prominent in areas with infrastructure and population, or cultural and environmental resources. Engineered structures such as seawalls, revetments, or bulkheads can be directly damaged through wave impacts or by scouring the foot of the structure and undermining it. Nonstructured shorelines, such as beaches and marshes, may be damaged by wave attack through erosion of the sediment that comprise these coastal environments. Beach berm and dune systems can be compromised from erosion. In addition to frontal erosion, wave attack can lead to wave runup and overtopping on dunes and coastal structures, which can scour the backside of dunes or structures and cause them to fail. Wave attack can also damage or destroy dune and marsh grasses, which anchor their respective systems in place and leave the remaining system more susceptible to additional erosion. As sea level rises, wave attack can be exacerbated in some areas due to increased water depths.

Areas of natural shorelines with sufficient room to migrate and naturally adapt will not likely see additional impacts from wave attack as sea level rises. However, areas with permanent shorelines (seawalls, revetments, etc.) and increased water depths from sea level rise could see larger impacts associated with increased wave heights (and damages). Structures that are sufficient to withstand current conditions may no longer be able to withstand future wave conditions and may need to be replaced with greater frequency.

Wave data (heights, periods, directions, etc.) are typically available in the form of measurements collected from offshore buoys. The majority of available buoys are operated by NOAA's National Data Buoy Center (NDBC), while other buoys are associated with partner programs, such as the Integrated Ocean Observing System (IOOS), National Ocean Service–Center for Operational Oceanographic Products and Services (NOS–COOPS), and the NERRS. Additional wave information can be found from hindcast models, which estimate wave conditions at output points along the coast. The USACE Wave Information Study (WIS) is one example of an available database that contains hindcast data from 1980 to 2014. The CHS tool provides a comprehensive modeled coastal hazards data set, including wave height data. Wave height and wave period modeled data were reported for various AEPs for current conditions and two sea level rise scenarios (2.73 feet and 7.35 feet). **Figure 4-6**, **Figure 4-7**, and **Figure 4-8** show the 1-percent AEP wave heights for three sea levels throughout North Carolina. Patterns in wave height throughout North Carolina seem to be trivial; these patterns are correlated to basic wave physics where larger waves occur in areas with deeper waters and large fetch. The largest waves occur in the open ocean where the water is deep and wave development is not fetch-limited. Other large waves occur in areas with large fetches and deeper waters such as the Pamlico Sound.

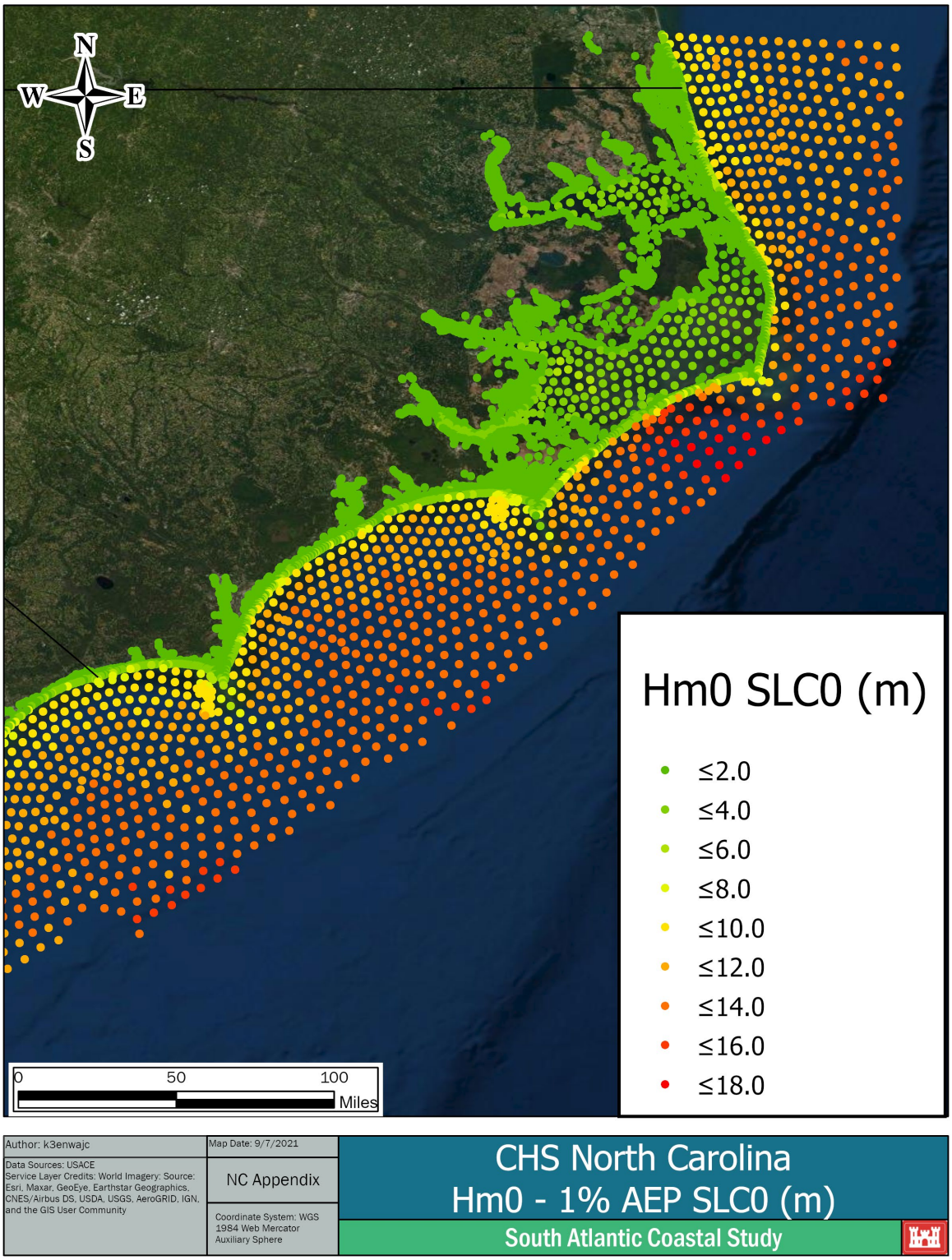


Figure 4-6: Coastal Hazards System Modeled Wave Height for the 1-Percent Annual Exceedance Probability Event at Existing Sea Level Rise conditions in North Carolina

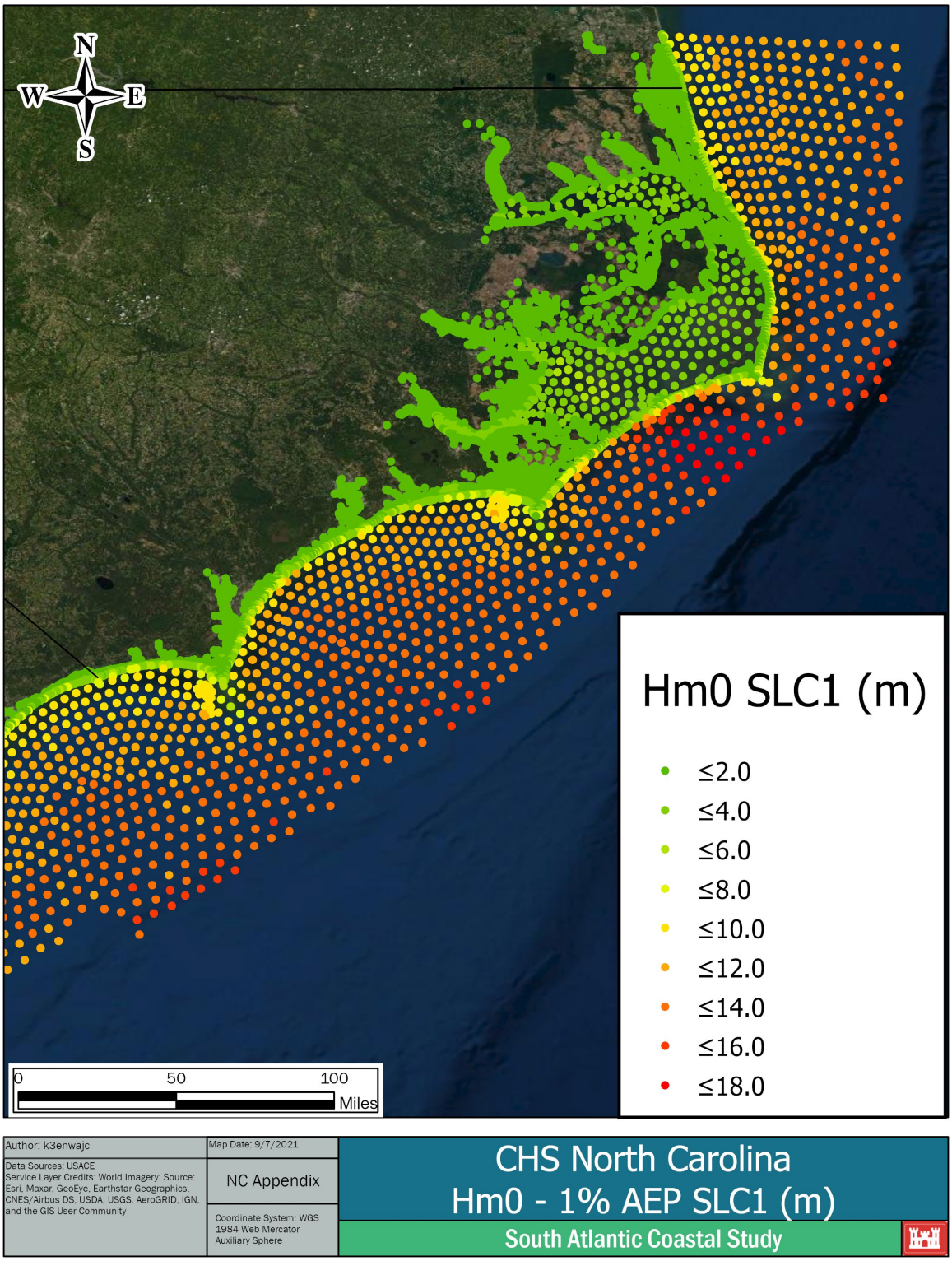


Figure 4-7: Coastal Hazards System Modeled Wave Height for the 1-Percent Annual Exceedance Probability Event with 2.73 Feet of Sea Level RIse in North Carolina

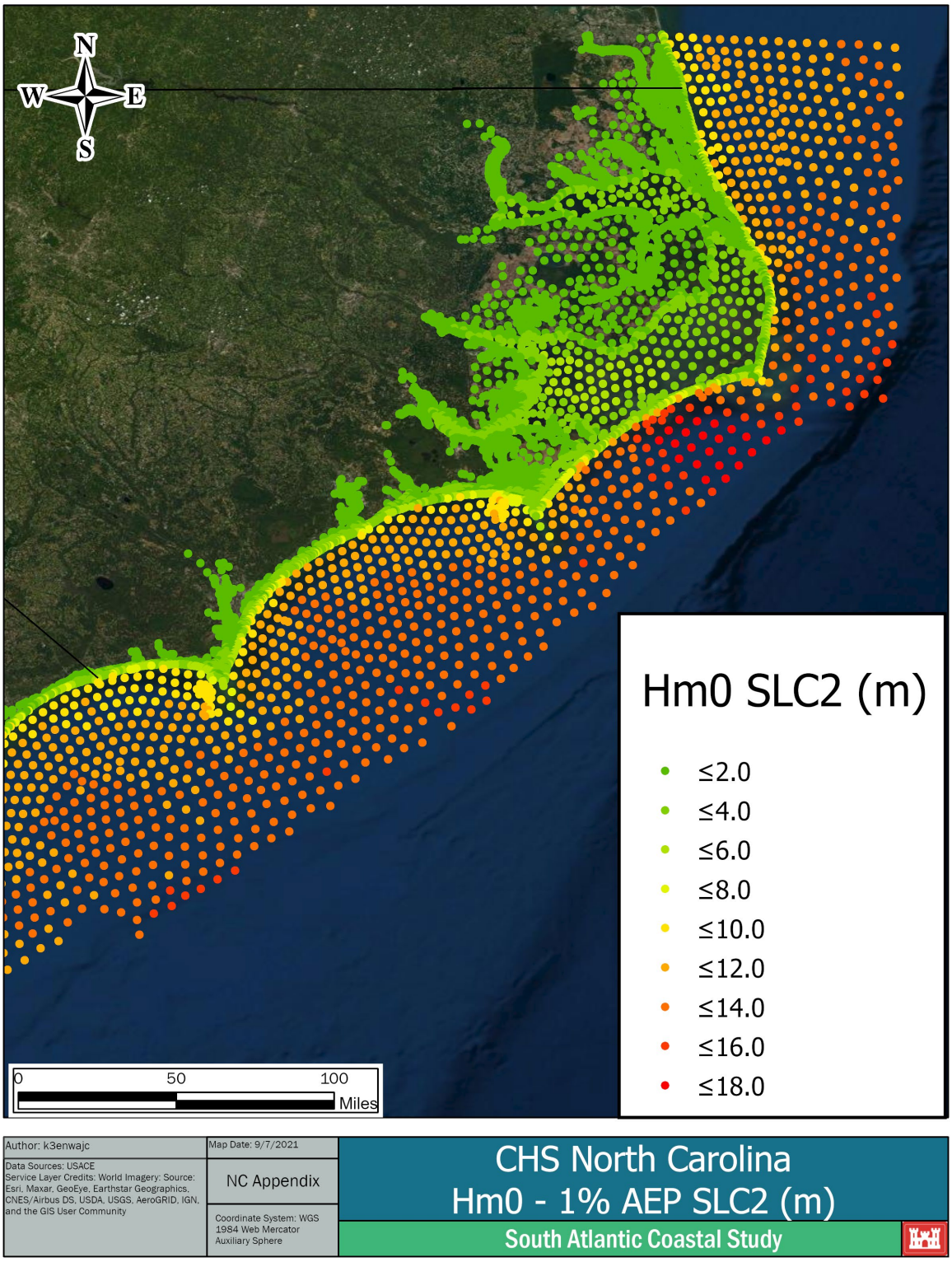


Figure 4-8: Coastal Hazards System Modeled Wave Height for the 1-Percent Annual Exceedance Probability Event with 7.35 Feet of Sea Level Rise in North Carolina

4.1.4.3 Erosion

Coastal erosion can be hazardous to natural shorelines such as marshes and sandy beaches. Erosion has led to increased vulnerability of North Carolina's oceanfront and back bay infrastructure, and cultural and environmental resources. An increase in sea level often results in acceleration of erosion rates (Kettle 2012) and, in the case of sandy substrate beaches, rising sea level can be a driver of coastal erosion (Leatherman et al. 2000; Theuerkauf et al. 2014). Coastal erosion can increase the extent and frequency of flood damages to public and private property and infrastructure.

Erosion on North Carolina's oceanfront shoreline has been investigated and monitored closely by the CRC and NCDEQ's NCDCM and NCDWR. The NCDEQ North Carolina Beach and Inlet Management Plan 2016 Update reports there are 160 miles of developed oceanfront and 19 active tidal inlets within their management area (NCDEQ 2009). NCDCM's North Carolina 2019 Oceanfront Setback Factors & Long-term Average Annual Erosion Rate Update Study: Methods Report (NCDCM 2019) provides the most current shoreline change rate methods accepted by the CRC. The NCDEQ-DCMs Interactive Map Viewer was used to acquire the most current (2020) data for shoreline change and erosion rates, and these data were used to assess erosion in the Tier 2 Economic Risk Assessment. The "long-term average annual erosion rate" is defined by NCDCM (2016) as the annual oceanfront shoreline change rate that includes a distinction between shoreline migration of the barrier islands and shoreline erosion due to hurricanes/tropical storms and large winter coastal storms. For coastal North Carolina, the average shoreline change rate was 2.1 feet/year (NCDCM 2019).

Erosion in coastal North Carolina is highly variable because shorelines erode and accrete at different rates. Fewer reports are available for erosion and shoreline change within the back bay and estuarine areas of North Carolina compared to the oceanfront shoreline. The North Carolina back bay region, which encompasses portions of both SACS planning reaches, includes greater than 4,000 miles of estuarine shoreline (Riggs and Ames 2003), and currently lacks a comprehensive CSRM program. The North Carolina back bay region experiences major impacts and devastation during hurricanes and other coastal storm events, including extensive inundation from storm surge, which is exacerbated by low-lying topography. Variables influencing estuarine erosion include fetch, geographic location, offshore sediment type, geometry of the shoreline, height and composition of the sediment bank, fringing vegetation, wake activity, and storm systems. Recent remote sensing studies indicated that shoreline composition represents an important control on shoreline erosion in North Carolina's estuaries (Cowart et al. 2010; Cowart et al. 2011).

As part of the Tier 2 Economic Risk Assessment, additional information was gathered from stakeholders concerning erosion in the back bay and estuarine areas. A 2003 study provided erosion rates by shoreline type and estuarine region for northeastern North Carolina (Riggs and Ames 2003). Coordination with NOAA provided recent studies using remote sensing techniques at Cedar Island (Cowart 2010), the Neuse River Estuary (Cowart et al. 2011), and the New River Estuary (Currin et al. 2015). In addition, a limited modeling effort for the Tar-Pamlico Estuary with a source-to-sink analysis was referenced (Eulie et al. 2018). An overview of current erosion data is provided by planning reach in Sections 4.2 and 4.3.

For the purpose of identifying additional high-risk areas not captured in the Tier 1 analysis, Critical Erosion Areas (CEAs) along the oceanfront were identified. Areas meeting this standard have average shoreline erosion rates more than 3 feet (include source) and medium-high to high risk from the Tier 1 analysis. CEAs will be presented by planning reach in Sections 4.2 and 4.3.

4.1.4.4 Wind

Another hazard considered in the Tier 2 Economic Risk Assessment is high wind. Tropical systems can produce high winds, which can cause severe damage to the environment and infrastructure. High winds have potential to damage roofs, mobile homes, and, if strong enough, can destroy entire buildings. Flying debris can cause additional damage to resources. Environmental resources may be damaged by winds through downing and defoliating large patches of trees and other vegetation, which can increase the vulnerability of areas to future events because damaged trees will not be able to provide the same amount of protection, soil stabilization, and wind shear reduction as healthy trees. Structures within the state are required to follow zone-based wind design criteria. **Table 4-2** describes some of the potential damages associated with tropical systems based on the Saffir-Simpson scale for wind speeds.

Table 4-2: Damage Description Based on Wind Speeds

Tropical System Category Saffir-Simpson Scale	Wind Speeds (mph)	Typical Damage Description
Tropical Depression	>39	Heavy rains and strong winds can cause minor flooding and property damage.
Tropical Storm	39–73	Minor damage will occur to many mobile homes. A few homes may receive mostly minor damage to roof shingles and siding.
Category 1 Hurricane	74–95	Damage is done primarily to shrubbery and trees; unanchored mobile homes are damaged; some signs are damaged; no real damage is done to structures.
Category 2 Hurricane	96–110	Some trees are toppled; some roof coverings are damaged; major damage is done to mobile homes.
Category 3 Hurricane	111–129	Large trees are toppled; some structural damage is done to roofs; mobile homes are destroyed; structural damage is done to small homes and utility buildings.

4.1.4.5 Compound Flooding

Compound flooding is a combination of hazards that magnify the overall hazard when they occur simultaneously. When storm surge is combined with flooding from rainfall runoff, high tides, and/or high groundwater table elevations, the resulting hazard is exacerbated, and the potential for flooding in low-lying coastal areas can be much greater than from any individual flood hazard source in isolation (**Figure4-9**).

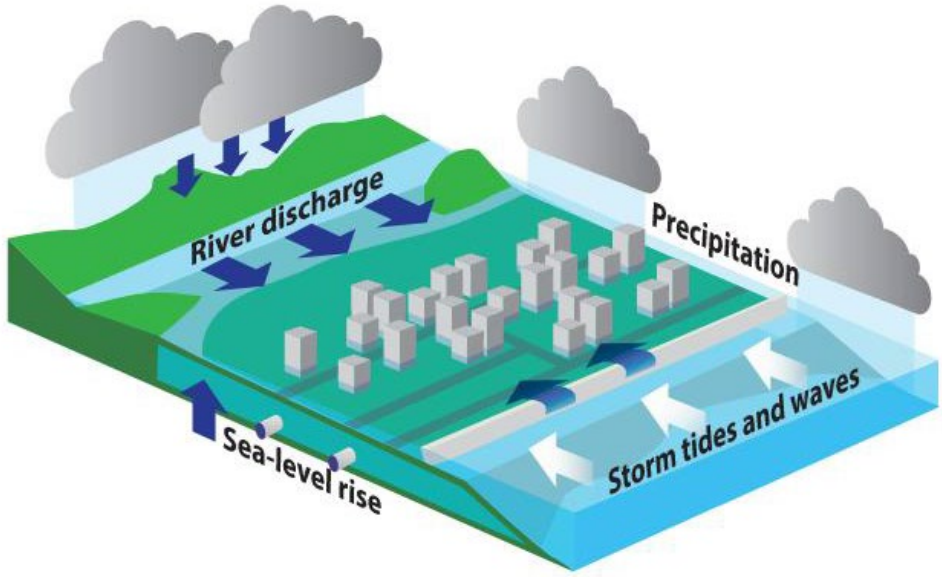


Figure 4-9: Illustration of Coastal Compound Flooding

In North Carolina, particularly in the downstream portion of river basins, compound flooding has been a reoccurring hazard, and its occurrence is dependent on multiple factors such as the rainfall patterns, the timing of storm surge and high tide, and the drainage response in the lower basins (Gori et al. 2020). SACS recognizes that additional studies are needed to accurately assess compound flooding.

4.1.4.6 Saltwater Inundation and Intrusion

Sometimes described as the leading edge of sea level rise, saltwater intrusion—the landward movement of salinity from the coast onto the coastal plain—is believed to have significant consequences on the environment and economy in eastern North Carolina (Tully et al. 2019 and Ury et al. 2019). Saltwater inundation of freshwater habitat occurs as a result of ocean surge from coastal storms, as well as horizontal intrusion via subsurface groundwater. Consequences of saltwater inundation and intrusion include upland forest retreat and reduction in agricultural productivity (Tully et al. 2019). Freshwater sources may also be impacted. With sea level rise, impacts from saltwater inundation and intrusion will continue to increase over time. There are many locations throughout coastal North Carolina that demonstrate the impacts of saltwater inundation and intrusion. The Tier 2 analysis does not consider this hazard in detail; however, other organizations are actively studying this hazard, including the U.S. Department of Agriculture and multiple universities within the state. Saltwater inundation and intrusion are recognized as emerging hazards and will require continued study.

4.1.5 Tier 2 Exposure

The Tier 1 exposure analysis incorporates national-level data sets to determine who or what may be impacted. The Tier 2 analysis builds on the Tier 1 analysis through the incorporation of additional localized data sets and studies, evaluating population and infrastructure, and environmental and cultural resources at a refined scale. The following sections provide an overview of the types and sources of Tier 2 exposure data. The data are discussed and applied in Sections 4.2.2 and 4.3.2.

4.1.5.1 Population and Infrastructure

The Tier 2 analysis for population and infrastructure used data from the National Structure Inventory, the U.S. Environmental Protection Agency (EPA) Integrated Climate and Land Use Scenario (ICLUS), and the 2016 North Carolina Hurricane Evacuation Study to develop an accurate understanding of the potential population and infrastructure exposed to hazards for the existing and future conditions (FEMA 2016). Additionally, information on the projected seasonal populations of eight coastal communities was collected from a variety of sources to help reflect the true magnitude of people that may be exposed to hazards such as coastal storms.

Military Installations

Although the Tier 1 Risk Assessment of population and infrastructure did include military installations, the assessment did not include military-specific assets (vehicles, equipment, munitions, etc.). Although these installations will receive and potentially benefit from the data and tools produced by SACS, the military is pursuing resiliency for their installations through parallel activities.

Seasonal Population

The Tier 1 Risk Assessment of census data does not capture the maximum seasonal population of many barrier island communities in North Carolina. Many coastal communities have a significant influx of population in the form of tourists and part-time residents, which occurs primarily during hurricane season, increasing exposure to hazards. Seasonal population data were retrieved for eight coastal communities throughout the study area, and that information was used to make seasonal population assumptions for all barrier island communities.

Population Growth Trends

Assessing future growth trends in population can indicate whether there will be an increase in people and associated infrastructure exposed to hazards in the future. Data were used to evaluate growth trends in coastal North Carolina for this study. Specifically, data were gathered from ICLUS using the county population projection data set provided by the EPA Office of Research and Development (ORD), the National Center for Environmental Assessment (NCEA), and the Global Change Research Program (GCRP).

4.1.5.2 Environmental and Cultural Resources

Cultural Resources

The Tier 1 Risk Assessment included regionally applicable and publicly available cultural resources-related data and information. These data included historic properties listed on the NPS's National

Register of Historic Places (NRHP), to include specific points and polygons approximating boundaries (NPS 2020). The Tier 2 analysis allowed for input from local stakeholder agencies, on a per-state basis, and for additional data inclusion. Specifically, collaborative discussions with the North Carolina Office of State Archaeology and State Historic Preservation Office (SHPO) sharpened the Tier 2 analysis. The SHPO's publicly available HPOWEB 2.0 GIS web service (North Carolina State Historic Preservation Office 2020) was used to identify exposed cultural resources beyond those captured in Tier 1. The HPOWEB service primarily draws upon the state's built environment (i.e., historic resources) and identifies known resources of national and local significance. Site locations and boundaries are drawn from georeferenced scans of NRHP survey maps supplemented with aerial photography, county tax parcel layers, and other sources; however, archaeological data and submerged resources are not included in the HPOWEB service. The Tier 2 analysis was expanded to include cultural resources that may not have been included on the NRHP but have significant historical value for the state of North Carolina.

Environmental Resources

The Tier 1 database of environmental resources is wide-ranging. The majority of the high-valued environmental resource areas were identified in Tier 1, but the areas may not be high risk due to the weighting of the CEI. An example of this is saltwater intrusion impacts to marsh and pine forests. Although the Tier 1 analysis indicates overlap in saltwater intrusion areas and marsh pine forest areas, the risk to these natural communities may not have been captured appropriately. The Tier 2 analyses refined the Tier 1 understanding of environmental exposure by incorporating state-level data. Exposed natural areas in North Carolina included upland forests, forested and herbaceous wetlands, beaches, and submerged communities. For additional information regarding Tier 2 exposed environmental resources, please refer to the Environmental Technical Report (USACE 2022b), specifically Appendix A: Natural Areas Exposure Tables. In the North Carolina Exposure Table, information from the North Carolina Natural Heritage Program, the North Carolina Wildlife Resources Commission, the USFWS, and the NOAA National Marine Fisheries Service were used to identify exposed natural areas.

4.1.6 Tier 2 Vulnerability

Vulnerability considerations were included in several Tier 2 data sources and assessments.

The Tier 2 Risk Assessment incorporates vulnerability through its use of FEMA's Hazus model, which considers infrastructure vulnerability using depth-damage functions to represent the performance of different types of infrastructure to flood hazards and to estimate the financial impact of flooding.

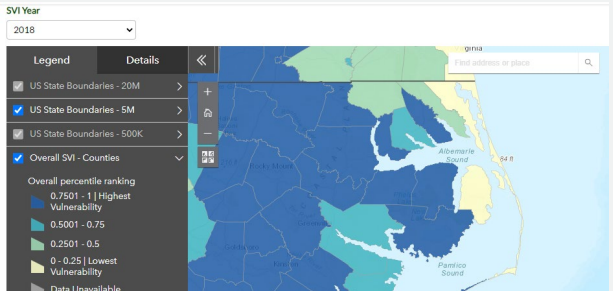
A Tier 2 analysis was conducted to assess the vulnerability of natural areas to coastal storm hazards and sea level rise. Findings of the Tier 2 Environmental Resources Vulnerability Analysis for North Carolina are located in Sections 4.2.2.3 (Planning Reach NC_01) and 4.3.2.3 (Planning Reach NC_02) of this report. In North Carolina, unconsolidated shore (i.e., ocean front beaches) and low-lying areas along the western shores of barrier islands and bordering Pamlico Sound are highly vulnerable to coastal storm hazards and sea level rise. For detailed information regarding the methodology and findings of the environmental technical analysis, please refer to the Environmental Technical Report (USACE 2022b).

Based on a qualitative assessment of vulnerability, historic resources located on North Carolina's barrier islands, along its coast, and in low-lying areas bordering tidally influenced water bodies are vulnerable to storm surge inundation, erosion, and wave attack. Vulnerabilities to these hazards are further addressed in Sections 4.2.2.3 and 4.3.2.3, specific to historic structures in each North Carolina planning reach. Storm surge inundation along the coast and up rivers to low-lying areas will flood historic properties and damage buildings. Damage may include, but is not limited to, structural damage and destruction of historic materials. The aftermath of a storm can pose long-term issues, such as the development of mold, mildew, and other potentially toxic residues in and on historic structures. Erosion and wave attack pose threats to historic properties and both terrestrial and submerged archaeological sites. Significant structural damage can be caused to historic properties by wave attack. Erosion can eliminate surface evidence of archaeological sites, wear away site layers, and displace materials from various cultural layers making recovery and interpretation challenging if not impossible. Erosion will impact features more severely due to the disturbed nature of the soil, while leaving intact topographic layers less damaged. Strong currents cause hydrographic change that can displace submerged cultural resources, including historic wrecks, as well as obscure or damage these resources due to storm debris. Currents and even wind can uproot trees and other vegetation, which can serve as a major source of disturbance and destruction for both historic properties and archaeological sites.

Social Vulnerability

The Social Vulnerability Index (SVI), developed by the Center for Disease Control (CDC), was used to assess Tier 2 Social Vulnerability. The CDC uses 15 census-derived factors on a percentile index to create a generalized SVI at the census tract level. The SVI groups the 15 census-derived factors into four themes (socioeconomics, household composition/disability, minority/language, and housing/transportation) that summarize vulnerability. The 15 census-derived factors and their groupings are as follows:

Center for Disease Control's Social Vulnerability Index: https://svi.cdc.gov/map.html



- Socioeconomic status (below poverty, unemployed, income, no high school diploma)
- Household composition and disability (aged 65 or older, aged 17 or younger, older than age 5 with a disability, single-parent households)
- Minority status and language (minority, speak English "less than well")
- Housing type and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters)

The SVI was used to determine the vulnerability scores presented in **Table 4-3**. Possible scores range from 0 (lowest vulnerability) to 1 (highest vulnerability). SVI indicates the relative vulnerability of

every census tract. SVI ranks the tracts on 15 social factors. Thus, each tract receives a ranking for each census variable and for each of the four themes, as well as an overall ranking. **Table 4-3** provides the SVI scores for each of the four coastal counties across the four social vulnerability themes and their total scores.

Table 4-3: Social Vulnerability Indices by County and Theme

County	Theme				Social Vulnerability Index Score
	Socioeconomic	Household Composition/ Disability	Minority/ Language	Housing/ Transportation	
Carteret	0.1212	0.596	0.1313	0.2424	0.1818
Craven	0.3535	0.6162	0.7576	0.7172	0.6465
Dare	0.0101	0.0505	0.3535	0.1818	0.0101
New Hanover	0.2020	0.0202	0.3333	0.4646	0.1919

Carteret County's SVI score is 0.1818, indicating a low level of vulnerability. Craven County has an overall SVI of 0.6465, suggesting a medium to medium-high social vulnerability. Dare County's overall SVI score is 0.0101, indicating a low level of vulnerability. New Hanover County's overall SVI score is 0.1919, indicating a low level of vulnerability. Social vulnerability characterization includes certain segments of the population that have difficulty preparing for and responding to coastal flood events. Based on the Social Vulnerability Exposure Index Analysis, some areas along the coastline and inland were identified as having relatively high socially vulnerability, and many areas showed medium and medium-high social vulnerability. This analysis identifies areas with low and relatively high social vulnerability within the Planning Reaches of NC_01 and NC_02 in both coastal and inland areas.

4.1.7 Reporting Results: Planning Reaches and U.S. Census Bureau Geographic Types

In addition to planning reaches, several results from Tier 1 and Tier 2 analyses are reported by geographic type, mainly census places and census blocks, as defined by the U.S. Census Bureau. The following description of these areas is excerpted from the University of Pittsburgh's website (University of Pittsburgh 2010).

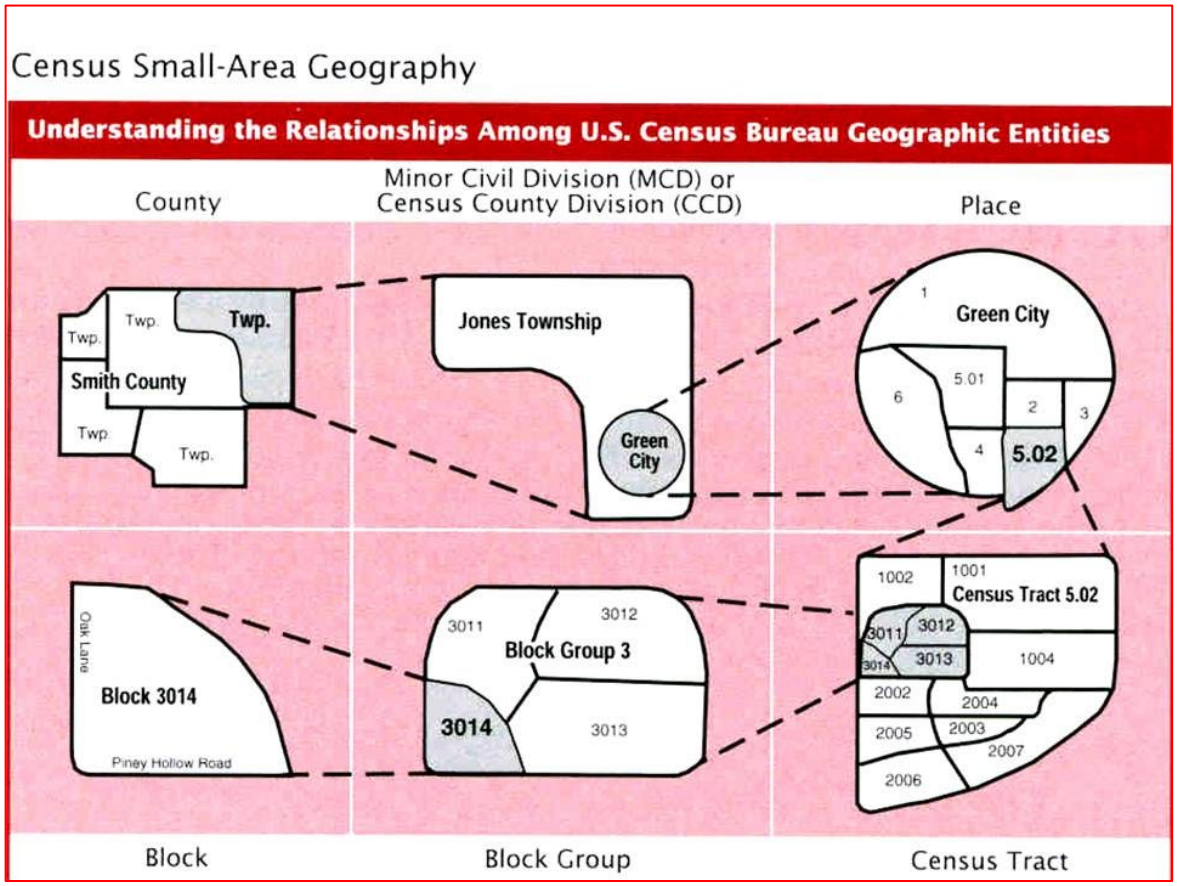


Figure 4-10: Census Small-area Geography (University of Pittsburg 2010)

Counties and equivalent areas are the primary divisions of most states, Puerto Rico, and the Island Areas. They include counties in 48 states; parishes in Louisiana; boroughs and census areas in Alaska; municipalities in Puerto Rico; independent cities in Maryland, Missouri, Nevada, and Virginia; and other entities in the Island Areas.

Census places are concentrations of population such as cities that have legally prescribed boundaries, powers, and functions.

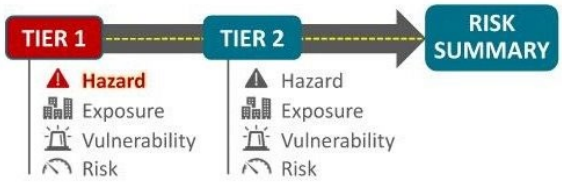
Census tracts generally contain between 1,000 and 8,000 people with an optimum size of 4,000 people. Census tract boundaries are delineated with the intention of being stable over many decades, so they generally follow relatively permanent visible features. However, they may follow governmental unit boundaries and other invisible features in some instances; the boundary of a state or county is always a census tract boundary.

Census blocks are statistical areas bounded by visible features, such as streets, roads, streams, and railroad tracks, and by nonvisible boundaries, such as selected property lines and city, township, school district, and county limits and short line-of-sight extensions of streets and roads.

4.2 Planning Reach NC_01 Risk Assessment

Planning Reach NC_01 is located in the northern half of the state and encompasses all or a portion of each of the following counties: Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Dare, Gates, Greene, Hertford, Hyde, Jones, Lenoir, Martin, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, and Washington. The following sub-sections within Section 4.2 provide detailed analysis for Planning Reach NC_01.

4.2.1 Planning Reach NC_01 Tier 1



4.2.1.1 Planning Reach NC_01 Tier 1 Hazard

Figure 4-11 displays existing and future flood hazards for Planning Reach NC_01. The 10-percent AEP water level (inundation) is modeled to cover a significant back bay area of the barrier islands as well as many of the back bay mainland areas throughout the entire reach. This inundation potential increases throughout the entire reach with 3 feet of sea level rise.

Tier 1 hazard data can be viewed from the SACS Geoportal: https://data-sacs.opendata.arcgis.com/

4.2.1.2 Planning Reach NC_01 Tier 1 Exposure

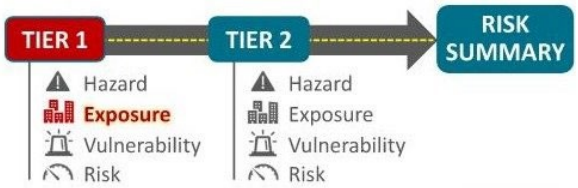


Figure 4-12 displays the Population and Infrastructure; Environmental and Culture Resources; Social Vulnerability Exposure Indices, and the Composite Exposure Index for Planning Reach NC_01.

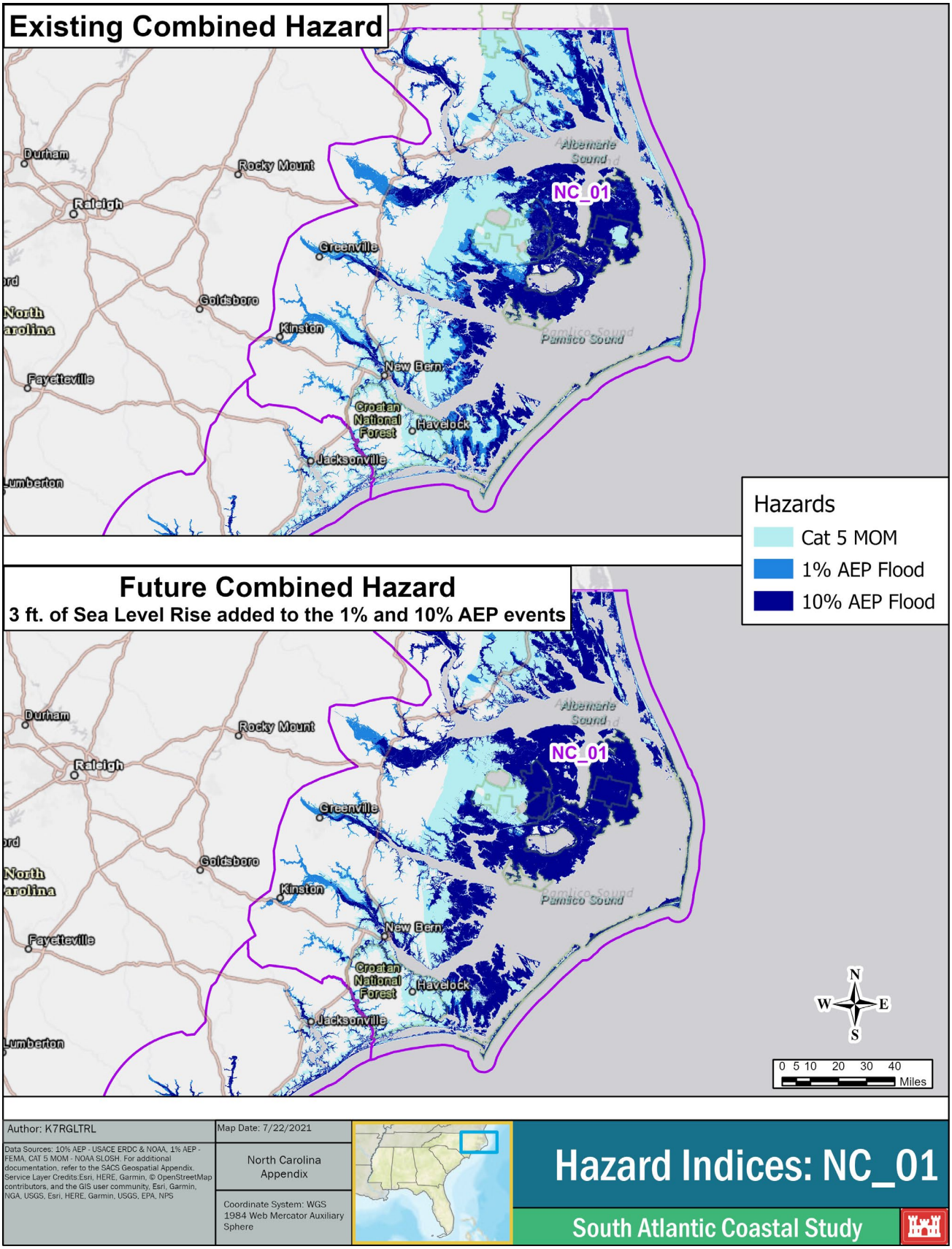


Figure 4-11: Existing and Future Flood Hazards for Planning Reach NC_01

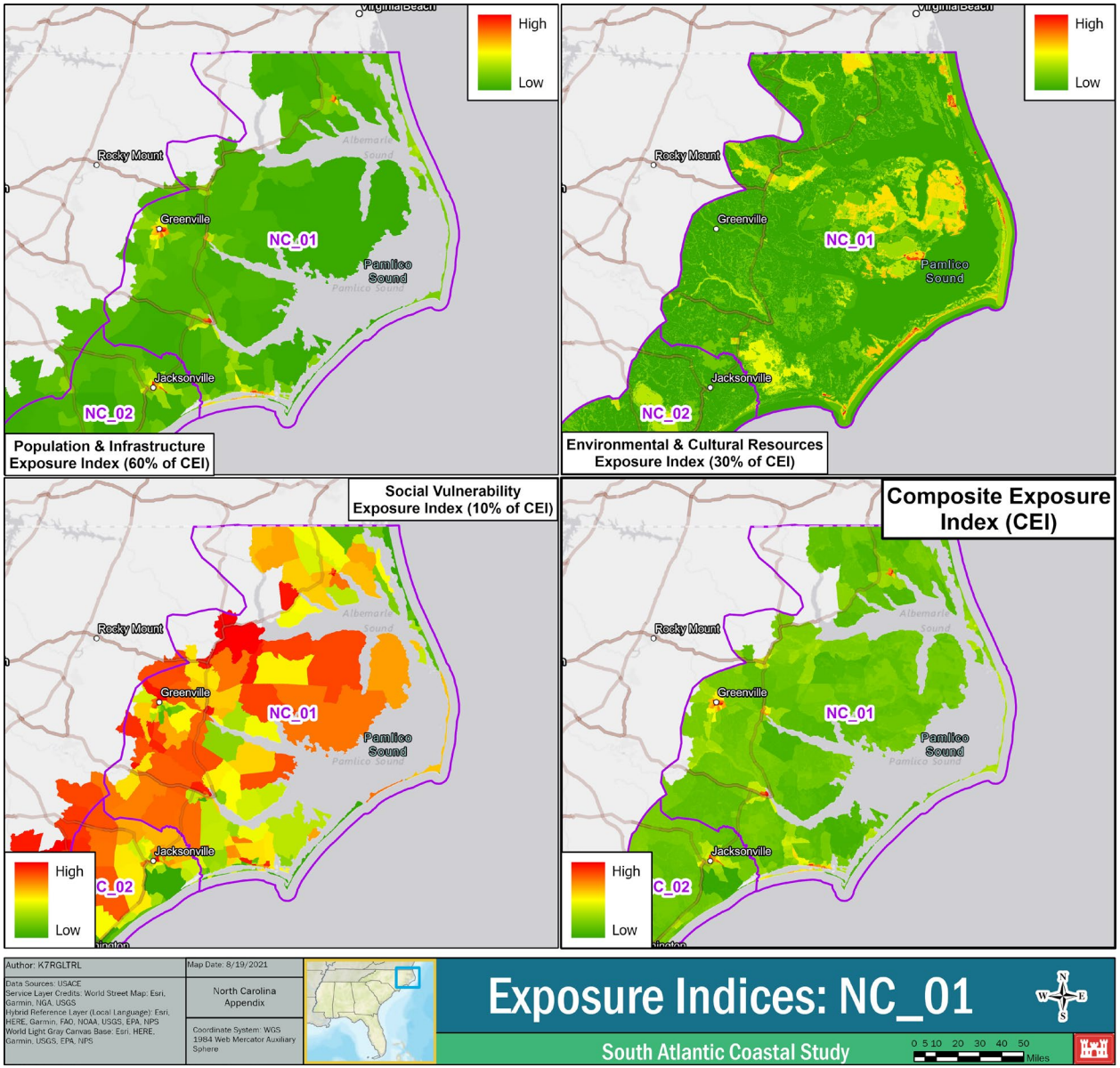


Figure 4-12: Exposure Maps for Planning Reach NC_01

Population and Infrastructure

The Tier 1 Population and Infrastructure Exposure Index shows four areas with a high density of exposed population and infrastructure within Planning Reach NC_01. High density is represented by amber and red in **Figure 4-12**. These areas are:

- **The Elizabeth City area within Pasquotank County**: Population of 13,000 with infrastructure including multiple hurricane evacuation routes, railroads, bridges, schools, law enforcement, fire stations, U.S. Coast Guard (USCG) Air Station Elizabeth City, and Elizabeth City State University.
- **The Greenville area located within Pitt County**: Population of 44,000 with infrastructure including multiple receiving hospitals, railroad bridges, schools, nursing homes, emergency shelters, law enforcement, fire stations, local emergency operations center (EOC), hospitals, and substations.
- **The New Bern area located within Craven County**: Population of 33,000 with infrastructure including urgent care, receiving hospital, railroad yard, railroad bridges, schools, nursing homes, shelters, law enforcement, fire stations, a local EOC, substations, and United States Marine Corps (USMC) Air Station Cherry Point.
- **The Morehead City and Bogue Banks area located within Carteret County**: Population of 16,000 with infrastructure including wastewater treatment plants, urgent care facilities, railroad yards, railroad bridges, public schools, power plant, port facilities, nursing homes, shelters, law enforcement, fire stations, hospital, substations, water treatment plants, railroads, navigable channels, USCG Base Fort Macon, and USCG Station Emerald Isle.

Environmental, Cultural, and Habitat Resources

The Tier 1 Environmental and Cultural Resources Exposure Index shows four areas with a high density of exposed environmental and cultural resources within Planning Reach NC_01. These areas are:

- Back bay areas of coastal Currituck County:
  - Environmental Resources (specific locations): Monkey Island, Mackay Island, Currituck Marshes–Pine Island, Currituck Banks, back bay areas, Currituck NWR, and Mackay Island NWR
  - Environmental Resources (general): SAV, wading bird nesting, and coastal marsh habitat
  - Cultural Resources: Caffey's Inlet Lifesaving Station, Currituck County Courthouse and Jail, Walker Family Buildings, Currituck Courthouse Historic District, Dr. W.T. Griggs House, Currituck Sound Rural Historic District, Currituck Beach Lighthouse Complex Boundary Expansion, Flyway Club, and Whalehead Club
- Various areas along the Outer Banks and eastern peninsula in Dare County:

  - Environmental Resources (specific locations): Old House Channel–Islands MN, C and L, Alligator River Lowlands, Rawls Island, Pea Island NWR, Roanoke Sound–Island G, Gull Island, Cape Hatteras National Seashore, Clam Shoal, Hatteras Island, Cape Hatteras, Nags Head Woods, Pine Island Bay, Alligator River NWR, Roanoke Island Juncus Marsh Easement, and Piping Plover habitat
  - Environmental Resources (general): Migrating bird habitat, sea turtle nesting habitat, SAV, and coastal marsh habitat
  - Cultural Resources: Theodore S. Meekins House, George Washington Creef House, John T. Daniels House, Manteo Historic District, and Fort Raleigh National Historic District

- Portions of Hyde County to include the area southeast of Mattamuskeet NWR, and Ocracoke Island:
  - Environmental Habitat (specific locations): Judith Island Point, Lake Mattamuskeet–Swan Quarter, Hog Island, Roos Point, Outer Green Island, Great Island, and Swanquarter NWR
  - Environmental Resources (general): sea turtle nesting habitat, SAV, and coastal marsh habitat
  - Cultural Resources: Ocracoke Historic District and Lake Landing Historic District
- Portions of Carteret County to include Cape Lookout National Seashore and the back bay areas of Back Sound:
  - Environmental Resources (specific locations): Cat (Wood) Island, Wainwright Island, Cedar Island Marsh, Chainshot Island, Morgan Island, Croatan Forest, Tump Island, Sand Bag Island, Middle Marsh, Carrot Island–Bird Shoal, North Rock Island, Raccoon Island, Beacon Island, Hammocks Beach, Shackleford Banks, Roosevelt Natural Area, Fort Macon, Cedar Island NWR, and Rachel Carson National Estuarine Research Reserve (NERR).
  - Environmental Resources (general): Loggerhead sea turtle and piping plover habitat, sea turtle nesting habitat, SAV, and coastal marsh habitats.
  - Cultural Resources: Carteret County Home, Gibbs House, Jacob Henry House, Morehead City Municipal Building, Salter-Battle Hunting and Fishing Lodge, Old Burying Ground, Bogue Park Subdivision, Clubfoot and Harlowe Creek Canal, Washburn Seminary Trade Training Workshop, Scott's Grocery, J.C. Stanley Grocery, Beaufort Graded School, Ward-Hancock House, Atlantic Historic District, Duke Marine Laboratory, Stacy Cemetery, Marshallberg Harbor, Gales Creek Cemetery, Oceanana Motel and Fish Pier, Stella Historic District, Newport Historic District, Portsmouth Village (Federal Nomination), Cape Lookout Light Station, Cape Lookout Coast Guard Station, Morehead City Historic District, Beaufort Historic District, and Cape Lookout Village Historic District.

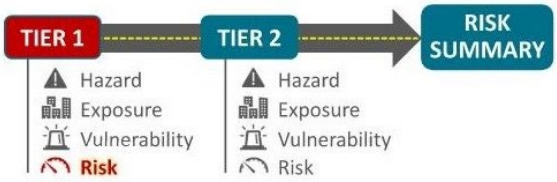
Social Vulnerability

The Tier 1 Social Vulnerability Exposure Index shows extensive areas with a high social vulnerability within Planning Reach NC_01 (**Figure 4-12**). These areas are on the mainland (i.e., not barrier island communities) with the exception of Ocracoke Island in Hyde County.

4.2.1.3 Planning Reach NC_01 Tier 1 Vulnerability

As stated in the Tier 1 vulnerability overview section (Section 4.1.3), if a resource is subject to a hazard, it is considered vulnerable in the Tier 1 analysis.

4.2.1.4 Planning Reach NC_01 Tier 1 High-Risk Locations



The CEI and coastal flood inundation hazards were used to identify potential areas at risk. Risk is a function of exposure and probability of hazard occurrence. The Engineering Appendix describes how each of the inundation hazards (Category 5 MOM, 1-percent AEP flood event, 10-percent flood event) and sea level rise were combined with the CEI to inform the Tier 1 Risk Assessment.

SACS Tier 1 Risk Assessment Viewer: https://sacs.maps.arcgis.com/apps/MapSeries/index.html?appid=c54beb5072a04632958f2373eb1151cf

Figure 4-13 displays existing and future potential risk for Planning Reach NC_01. Tier 1 high-risk locations are those where potential medium-high (amber) and high (red) composite risk exists. U.S. Census Bureau "census places" were used to define the boundaries of high-risk locations. Medium-high and/or high composite risk census places were defined as at least 50 acres and 0.5 percent of the total area of a census place designated as high-risk.

The Tier 1 Risk Assessment identified multiple composite high-risk areas in North Carolina. Four of the top five at-risk census places are located in Carteret County. These four census areas are Indian Beach, on the Bogue Banks, and the areas of Morehead City, Newport, and Beaufort. Other high-risk areas include the Elizabeth City area, the Washington area, and the New Bern area. The Tier 1 Risk Assessment revealed a significant potential risk throughout this area due to the presence of population and infrastructure, critical environmental resources and habitat, and social vulnerability.

The Tier 1 mean composite medium-high and high-risk index by census place for existing and future conditions in North Carolina are shown in **Figure 4-14** and **Figure 4-15** respectively. Comparing these two figures highlights that potential risk increases significantly with sea level rise for the following communities: Greenville, Washington, and New Bern.

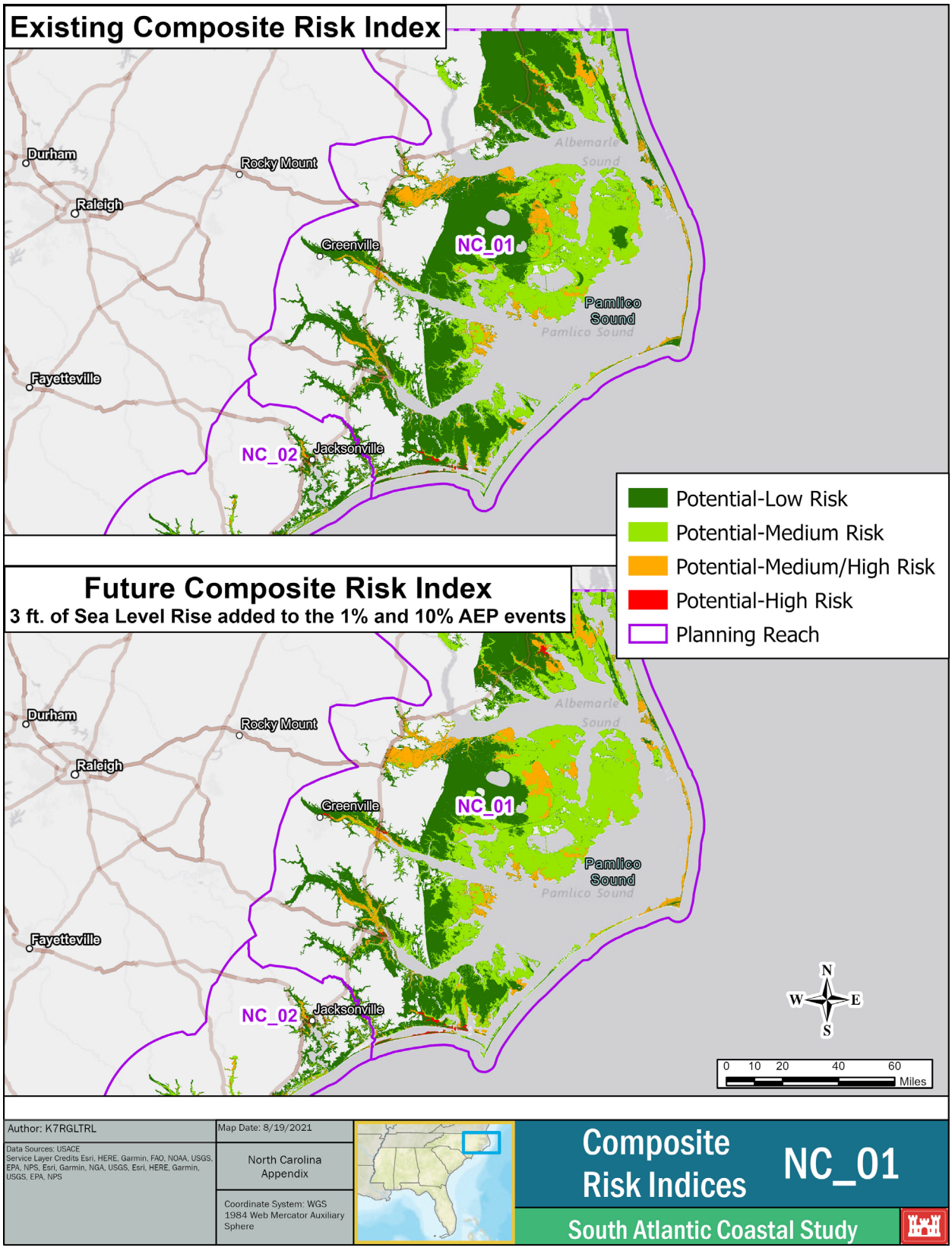


Figure 4-13: Tier 1 Existing and Future Composite Risk Index for Planning Reach NC_01

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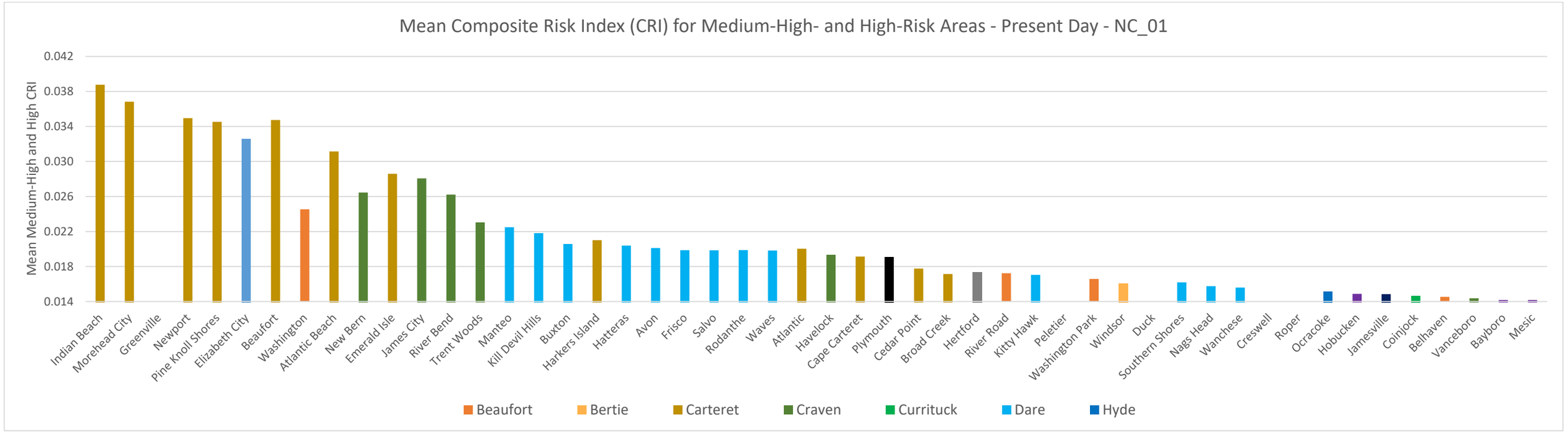

Figure 4-14: Tier 1 Potential Composite Medium-High and High Risk by Census Place with Existing Conditions

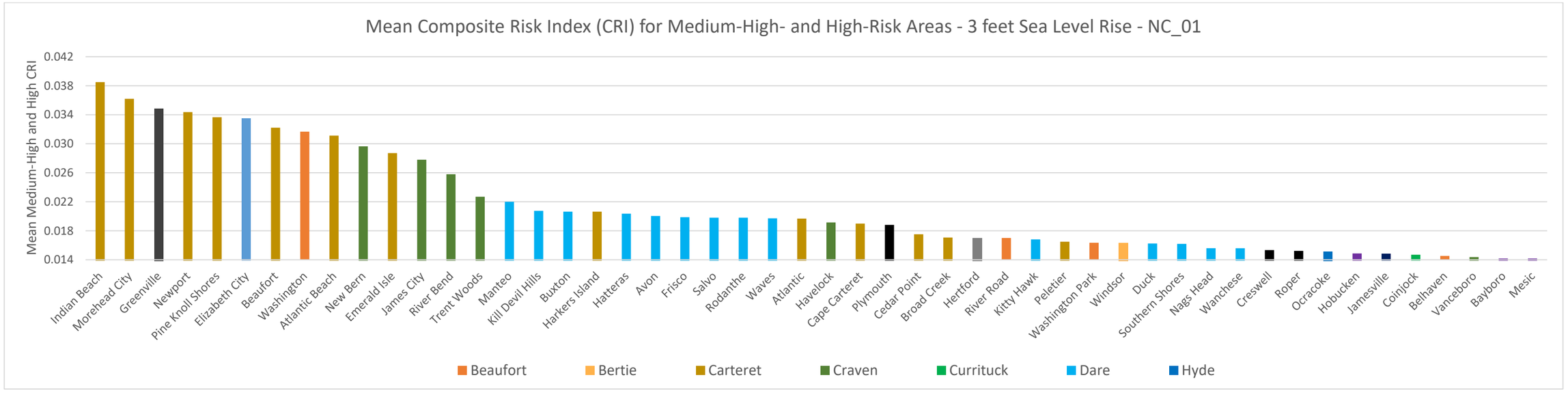

Figure 4-15: Tier 1 Potential Composite Medium-High and High Risk by Census Place with Sea Level Rise

The total acreage impacted (defined as having a medium-high and/or high CRI) provides the spatial scale of the potential risk in the existing and future conditions. Indian Beach has a high mean CRI score (**Figure 4-14**) because of the relative high density of population, infrastructure, and environmental and cultural resources. Yet, **Figure 4-16** shows that the acreage potentially impacted in Elizabeth City, New Bern, and Kitty Hawk is greater. Further, in the future condition, over 2,000 and 1,000 acres for Elizabeth City and New Bern, respectively, are considered at risk. This consideration underscores the need to further evaluate risk from storm surge inundation and begin needed planning activities to reduce risk. The footprint of expanded medium-high and high potential risk in the future condition can be seen in the Tier 1 Risk Assessment Viewer.

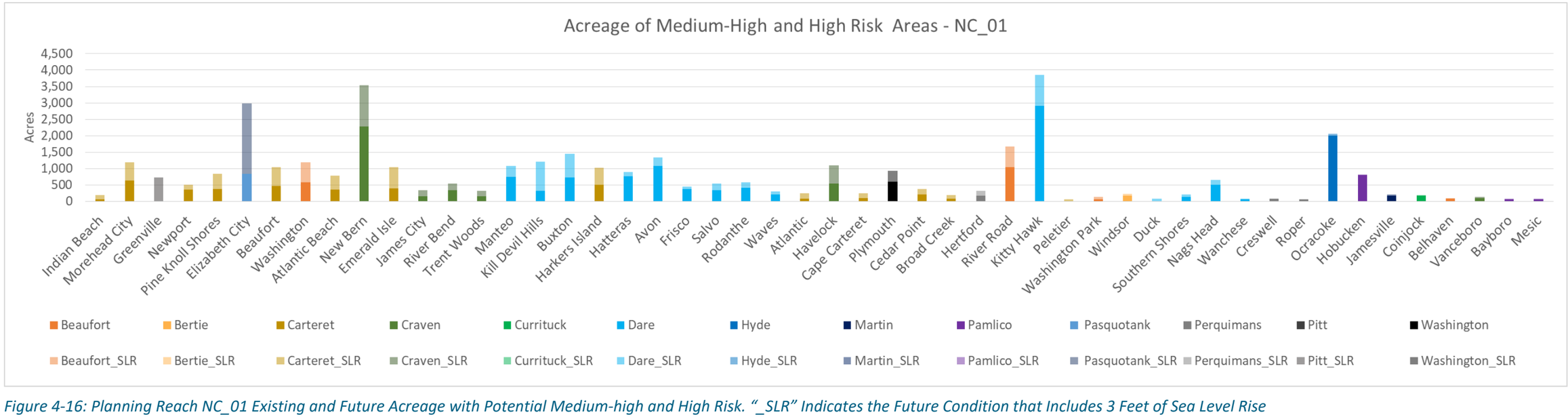

Figure 4-16: Planning Reach NC_01 Existing and Future Acreage with Potential Medium-high and High Risk. "_SLR" Indicates the Future Condition that Includes 3 Feet of Sea Level Rise

Figure 4-17 shows the percentage of the census place area designated as medium-high or high risk from the Tier 1 analysis. Since census places represent population centers and areas of economic activity, a large percentage of a potentially at-risk census place threatens the continued ability of that place to support populations and economic activity without adequate planning and actions.

For Planning Reach NC_01, of the 14 places with high-risk areas in Dare County, eight places have more than 50 percent of their area rated as medium-high and/or high potential risk (**Figure 4-17**). In the future condition, nine census places will have over 70 percent of their area rated as medium-high or high potential risk.

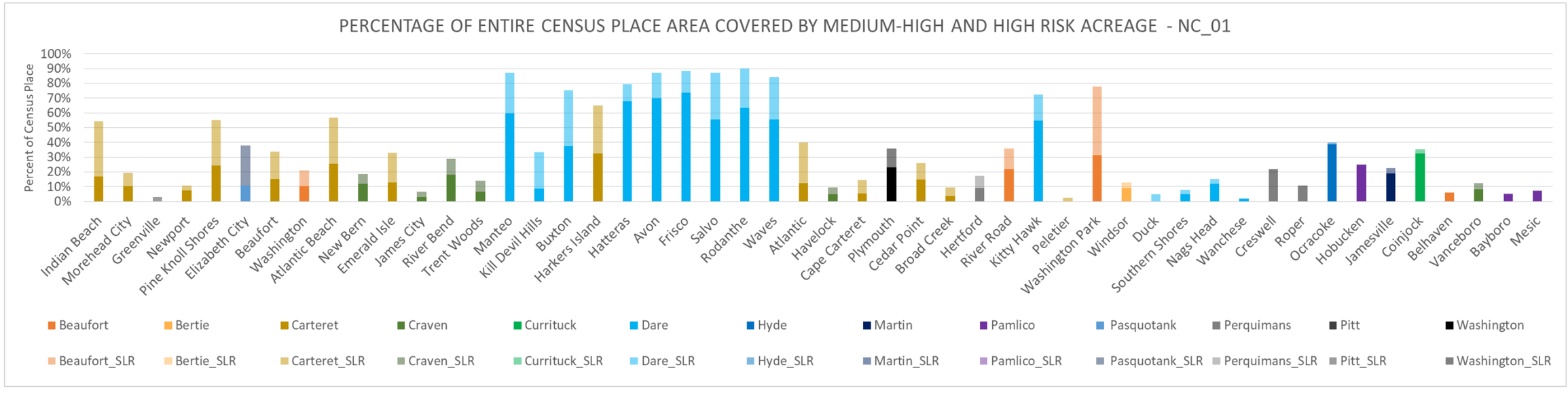

Figure 4-17: Planning Reach NC_01 Existing and Future Percentages of Census Place Areas Rated as Medium-High and/or High Risk. "_SLR" Indicates the Future Condition that includes 3 Feet of Sea Level Rise

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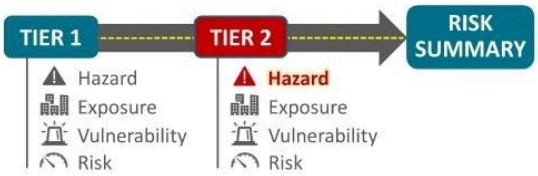
4.2.2 Planning Reach NC_01 Tier 2

The Tier 2 analysis expanded upon the regional Tier 1 analysis through inclusion of state-level data sources and additional evaluation.

4.2.2.1 Planning Reach NC_01 Tier 2 Hazard



Tier 2 hazards are described in the Overview section (Section 4.1). Areas subject to Tier 2 hazards in Planning Reach NC_01 are identified subsequently.

Inundation

The Tier 2 analysis considered inundation depths as well as extent of coastal storm flooding. Both Hazus and CHS data were used to evaluate additional coastal storm flood hazards. SWLs, an output of the CHS model, are shown in **Table 4-4** at various locations throughout the planning reach for several AEP with existing sea level conditions. **Table 4-5** shows the same data, but for the high (7.35-feet) sea level rise scenario modeled in CHS. Nonlinear effects, which are changes to SWLs due to sea level rise that are not a simple addition of the sea level rise value, are evident in this planning reach. Nonlinear effects take place primarily in the back bay regions. For example, the 1-percent AEP SWL in the back bay region of Ocracoke is modeled to be 11.84 feet, which is an additional 2.33 feet above the 7.35 feet of added sea level rise. Alternatively, on the ocean side of Ocracoke, the modeled 1-percent AEP SWL with 7.35 feet of sea level rise is lower than the additive 7.35 feet plus the existing sea level. **Figure 4-18** through **Figure 4-20** display the CHS modeled depth for the 1-percent AEP event within Planning Reach NC_01 under existing, intermediate and the high sea level rise scenarios.

Table 4-4: Planning Reach NC_01 Stillwater Elevations from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Duck	4.60	5.08	5.59	5.91	6.58
Albemarle Sound	2.11	2.56	3.00	3.25	3.72
Alligator River	2.00	2.28	2.64	2.89	3.41
Pamlico Sound - Near Oregon Inlet	2.79	3.18	3.57	3.87	4.55
Rodanthe	3.87	4.13	4.39	4.56	5.34
Pamlico Sound - Near Hatteras	1.88	2.08	2.27	2.39	2.85
Ocracoke - Ocean	3.78	4.04	4.44	4.76	5.49
Ocracoke - Pamlico Sound	1.75	1.93	2.09	2.19	2.65
Pamlico Sound - Cedar Island	3.08	3.68	4.43	4.94	6.02
Neuse River - MCAS Cherry Point	5.30	6.63	8.10	9.08	10.89
Neuse River - New Bern	6.09	7.55	9.04	10.01	11.65
Cape Lookout National Seashore	4.10	4.47	5.09	5.60	6.55
Core Sound - Davis	4.15	5.35	6.62	7.67	8.85
Morehead City	4.99	5.70	6.84	7.75	9.86
Emerald Isle	5.61	5.95	6.64	7.30	9.16
Bogue Sound - Emerald Isle	5.59	6.87	8.08	8.81	11.42
White Oak River	5.89	6.97	8.29	9.32	10.69

Table 4-5: Planning Reach NC_01 Stillwater Elevations from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Duck	11.85	12.31	12.79	13.08	13.67
Albemarle Sound	10.31	10.79	11.38	11.79	12.55
Alligator River	10.02	10.36	10.74	10.99	11.54
Pamlico Sound - Near Oregon Inlet	10.64	11.25	12.00	12.46	13.26
Rodanthe	11.15	11.38	11.61	11.75	12.31
Pamlico Sound - Near Hatteras	10.28	10.60	11.08	11.41	12.01
Ocracoke - Ocean	11.08	11.29	11.62	11.87	12.47
Ocracoke - Pamlico Sound	10.36	10.83	11.45	11.84	12.52
Pamlico Sound - Cedar Island	11.11	12.06	13.20	13.83	14.94
Neuse River - MCAS Cherry Point	13.08	14.65	16.19	17.16	18.95
Neuse River - New Bern	13.62	15.17	16.75	17.72	19.50
Cape Lookout National Seashore	11.37	11.67	12.11	12.49	13.24
Core Sound - Davis	12.65	14.18	15.58	16.35	17.69
Morehead City	12.34	13.20	14.44	15.43	17.65
Emerald Isle	12.90	13.20	13.73	14.27	15.90
Bogue Sound - Emerald Isle	12.66	14.02	15.49	16.40	19.19
White Oak River	12.89	14.15	15.71	16.76	18.54

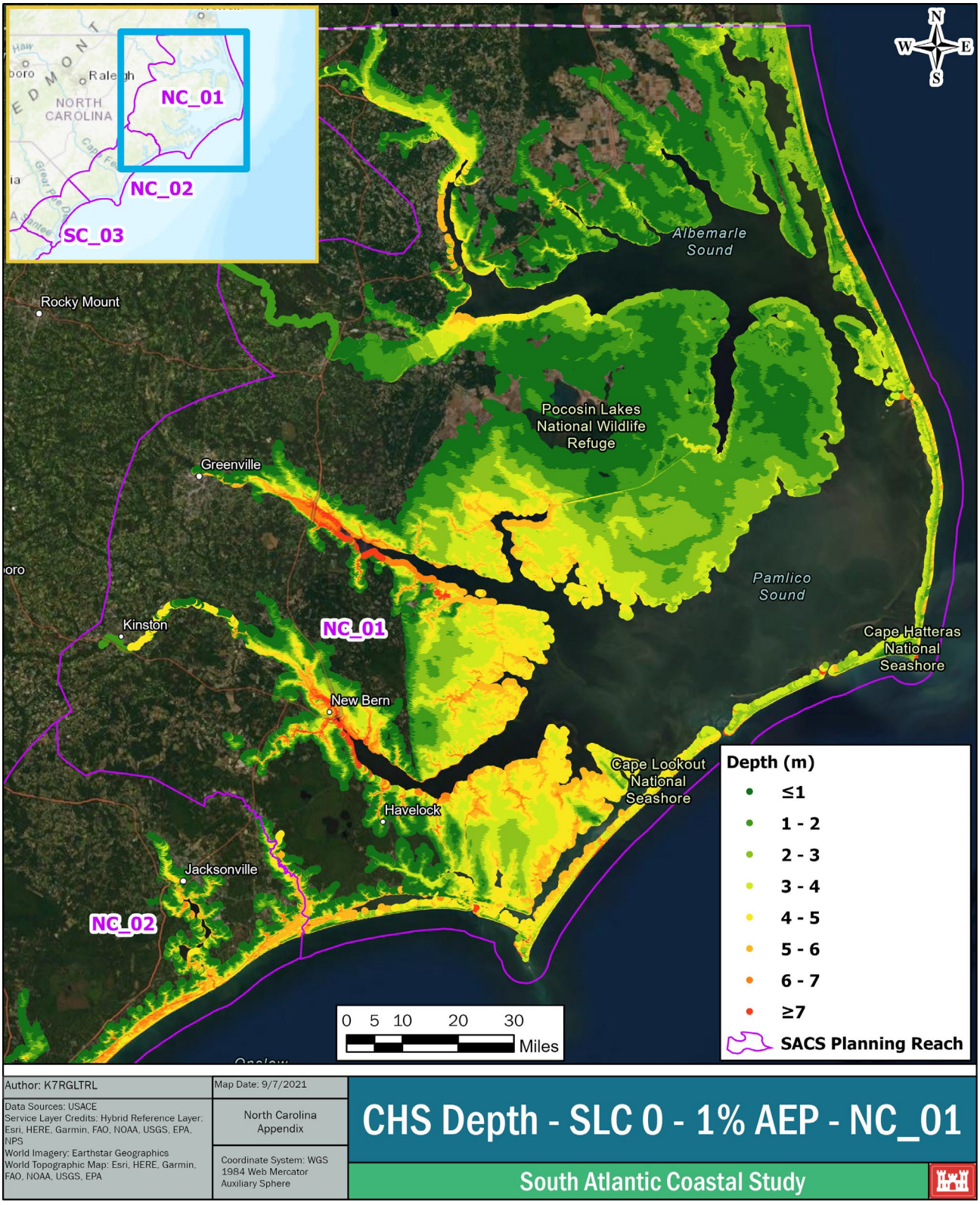


Figure 4-18: Coastal Hazards System Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability within Planning Reach NC_01 Under Existing Sea Level Conditions

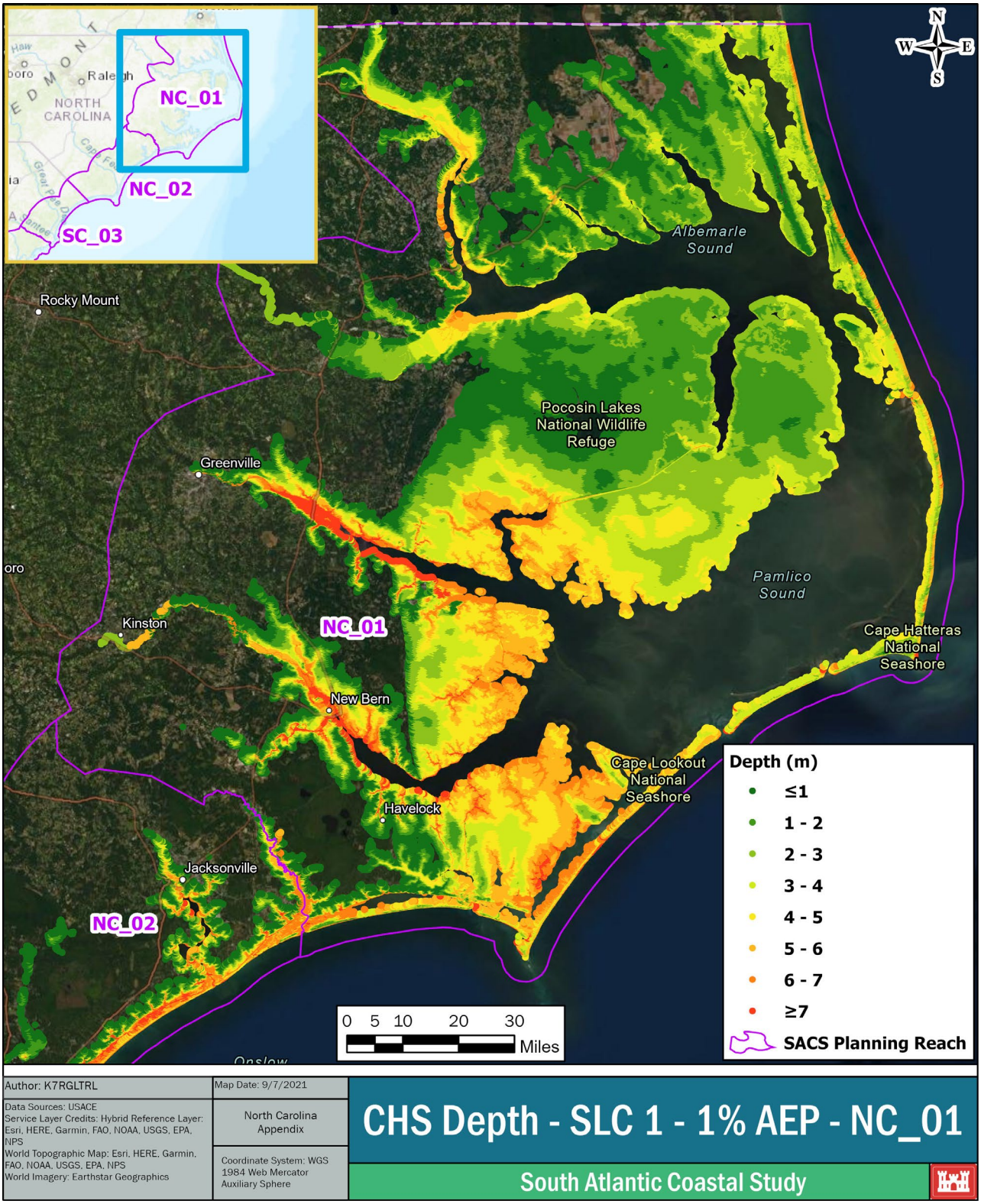


Figure 4-19: Coastal Hazards System Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 2.73 Feet of Sea Level Rise in Planning Reach NC_01

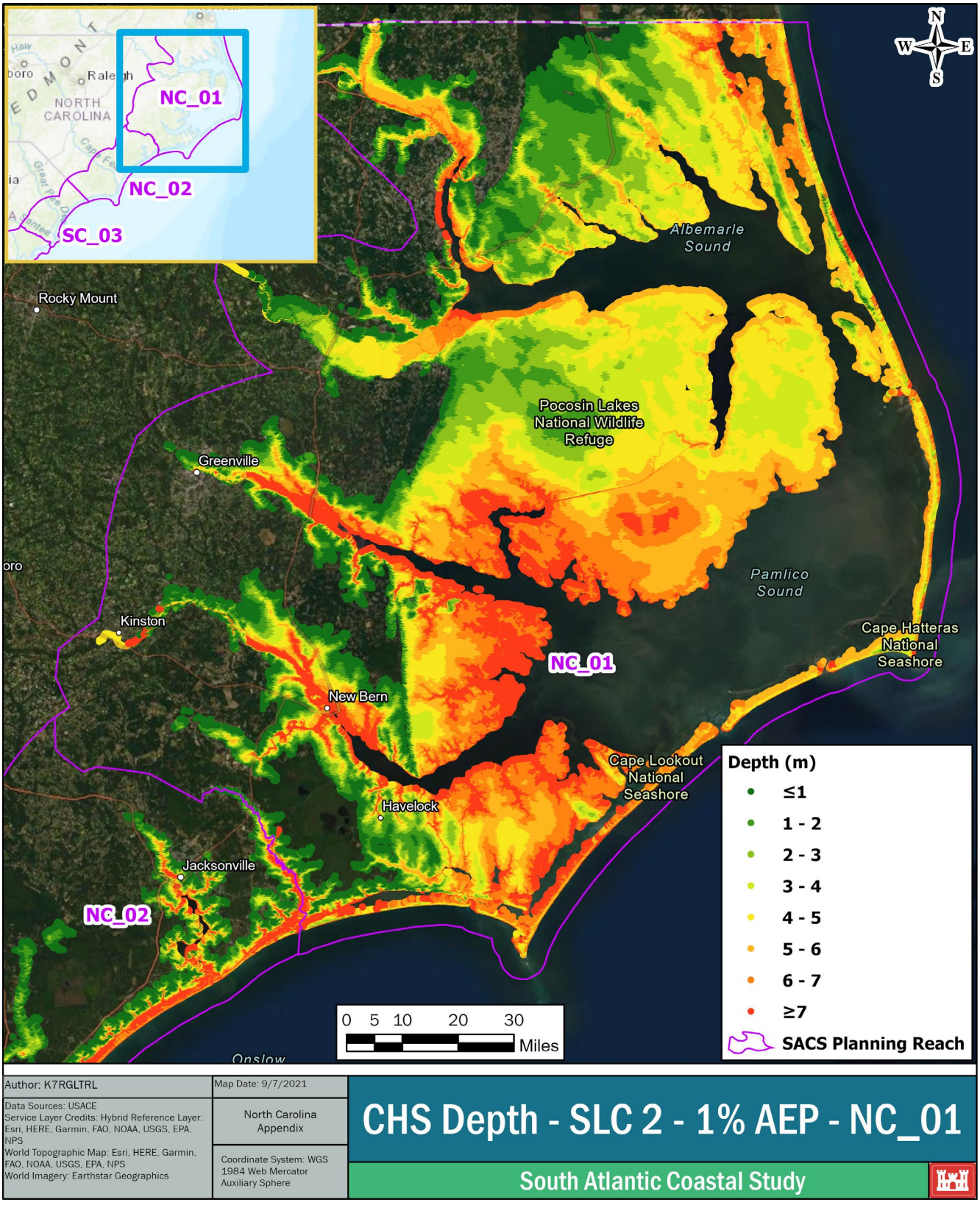


Figure 4-20: Coastal Hazards System Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 7.35 Feet of Sea Level Rise in Planning Reach NC_01

Wave Attack

Wave attack is most significant in this planning reach along oceanfront shorelines and large back bay areas. Because wave height correlates to fetch (length over which wind stress is applied), duration (amount of time for sustained wind stress), and water depth, shorelines along the Atlantic Ocean and adjacent to larger back bay areas like the Pamlico Sound are more vulnerable to larger waves. **Table 4-6** provides wave heights at various locations throughout the planning reach for several AEP events with existing sea level conditions. **Table 4-7** shows the same information, but for the high (7.35-feet) sea level rise scenario modeled in CHS. Because increased sea levels will allow waves to develop in deeper water and reduced land area will lead to increased fetch, wave heights are modeled to generally increase with sea level rise. **Figure 4-21** depicts the wave heights within NC_01 under existing sea levels.

Table 4-6: Planning Reach NC_01 Wave Heights from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Duck	22.60	25.62	28.84	30.76	34.22
Albemarle Sound	3.85	4.17	4.49	4.75	5.36
Alligator River	2.98	3.30	3.66	3.93	4.58
Pamlico Sound - Near Oregon Inlet	5.08	5.58	5.99	6.25	6.67
Rodanthe	25.96	29.83	34.02	36.16	39.48
Pamlico Sound - Near Hatteras	6.34	7.20	7.96	8.41	9.17
Ocracoke - Ocean	35.68	41.22	45.59	47.85	51.50
Ocracoke - Pamlico Sound	8.08	9.21	10.43	11.01	12.15
Pamlico Sound - Cedar Island	7.32	8.26	9.18	9.74	10.74
Neuse River - MCAS Cherry Point	4.35	5.25	6.18	6.72	7.71
Neuse River - New Bern	2.60	3.28	4.03	4.45	5.24
Cape Lookout National Seashore	28.04	32.87	36.75	38.96	42.21
Core Sound - Davis	3.15	3.77	4.38	4.74	5.33
Morehead City	2.97	3.65	4.30	4.66	5.35
Emerald Isle	23.11	27.00	30.48	32.52	36.52
Bogue Sound - Emerald Isle	3.76	4.75	5.78	6.22	7.40
White Oak River	1.75	2.33	3.00	3.36	4.06

Table 4-7: Planning Reach NC_01 Wave Heights from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Duck	23.27	26.63	30.16	32.19	35.76
Albemarle Sound	5.37	6.01	6.57	6.90	7.55
Alligator River	2.80	3.01	3.46	3.85	4.66
Pamlico Sound - Near Oregon Inlet	7.09	8.06	8.84	9.25	9.97
Rodanthe	26.69	31.43	36.43	38.98	42.97
Pamlico Sound - Near Hatteras	8.25	9.38	10.30	10.82	11.74
Ocracoke - Ocean	36.38	42.40	47.48	50.07	54.31
Ocracoke - Pamlico Sound	9.64	11.08	12.45	13.19	14.49
Pamlico Sound - Cedar Island	8.60	9.94	11.25	11.98	13.24
Neuse River - MCAS Cherry Point	4.82	5.71	6.57	7.08	8.00
Neuse River - New Bern	3.44	4.24	5.11	5.63	6.55
Cape Lookout National Seashore	28.65	33.93	38.50	41.02	44.95
Core Sound - Davis	5.99	6.98	7.94	8.45	9.36
Morehead City	3.69	4.50	5.38	5.87	6.73
Emerald Isle	24.37	28.47	32.09	34.20	38.26
Bogue Sound - Emerald Isle	7.12	8.21	9.33	9.87	11.04
White Oak River	2.65	3.25	4.00	4.43	5.23

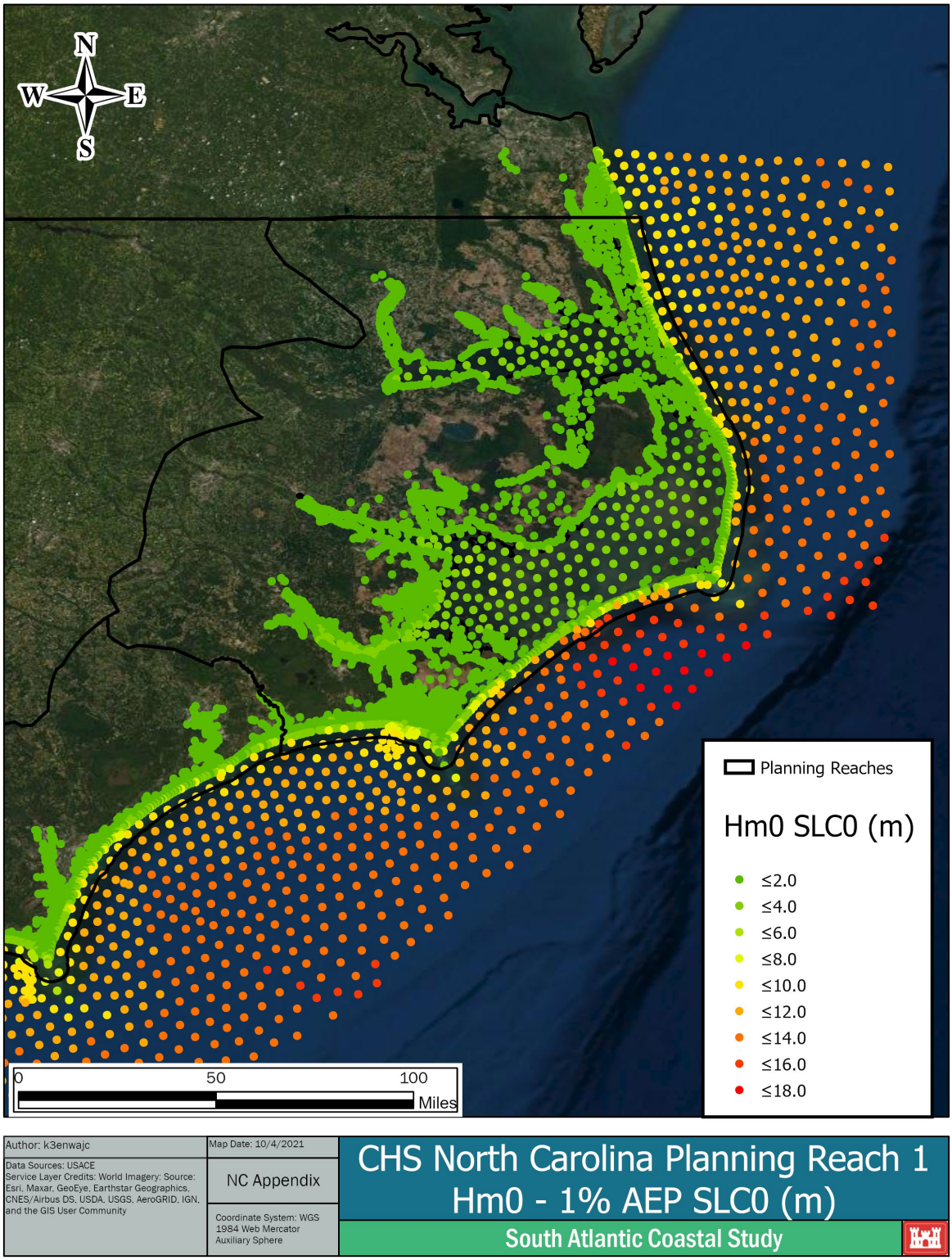


Figure 4-21: Coastal Hazards System Modeled Wave Heights in Planning Reach NC_01 Under Existing Sea Level Rise Conditions

Erosion

Erosion is threatening coastal environments, environmental resources, cultural resources, communities, and infrastructure in Planning Reach NC_01. Nearly all beachfront coastlines within Planning Reach NC_01 are experiencing erosion (NCDCM 2019), including the entirety of the Outer Banks barrier complex, with smaller areas of accretion occurring often near sediment nourishment projects, such as Kill Devil Hills, Pea Island, and Fort Macon, or near inlet management areas, such as Oregon Inlet and the Morehead City Harbor. The average shoreline change rate for eroding beaches for Planning Reach NC_01 ranged between -0.34 feet/year at Pine Knoll Shores and -6.69 feet/year at Bodie Island (NCDCM 2019). For accreting beaches, the average shoreline change rate varied between 0.27 feet/year at Emerald Isle and 1.32 feet/year at Fort Macon, both sites of nourishment projects.

Stakeholder coordination identified three locations within Planning Reach NC_01 with existing erosion data in the back bay area: Cedar Island, Neuse River Estuary, and New River Estuary. Shoreline change rates at Cedar Key averaged -0.79 feet/year with 88 percent of the shoreline eroding (Cowart et al. 2010). The Neuse River Estuary experienced a shoreline change rate of -1.90 feet/year with 93 percent of the area eroding, and the New River Estuary had an average shoreline change rate of -0.98 feet/year (Cowart et al. 2011; Currin et al. 2015). Additional shoreline erosion data from Riggs and Ames (2003) included an average of -2.7 feet/year for the northeastern North Carolina estuarine shoreline region and an estimated 25-year land loss of 527 square feet from 1975 to 2000. Additional average erosion rates were reported for the Albemarle Pamlico Estuarine region (Rigg and Ames 2003):

- Inner Pamlico River: -1.1 feet/year
- Outer Pamlico River: -3.8 feet/year
- Albemarle Pamlico Sounds: -2.2 feet/year
- Back Barrier Northern Outer Banks: -2.7 feet/year

Back bay erosion has not been assessed statewide to the extent that oceanfront erosion has.

Examples of back bay erosion can be seen at Midgett Cemetery, on the sound side of Hatteras Island, and the Elizabethan Gardens on Roanoke Island. At the Midgett Cemetery, headstones, which date back to the 1800s, have broken or washed away. Recent risk management work has been done in this area to protect the cemetery.

Other specific locations impacted by back bay erosion include, but are not limited to, key historic sites along Roanoke Island in Pamlico Sound.

The NCDCM Oceanfront Erosion Rates data set for 2020 shows areas along coastal North Carolina that are either losing sand ("eroding"), growing through accumulation of sand ("accreting"), or remaining the same ("stable") (NCDCM 2020a). **Figure 4-22** illustrates the oceanfront shoreline change data within Planning Reach NC_01. These data are also located in **Table 4-8**.

For the purposes of identifying additional high-risk areas not captured in the Tier 1 analysis, critical erosion areas were identified along the oceanfront shoreline. This Tier 2 analysis overlaid the 2019 state shoreline change rate data with the SACS Tier 1 Composite Risk Index. Those areas with erosion greater than 3 feet and a medium-high or high composite risk were identified as critical erosion areas, thereby adding additional high-risk locations to the analysis beyond Tier 1. The three-foot erosion threshold was chosen based on the USGS Open-File Report 2010-1118 – *National Assessment of Shoreline Change: Historical Shoreline Change along the New England and Mid-Atlantic Coasts* (USGS 2010). Critical erosion areas include Kitty Hawk, Kill Devil Hills, Nags Head, Rodanthe, Waves, Avon, Buxton, Hatteras, and Ocracoke. As of the time of this writing, the NPS is completing an oceanfront erosion assessment ranging from Nags Head to Ocracoke, to evaluate trends from the 1950s through 2020 and then project forward 30 years. Upon completion, these data will be valuable in further providing information regarding risk from the erosion hazard along Cape Lookout National Seashore.

Because NCDCM shoreline change rates are calculated by taking the distance (feet) between two shorelines and dividing by the number of years between shoreline measurements, some shoreline change rates can be skewed by human activity. For instance, if the second shoreline was measured shortly after a beach renourishment event, the shoreline would artificially reflect more accretion than if the shoreline was measured before the renourishment event. Using records from the USACE SAW for its CSRM study in Wrightsville Beach (Planning Reach NC_02), the shoreline erosion rate is -4.3 feet/year if shorelines are measured between renourishment events to exclude human activity. NCDCM shows Wrightsville Beach to be accreting 3.2 feet/year due to the timing of shoreline measurements. Most CSRM shorelines in North Carolina are not monitored to the extent that Wrightsville Beach is monitored, so values from NCDCM are still the best available data regarding shoreline change within the state. The column "human interference" is included in **Table 4-8** to reflect areas in which human activity could impact shoreline change rates by placing sand from other (e.g., navigational) projects on the beach, renourishment as a federal CSRM measure by USACE, or renourishment using private or local support. These are labeled "placement," "CSRM," and "non-federal," respectively. If there is no known action, the column is labeled "N/A."

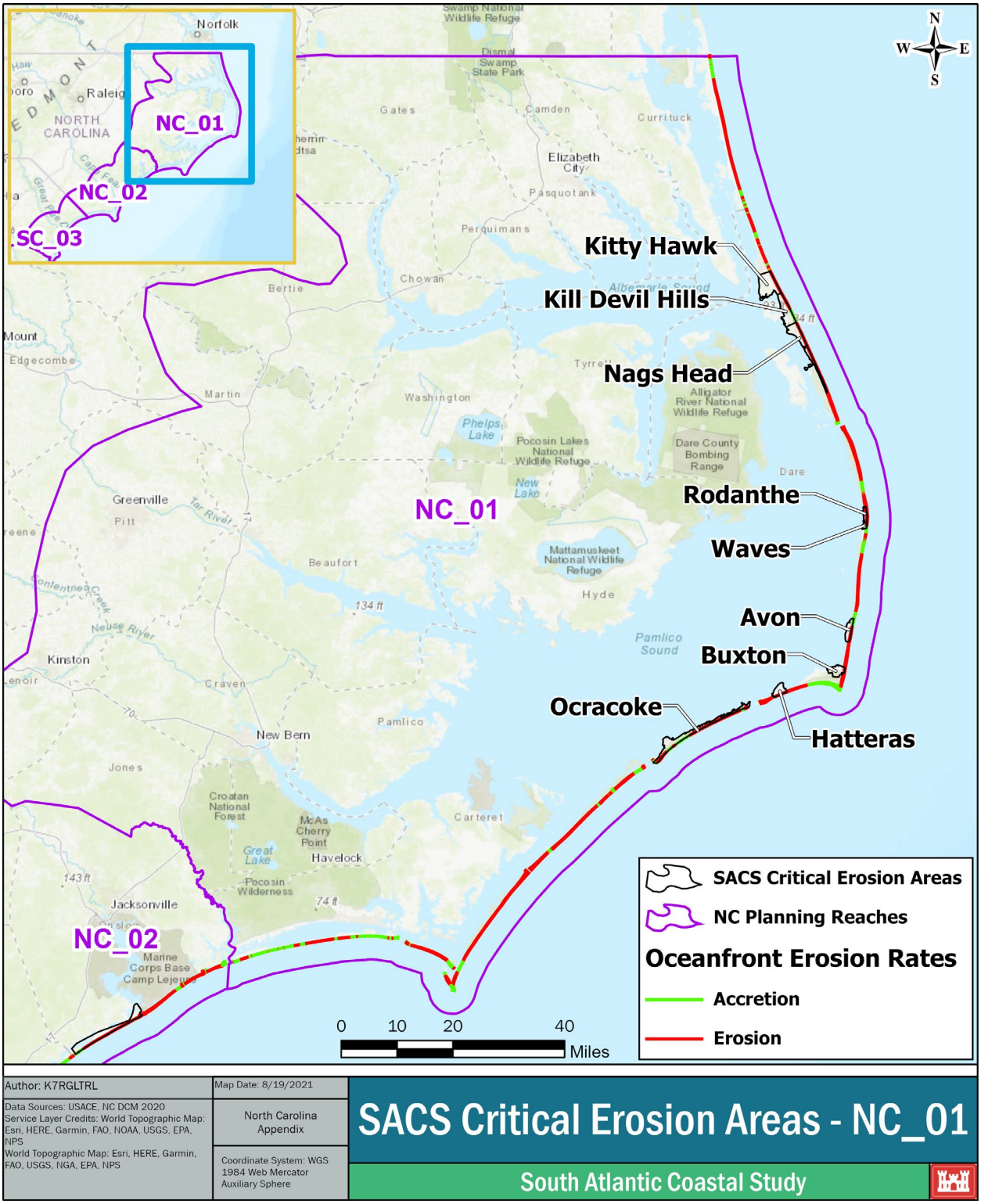


Figure 4-22: Oceanfront Shoreline Change in North Carolina Planning Reach NC_01 (NCDCM 2020a)

Table 4-8: Oceanfront Shoreline Changes Rates in Planning Reach NC_01 (NCDEQ 2020a)

Location	2020 Shoreline Change	Average Shoreline Change Rate (feet/year)	Human Influence*
Atlantic Beach	Erosion	-2.16	Non-federal
Core Banks–Cape Lookout to Drum Inlet	Erosion	-4.27	–
Core Banks–Drum Inlet to Ocracoke Inlet	Erosion	-5.26	–
Emerald Isle	Accretion	0.27	Non-federal
Fort Macon State Park	Accretion	1.32	Placement
Indian Beach	Erosion	-0.71	Placement
Ocracoke	Erosion	-3.22	–
Outer Banks–Bodie Island	Erosion	-6.69	–
Outer Banks–Cape Hatteras	Erosion	-0.93	–
Outer Banks–Cape Hatteras to Oregon Inlet	Erosion	-3.89	–
Outer Banks–Kill Devil Hills	Erosion	-0.85	Non-federal
Outer Banks–Kitty Hawk	Erosion	-2.24	Non-federal
Outer Banks–Nags Head	Erosion	-2.99	Non-federal
Outer Banks–Southern Shores	Erosion	-0.49	–
Outer Banks–Southern Shores to VA	Erosion	-2.2	–
Pine Knoll Shores	Erosion	-0.34	Placement
Salter Path	Erosion	-2.56	–
Shackleford Banks	Erosion	-2.56	–

* Denotes locations where human sand placement activities may influence erosion rates.

Compound Flooding

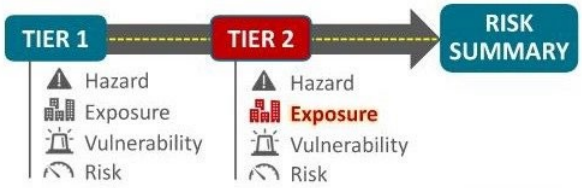
Within Planning Reach NC_01, areas along the Neuse River such as the City of New Bern and other nearby communities experienced the effects of compound flooding during Hurricane Florence. SACS recognizes that additional studies are needed to accurately assess compound flooding.

Saltwater Inundation and Intrusion

Areas such as the Albemarle and Pamlico Sounds are susceptible to saltwater inundation and intrusion because of their low-lying elevations and network of drainage ditches throughout the region, which can unintentionally increase the inflow of saltwater inland to a wide area (Bhattachan 2018). Effects can be seen along the Alligator River where dead or dying trees line the edges of the water and damaged crops are indicated. There are currently multiple efforts underway to study the issue of saltwater intrusion and its impacts in North Carolina.

4.2.2.2 Planning Reach NC_01 Tier 2 Exposure

This section highlights details of the Tier 2 exposure to determine who or what may be impacted by coastal hazards for the Planning Reach NC_01. An overview of each exposure element is presented in Section 4.1.5.



Population and Infrastructure

Tier 2 population and infrastructure exposure was first assessed using data from the National Structure Inventory, developed by the USACE Hydrologic Engineering Center and FEMA. **Figure 4-23** displays infrastructure data from the National Structure Inventory that is within the footprint of the 0.2-percent AEP event floodplain with 3 feet of sea level rise. The pie chart shows the proportional relationship, as values, between the general infrastructure types.

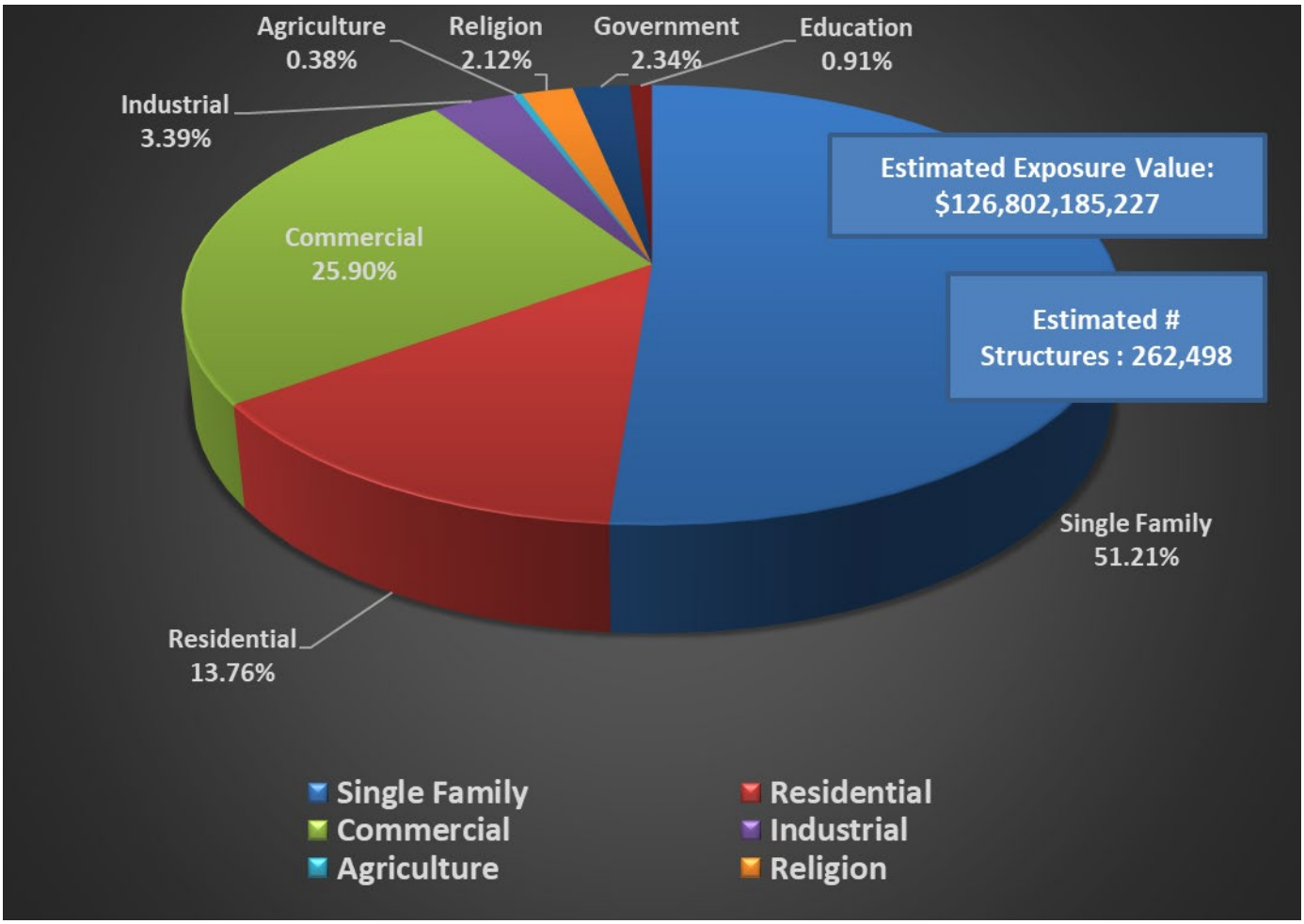


Figure 4-23: Estimated Exposure Value – Planning Reach NC_01 (USACE n.d.-b)

Within Planning Reach NC_01 there are approximately 262,000 structures exposed, with an estimated exposure value of $127 billion. The greatest value is estimated to be single-family and multi-family residential infrastructure, consisting of approximately 235,000 structures (90% of total structures) with an exposure value of $82 billion dollars (**Table 4-9**). **Table 4-10** provides an outline of estimated population at risk within Planning Reach NC_01.

Table 4-9: Estimated Structure Exposure Value for Planning Reach NC_01 (FEMA n.d.)

General Occupancy	Number of Structures	% of Structures	Estimated Exposure Value (Billions)	% of Exposed Value
Single Family	194,938	74.3%	$64.90	51.2%
Residential	40,008	15.2%	$17.40	13.8%
Commercial	19,083	7.3%	$3.80	25.9%
Industrial	3,783	1.4%	$4.30	3.4%
Agriculture	970	0.4%	$0.50	0.40%
Religion	1,843	0.7%	$.70	2.1%
Government	1,481	0.6%	$3.0	2.3%
Education	392	0.1%	$1.20	0.90%
Total	**262,498**	**100%**	**$95.8**	**100.0%**

Table 4-10: Planning Reach NC_01 Estimated Population at Risk

General Occupancy	Daytime Population at Risk (PAR)	% of Daytime PAR	Nighttime PAR	% of Nighttime PAR	Est. Avg PAR	% of PAR by Occupancy
Single Family	188,363	40%	378,276	75%	283,337	58.1%
Residential	67,080	14%	116,445	23%	91,935	18.9%
Commercial	100,510	21%	5,098	1%	52,916	10.9%
Industrial	16,189	3%	791	0%	8,519	1.7%
Agriculture	1,620	0%	77	0%	857	0.2%
Religion	3,607	1%	195	0%	1,906	0.4%
Government	12,758	3%	628	0%	6,719	1.4%
Education	82,475	17%	449	0%	41,470	8.5%
Total	**472,602**	-	**501,959**	-	487,659	**100%**

Military Installations

There are 20 major military installations within Planning Reach NC_01 (**Table 4-11**), which represent a substantial volume of all exposed infrastructure in coastal North Carolina. In addition, there are numerous Coast Guard stations not listed, including Fort Macon, Cape Hatteras, Wanchese, and Oregon Inlet. Two installations participate in the Readiness and Environmental Protection Integration (REPI) program: Dare County Bombing Range and the Marine Corps Air Station (MCAS) at Cherry Point. The Dare County Bombing Range includes 16,111 acres of preserved forested wetlands in partnership with the U.S. Air Force, the U.S. Navy, and The Nature Conservancy. The MCAS Cherry Pointe includes 11,836 acres of preserved forest and agricultural lands representing REPIs first multi-installation agreement. The goal of this innovative regional approach is to facilitate collective projects with state and non-profit partners at MCAS Cherry Point, MCAS New River, and Marine Corps Base (MCB) Camp Lejeune.

Table 4-11: Military Installations within North Carolina Planning Reach NC_01

Site Name	Main Institution	Location
Dare County Range	Seymour Johnson Air Force Base (AFB)	Dare County
Harvey Point, NC	NAVSTA Norfolk, VA	Hertford
Naval Air Station (NAS) Oceana Palmetto Point	NAS Oceana, VA	Columbia
Radio Island	Joint Expeditionary Base Little Creek Ft. Story, VA	Morehead City
Columbia, NC	NAS Oceana, VA	Columbia
Swan Quarter, NC	NAS Oceana, VA	Swanquarter
Area 5A	Marine Corps Air Station (MCAS) Cherry Point, NC	Cherry Point
Ft. Macon Housing	MCAS Cherry Point, NC	Cherry Point
Hancock Island 1	MCAS Cherry Point, NC	Cherry Point
Hancock Island 2	MCAS Cherry Point, NC	Cherry Point
Outlying Field Atlantic	MCAS Cherry Point, NC	Bogue
Brandt Island	MCAS Cherry Point, NC	Bayboro
Cat Island Target	MCAS Cherry Point, NC	Bayboro
Point of Marsh Target	MCAS Cherry Point, NC	Atlantic
Marine Corps Air Station Cherry Point	MCAS Cherry Point, NC	Cherry Point
Auxiliary Landing Field Bogue	MCAS Cherry Point, NC	Bogue
Marine Corps Base (MCB) Camp Lejeune Oak Grove	MCB Camp Lejeune, NC	Pollocksville
MCB Camp Lejeune Morehead City NC	MCB Camp Lejeune, NC	Morehead City
Pamlico Point Target	MCB Cherry Point, NC	Bayboro
Maw Point Target	MCB Cherry Point, NC	Bayboro

According to data from the 2016 North Carolina Hurricane Evacuation Study (HES), within the current condition, the total permanent population potentially exposed to Category 5 MOM storm surge in the coastal counties within Planning Reach NC_01 is approximately 325,000. Within the planning reach, the counties with the largest numbers of exposed people are Craven (80,000 people), Carteret (57,000 people), Pasquotank (41,000 people), and Dare (31,000 people). The storm surge data also identify several counties that are extremely exposed to coastal storm surge due to their low-lying, flat topography even though population numbers may not be high. These counties have a high percentage of their population exposed to potential storm surge. The counties with the highest percentage of exposure to Category 5 MOM storm surge inundation per county population are Camden (100%), Hyde (100%), Pasquotank (100%), Tyrell (100%), Currituck (98%), Perquimans (96%), and Dare (89%). **Figure 4-24** through **Figure 4-27** display the Category 5 MOM storm surge exposure to the people of the counties in Planning Reach NC_01.

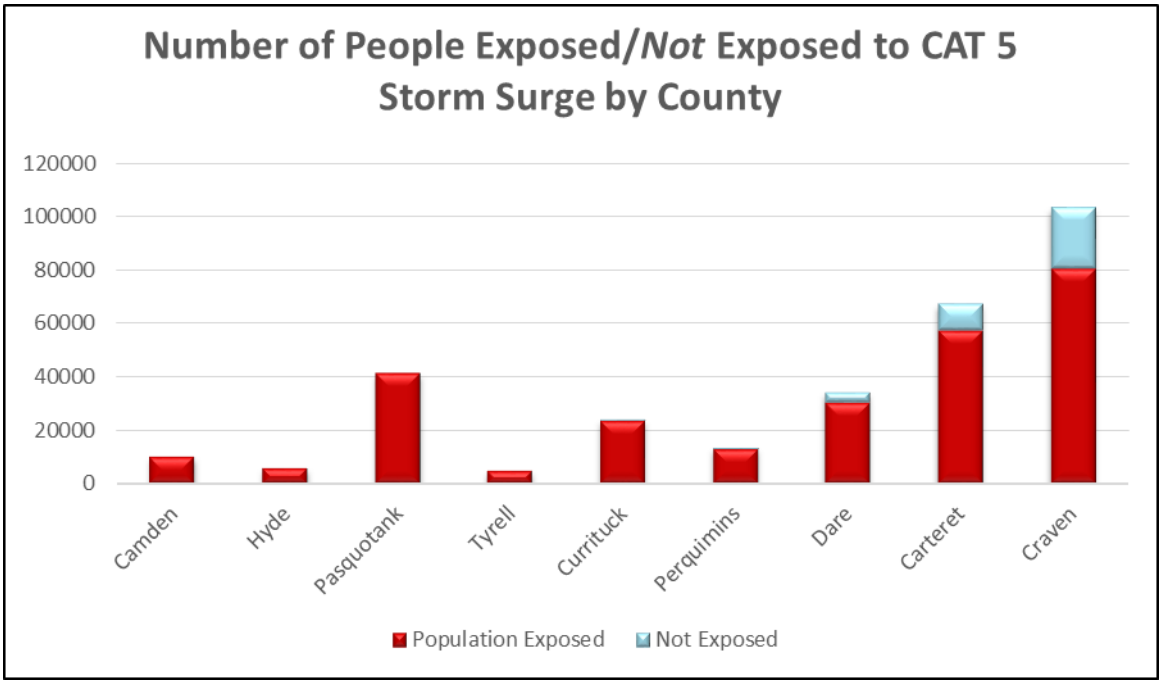


Figure 4-24: Number of People Exposed/Not Exposed to Category 5 Storm Surge by County (FEMA 2016)

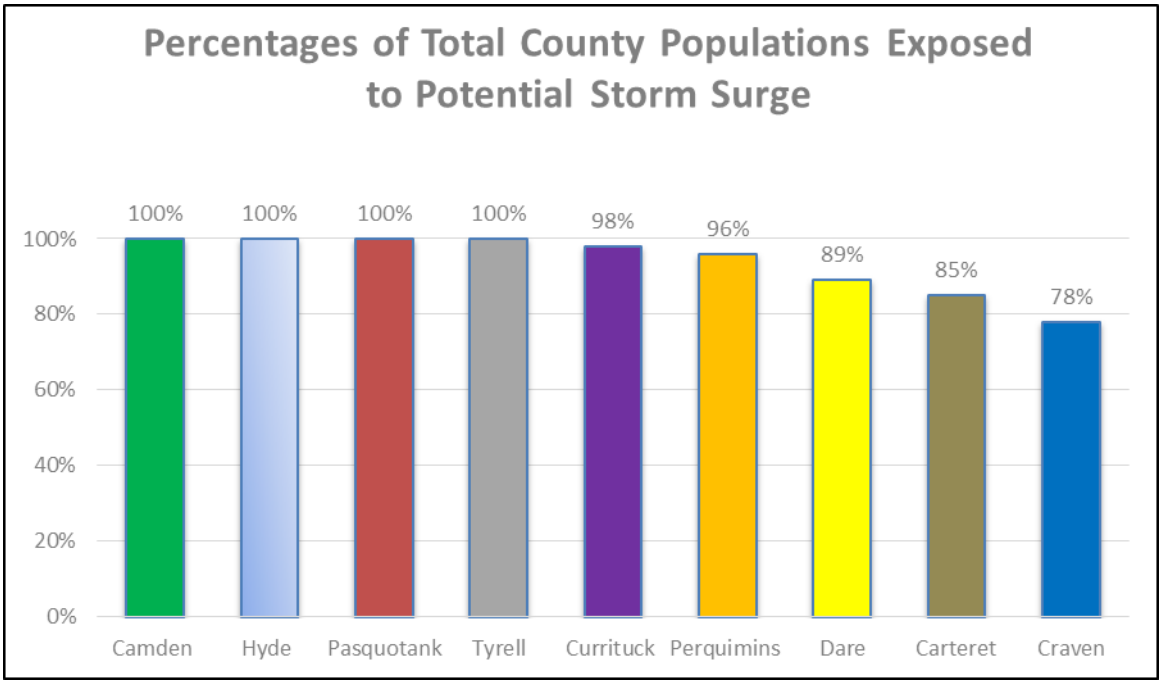


Figure 4-25: Percentages of Total County Populations Exposed to Potential Storm Surge (FEMA 2016)

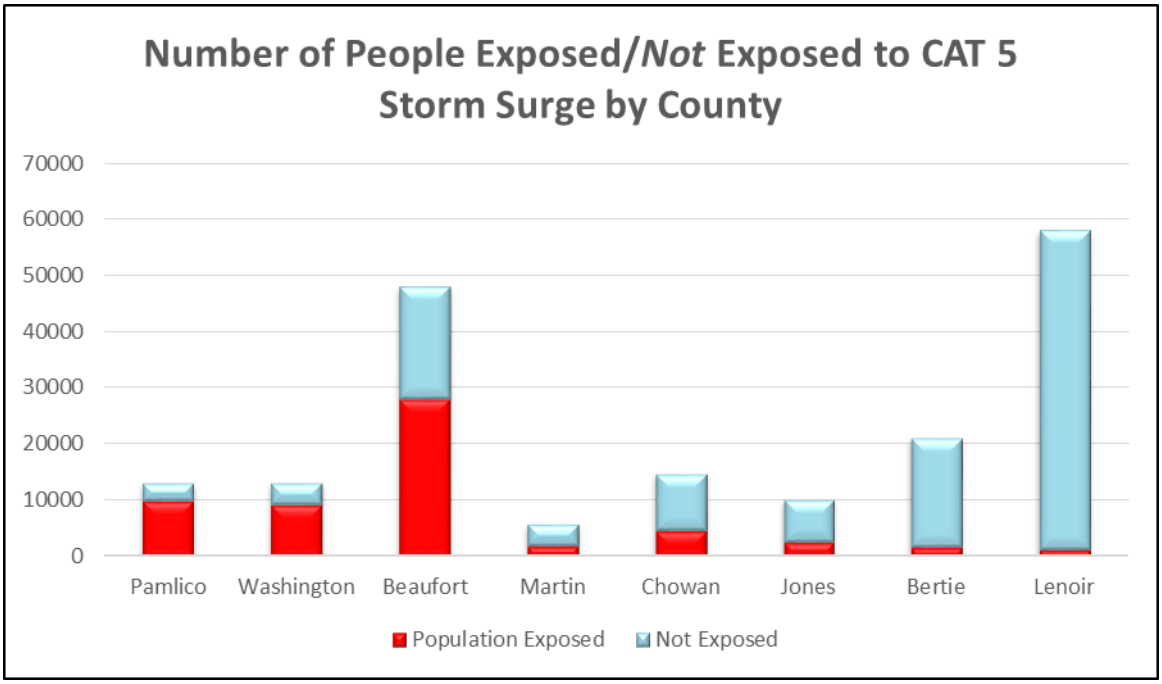


Figure 4-26: Number of People Exposed/Not Exposed to Category 5 Storm Surge by County (FEMA 2016)

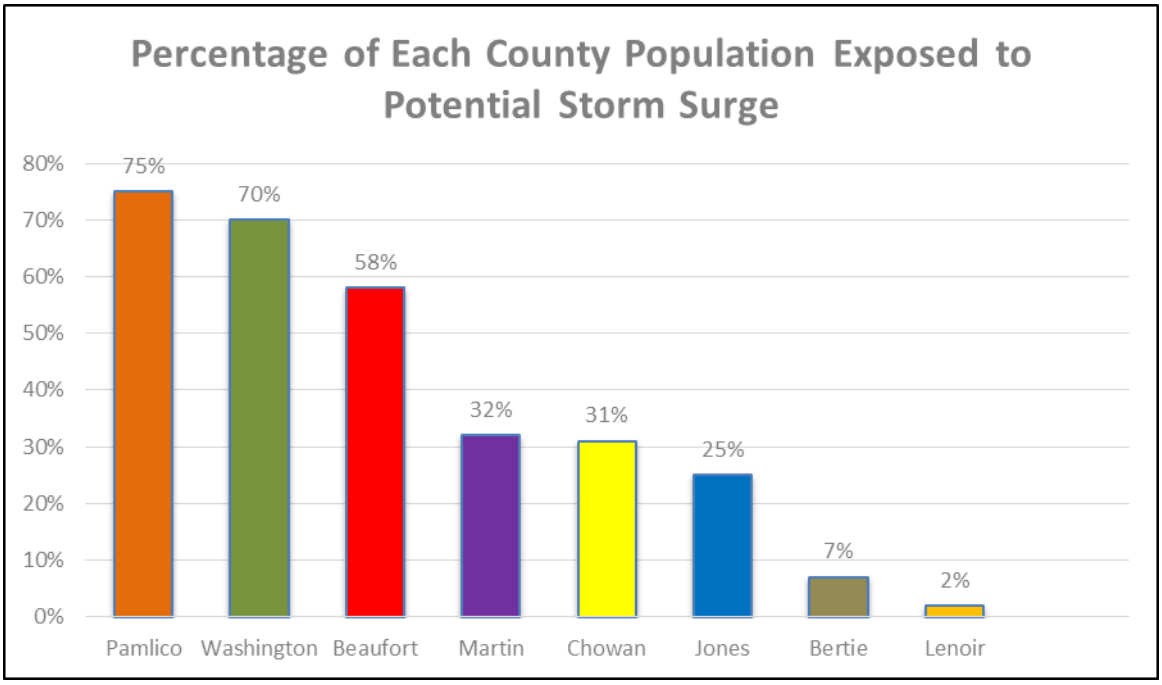


Figure 4-27: Percentages of Total County Populations Exposed to Potential Storm Surge (FEMA 2016)

Seasonal Population

The Tier 1 analysis, through census data, does not capture the maximum seasonal populations of many barrier island communities in North Carolina. For example, Tier 1 population in Dare County is approximately 35,000. However, the maximum seasonal population (May through September) during hurricane season is approximately 250,000, or seven times greater than the Tier 1 Risk Assessment indicates (Tippett 2015). Therefore, during hurricane season, the exposure to hazards in tourism-heavy areas is significantly greater than originally assessed in Tier 1.

Population Growth Trends

ICLUS data provides information regarding populations throughout the North Carolina study area, including small populations in riverbank and estuary communities of the Pamlico/Albemarle Estuarine system. Inner estuarine counties, such as Hyde and Pamlico County, are expected to see population decline through 2100. Washington and Perquimans County are expected to experience significant population declines, potentially nearing 50 percent in 2100. In addition to these areas, the counties of Beaufort, Martin, and Bertie are also projected to see population declines. **Figure 4-28** illustrates the ICLUS projected population growth data.

According to ICLUS projections, increases in infrastructure and development will occur across Pitt County, which is projected to experience population growth of nearly 74 percent by 2100. Under future condition with 3 feet of sea level rise, areas bordering the Tar River will be exposed to the 1-percent AEP flood hazard, as well as the 10-percent AEP flood hazard in some locations. Dare County will see an increase in population of nearly 50 percent by 2100, where most of the growth and development is expected to occur along the Outer Banks barrier island system. Carteret and Craven Counties are also projected to experience steady increases in population through 2100. As depicted in **Figure 4-29,** significant portions of these counties would be exposed to both the 1- and 10-percent AEP flood hazard under future sea level rise conditions. **Figure 4-29** illustrates ICLUS development projection data.

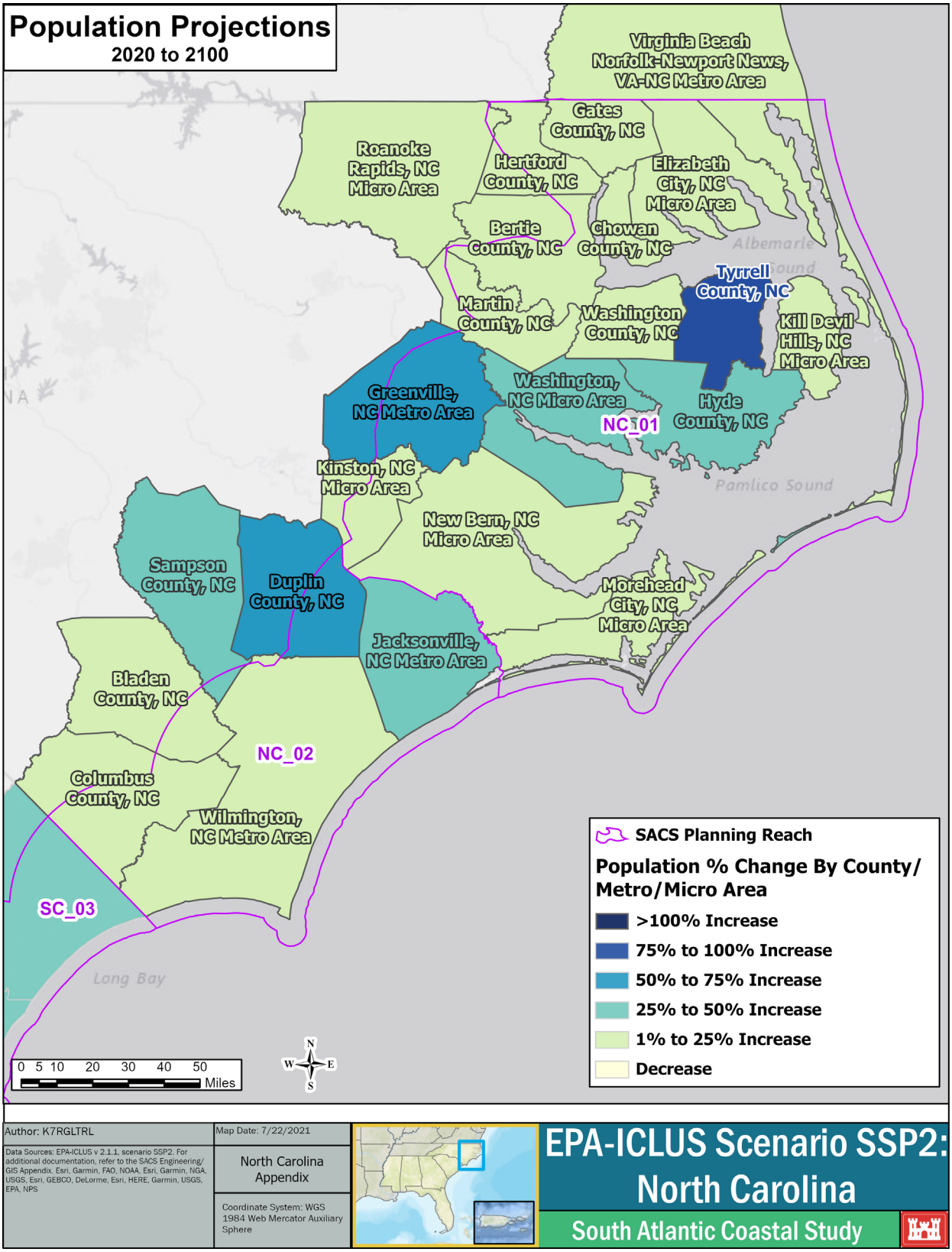


Figure 4-28: Population Change Projections in Coastal Counties, 2020–2100 (EPA 2009)

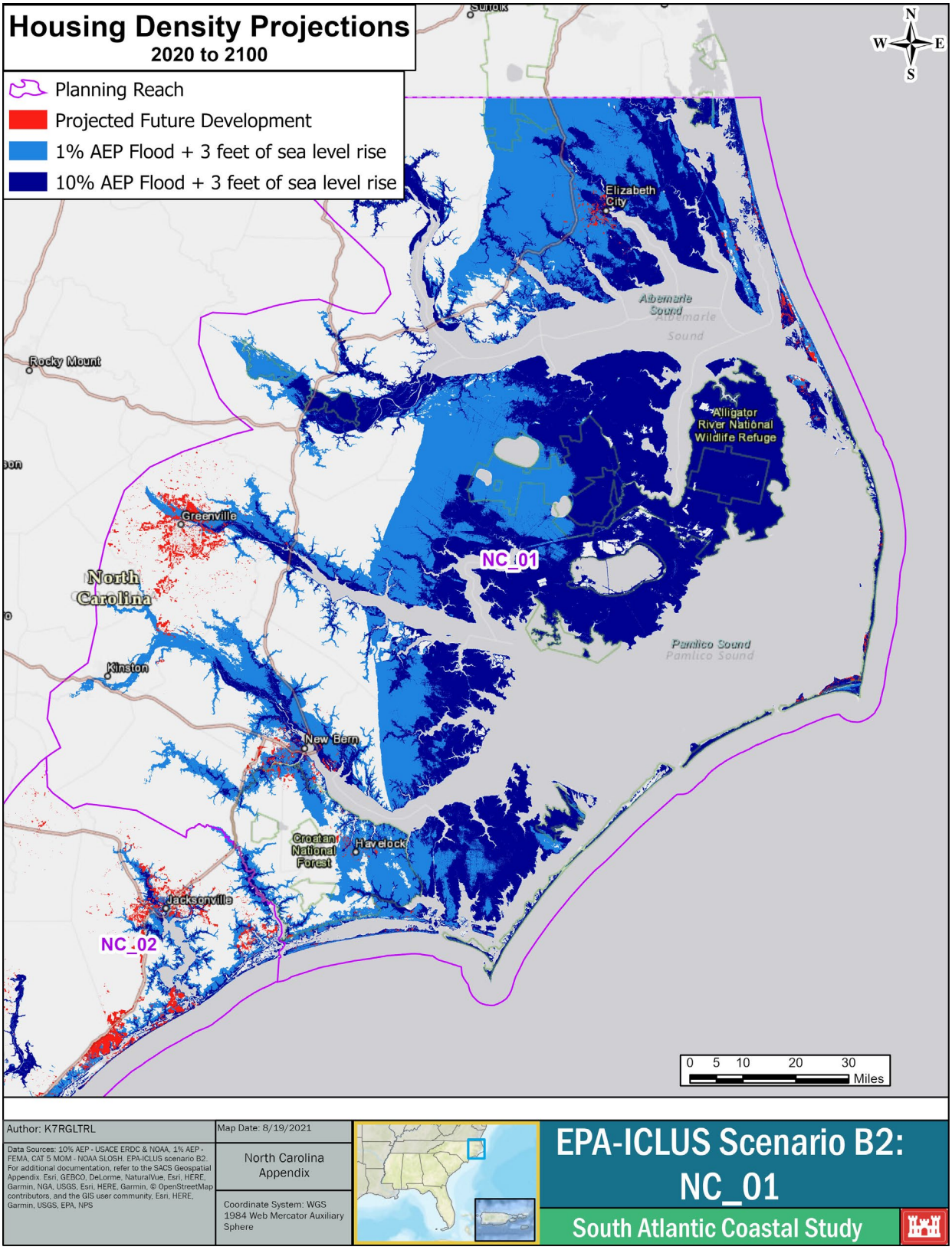


Figure 4-29: Tier 1 Inundation Hazards and Future Development Projections in Planning Reach NC_01 (EPA 2009)

Cultural Resources

GIS analysis of multiple data sets determined which cultural resources in Planning Reach NC_01 were exposed to coastal storm hazards, including those made available to the public by the National Park Service (2020) and the North Carolina State Historic Preservation Office (2020). Multiple historic sites and places are present in Planning Reach NC_01 and exposed to coastal hazards including coastal storm inundation, erosion, and wave attack.

Well-studied and documented examples of cultural resources within Planning Reach NC_01 include Fort Macon, the Beaufort Historic District, the Cape Lookout Light Station, Portsmouth Village, the Wright Brothers National Memorial, and the Ocracoke Historic District. Archaeological sites include, but are not limited to, prehistoric shell middens, ruins from early European settlements, and submerged shipwrecks in the ocean and near inlet complexes. For a complete inventory of identified exposed cultural resources of particular importance and their locations, please refer to the Cultural Resources of Importance in Planning Reach NC_01 Table (**Table 4-12**) and the Tier 1 and Tier 2 High-Risk Areas table (**Table 4-16**). Most all resources included in **Table 4-12** and **Table 4-16** are listed on the National Register of Historic Places and were identified through coordination with the North Carolina Office of State Archaeology/State Historic Preservation Office. Resources identified in **Table 4-12** and **Table 4-16** do not represent a complete list of all cultural resources within Planning Reach NC_01. A selection of exposed and potentially at-risk cultural resources is further described in each of North Carolina's three FAAS reports.

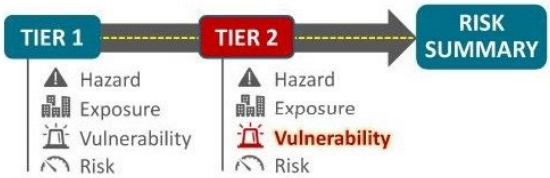
Programs presently underway to protect specific exposed cultural resources in Planning Reach NC_01 include efforts of the National Park Service at Cape Hatteras, which will actively address climate change-related protection options for exposed cultural examples along the Cape Hatteras and Cape Lookout National Seashores. Additionally, multiple historic preservation societies including the Outer Banks Conservationists, the Ocracoke Preservation Society, the Ocracoke Foundation, and the Whalehead Club have great interest in cultural resources preservation and protection. Furthermore, North Carolina Flood Insurance assists affected historic homeowners in protecting cultural resources and historic structures.

Environmental Resources

State resource agencies and local environmental stakeholder entities have provided additional information regarding environmental exposure analyses as compared to Tier 1, notably the North Carolina Natural Heritage Program through its data explorer webtool (NCNHP 2020) and North Carolina Forest Service via email communication.

In Planning Reach NC_01, specifically, barrier islands and the back bay forest and marsh habitats are particularly exposed to coastal storms and sea level rise. Additionally, inland fresh/brackish marsh and forest habitats offer high-value habitat to North Carolina's wild flora and fauna. These unique areas are home to numerous threatened and endangered and other high-value species, and the areas represent some of the most contiguous undeveloped habitat areas in the state. Additional habitat types within this reach experiencing exposure to coastal storm and sea level rise hazards are featured in Appendix A (Natural Area Exposure Tables) of the Environmental Technical Report (USACE 2022b).

4.2.2.3 Planning Reach NC_01 Tier 2 Vulnerability



An overview of the incorporation of vulnerability into the Tier 2 analysis is described in greater detail in the Overview (Section 4.1) of this Appendix.

The Tier 2 Economic Risk Assessment used FEMA's Hazus model to estimate damages to infrastructure. Hazus used damage functions to represent the vulnerability of different types of infrastructure to flood hazards and to estimate the impact of flooding.

Natural features were assessed in terms of vulnerability to hazards, including inundation (short-term and long-term), erosion/wave attack, and wind. Exposed resources considered vulnerable to hazards were then scored, with higher scores translating to increased vulnerability. The Environmental Technical Report associated natural community types as defined by the North Carolina Natural Heritage Program (NCNHP 2020, 2021) and North Carolina Wildlife Resources Commission (NCWRC 2021) with NOAA C-CAP classes (NOAA 2013). Association was accomplished through referencing reports such as the U.S. Fish and Wildlife Service's Planning Aid Report (2020), collaboration with environmental stakeholders, and best professional judgement, and it allowed for visualization of North Carolina's most vulnerable natural communities. Vulnerable environmental resources are shown in **Figure 4-30** and in the SACS Environmental Analysis Web-Mapping Tool.

Barrier islands are home to several of North Carolina's most vulnerable natural communities regarding sensitivity to coastal storm-related hazards (e.g., storm surge inundation, erosion, wave attack). More specifically, the most vulnerable natural communities in North Carolina are deciduous forests, estuarine forested wetlands, and unconsolidated shore (e.g., beaches and dunes). As an example of how vulnerability accounts for hazard susceptibility, unconsolidated shores are vulnerable to storm surge inundation in terms vegetation loss and erosion, to saltwater intrusion from sea level rise in terms of physical habitat area reduction, and to wind, erosion, and wave attack in terms of physical substrate (i.e., sand) movement. For additional information regarding environmental resources vulnerable to coastal storm and sea level rise hazards in North Carolina, please reference the Environmental Technical Report (USACE 2022b), specifically Appendix B (Vulnerability Tables).

Cultural resources vulnerabilities were based on qualitative assessment and consider the input of the North Carolina Office of State Archaeology and State Historic Preservation Office. **Table 4-12** displays exposed cultural resources of particular importance in Planning Reach NC_01 and their vulnerability to storm surge inundation, erosion, and wave attack hazards.

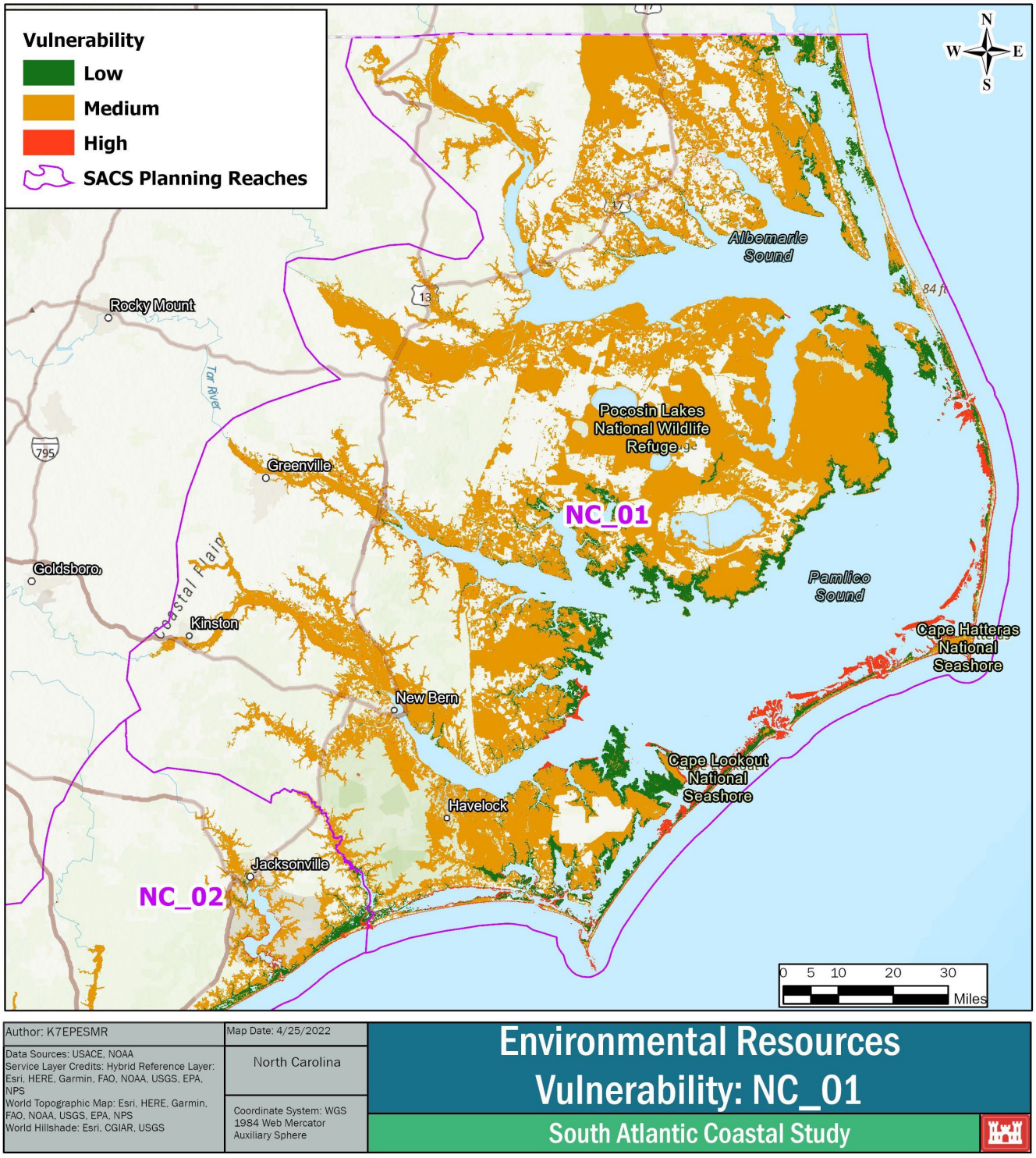


Figure 4-30: Environmental Vulnerability for Planning Reach NC_01

Table 4-12: Cultural Resources of Importance and Associated Vulnerability to Tier 2 Hazards – Planning Reach NC_01

Exposed Cultural Resources	Storm Surge Inundation	Erosion	Wave Attack
Bath Historic District (BF0002)	Y	Y	N
Fort Macon (CR0003)	Y	Y	Y
Beaufort Historic District (CR0001)	Y	Y	Y
Cape Lookout Light Station (CR0002)	Y	Y	N
Cape Lookout Village HD (CR0266)	Y	Y	Y
Portsmouth Village (CR0007)	Y	Y	Y
Edenton Historic District (CO0017)	Y	Y	N
Multiple Historic Districts in New Bern, NC	Y	Y	N
Clubfoot and Harlow Creek Canal (CR0565)	Y	Y	N
Currituck Beach Lightkeepers House (CK0001)	Y	N	N
Currituck Beach Lighthouse (CK0002)	Y	N	N
Whalehead Club (CK0005)	Y	N	N
Currituck County Courthouse and Jail (CK0096)	Y	N	N
Fort Raleigh National Historic Site (DR0008)	Y	Y	Y
Hatteras Weather Bureau Station (DR0009)	Y	N	N
Wright Brothers National Memorial (DR0014)	N	N	N
Wright Brothers National Memorial Visitor Center (DR0273)	N	N	N
First Colony Inn (DR0022)	Y	N	N
Mattie Midgett Store and House (DR0574)	Y	N	N
Nags Head Beach Cottage Row Historic District (DR0011)	Y	Y	Y
Bodie Island Lighthouse (DR0001)	Y	N	N
Oregon Inlet Coast Guard Station (DR0012) w/in Pea Island WLR	Y	Y	Y
Cape Hatteras Lighthouse (DR0004)	Y	N	N
Salvo Post Office (DR0023)	Y	N	N
Chicamacomico Life Saving Station (Rodanthe) (DR0006)	Y	N	N

Exposed Cultural Resources	Storm Surge Inundation	Erosion	Wave Attack
Ocracoke Historic District (HY0634)	Y	Y	Y
Ocracoke Light Station (HY0004)	Y	N	N
Hyde County Courthouse (HY0001)	Y	N	N
Lake Mattamuskeet Pump Station (HY0003)	Y	N	N

Social vulnerability refers to a community's capacity to prepare for and respond to the stress of hazardous events. The CDC SVI was used to evaluate social vulnerability within Planning Reaches NC_01 and NC_02 by assessing overall SVI percentile rankings at the census tract scale. The CDC uses 15 census-derived factors on a percentile index to create a generalized SVI at the census tract level. The SVI groups the 15 census-derived factors into four themes (socioeconomics, household composition/disability, minority/language, and housing/transportation) that summarize the extent to which the area is socially vulnerable to disaster. The 15 census-derived factors and their groupings are:

- Socioeconomic status (below poverty, unemployed, income, no high school diploma)
- Household composition and disability (aged 65 or older, aged 17 or younger, older than age 5 with a disability, single-parent households)
- Minority status and language (minority, speak English "less than well")
- Housing type and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters)

The CDC SVI was used to determine the vulnerability scores for counties within Planning Reach NC_01 presented in **Table 4-13**. Possible scores range from 0 (lowest vulnerability) to 1 (highest vulnerability).

Table 4-13: Social Vulnerability Indices by County and Theme (NC_01)

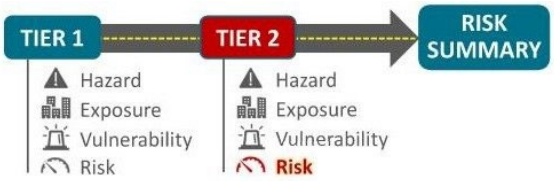
County	Theme				Social Vulnerability Index Score
	Socioeconomic	Household Composition/ Disability	Minority/ Language	Housing/ Transportation	
Beaufort	0.5657	0.7172	0.4545	0.3939	0.5454
Bertie	0.9495	0.7071	0.5657	0.5657	0.8788
Chowan	0.6970	0.7677	0.2525	0.5788	0.7071
Craven	0.3535	0.6162	0.7576	0.7172	0.6465

The overall CDC SVI ranking for Beaufort is 0.5454, which indicates moderate level of vulnerability within the county. Bertie County's SVI score is 0.8788, indicating a very high level of vulnerability and a more vulnerable population. Chowan County's overall CDC SVI ranking is 0.7071, indicating a high

level of vulnerability. Craven County's overall index of 0.6465 suggests a medium to medium-high social vulnerability. This analysis identifies areas with medium and relatively high social vulnerability within the Planning Reach of NC_01 in both coastal and inland areas.

4.2.2.4 Planning Reach NC_01 Tier 2 High-Risk Locations

Tier 2 high-risk locations were determined from data presented in the hazards, exposure, and vulnerability sections.



Hazus was used to identify locations of high risk to infrastructure damage. The Tier 2 Economic Risk Assessment Report provides additional detail on the methods used (USACE 2022d). The risk classification thresholds identified in **Table 4-14** were based on the Planning Reach NC_01 specific lower and upper bounds of the FEMA Hazus Flood Model-derived damages. The damage range was statistically classified into five classes (low, low-medium, medium, medium-high, and high) using the Jenks optimization method, also referred to as the Jenks natural breaks classification method. For Planning Reach NC_01, a high-risk location was defined as a census place with expected annual damages (EAD) above approximately $10,932,000, and a medium- high-risk location was defined as any location with EAD above approximately $5,530,000.

Table 4-14: Federal Emergency Management Agency Hazus Flood Model Risk Classification Thresholds for Planning Reach NC_02

Bin	Risk	Census Places		Census Blocks	
		Low Bound	Upper Bound	Low Bound	Upper Bound
NC	5–Low Risk	$0	$868,054	$0	$53,460
NC	4–Low-Med Risk	$868,055	$2,555,902	$53,461	$189,656
NC	3–Med Risk	$2,555,903	$5,529,913	$189,657	$449,380
NC	2–Med-High Risk	$5,529,914	$10,932,263	$449,381	$928,714
NC	1–High Risk	$10,932,264	$21,678,824	$928,715	$2,219,828

Table 4-15 displays the county distribution of locations identified with a risk rating of medium-high to high in the future conditions, considering 3 feet of sea level rise. Understanding the spatial distribution of economic risk from coastal floods under existing and future sea level rise conditions can help inform communities about which potential actions should be implemented to mitigate the potential economic risks.

Table 4-15: Tier 2 Economic Risk Assessment Medium, Medium-High, and High-Risk Locations Categorized by County

County	Census Place	Existing EAD	Existing Risk Rating	Future EAD	Future Risk Rating	Percent Increase in EAD in Future Condition
Beaufort	Belhaven	$3,638,000	Med	$8,974,000	Med-High	147%
Carteret	Morehead City	$5,602,000	Med-High	$15,671,000	High	180%
Carteret	Atlantic Beach	$4,172,000	Med	$10,403,000	Med-High	149%
Carteret	Beaufort	$2,729,000	Med	$10,343,000	Med-High	279%
Craven	Davis	$1,168,000	Low-Med	$3,266,000	Med	180%
Craven	New Bern	$4,935,000	Med	$15,032,000	High	205%
Dare	Fairfield Harbour	$3,939,000	Med	$11,733,000	High	198%
Dare	Kitty Hawk	$4,110,000	Med	$8,141,000	Med-High	98%
Dare	Hatteras	$3,398,000	Med	$8,348,000	Med-High	146%
Dare	Southern Shores	$2,848,000	Med	$7,658,000	Med-High	169%
Dare	Duck	$2,413,000	Low-Med	$8,563,000	Med-High	255%
Dare	Avon	$2,326,000	Low-Med	$8,187,000	Med-High	252%
Dare	Kill Devil Hills	$1,838,000	Low-Med	$6,766,000	Med-High	268%
Dare	Nags Head	$1,596,000	Low-Med	$6,126,000	Med-High	284%
Craven	Manteo	$4,247,000	Med	$10,788,000	Med-High	154%

Tier 2 Cultural Resources Risk Analysis

Based on a qualitative assessment, there are multiple historic sites in Planning Reach NC_01 at risk of damage or loss from coastal storm hazards and sea level rise. These resources are invaluable, and their loss would be an irreplaceable, tangible link to North Carolina and United States history. Especially in areas in which erosion is already degrading site quality, such as at Fort Raleigh on Manteo Island, resource loss may be expected to continue without intervention. Damage to historic properties can sometimes be repaired, but this can be costly and may lack support if more essential recovery efforts are needed in the area to restore infrastructure. Archaeological sites are non-renewable resources that cannot be replaced once lost. Loss of historic properties and archaeological sites not only means a loss to the historical record that helps us to understand and explain the past, but it can also mean a loss to local tourism. Visitors are drawn, in part, to this planning reach due to the many historic districts, lighthouses, and colonial historical sites. Damage caused by storms may result in the complete loss of all or portions of historic properties. Years of costly repairs can close these sites indefinitely until the site can be restored and are deemed safe for visitors. The loss of archaeological sites could pose a significant hit to the academic community as well, limiting research into and interpretation of prehistoric and historic sites in this reach.

Critical Erosion Risk Assessment

This study recognizes that there is significant erosion occurring in many back bay areas throughout Planning Reach NC_01. Rodanthe and Cape Lookout National Seashore were identified as being underrepresented risk areas for erosion. Rodanthe experiences erosion rates of four to 14 feet per year with the highest values near Rodanthe Beach and decreasing northward and southward. Nearly all of the Cape Lookout National Seashore is experiencing erosion, from Beaufort Inlet to Ocracoke Inlet. The oceanfront shoreline has been designated as potential low risk while the estuary side is designated potential medium risk. Shackelford Banks to Barden Inlet experiences erosion rates of two to 7 feet per year. The eastern coast of Cape Lookout experiences erosion rates of two to five feet per year while the western coast experiences two to 13 feet per year. Erosion rates on the eastern side of Cape Lookout National Seashore increase northward from five to 25 feet per year, and up to 43 feet per year at Drum Inlet. The opposite side of Drum Inlet at Ophelia Banks experiences erosion rates of 25 feet per year and decreases northward before exhibiting accretion at Old Drum Inlet. Additional follow-on analysis is needed to further define this hazard in the back bay (see Recommendations Section 7).

Figure 4-22 identifies CEAs on the oceanfront shoreline within Planning Reach NC_01. CEAs are elevated erosion rates (three feet per year or greater) and a greater presence of exposed resources, which would be threatened by the erosion hazard. All of the SACS-identified CEAs are located in Dare County and Ocracoke Island.

Tier 2 Environmental Resources Inundation Risk Analysis

Environmental risk is a product of exposure to coastal storm-related hazards and vulnerability to those hazards. Risk considers the ability of flora and fauna to endure the short- and long-term effects of coastal storms and the potential for habitat alteration. For example, lower elevation areas are more at risk to wave attack than are upland areas. Similarly, salt-intolerant habitats are more at risk to sea level rise than are salt-tolerant habitats. The risk areas in North Carolina were separated into categories of potential high, medium and low, as depicted in **Figure 4-31** and shown in the SACS Environmental Analysis Web-Mapping Tool.

Areas of unconsolidated shore are considered to be at high risk due to their low elevation, susceptibility to erosion, storm surge inundation, and wave attack, as well as their use by nesting shorebirds, sea turtles, unique flora, and other endangered species and species of concern. Similarly, palustrine wetlands are considered to be at moderate risk. These wetlands are typically located further inland than are consolidates shores and are physically further from hazard exposure, thus at lesser risk from coastal storm hazards. However, palustrine wetlands remain vulnerable to impacts of storm surge inundation (i.e., saltwater intolerance), wind damage, and erosion.

Priority Environmental Areas (PEAs) are natural areas or features at medium to high-risk to storm surge inundation and sea level rise. PEAs support priority biological resources (defined in the U.S. Fish and Wildlife Service SACS Planning Aid Report as federally listed threatened and endangered species, waterbird nesting colonies, breeding and wintering shorebirds, or other managed species) and are considered high priorities for others, including state and federal agencies and non-governmental organizations (for example, USFWS critical habitats or national wildlife refuges, Audubon Important Bird Areas, state heritage preserves and wildlife management areas, areas of national and state environmental significance, etc.) (USFWS 2020). These areas can be considered by stakeholders when

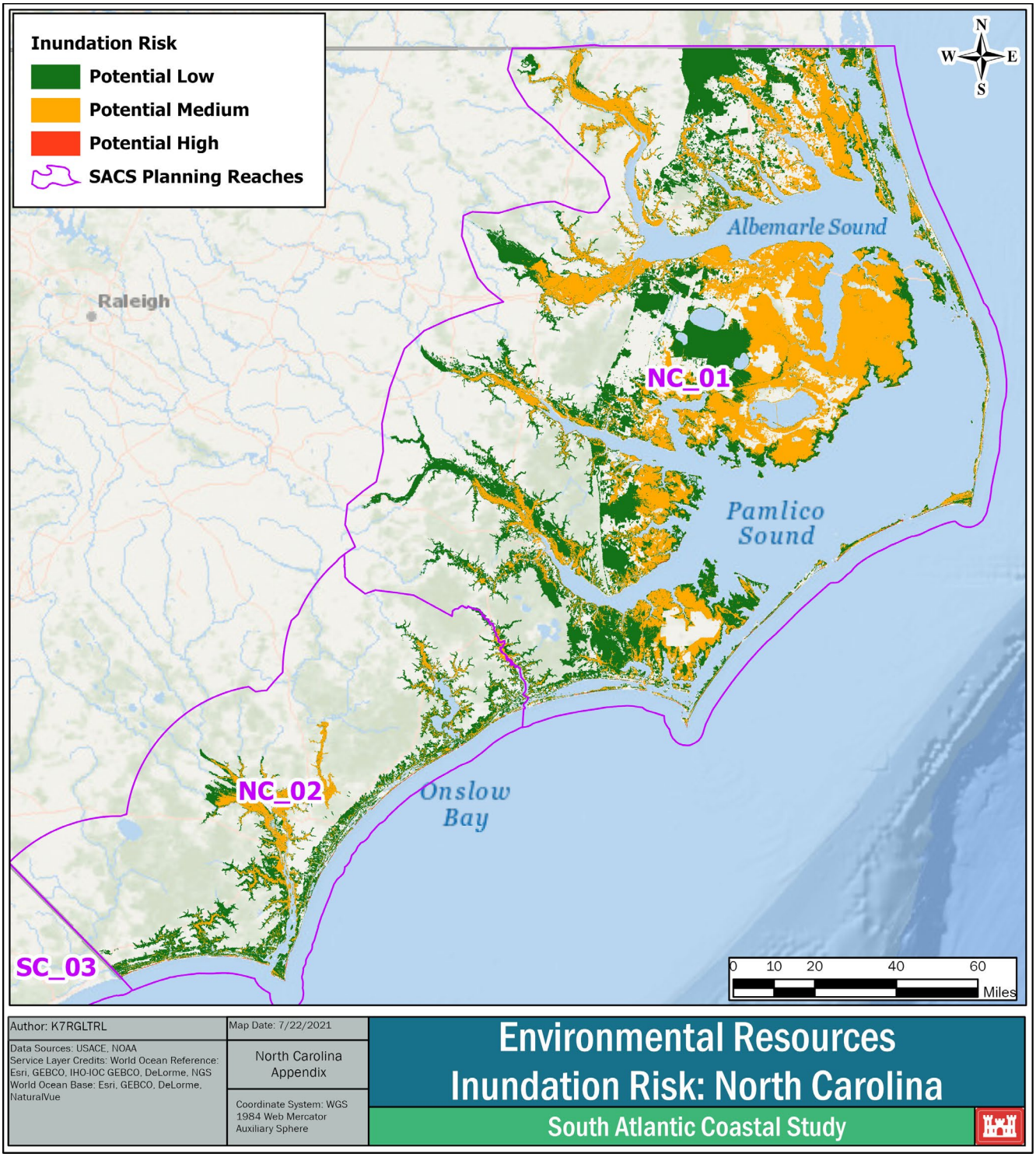


Figure 4-31: Tier 2 Environmental Resources Inundation Risk for Planning Reaches NC_01 and NC_02 (USACE 2022b)

looking for environmental resources to conserve and/or manage. Designation as a PEA by USACE does not create a special legal protection or status of the area and does not change how the area is regulated under federal and state laws.

PEAs found in Planning Reach NC_01 are shown in **Figure 4-32** and are listed below. All North Carolina PEAs are featured in Appendix C of the Environmental Technical Report (USACE 2022b), where selection criteria and consequences of exposure to coastal storms and sea level rise are summarized. A selection of PEAs is described further in each of North Carolina's three FAAS reports.

Priority Environmental Areas

- Alligator River National Wildlife Refuge
- Cape Lookout National Seashore
- Cape Hatteras National Seashore
- Cedar Island National Wildlife Refuge
- Croatan National Forest
- Currituck Banks / Corolla Natural Area
- Mattamuskeet National Wildlife Refuge
- Pea Island National Wildlife Refuge
- Pocosin Lakes National Wildlife Refuge
- Swanquarter National Wildlife Refuge
- Upper Broad Creek Natural Area

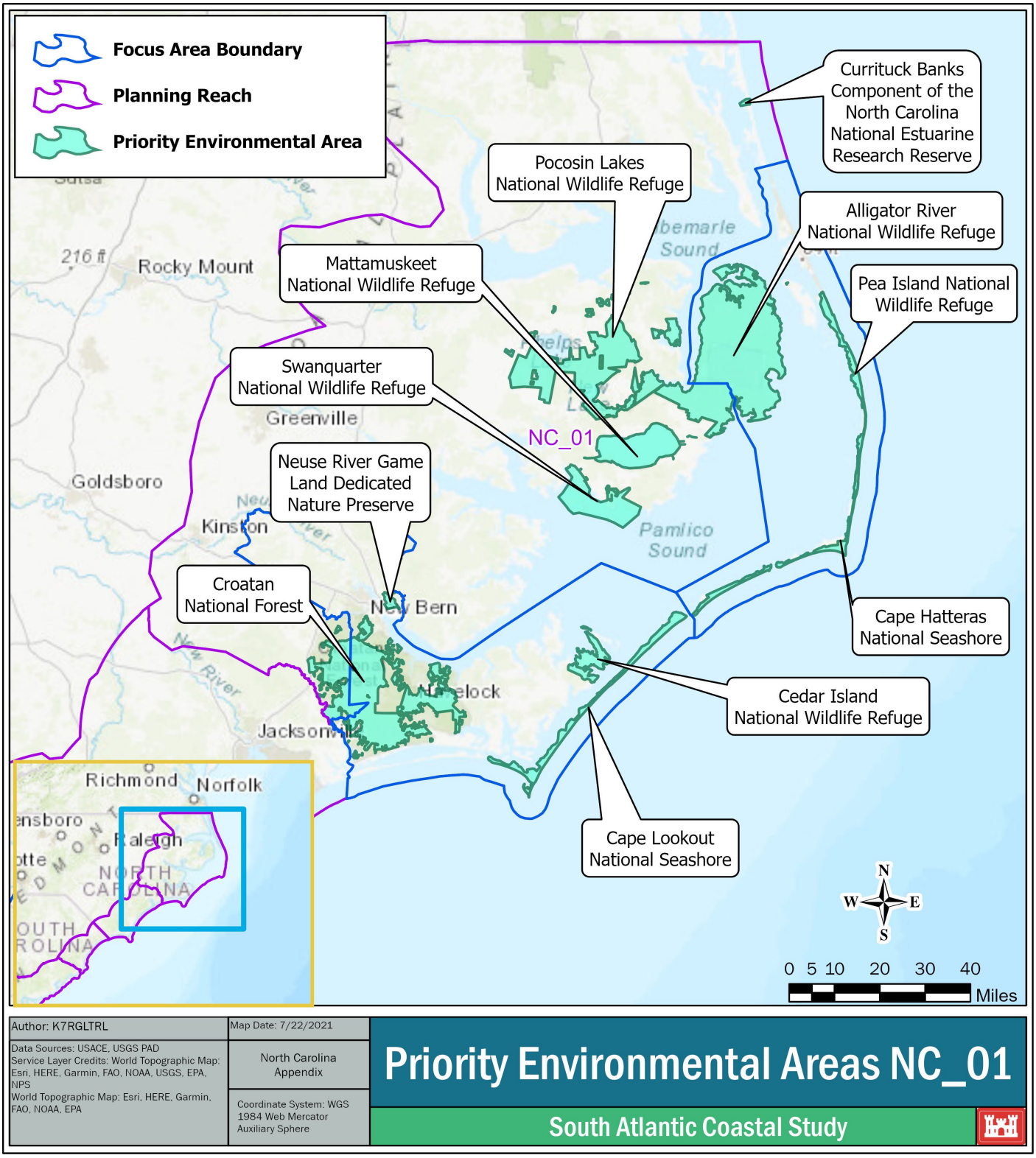
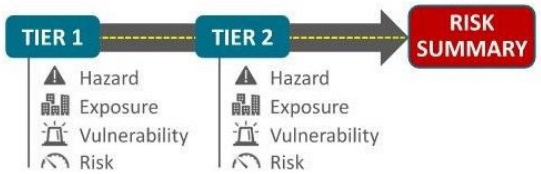


Figure 4-32: Priority Environmental Areas within Planning Reach NC_01

4.2.3 Planning Reach NC_01 Summary of High-Risk Locations

Additional high-risk areas in Planning Reach NC_01 were determined by census place and through a set of specific screening criteria. To be considered high risk, a location would need to meet one of the following criteria:



9. Medium-high to high-risk in the Tier 1 Risk Assessment
10. Medium-high to high-risk in Hazus inundation damage rating
11. Meet SACS CEA threshold for North Carolina (see Erosion Section 4.1.4.3 for details)
12. Seasonal population (assumed for all shorefront communities based on comparative data)
13. PEA or cultural resource identified with significant risk

Although other risks were identified for Planning Reach NC_01, the aforementioned risks were considered the significant factors for determining higher risk to population and infrastructure and environmental, cultural, and habitat resources.

High-risk areas for Planning Reach NC_01 for both Tier 1 and Tier 2 are shown in **Table 4-16**.

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Table 4-16: Planning Reach NC_01 Tier 1 and Tier 2 High-Risk Areas

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Beaufort	Belhaven	X	X	$3,638,000	Med	$8,974,000	Med-High								4
Beaufort	River Road	X	X	$1,948,000	Low-Med	$5,035,000	Med								3
Beaufort	Washington	X	X	$1,145,000	Low-Med	$5,709,000	Med-High								3
Beaufort	Washington Park	X	X	$193,000	Low	$587,000	Low								2
Beaufort	Bath			$134,000	Low	$324,000	Low				X	Bath Historic District (BF0002)			1
Bertie	Windsor	X	X	$187,000	Low	$550,000	Low								2
Carteret	Morehead City	X	X	$5,602,000	Med-High	$15,671,000	High								4
Carteret	Atlantic Beach	X	X	$4,172,000	Med	$10,403,000	Med-High			X					5
Carteret	none (closest community is Atlantic Beach census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Fort Macon (CR0003)			1
Carteret	Beaufort	X	X	$2,729,000	Med	$10,343,000	Med-High				X	Beaufort Historic District (CR0001)			5
Carteret	none (closest census place communities are Beaufort, Harkers Island, Marshallberg, Davis, and Portsmouth. closest non-census place communities are Lenoxville, Stacy, Sealevel, and Lola.)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Cape Lookout National Seashore	1

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Carteret	none (closest non-census place communities are Cedar Island, Godwin Hills, Roe, and Lola.)												X	Cedar Island National Wildlife Refuge	1
Carteret	Marshallberg			$1,211,000	Low-Med	$2,610,000	Med								1
Carteret	Davis			$1,168,000	Low-Med	$3,266,000	Med								1
Carteret	Emerald Isle	X	X	$1,164,000	Low-Med	$4,261,000	Med			X					4
Carteret	Cedar Point	X	X	$954,000	Low-Med	$2,153,000	Low-Med						X	Cedar Island National Wildlife Refuge	3
Carteret	Harkers Island	X	X	$903,000	Low-Med	$2,248,000	Low-Med								2
Carteret	none (closest community is Harkers Island census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Cape Lookout Light Station (CR0002), Cape Lookout Village HD (CR0266)			1
Carteret	Pine Knoll Shores	X	X	$730,000	Low	$2,846,000	Med			X					4
Carteret	Gloucester			$673,000	Low	$2,982,000	Med								1
Carteret	Broad Creek	X	X	$554,000	Low	$1,330,000	Low-Med						X	Croatan National Forest	3
Carteret	Cape Carteret	X	X	$513,000	Low	$1,392,000	Low-Med						X	Croatan National Forest	3
Carteret	Newport	X	X	$297,000	Low	$851,000	Low						X	Croatan National Forest	3
Carteret	Atlantic	X	X	$247,000	Low	$995,000	Low-Med								2
Carteret	Peletier		X	$103,000	Low	$257,000	Low						X	Croatan National Forest	2

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Carteret	Bogue			$28,000	Low	$181,000	Low						X	Croatan National Forest	1
Carteret	Stella (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Carteret	Holly Springs (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Carteret	Ocean (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Carteret	Union Point (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Carteret	Wildwood (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Carteret	none (closest community is Ocracoke census place [Hyde County])	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Portsmouth Village (CR0007)			1
Chowan	Edenton			$205,000	Low	$753,000	Low				X	Edenton Historic District (CO0017)			1
Craven	New Bern	X	X	$4,935,000	Med	$15,032,000	High				X	Multiple National Register Historic Districts	X	Croatan National Forest	6
Craven	Fairfield Harbor			$3,939,000	Med	$11,733,000	High						X	Upper Broad Creek Natural Area	3
Craven	River Bend	X	X	$1,303,000	Low-Med	$3,779,000	Med								3
Craven	Brices Creek			$846,000	Low	$1,864,000	Low-Med						X	Croatan National Forest	1
Craven	Trent Woods	X	X	$610,000	Low	$2,013,000	Low-Med								2
Craven	Havelock	X	X	$489,000	Low	$1,138,000	Low-Med						X	Croatan National Forest	3

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Craven	James City	X	X	$363,000	Low	$1,360,000	Low-Med								2
Craven	Neuse Forest			$69,000	Low	$194,000	Low						X	Croatan National Forest	1
Craven	Vanceboro	X	X	$12,000	Low	$65,000	Low								2
Craven	Harlowe (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Clubfoot & Harlow Creek Canal (CR0565)	X	Croatan National Forest	2
Craven	North Harlowe (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Blades (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Riverdale (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Pine Grove (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Slocum Village (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Havelock Station (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Hancock Village (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Craven	Cherry Point (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Croatan National Forest	1
Currituck	Coinjock	X	X	$146,000	Low	$607,000	Low								2

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Currituck	Corolla (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Currituck Beach Lightkeepers House (CK0001), Currituck Beach Lighthouse (CK0002), Currituck Beach Lighthouse Complex (CK0106), Whalehead Club (CK0005	X	Currituck Banks / Corolla Natural Area	2
Currituck	Sligo (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Currituck County Courthouse and Jail (CK0096)			1
Dare	Kitty Hawk	X	X	$4,110,000	Med	$8,141,000	Med-High		X	X					6
Dare	Hatteras	X	X	$3,398,000	Med	$8,348,000	Med-High		X	X	X	Hatteras Weather Bureau Station (DR0009)	X	Cape Hatteras National Seashore	8
Dare	Southern Shores	X	X	$2,848,000	Med	$7,658,000	Med-High			X					5
Dare	Wanchese	X	X	$2,485,000	Low-Med	$7,005,000	Med-High								3
Dare	Duck		X	$2,413,000	Low-Med	$8,563,000	Med-High			X					3
Dare	Avon	X	X	$2,326,000	Low-Med	$8,187,000	Med-High		X	X			X	Cape Hatteras National Seashore	6
Dare	Kill Devil Hills	X	X	$1,838,000	Low-Med	$6,766,000	Med-High		X	X	X	Wright Brothers National Memorial (DR0014), *Wright Brothers National Memorial Visitor Center (DR0273)*			6
Dare	Frisco	X	X	$1,784,000	Low-Med	$5,512,000	Med			X			X	Cape Hatteras National Seashore	5

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Dare	Nags Head	X	X	$1,596,000	Low-Med	$6,126,000	Med-High		X	X	X	First Colony Inn (DR0022), Mattie Midgett Store and House (DR0574), Nags Head Beach Cottage Row Historic District (DR0011)	X	Cape Hatteras National Seashore	7
Dare	none (closest community is Nags Head census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Bodie Island Lighthouse (DR0001), Oregon Inlet Coast Guard Station (DR0012) w/in Pea Island WLR			1
Dare	Buxton	X	X	$1,368,000	Low-Med	$3,861,000	Med		X	X			X	Cape Hatteras National Seashore	6
Dare	none (directly abuts Buxton census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	*Cape Hatteras Lighthouse (DR0004)*			1
Dare	Salvo	X	X	$976,000	Low-Med	$1,837,000	Low-Med			X	X	Salvo Post Office (DR0023)	X	Cape Hatteras National Seashore	5
Dare	Manns Harbor			$938,000	Low-Med	$2,406,000	Low-Med						X	Alligator River National Wildlife Refuge	1
Dare	Mashoes (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Alligator River National Wildlife Refuge	1
Dare	East Lake (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Alligator River National Wildlife Refuge	1
Dare	Buffalo City (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Alligator River National Wildlife Refuge	1

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Dare	Stumpy Point (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Alligator River National Wildlife Refuge	1
Dare	Waves	X	X	$654,000	Low	$1,448,000	Low-Med		X	X			X	Cape Hatteras National Seashore	5
Dare	Rodanthe	X	X	$120,000	Low	$544,000	Low		X	X	X	Chicamacomico Life Saving Station (Rodanthe) (DR0006)	X	Cape Hatteras National Seashore	6
Dare	none (directly abuts Rodanthe census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pea Island National Wildlife Refuge	1
Hyde	Ocracoke	X	X	$1,542,000	Low-Med	$4,475,000	Med		X	X	X	Ocracoke Historic District (HY0634), Ocracoke Light Station (HY0004)	X	Cape Hatteras National Seashore	7
Hyde	Engelhard			$1,362,000	Low-Med	$3,256,000	Med								1
Hyde	none (closest community is Engelhard census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Alligator River National Wildlife Refuge	1
Hyde	Swindell Fork (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1
Hyde	Hydeland (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1
Hyde	New Holland (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1
Hyde	Gull Rock (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	(Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
Hyde	Lake Landing (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1
Hyde	Rose Bay (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Mattamuskeet National Wildlife Refuge	1
Hyde	Swan Quarter			$714,000	Low	$2,052,000	Low-Med				X	Hyde County Courthouse (HY0001)	X	Swanquarter National Wildlife Refuge	2
Hyde	none (closest community is Swan Quarter census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Lake Mattamuskeet Pump Station (HY0003)			1
Hyde	Fairfield			$651,000	Low	$1,390,000	Low-Med						X	Mattamuskeet National Wildlife Refuge	1
Martin	Jamesville	X	X	$45,000	Low	$109,000	Low								2
Pamlico	Oriental			$926,000	Low-Med	$4,584,000	Med								1
Pamlico	Hobucken	X	X	$562,000	Low	$2,356,000	Low-Med								2
Pamlico	Mesic	X	X	$488,000	Low	$1,508,000	Low-Med								2
Pamlico	Bayboro	X	X	$160,000	Low	$713,000	Low								2
Perquimans	Hertford	X	X	$90,000	Low	$284,000	Low								2
Pitt	Greenville		X	$10,000	Low	$116,000	Low								1
Tyrrell	Columbia			$762,000	Low	$2,931,000	Med						X	Pocosin Lakes National Wildlife Refuge	2
Tyrrell	Travis (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1
Tyrrell	Woodley (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1

Planning Reach NC_01		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long-term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as Area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as Area with PEA or Resource At-Risk	Environmental Resource Name	
Tyrrell	Cross Landing (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1
Tyrrell	Gum Neck (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1
Tyrrell	Kilkenny (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1
Washington	Plymouth	X	X	$467,000	Low	$1,190,000	Low-Med								2
Washington	Roper		X	$4,000	Low	$38,000	Low								1
Washington	Creswell		X	$0	Low	$211,000	Low								1
Washington	Cherry (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Pocosin Lakes National Wildlife Refuge	1
Pasquotank	Elizabeth City	X	X	$868,000	Low	$7,020,000	Med-High								3
Carteret	Indian Beach	X	X	$353,000	Low	$1,246,000	Low-Med			X					3
Craven	Manteo	X	X	$4,247,000	Med	$10,788,000	Med-High								4

[1]Assumptions based on data from 8 beach communities across study area, assumes applicability to all barrier island communities. Study acknowledged there are likely other locations where increased seasonal population also exists.

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4.3 Planning Reach NC_02 Risk Assessment

4.3.1 Planning Reach NC_02 Tier 1

Planning Reach NC_02 is located in the southern half of the state and encompasses all or a portion of each of the following counties: Bladen, Brunswick, Columbus, Duplin, New Hanover, Onslow, Pender, and Sampson. A map is located in Section 3.2 of this appendix.

4.3.1.1 Planning Reach NC_02 Tier 1 Hazard

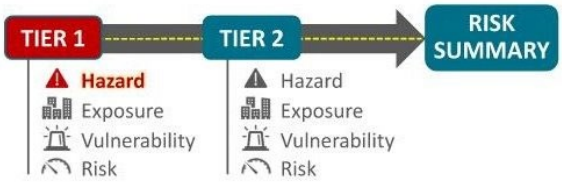


Figure 4-33 displays existing and future flood hazards for Planning Reach NC_02. The 10-percent AEP water level (inundation) has a significant impact in the back bay areas of the barrier islands and many of the back bay mainland areas throughout the reach. This impact increases significantly throughout the reach in the future scenario, with 3 feet of sea level rise.

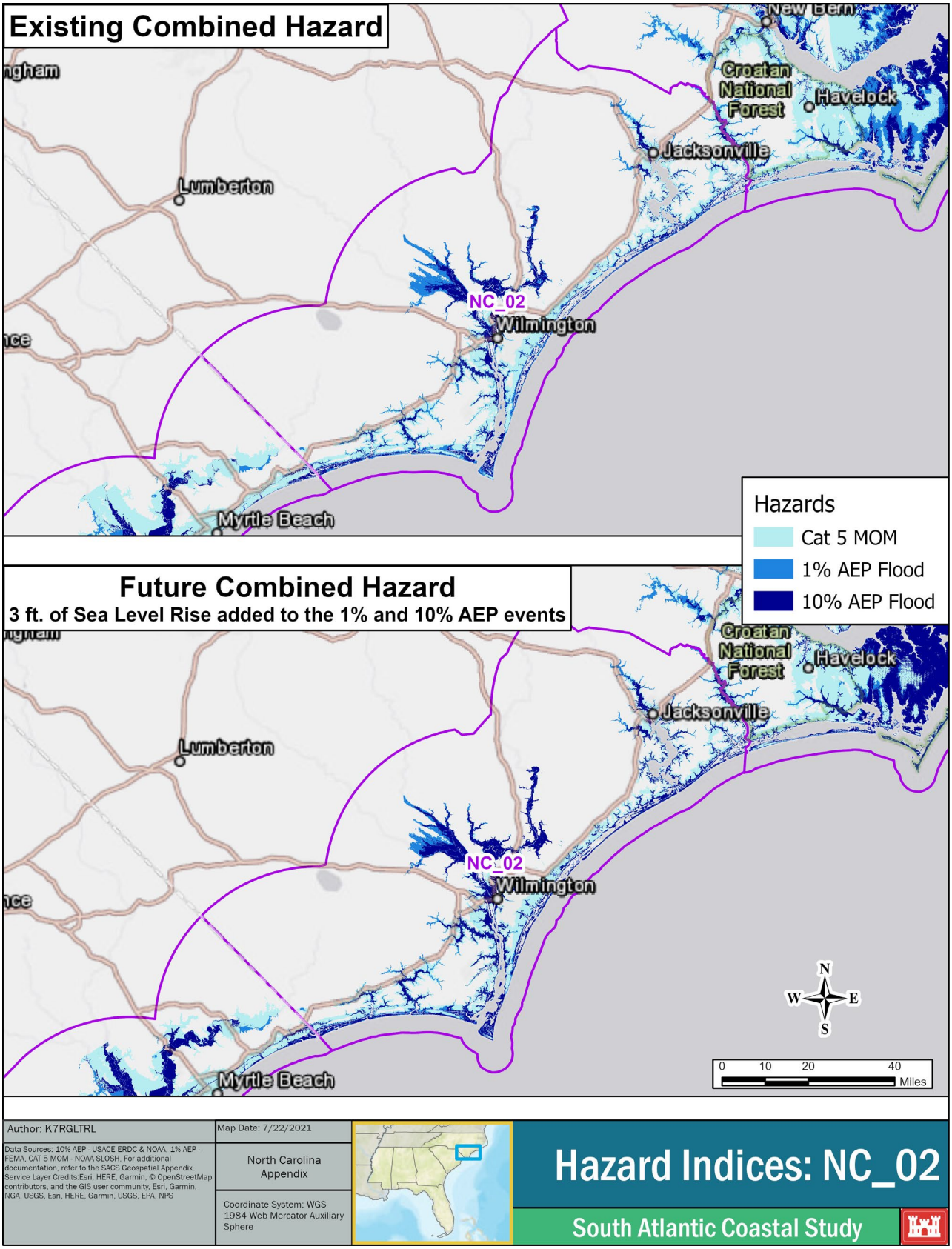
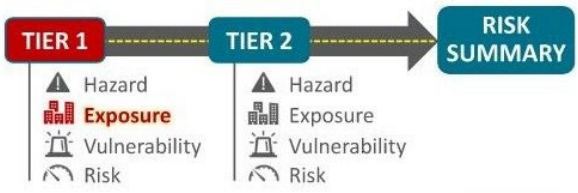


Figure 4-33: Existing and Future Flood Hazards for Planning Reach NC_02

4.3.1.2 Planning Reach NC_02 Tier 1 Exposure

Figure 4-34 displays Population and Infrastructure; Environmental and Cultural Resource; and Social Vulnerability Exposure Indices.



Population and Infrastructure

The Tier 1 Population and Infrastructure Exposure Index shows two areas with a high density of exposed population and infrastructure within Planning Reach NC_02. High density is represented in **Figure 4-34** with amber and red colors. These areas are:

- **The Jacksonville area within Onslow County**: The Jacksonville area is urbanized with a population of 80,000. Infrastructure includes wastewater treatment plants, schools, military installations, nursing homes, bridges, law enforcement, fire stations, EMS, substations, college, and hurricane evacuation routes.
- **The Wilmington area located within New Hanover County**: With a population of 128,000, the Wilmington area's infrastructure includes wastewater treatment plants, urgent care facilities, receiving hospitals, railroad bridges, public schools, college and university, port facilities, nursing homes, shelter, law enforcement, fire stations, hurricane evacuation route, local EOC, and substations.

Environmental and Cultural Resources

The Tier 1 Environmental and Cultural Resources Exposure Index shows seven areas with a high density of exposed environmental and cultural resources within Planning Reach NC_02. These areas are:

- Back bay areas along Topsail Island in Onslow County: Topsail Beach, Hammocks Beach.
  - Environmental Resources: SAV, migratory bird habitat, and coastal marsh habitat.
- Back bay areas in central Wrightsville Beach in New Hanover County: Gabriel's Landing.
  - Environmental Resources: SAV, migratory bird habitat, and coastal marsh habitat.
- Masonboro Island in New Hanover County:
  - Environmental Resources: Piping plover and loggerhead critical habitat, coastal marsh and maritime forest habitat, shorebird nesting habitat. Onslow Bay, and Masonboro Sound Historic District.
- Fort Fisher State Recreation Area in New Hanover County: Zeke's Island Estuarine Reserve and Fort Fisher State Historic Site.
- Alligator Creek and USS NC Battleship Memorial Area in Brunswick County
  - Environmental Resources: Coastal marsh habitat

- Orton Plantation and Old Brunswick Town in Brunswick County:
  - Environmental Resources: Red cockaded woodpeckers and Venus flytrap habitat.
- Battery Island, off of Southport's coast:
  - Environmental Resources: Wading bird habitat

Social Vulnerability

The Tier 1 Social Vulnerability Exposure Index shows extensive areas with a high density of social vulnerability within Planning Reach NC_02. These areas are on the mainland (i.e., not barrier island communities) and tend to increase farther inland in the SACS study area.

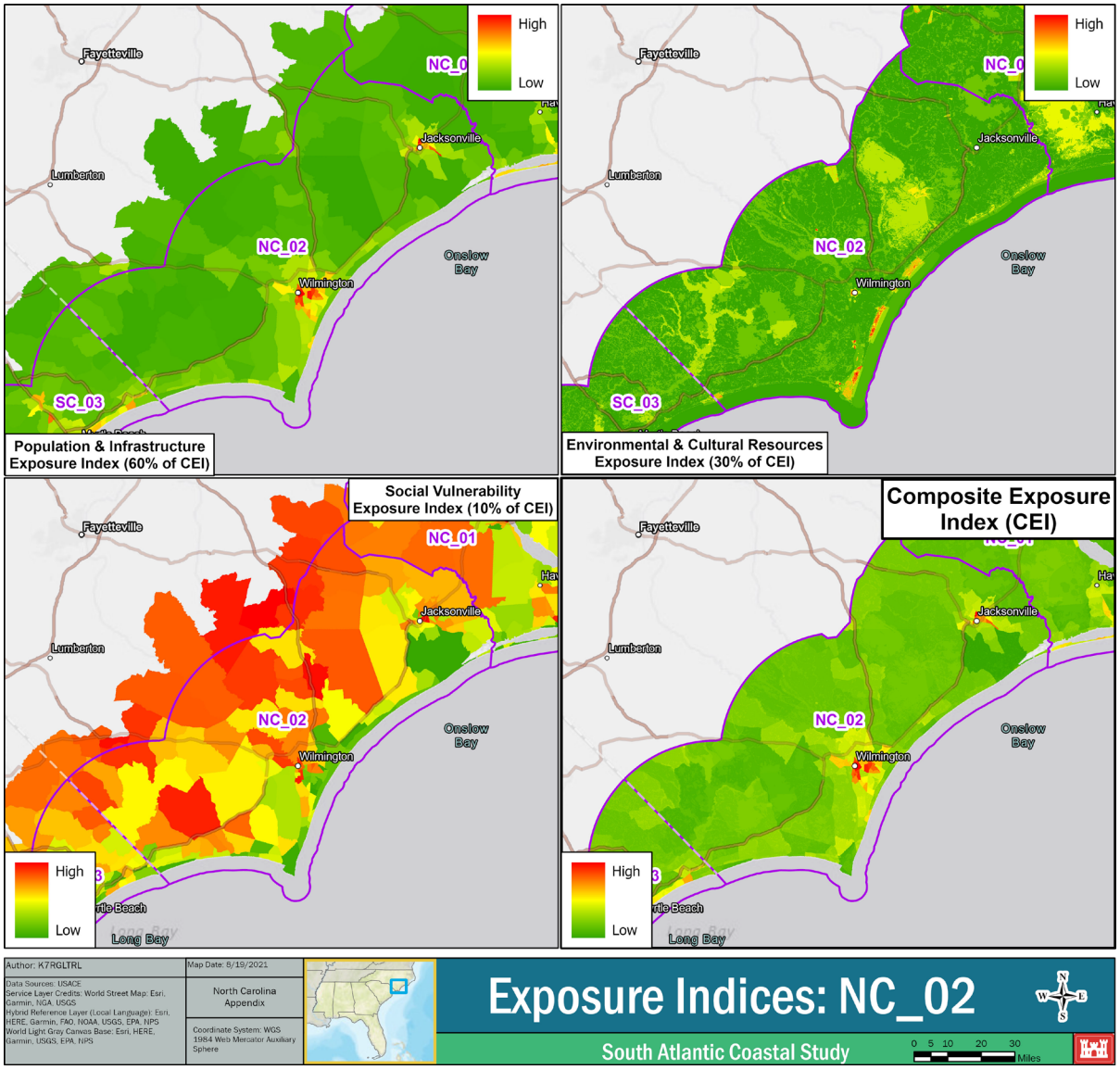
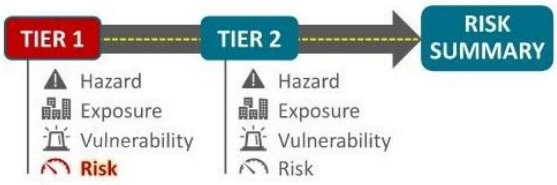


Figure 4-34: Tier 1 Exposure for Planning Reach NC_02

4.3.1.3 Planning Reach NC_02 Tier 1 Vulnerability

Vulnerability was incorporated into Tier 1 as described in Section 4.1.

4.3.1.4 Planning Reach NC_02 Tier 1 High-Risk Locations



The Composite Exposure Index and coastal flood inundation hazards were used to identify potential areas at risk. Risk is a function of exposure and probability of hazard occurrence. The Engineering Appendix describes how each of the inundation hazards (Category 5 MOM 1-percent AEP flood event, 10-percent AEP flood event) and sea level rise were combined with the Composite Exposure Index to generate potential risk data presented in the Tier 1 Risk Assessment. **Figure 4-35** displays existing and future potential risk for Planning Reach NC_02. Tier 1 high-risk locations are those where potential medium-high (amber) and high (red) composite risk exists. U.S. Census Bureau "census places" were used to define the boundaries of high-risk locations. Medium-high and/or high composite risk census places were defined as at least 50 acres and 0.5 percent of the total area of a census place designated as high-risk.

The Tier 1 Risk Assessment identified multiple composite high-risk areas in North Carolina. The majority of the areas with the highest composite risk within Planning Reach NC_02 are located within New Hanover County (**Figure 4-36**), with the greater density of population and infrastructure impacting the risk level. Tier 1 also indicates that potential risk increases significantly with sea level rise in Riegelwood, Varnamtown, and Bayshore (**Figure 4-37**).

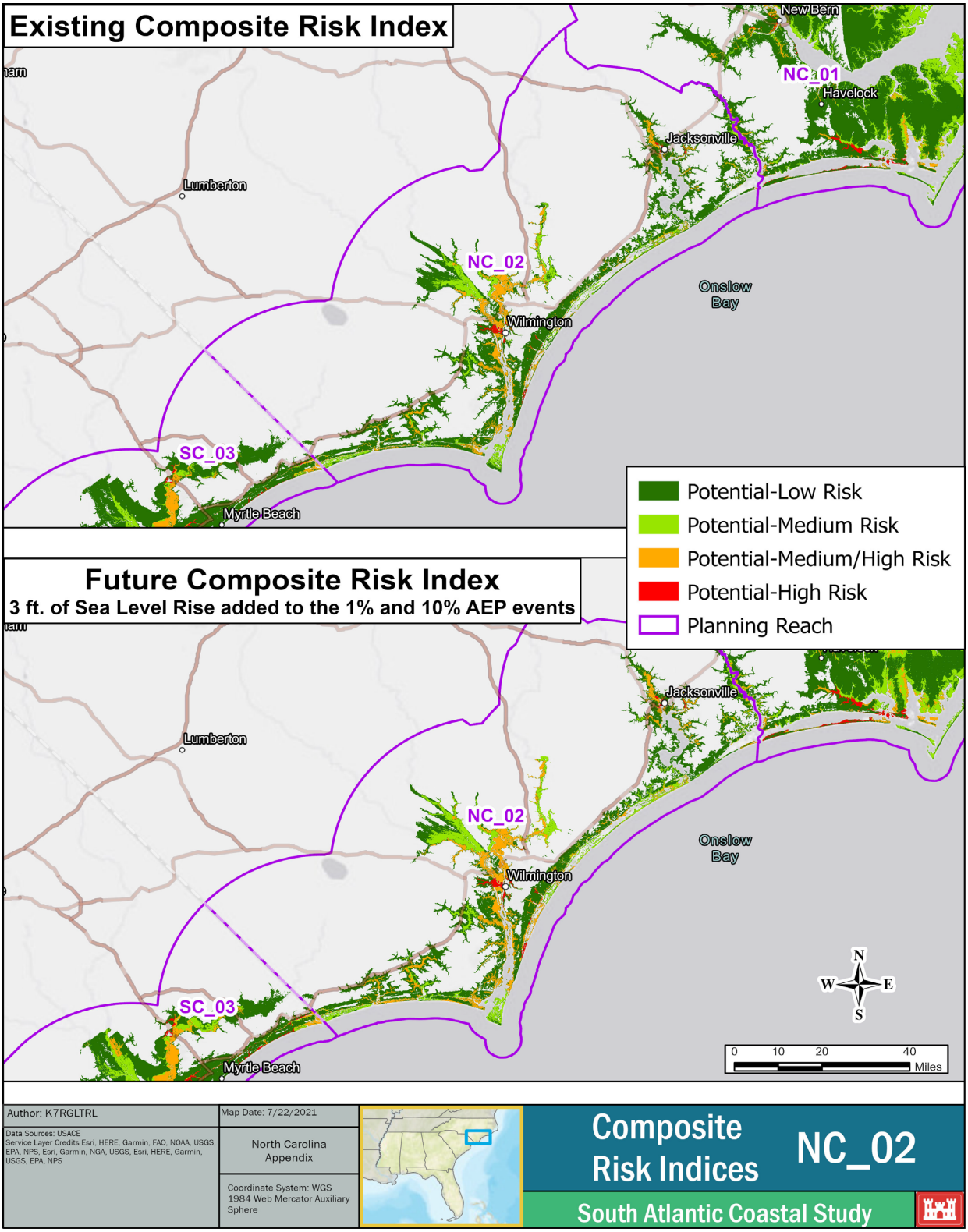


Figure 4-35: Tier 1 Existing and Future Composite Risk Index for Planning Reach NC_02

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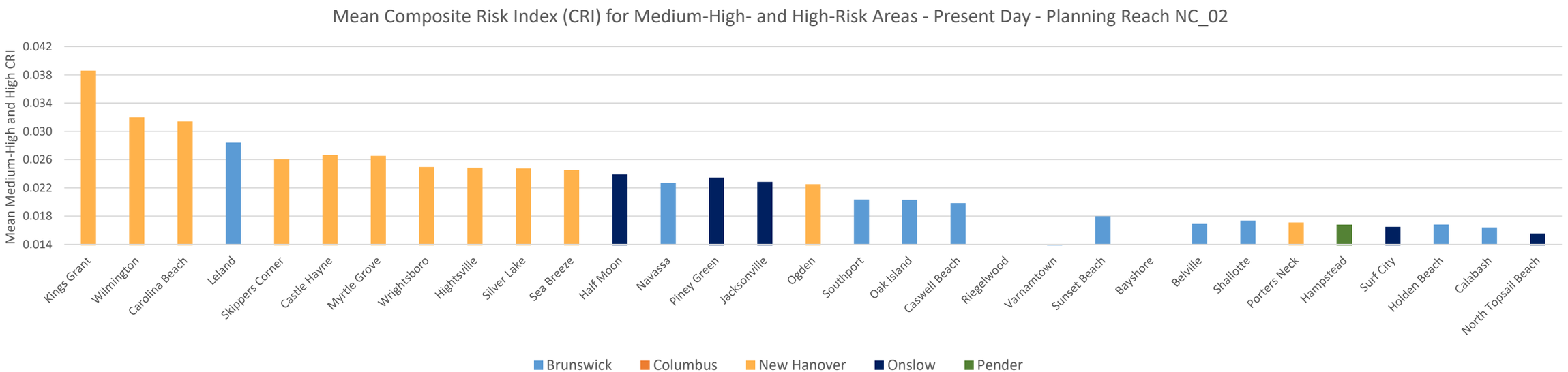

Figure 4-36: Tier 1 Potential Composite Medium-high- and High-Risk by Census Place

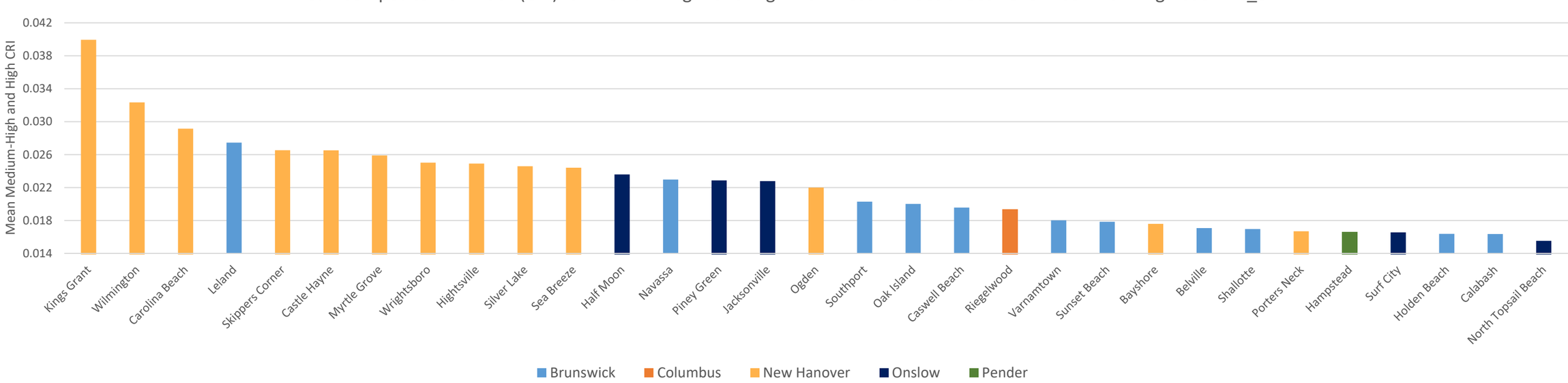

Figure 4-37: Tier 1 Potential Composite Medium-high- and High-Risk by Census Place with Projected Sea Level Rise Included

Examination of the total acreage impacted (defined as having a medium-high and/or high CRI) allows for comprehension of the spatial scale of the potential risk in the existing and future conditions. Wilmington has a high mean CRI score (**Figure 4-36**) because of the relative high density of population, infrastructure, and environmental and cultural resources; however, **Figure 4-38** shows that the acreage of medium-high to high-risk areas potentially impacted in Jacksonville is greater. Further, in the future condition, large amounts of additional acreage for Wilmington and Jacksonville are impacted. This consideration underscores the need to further evaluate risk from storm surge inundation and begin needed planning activities to reduce risk. The footprint of expanded medium-high and high potential risk in the future condition can be seen in the Tier 1 Risk Assessment Viewer.

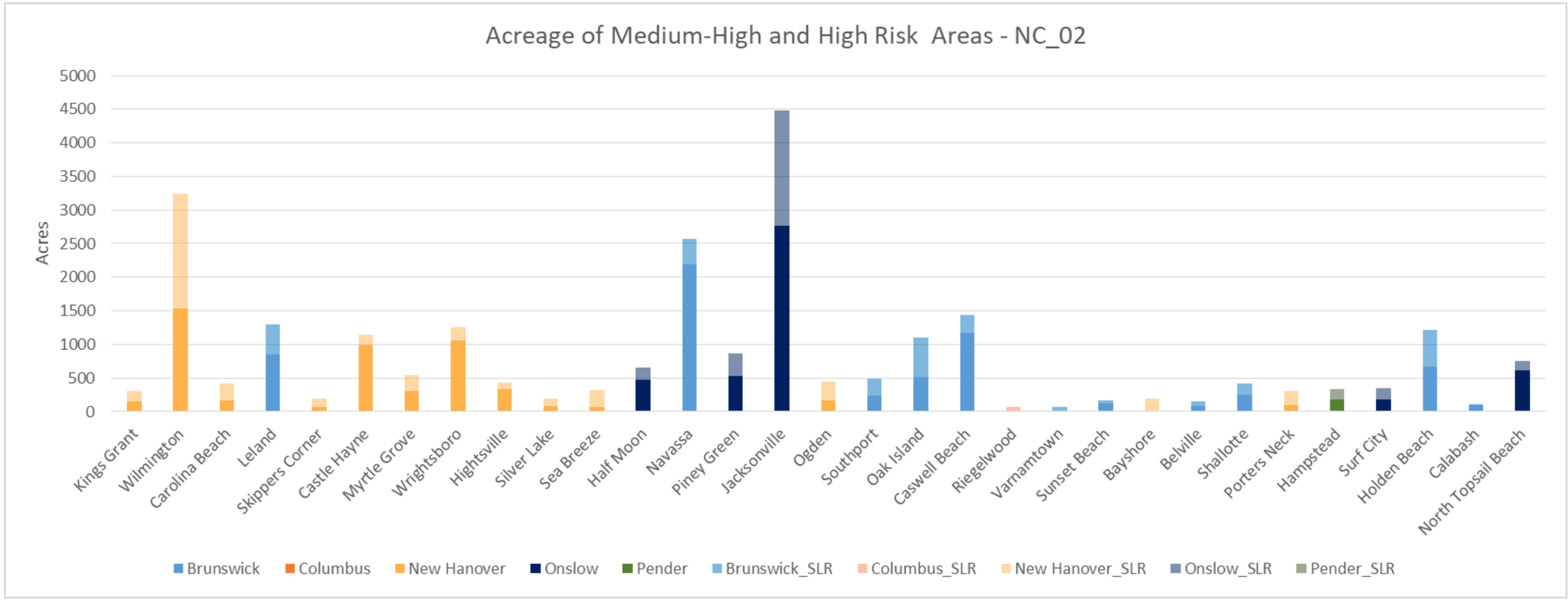

Figure 4-38: Planning Reach NC_02 (North Carolina) Existing and Future Acreage with Potential Medium-high and High Risk. "_SLR" Indicates the Future Condition that Includes 3 Feet of Sea Level Rise

Figure 4-39 shows the percentage of the census place area designated as medium-high or high risk from the Tier 1 analysis. Since census places represent population centers and areas of economic activity, a large percentage of a census place potentially at risk threatens the continued ability of that place to support populations and economic activity without adequate planning and actions.

For Planning Reach NC_02, both Holden Beach and Caswell Beach in Brunswick County will have over 50 percent of their areas rated at medium-high and/or high potential risk in the future condition, with the potential risk of Holden Beach nearly doubling from existing to future conditions (**Figure 4-39**).

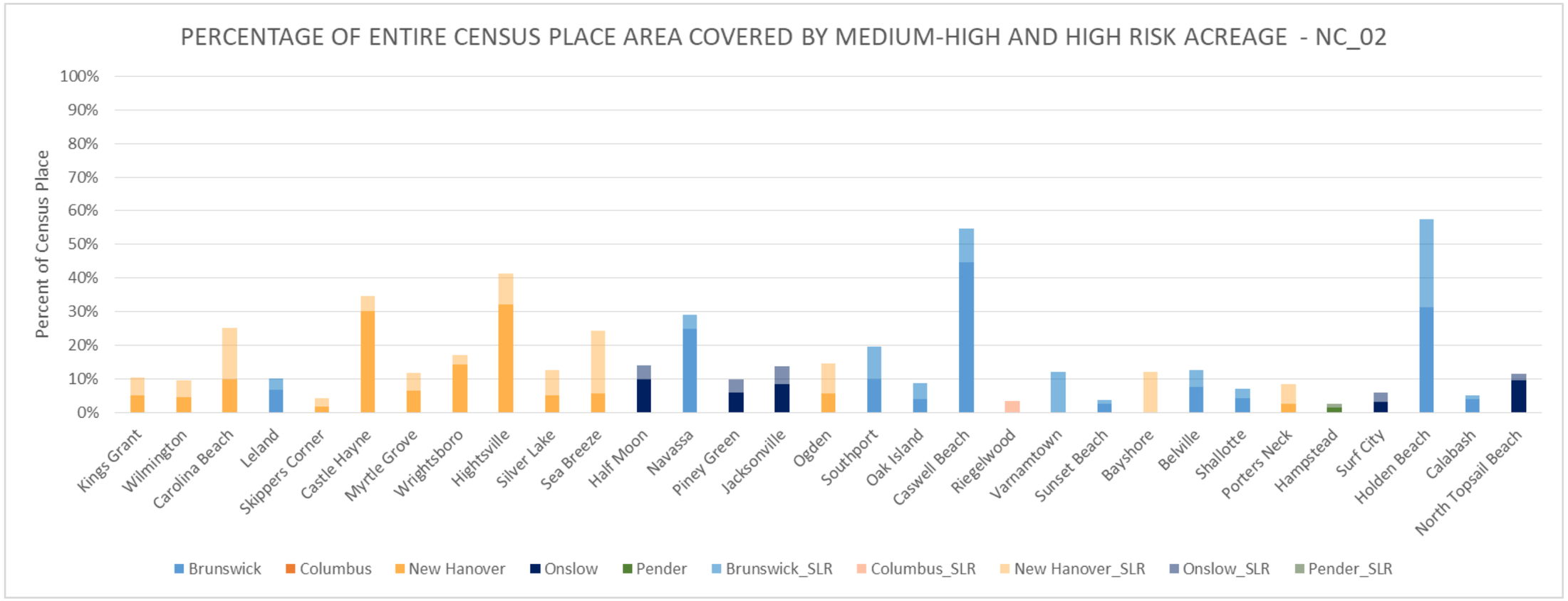

Figure 4-39: Planning Reach NC_02 (North Carolina) Existing and Future Percentages of Census Place Areas Rated as Medium-high and/or High Risk. "SLR" Indicates the Future Condition that Includes 3 Feet of Sea Level Rise

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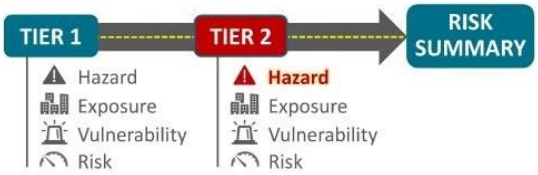
4.3.2 Planning Reach NC_02 Tier 2

The Tier 2 analysis expanded upon the regional Tier 1 analysis through inclusion of state-level data sources and additional evaluation.

4.3.2.1 Planning Reach NC_02 Tier 2 Hazards

Tier 2 hazards are described in Section 4.1. Areas subject to Tier 2 Hazards in Planning Reach NC_02 are identified subsequently.



Inundation

The Tier 2 analysis considered inundation depths as well as extent from coastal storm flooding. Both Hazus and CHS data were used to evaluate additional coastal storm flood hazards. SWLs, an output of the CHS model, are shown in **Table 4-17** at various locations throughout the planning reach for several AEPs with existing sea level conditions. **Table 4-18** shows the same data, but for the high (7.35 feet) sea level rise scenario modeled in CHS. Nonlinear effects, which are changes to SWLs due to sea level rise that are not a simple addition of the sea level rise value, are evident in this planning reach. Unlike Planning Reach NC_01, nonlinear effects primarily seem to reduce the water levels in this planning reach, with an average reduction of 0.41 feet for the 1-percent AEP among the model output locations displayed in **Table 4-18**. The largest nonlinear effect took place at the Carolina Beach Yacht Basin, with a reduction in 0.90 foot.

Table 4-17: Planning Reach NC_02 Stillwater Elevations from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Wrightsville Beach	6.70	7.21	8.37	9.37	11.56
Atlantic Intracoastal Waterway (AIWW) - Wrightsville Beach	7.49	8.91	10.85	12.02	14.55
Carolina Beach	6.73	7.27	8.36	9.29	11.24
Cape Fear River - MOTSU	5.96	6.51	7.59	8.39	9.83
Cape Fear River - Wilmington	5.66	6.36	7.51	8.24	9.61
Carolina Beach Yacht Basin	7.53	8.85	10.48	11.68	13.97
Oak Island	7.79	8.17	8.79	9.38	10.71
AIWW - Holden Beach	8.38	9.09	10.54	11.60	13.72
Ocean Isle Beach	8.43	8.83	9.60	10.40	12.35

Table 4-18: Planning Reach NC_02 Stillwater Elevations from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Wrightsville Beach	13.93	14.35	15.24	16.03	18.03
AIWW - Wrightsville Beach	14.78	15.95	17.55	18.60	20.83
Carolina Beach	13.95	14.41	15.26	16.05	17.84
Cape Fear River - MOTSU	13.78	14.69	15.82	16.54	17.95
Cape Fear River - Wilmington	13.30	14.06	15.01	15.62	16.83
Carolina Beach Yacht Basin	14.62	15.72	17.16	18.13	20.19
Oak Island	15.09	15.43	15.92	16.43	17.46
AIWW - Holden Beach	15.68	16.24	17.39	18.24	20.01
Ocean Isle Beach	15.68	16.07	16.55	17.17	18.61

The southern portion of North Carolina (SACS Planning Reach NC_02) experiences higher SWLs than the northern half of the state's coast. This will cause inundation to be more threatening to low-lying areas in Planning Reach NC_02 compared to areas of similar elevations in Planning Reach NC_01. **Figure 4-40** through **Figure 4-42** display the CHS modeled depth for the 1-percent AEP event within Planning Reach NC_02 under existing, intermediate and the high sea level rise scenarios.

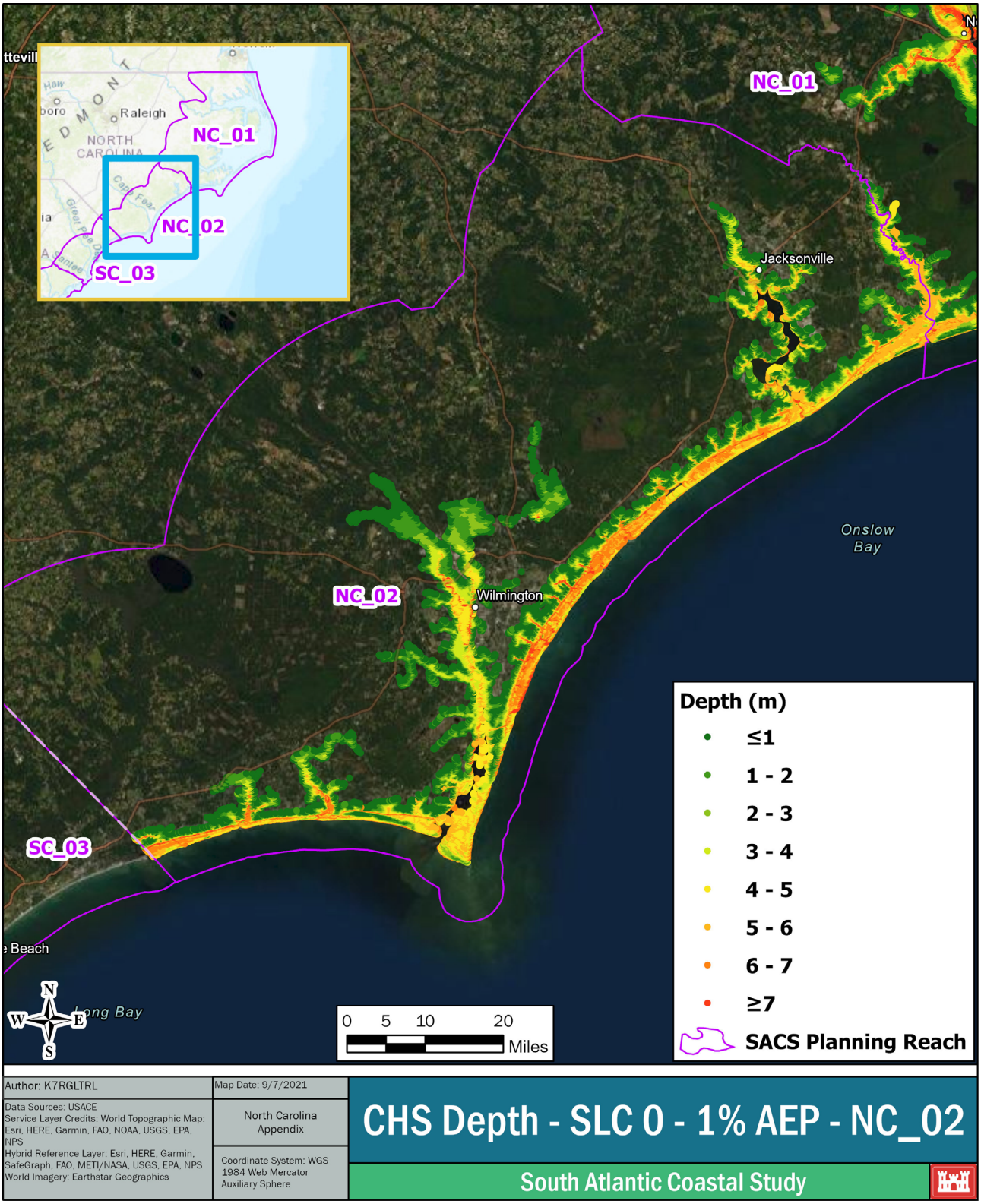


Figure 4-40: Coastal Hazards System Modeled Inundation Depth Within Planning Reach NC_02 Under Existing Sea Level Rise Conditions

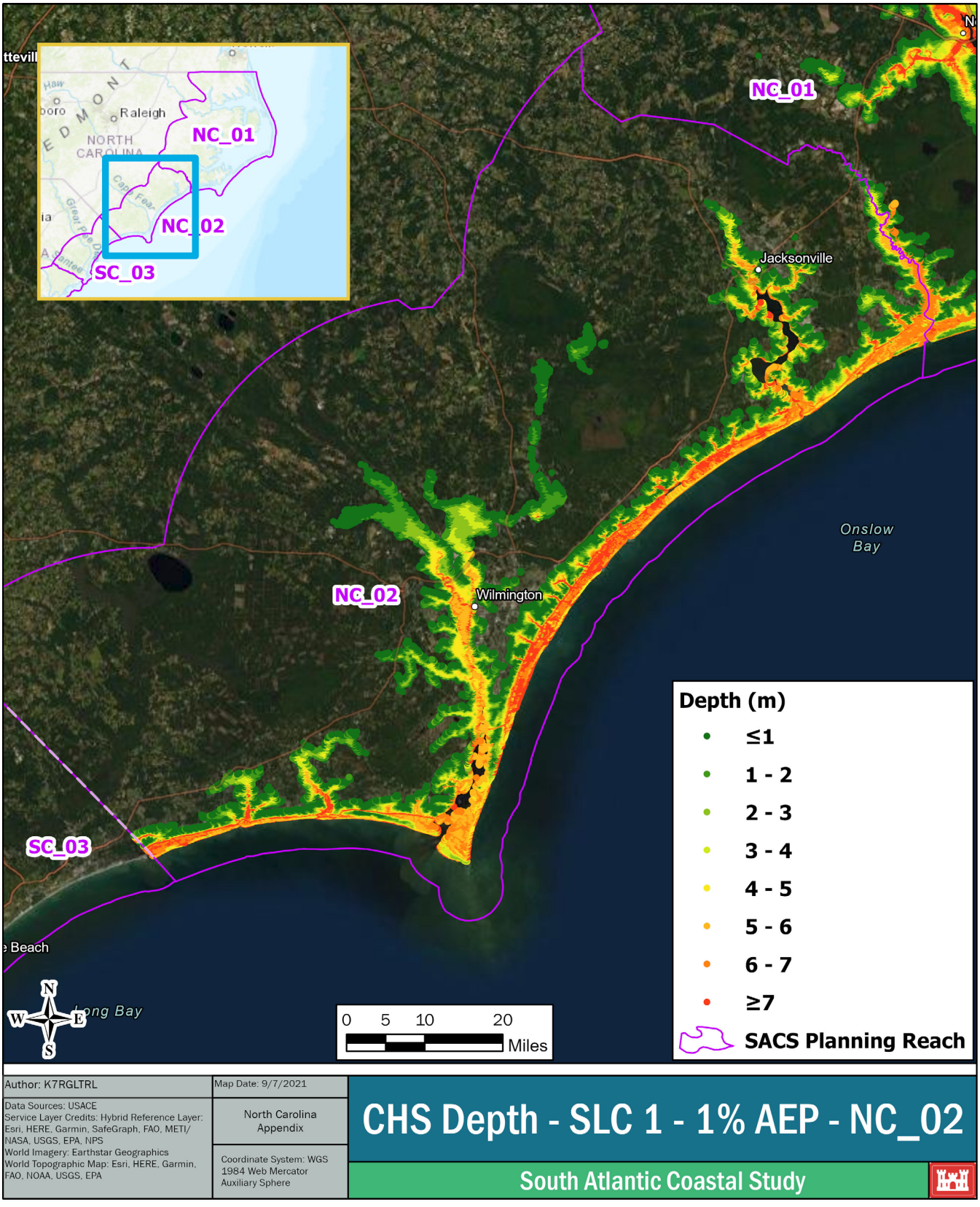


Figure 4-41: Coastal Hazards System Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 2.73 Feet of Sea Level Rise in Planning Reach NC_02

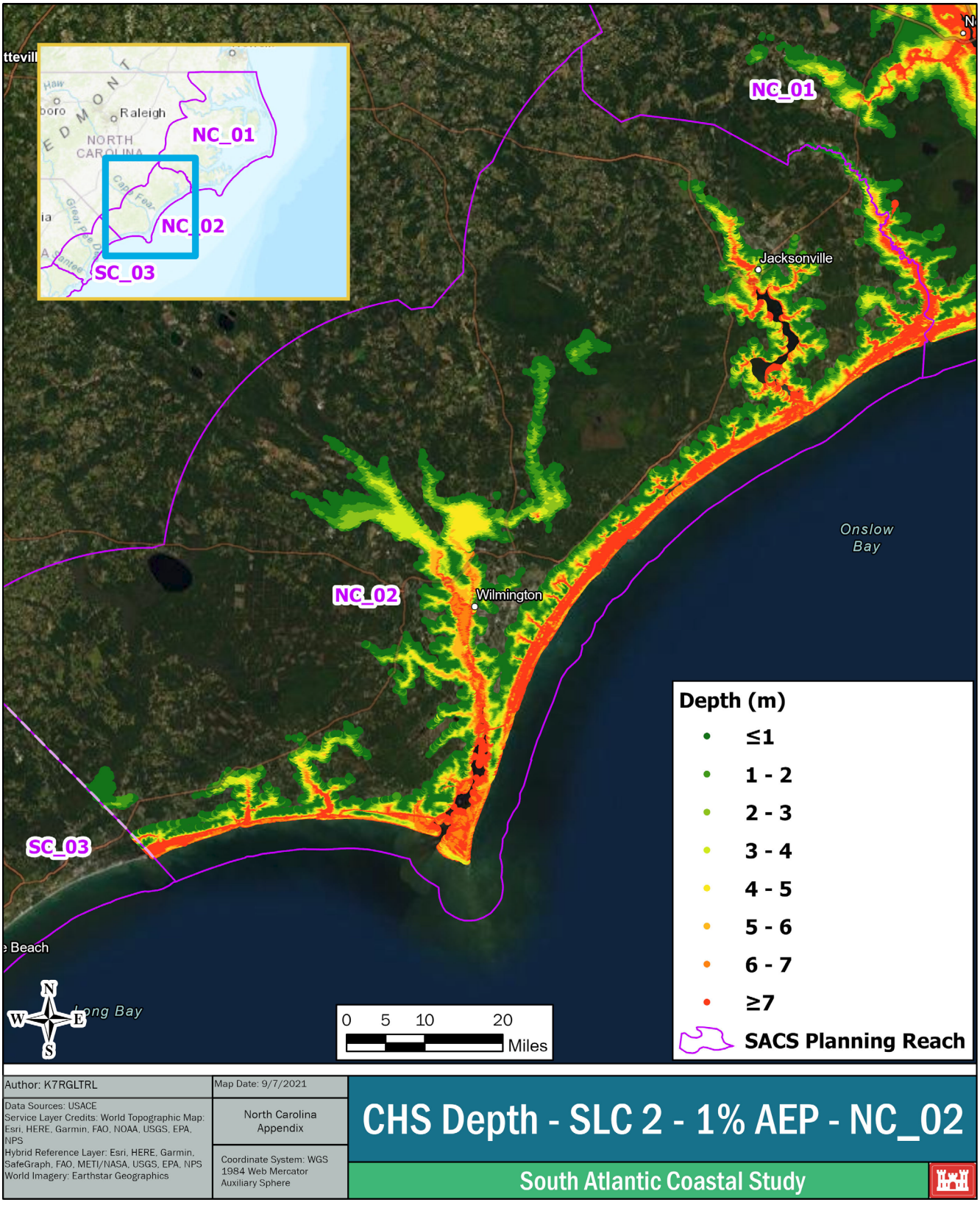


Figure 4-42: Coastal Hazards System Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 7.35 Feet of Sea Level Rise in Planning Reach NC_02

Wave Attack

Wave attack is most significant in this planning reach along oceanfront shorelines and larger back bay areas. Because wave height correlates to fetch (length over which wind stress is applied), duration (amount of time for sustained wind stress), and water depth, shorelines along the Atlantic Ocean and adjacent to larger back bay areas like Bogue Sound are more vulnerable to larger waves. **Table 4-19** provides wave heights at various locations throughout the planning reach for several AEPs with existing sea level conditions. **Table 4-20** shows the same information, but for the high (7.35 feet) sea level rise condition modeled in CHS. Because increased sea levels will allow waves to develop in deeper water, and reduced land area will lead to increased fetch, wave heights are modeled to generally increase with sea level rise.

Table 4-19: Planning Reach NC_02 Wave Heights from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Wrightsville Beach	22.20	25.52	28.52	30.14	33.10
AIWW - Wrightsville Beach	2.05	2.68	3.46	3.87	5.07
Carolina Beach	23.18	26.39	28.84	29.91	32.68
Cape Fear River - MOTSU	2.91	3.49	4.31	4.64	5.43
Cape Fear River - Wilmington	2.15	2.61	3.21	3.55	4.40
Carolina Beach Yacht Basin	2.13	2.78	3.54	4.04	5.00
Oak Island	17.45	19.06	21.23	22.60	24.43
AIWW - Holden Beach	0.90	1.17	1.65	2.02	2.79
Ocean Isle Beach	19.62	21.93	24.17	25.33	27.39

Table 4-20: Planning Reach NC_02 Wave Heights from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Wrightsville Beach	23.46	26.99	30.21	32.01	33.46
AIWW - Wrightsville Beach	4.57	5.60	6.78	7.42	8.05
Carolina Beach	24.58	28.11	30.91	32.20	33.45
Cape Fear River - MOTSU	3.60	4.32	5.19	5.62	6.00
Cape Fear River - Wilmington	2.55	3.01	3.57	3.86	4.11
Carolina Beach Yacht Basin	5.03	6.08	7.19	7.89	8.47
Oak Island	19.25	21.29	23.72	25.10	26.11
AIWW - Holden Beach	2.28	2.99	3.81	4.31	4.74
Ocean Isle Beach	21.17	23.83	26.27	27.52	28.54

The southern portion of North Carolina (SACS Planning Reach NC_02) experiences lower average wave heights than the northern half of the state's coast (**Figure 4-43**). Because wave height is correlated to wave energy, while still a hazard, Planning Reach NC_02 may experience less wave damage and corresponding erosion from major storms as compared with Planning Reach NC_01.

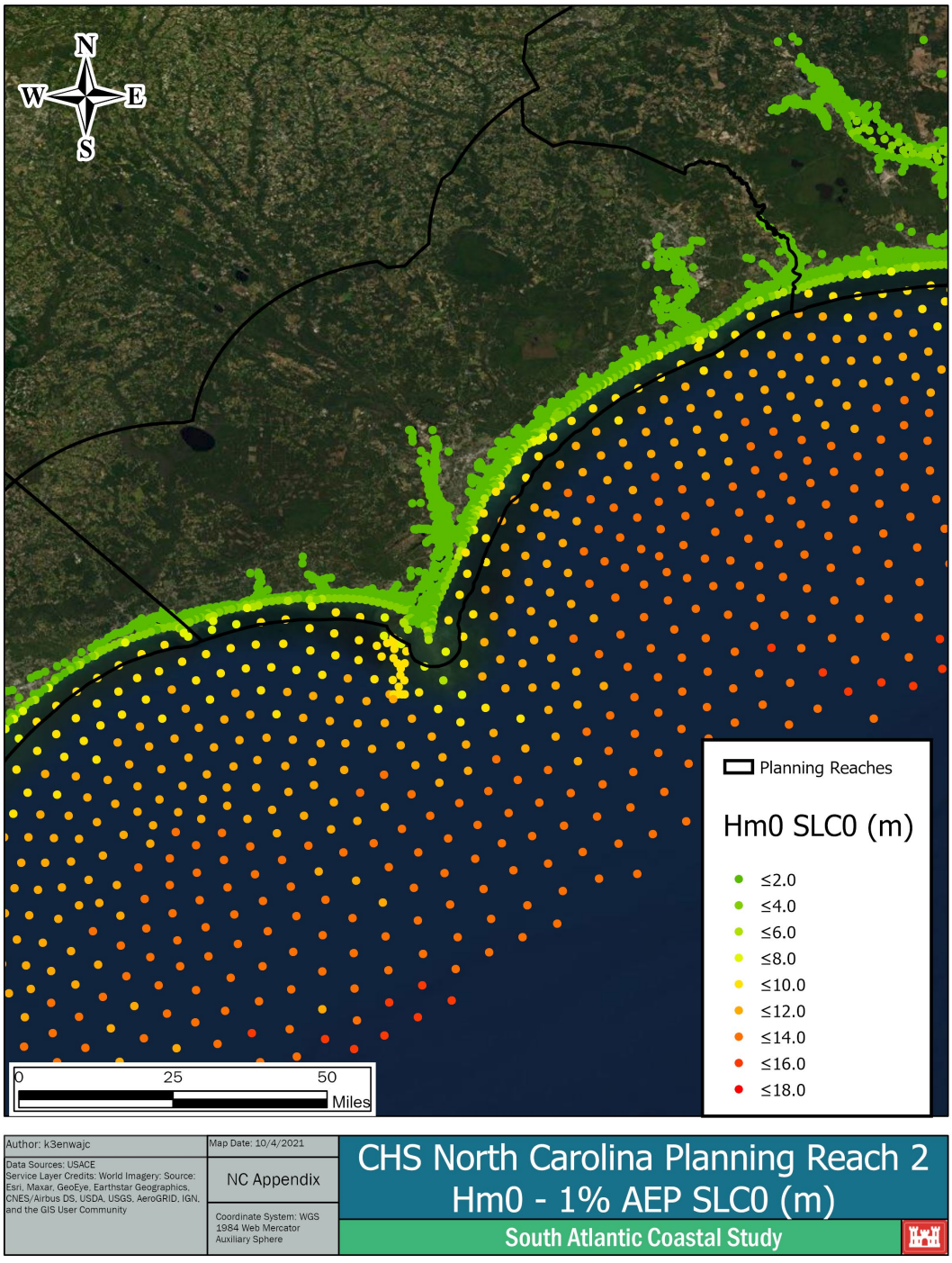


Figure 4-43: Coastal Hazards System Modeled Wave Heights in Planning Reach NC_02 Under Existing Conditions

Erosion

Erosion is threatening coastal environments, environmental resources, cultural resources, communities, and infrastructure in Planning Reach NC_02. Impacted locales include, but are not limited to, key historic sites, such as Brunswick Town and Fort Anderson on the Cape Fear River, and Cape Fear River shoreline communities, such as the City of Southport (**Figure 4-42**). For Planning Reach NC_02, erosion is highly variable for eroding beaches, with long-term annual shoreline change rates ranging from -0.09 foot/year at Kure Beach, North Carolina, to -6.75 feet/year at Lea Hutaff Island (NCDCM 2020). Masonboro Island and Lea Hutaff Island, both environmental resources, had the greatest historic shoreline change. For accreting beaches in Planning Reach NC_02, results were still highly variable, ranging from 0.18 foot/year at Surf City, North Carolina, to 5.5 feet/year at Sunset Beach (NCDCM 2020).

Erosion on the oceanfront shoreline has been quantified in more detail. A 2016 report from NCDCM states that there are 160 miles of developed oceanfront in North Carolina. A distinction is made between shoreline migration of the barrier islands and shoreline erosion due to hurricanes/tropical storms and large winter coastal storms. The NCDCM Oceanfront Shoreline Change Rates data set for 2019 shows areas along coastal North Carolina that are either eroding, accreting, or stable. **Figure 4-44** and **Table 4-21** illustrate the oceanfront shoreline change rate data within Planning Reach NC_02. CEAs include North Topsail Beach, Masonboro Island, and Holden Beach.

Because NCDCM shoreline change rates are calculated by taking the distance (feet) between two shorelines and dividing by the number of years between shoreline measurements, some shoreline change rates can be skewed by human activity. For instance, if the second shoreline was measured shortly after a beach renourishment event, the shoreline would artificially reflect more accretion than if the shoreline was measured before the renourishment event. Using records from the USACE Wilmington District (SAW) for its CSRM study in Wrightsville Beach, the shoreline erosion rate is -4.3 feet/year if shorelines are measured between renourishment events to exclude human activity. In **Table 4-21**, Wrightsville Beach is shown to be accreting 3.2 feet/year due to the timing of shoreline measurements. Most CSRM shorelines in North Carolina are not monitored to the extent Wrightsville Beach is monitored, so values from NCDCM are still the best option for most shorelines in the state. The column “human interference” is included in the table to reflect areas in which human activity could impact shoreline change rates by placing sand from other (e.g., navigational) projects on the beach, renourishment as a federal CSRM measure by USACE, or renourishment using private or local support. These are labeled “placement,” “CSRM,” and “non-federal,” respectively. If there is no known action, the column is labeled “N/A.” In general, volumes placed on beaches from placement operations are less than volumes placed for federal or non-federal CSRM projects and have less effect on the shoreline erosion rate. Despite human interference, natural erosion rates will vary throughout the state depending on many factors such as shoreline orientation, seasonal variation in wave and water level conditions, sediment sources and sinks, and bathymetric features.

Inclusion of this shoreline erosion data in the Tier 2 analysis further refined the understanding of hazards based on the Tier 1 analysis. For Planning Reach NC_02, Onslow Beach, Masonboro Island, Bald Head Island, and Holden Beach were identified as being underrepresented areas of high erosion from the Tier 1 analysis.

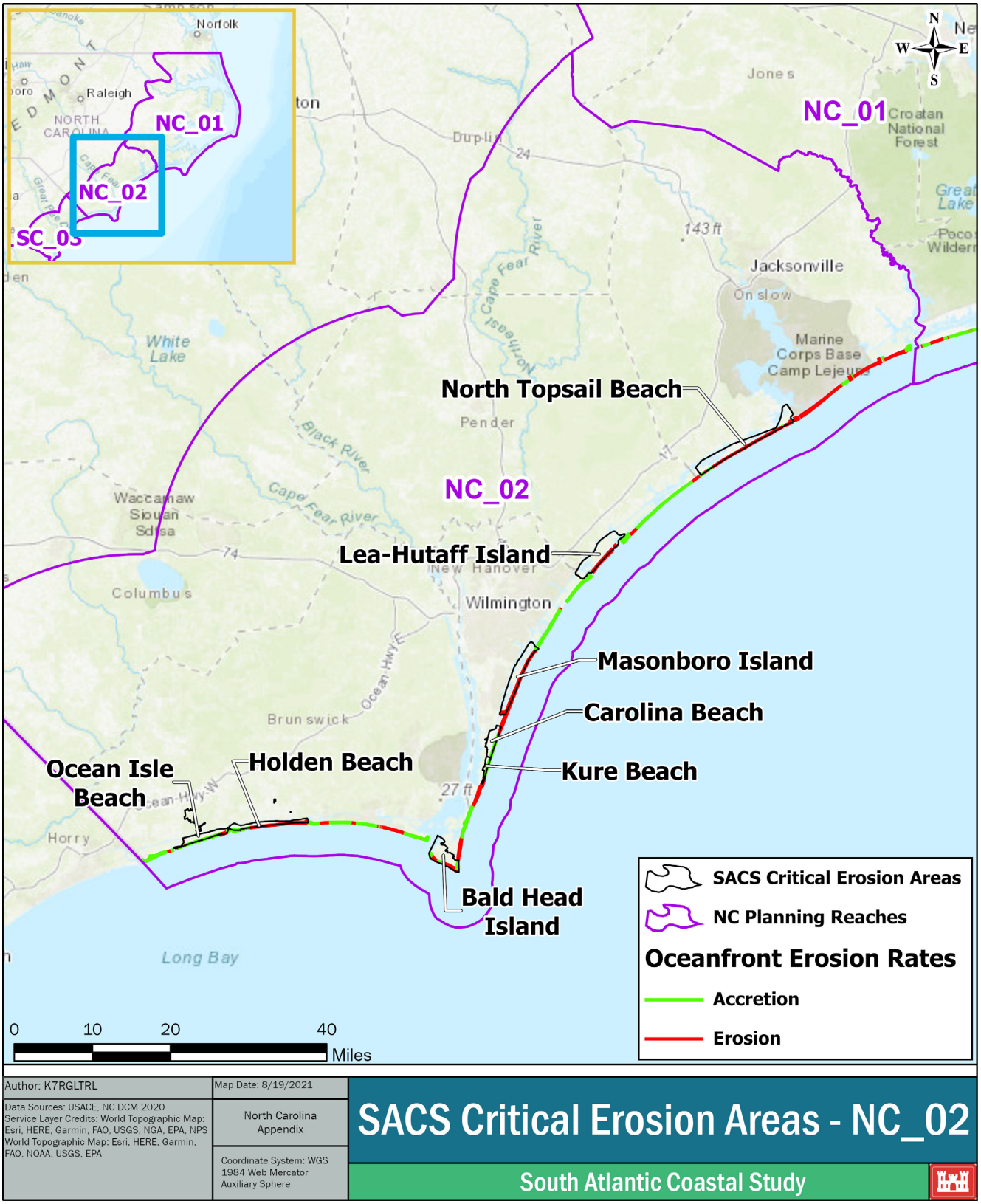


Figure 4-44: Oceanfront Shoreline Change Rates in North Carolina Planning Reach NC_02

Table 4-21: Oceanfront Shoreline Change Rates in Planning Reach NC_02

Location	2020 Rate	Average (feet/year)	Human-Influenced Beaches
Bald Head Island	Erosion	-2.04	Placement
Bear Island	Accretion	0.67	-
Brown's Island	Erosion	-3.52	Placement
Carolina Beach	Erosion	-0.95	CSRM/Placement
Caswell Beach	Accretion	0.77	Placement
Figure Eight Island	Accretion	3.24	Non-federal
Fort Caswell	Accretion	5.05	Placement
Fort Fisher	Erosion	-1.85	-
Holden Beach	Erosion	-0.47	Placement
Kure Beach	Erosion	-0.09	CSRM
Lea-Hutaff Island	Erosion	-6.75	-
Masonboro Island	Erosion	-6.36	Placement
North Topsail Beach	Erosion	-1.12	Placement/Non-federal*
Oak Island	Accretion	0.42	Placement
Ocean Isle	Accretion	1.19	CSRM/Placement
Onslow Beach	Erosion	-4.42	-
Sunset Beach	Accretion	5.5	-
Surf City	Accretion	0.18	Placement/Non-federal*
Topsail Beach	Accretion	3.56	Non-federal*
Wrightsville Beach	Accretion	3.2	CSRM
Zeke's Island	Erosion	-0.27	-

*Authorized as a federal project, but construction has not yet begun.

Compound Flooding

Within Planning Reach NC_02, areas in the lower Cape Fear River basin have experienced the effects of compound flooding during multiple coastal storm events, including Hurricanes Floyd (1999) and Hermine (2016). Research within this specific river basin indicates that multiple factors likely come into play, which could result in the compounding of flood factors, including the relative timing and magnitude between storm surge, tide, rainfall runoff, and river flows. High-intensity rain bands in advance of the landfall of an approaching coastal storm, or high-intensity precipitation occurring at the time of landfall, can result in compound flooding (Gori et al. 2020). SACS recognizes that additional studies are needed to accurately assess compound flooding.

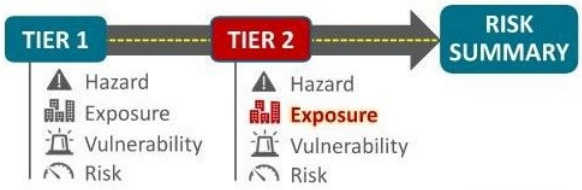
Saltwater Intrusion and Inundation

Saltwater intrusion and inundation are two factors that can negatively affect tree health, especially in low lying estuarine and riverine areas exposed to tidal influence. Some rivers, such as the lower Cape Fear River, have been artificially deepened (i.e., dredged) multiple times over the past centuries. Dredging shipping channels accommodates large-scale maritime commerce and supports regional

and national economic interests. A practical effect of deepening may be to increase the negative effects of tides and storm surge on nearby affected trees. The extent to which deepening contributes to these negative ecological effects is unknown, although modeling suggests that when Cape Fear River shipping channels were half their current depth, storm surge was 6 feet lower than the currently estimated 18 feet (Famikhalili et al. 2016). One example of a local effort to combat saltwater intrusion was the construction of a levee in Hyde County to protect agricultural land. There are currently multiple efforts underway to study the issue of saltwater intrusion and its impacts in North Carolina.

4.3.2.2 Planning Reach NC_02 Tier 2 Exposure

This section highlights details of the Tier 2 exposure to determine who or what may be impacted for Planning Reach NC_02. An overview of each exposure element is presented in Section 4.1.5.



Population and Infrastructure

Tier 2 population and infrastructure exposure was first assessed using data from the National Structure Inventory, developed by the USACE Hydrologic Engineering Center and FEMA. **Figure 4-45** displays infrastructure data from the National Structure Inventory that is within the footprint of the 0.2-percent AEP event floodplain with a three-foot sea level rise. The pie chart shows the proportional relationship, in value, between the general infrastructure types.

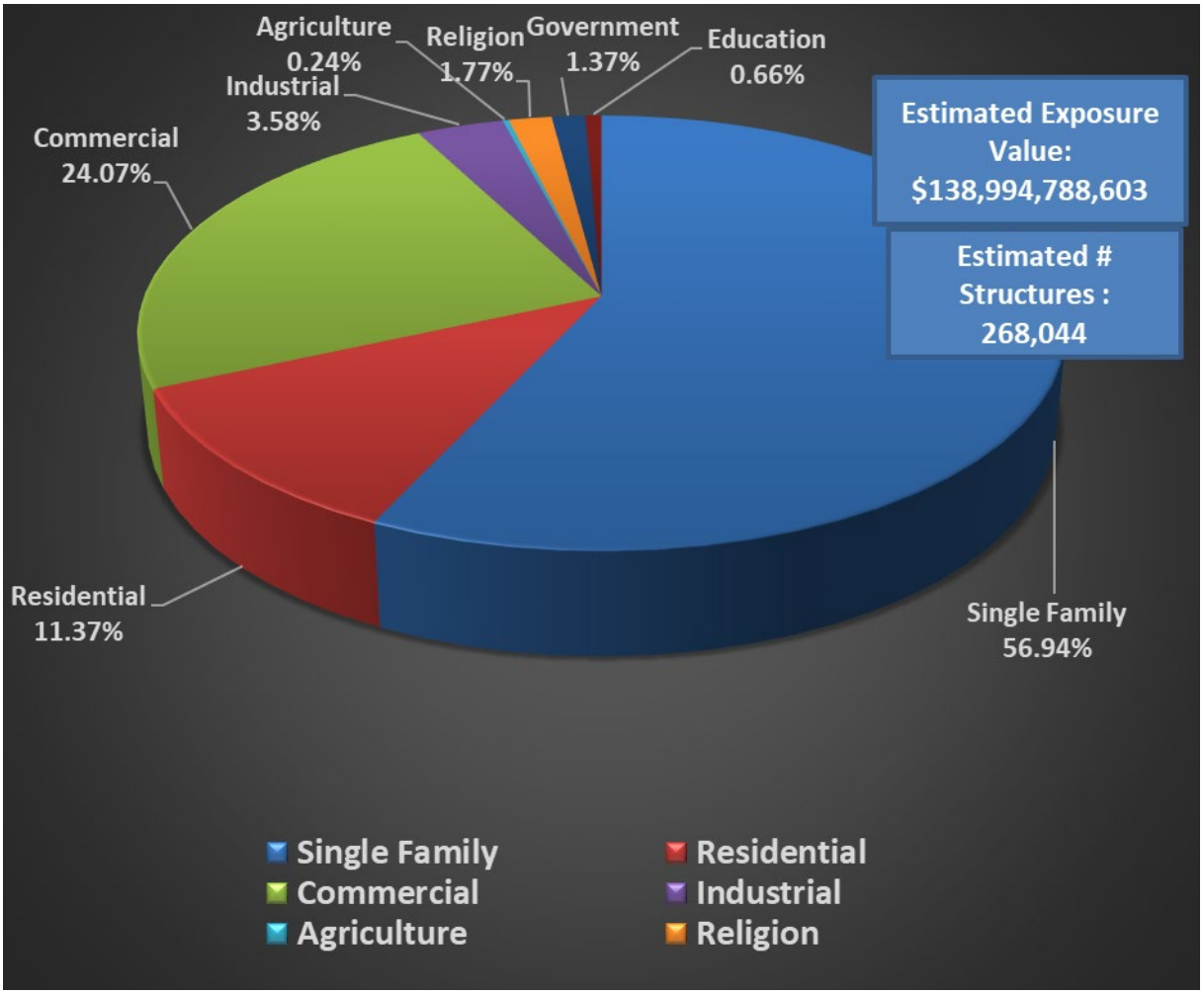


Figure 4-45: Estimated Exposure Value – Planning Reach NC_02 (FEMA n.d.)

Planning Reach NC_02 contains an estimated 268,000 structures with an estimated value of $140 billion. More than 90 percent of exposed structures are categorized as single-family or residential housing (**Table 4-22**).

Table 4-22: Estimated Exposure Values – Planning Reach NC_02 (FEMA n.d.)

General Occupancy	Number of Structures	% of Structures	Estimated Exposure Value (Billions)	% of Exposed Value
Single Family	199,017	74.2%	$79.14	57.0%
Residential	43,351	16.2%	$15.80	11.3%
Commercial	18,801	7.0%	$33.46	24.0%
Industrial	3,765	1.4%	$4.97	3.6%
Agriculture	690	0.3%	$0.33	0.24%
Religion	1,265	0.5%	$2.46	1.8%
Government	766	0.3%	$1.91	1.44%
Education	389	0.1%	$0.92	0.70%
Total	**268,044**	**100%**	**$139.00**	**100.0%**

Figure 4-46 displays the Category 5 MOM storm surge exposure in Planning Reach NC_02.

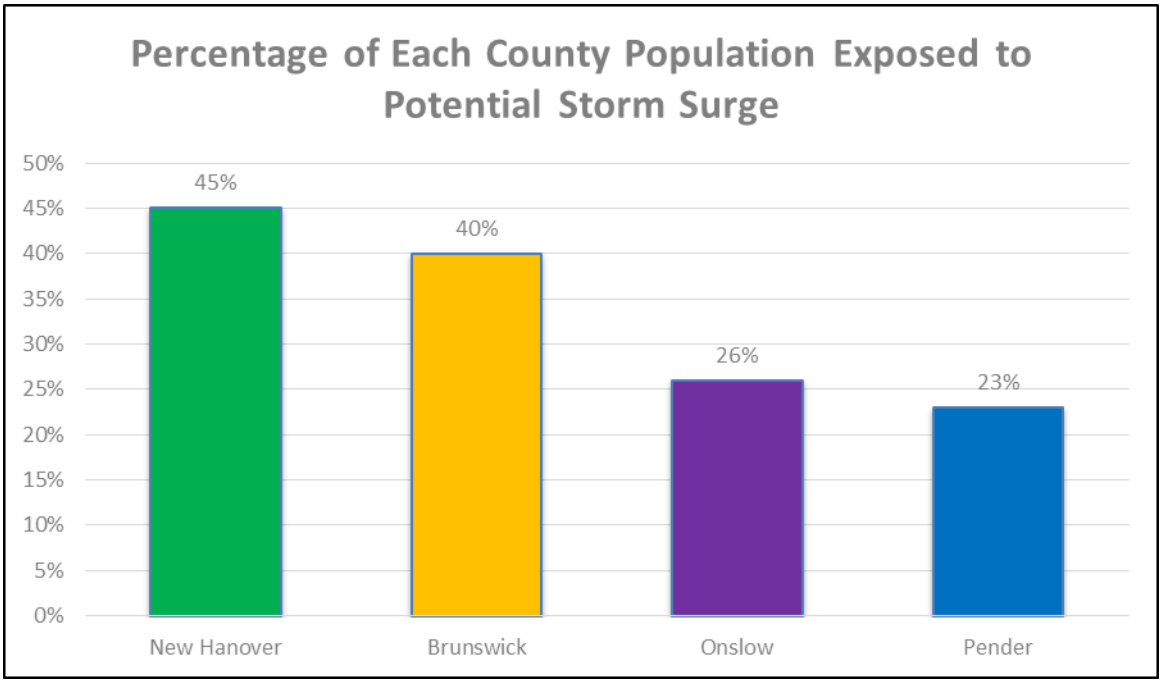


Figure 4-46: Percentages of Total County Populations Exposed to Potential Storm Surge (FEMA 2016)

Seasonal Population

The Tier 1 Risk Assessment, through census data, does not capture the maximum seasonal population of many barrier island communities in North Carolina. For Tier 2, data from local governments was used to compare best estimates for seasonal populations, which coincide with hurricane season, with the permanent populations used in Tier 1 (**Figure 4-47**). Therefore, during hurricane season, the exposure to hazards in tourism-heavy areas is significantly greater than originally assessed in Tier 1.

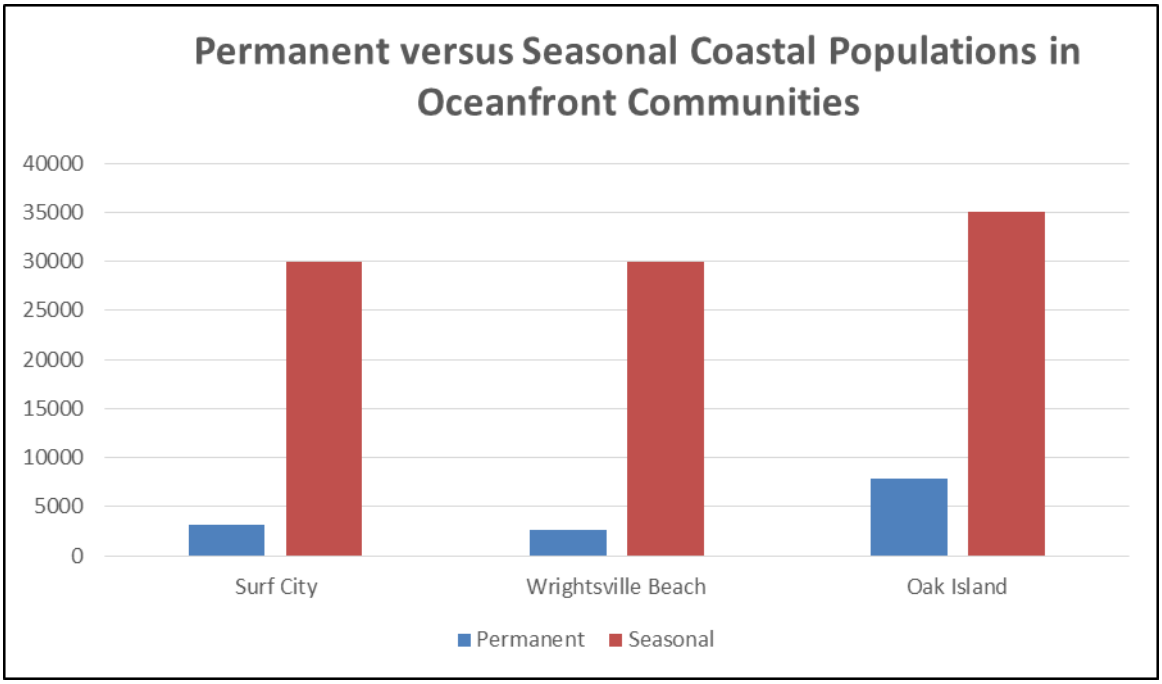


Figure 4-47: Permanent versus Seasonal Coastal Populations in Oceanfront Communities within Planning Reach NC_02

Military Installations

Table 4-23 lists all major military installations located within Planning Reach NC_02. In addition, there are numerous Coast Guard Stations, not listed, including Wrightsville Beach and Oak Island. Although the Tier 1 Risk Assessment of population and infrastructure included military installations, the assessment did not include military-specific assets such as equipment, air/land/water vehicles, munitions, and heavy machinery. Although these installations will receive and potentially benefit from the data and tools produced by SACS, the military is pursuing resiliency for their installations through parallel activities. MCB Camp Lejeune participates in the REPI program that is preserving 19,705 acres of habitat and working lands and is assisting in red-cockaded woodpecker recovery. This effort was implemented with the collective, multi-installation effort with MCAS Cherry Point, MCAS New River, and MCB Camp Lejeune.

Table 4-23: Military Installations within Planning Reach NC_02

Site Name	Main Installation	Location
NG MTA Fort Fisher Air Force Station	North Carolina National Guard	Kure Beach
Military Ocean Terminal Sunny Point	Military Ocean Terminal Sunny Point	Southport
Fort Fisher Recreation Site	Seymour Johnson AFB	Kure Beach
MCB Camp Lejeune	MCB Camp Lejeune NC	Camp Lejeune
MCB Camp Lejeune North Site	MCB Camp Lejeune NC	Camp Lejeune
MCB Camp Lejeune West Site	MCB Camp Lejeune NC	Camp Lejeune
MCB Camp Lejeune Midway Park	MCB Camp Lejeune NC	Camp Lejeune
USO 9 Tallman Jax NC	MCB Camp Lejeune NC	Jacksonville

Population Growth Trends

Figure 4-48 represents the expected percentage of growth or decline in total county populations for 2020 to 2100. Counties depicted in green are expected to experience population growth, while counties depicted in orange are expected to experience population decline. The ICLUS project uses the conservative B2 SRES storyline, which represents a "regionally-oriented world of moderate population growth and local solutions to environmental and economic problems with a medium fertility rate, a low international and domestic migration, a focus on sustainability, and an increasing number of jobs in urban centers."

Figure 4-49 shows areas of projected development from 2020 to 2100. Within Planning Reach NC_02, development is projected to overlap in areas where coastal storm surge inundation hazards will increase with sea level rise. This is most concentrated in the areas east of Highway 17 in Pender County, which continues to be a fast-growing area for development. Other areas include the urban centers of Jacksonville and Wilmington, as well as the barrier island communities of Brunswick, New Hanover, Pender, and Onslow Counties.

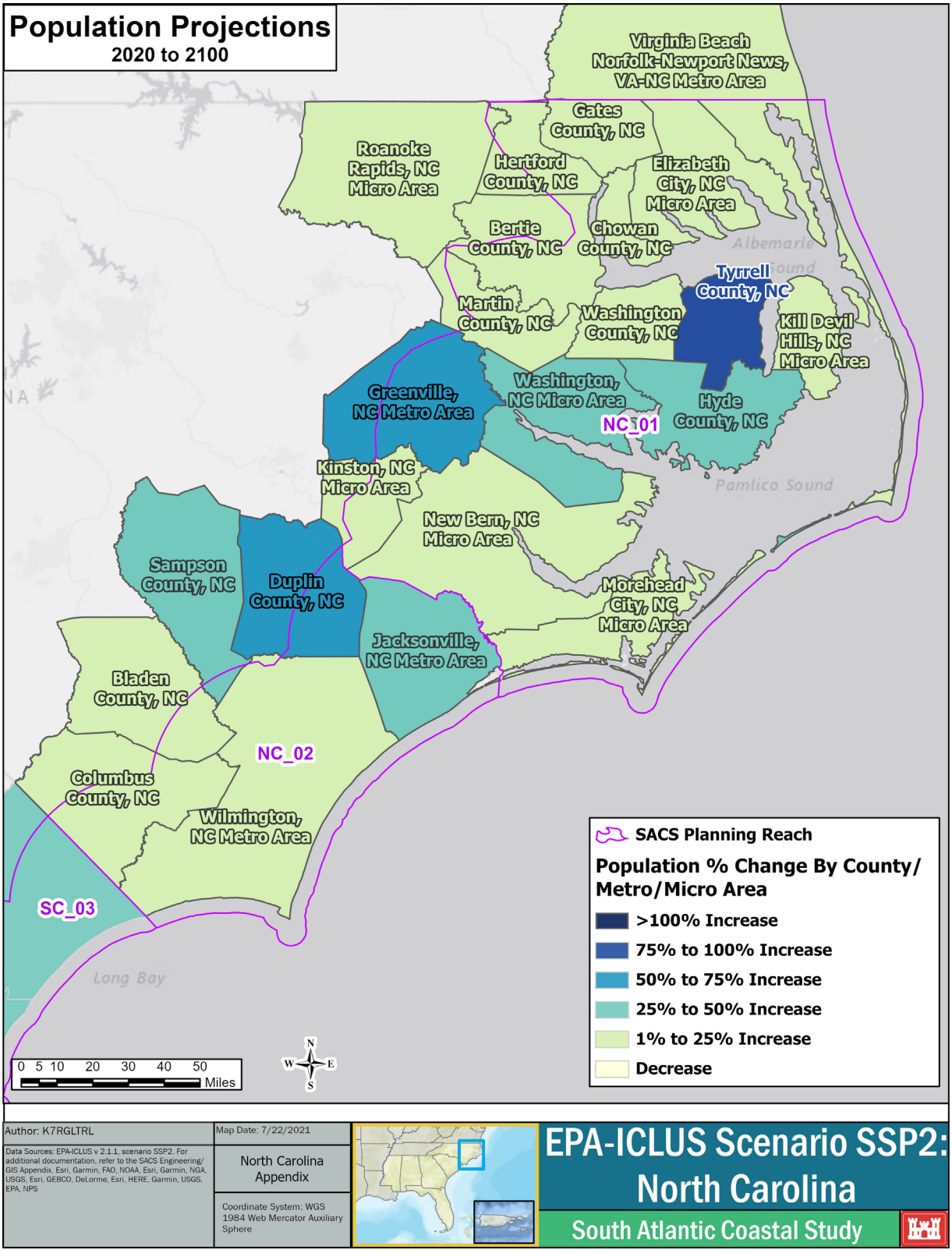


Figure 4-48: Project Population Change in North Carolina by County 2020–2100 (Source: EPA's Integrated Climate and Land Use Scenarios [ICLUS] data)

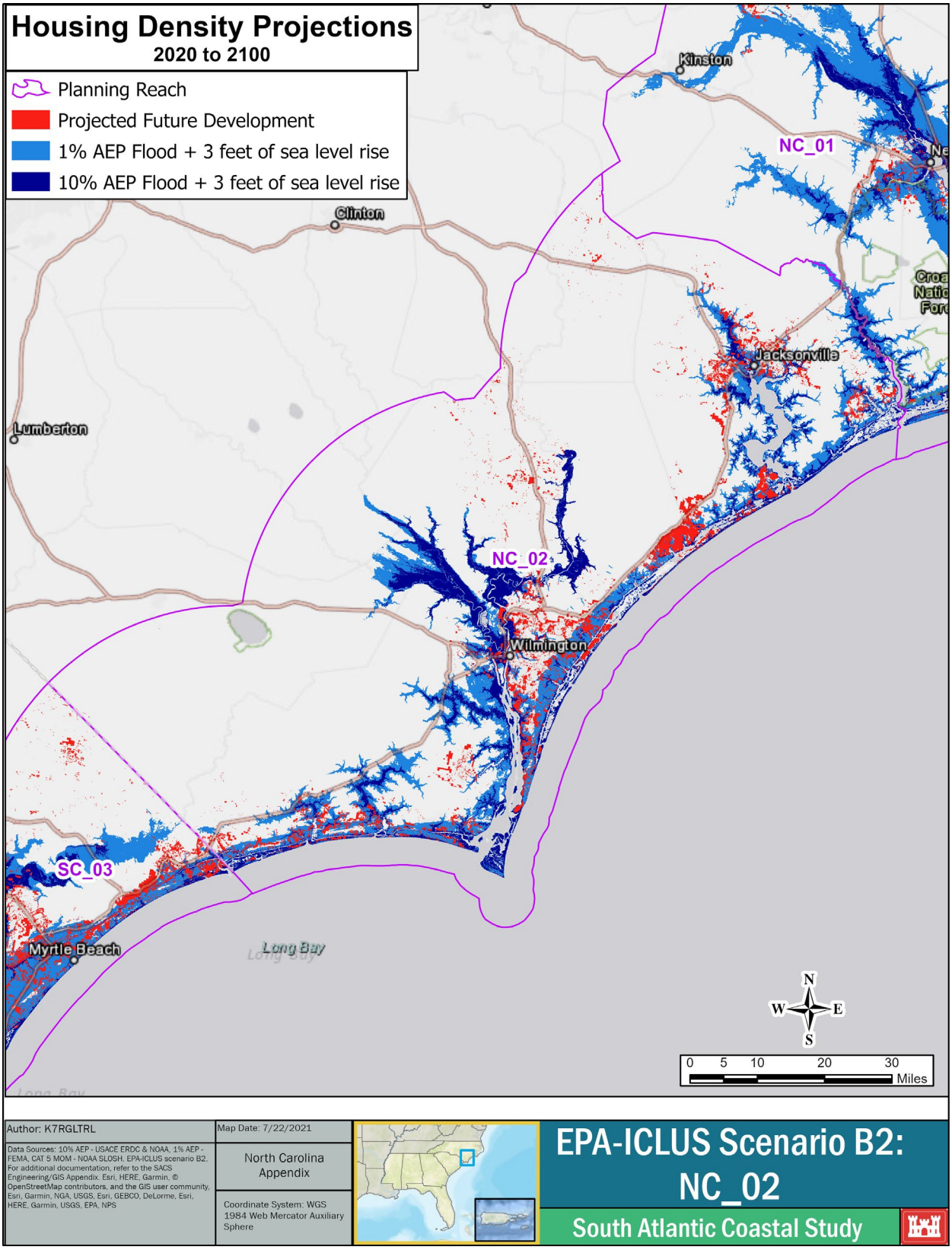


Figure 4-49: Tier 1 Inundation Hazards and Projected Development in Planning Reach NC_02 by County 2020–2100 (Source: EPA's Integrated Climate and Land Use Scenarios [ICLUS] data)

Cultural Resources

GIS analysis of multiple data sets determined which cultural resources in Planning Reach NC_02 were exposed to coastal storm hazards, including those identified by the National Park Service (2020) and the North Carolina State Historic Preservation Office (2020). Multiple historic sites and places are present in Planning Reach NC_02 and exposed to coastal hazards, including coastal storm inundation, erosion, and wave attack.

Well-studied and documented examples of cultural resources within Planning Reach NC_02 include the Fort Caswell Historic District, Brunswick Town/Fort Anderson, the USS North Carolina, and Fort Fisher. Archaeological sites include, but are not limited to, prehistoric shell middens, ruins from early European settlements, sites, and structures with significance to the Gullah Geechee community, and submerged shipwrecks in the ocean, within the Cape Fear River and near inlet complexes. For a complete inventory of identified exposed cultural resources of particular importance and their locations, please refer to the Cultural Resources of Importance in Planning Reach NC_02 table (**Table 4-24**) and the Tier 1 and Tier 2 High-Risk Areas table (**Table 4-28)**. Most all resources included in **Table 4-24** and **Table 4-28** are listed on the National Register of Historic Places and were identified through coordination with the North Carolina Office of State Archaeology/State Historic Preservation Office. Resources identified in **Table 4-24** and **Table 4-28** do not represent a complete list of all cultural resources within Planning Reach NC_02. A selection of at-risk cultural resources is further described in each of North Carolina's three FAAS reports.

Programs presently underway to protect specific exposed cultural resources in Planning Reach NC_02 include examples such as a partnership between the University of North Carolina at Wilmington and the U.S. Naval Academy for the construction and monitoring of wave attenuators at Brunswick Town/Fort Anderson in Brunswick County to slow the loss of a historic wharf to erosion. Efforts to provide aid to local governments' Historic Preservation Commissions to assist with physically raising historic resource elevations are underway. North Carolina Flood Insurance provides assistance to affected historic homeowners in protecting cultural resources and historic structures

Environmental Resources

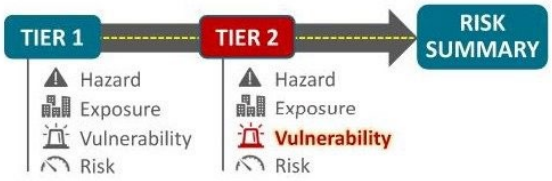
As mentioned in Section 4.2.2.2, state resource agencies and local environmental stakeholder entities have provided additional information regarding environmental exposure analyses as compared to Tier 1, notably the North Carolina Natural Heritage Program through its data explorer web tool (NCNHP 2020) and North Carolina Forest Service via email communication.

On September 30th, 2020, a SACS Environmental Webinar was conducted to present preliminary Tier 2 findings to interested environmental stakeholders. Following this meeting, participants were asked to provide USACE with pointed feedback regarding sensitive or otherwise underrepresented natural communities in terms of exposure, vulnerability, and risk to sea level rise and storm surge hazards.

In Planning Reach NC_02, many barrier islands are densely populated and altered to benefit the human environment. Few barrier islands, such as Masonboro Island and Sunset Beach Bird Island, remain undeveloped. Carolina Bays and other inland areas are high-value habitat to North Carolina's wild flora and fauna. These unique areas are home to numerous threatened, endangered, and other high-value species, and the areas represent some of the most contiguous undeveloped habitat areas

in the reach. Additional habitat types within this reach experiencing exposure to coastal storm and sea level rise hazards are featured in Appendix A (Natural Area Exposure Tables) of the Environmental Technical Report (USACE 2022b).

4.3.2.3 Planning Reach NC_02 Tier 2 Vulnerability



An overview of the incorporation of vulnerability into the Tier 2 analysis is described in greater detail in the Overview (Section 4.1) of this Appendix.

The Tier 2 Economic Risk Assessment used FEMA's Hazus model to estimate damages to infrastructure. Hazus used damage functions to represent the vulnerability of different types of infrastructure to flood hazards and to estimate the impact of flooding.

Natural features were assessed in terms of vulnerability to hazards including inundation (short-term and long-term), erosion/wave attack, and wind. Exposed resources considered vulnerable to hazards were then scored, with higher scores translating to increased vulnerability. Tier 2 Environmental Resources Vulnerability Analysis associated natural community types as defined by the NC Natural Heritage Program (NCNHP 2020, 2021) and NCWRC (NCWRC 2021) with NOAA C-CAP classes (NOAA 2013). Association was accomplished through referencing reports such as the US Fish and Wildlife Service's Planning Aid Report (2020), collaboration with environmental stakeholders, and best professional judgement and allowed for visualization of North Carolina's most vulnerable natural communities. Vulnerable environmental resources are shown in **Figure 4-50** and the SACS Environmental Analysis Web-Mapping Tool. This figure illustrates that unconsolidated shores (e.g., beaches and dunes) and estuarine emergent wetlands are this planning reach's most vulnerable natural communities regarding sensitivity to coastal storm related hazards (e.g., storm surge inundation, erosion, wave attack).

As an example of how vulnerability accounts for hazard susceptibility, unconsolidated shores are vulnerable to storm surge inundation in terms of vegetation loss and erosion, and to wind, erosion, and wave attack in terms of physical substrate (i.e., sand) movement. As a second example of vulnerability accounting for hazard susceptibility, deciduous forests are vulnerable to storm surge in terms of limited salt tolerance. For additional information regarding environmental resources vulnerable to coastal storm and sea level rise hazards in North Carolina, please reference the Environmental Technical Report (USACE 2022b) and specifically Appendix B (Vulnerability Tables).

Cultural resources vulnerabilities were based on qualitative assessment and considered the input of the North Carolina Office of State Archaeology and State Historic Preservation Office. **Table 4-24** displays exposed cultural resources of particular importance in Planning Reach NC_02 and their vulnerability to storm surge inundation, erosion, and wave attack hazards.

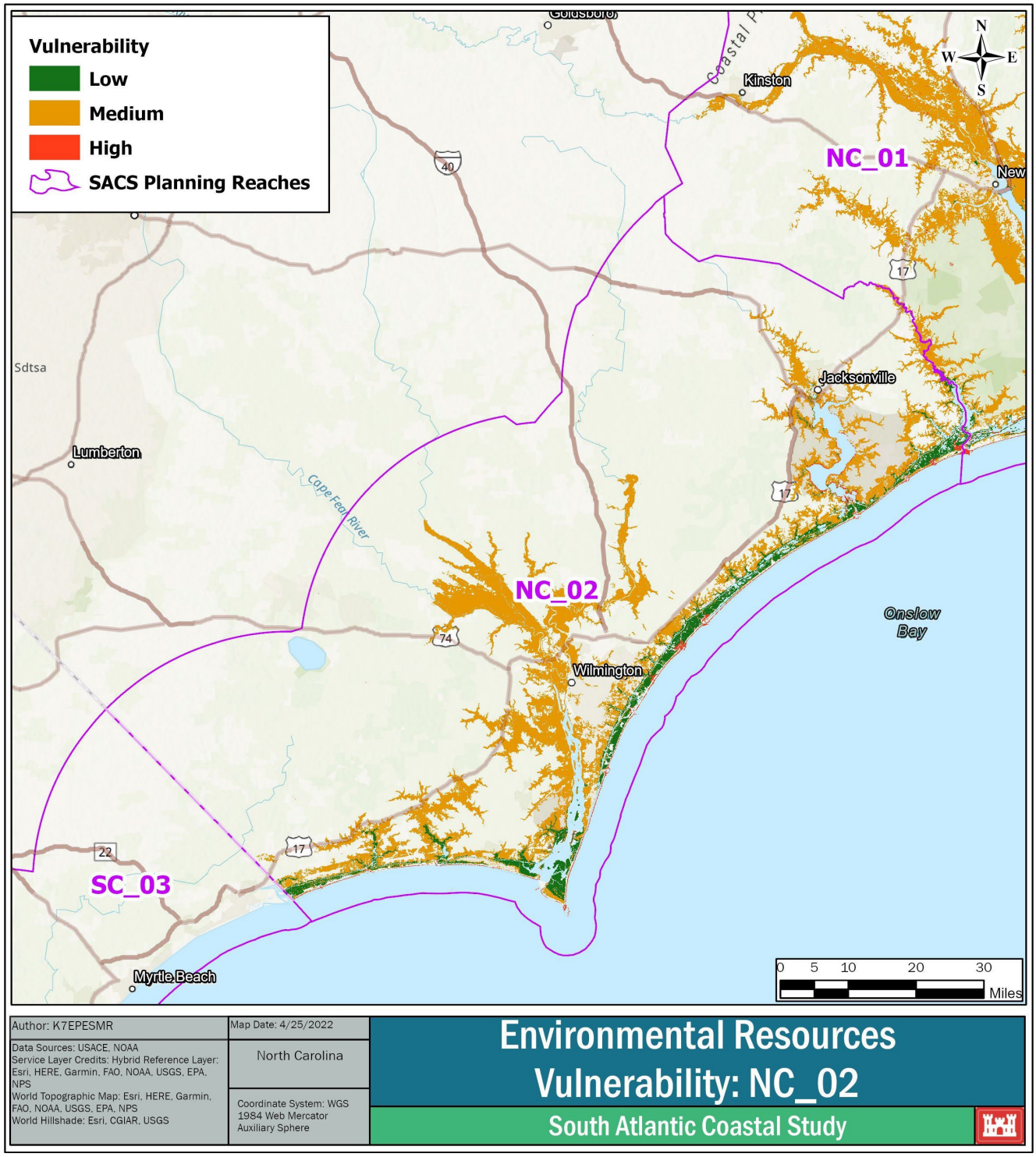


Figure 4-50: Environmental Vulnerability for Planning Reach NC_02

Table 4-24: Cultural Resources of Importance and Associated Vulnerability to Tier 2 Hazards – Planning Reach NC_02

Exposed Cultural Resources	Storm Surge Inundation	Erosion	Wave Attack
Oak Island Life Saving Station (BW0259)	Y	Y	Y
Oak Island Lighthouse (BW0260)	Y	N	N
Fort Caswell Rifle Range (BW0640)	N	N	N
Old Baldy Lighthouse (BW0001)	Y	N	N
Cape Fear Lighthouse Complex (BW0003)	Y	Y	Y
Battery Holmes (DOE) (BW0261)	Y	N	N
Fort Caswell Historic District (BW0230)	Y	Y	Y
Clarendon Plantation (BW0227)	Y	N	N
Southport NRHD (BW0008)	N	N	N
Price's Creek Lighthouse (BW0573)	Y	Y	Y
Brunswick Town/Fort Anderson (BW0002)	Y	Y	Y
Cape Fear Memorial Bridge (NH2326)	N	Y	Y
NRHP Historic Districts in Wilmington and Masonboro Sound	Y	Y	Y
USS North Carolina (NH0004)	N	Y	Y
Joy Lee Apartment Building and Annex, Carolina Beach (NH 0628)	Y	N	N
James and Frances Sprunt Cottage, Wrightsville Beach (NH 0683)	Y	Y	N
Locally Designated cottages in Wrightsville Beach	Y	Y	Y
Fort Fisher (NH 0562)	Y	Y	Y
Battery Buchanan (NH1473) – part of Fort Fisher	Y	Y	Y
The Rocks (BW0248)	Y	Y	Y

The CDC SVI was used to determine the vulnerability scores for counties within Planning Reach NC_02 presented in **Table 4-25**. Possible scores range from 0 (lowest vulnerability) to 1 (highest vulnerability).

Table 4-25: Social Vulnerability Indices by County and Theme (NC_02)

County	Theme				Social Vulnerability Index Score
	Socioeconomic	Household Composition/ Disability	Minority/ Language	Housing/ Transportation	
Bladen	0.8485	0.9697	0.7778	0.7576	0.8889
Columbus	0.7576	0.9192	0.6970	0.8788	0.8586
Dauphin	0.9596	0.8788	09495	0.8586	0.9495
Sampson	0.9091	0.889	0.9495	0.8283	0.9394

The overall CDC SVI vulnerability ranking for all counties in NC_02 were very high. Dauphin County and Sampson County have the highest vulnerability index compared to adjacent counties. Social vulnerability characterization includes certain segments of the population that have difficulty preparing for and responding to coastal flood events. Based on the Social Vulnerability Exposure Index Analysis, some areas on the coastline and inland were identified as having relatively high social vulnerability, and many areas showed high and relatively high social vulnerability.

4.3.2.4 Planning Reach NC_02 Tier 2 High-Risk Locations

Tier 2 high-risk locations were determined from data presented in the hazards, exposure, and vulnerability sections.

Hazus was used to identify locations of high infrastructure damage risk. The SACS Tier 2 Economic Risk Assessment report provides additional detail on methods used. The risk classification thresholds identified in **Table 4-26** were based on the Planning Reach NC_02 specific lower and upper bounds of the FEMA Hazus Flood model-derived damages. The damage range was statistically classified into five classes (low, low-medium, medium, medium-high, high) using the Jenks optimization method, also referred to as the Jenks natural breaks classification method. For Planning Reach NC_02, a high-risk location was defined as a census place with EAD above approximately $10,932,000, and a medium- high-risk location was defined as any location with EAD above approximately $5,530,000.

Table 4-26: Federal Emergency Management Agency Hazus Flood Model Risk Classification Thresholds for Planning Reach NC_02

Bin	Risk	Census Places		Census Blocks	
		Low Bound	Upper Bound	Low Bound	Upper Bound
NC	5–Low Risk	$0	$868,054	$0	$53,460
NC	4–Low-Med Risk	$868,055	$2,555,902	$53,461	$189,656
NC	3–Med Risk	$2,555,903	$5,529,913	$189,657	$449,380
NC	2–Med-High Risk	$5,529,914	$10,932,263	$449,381	$928,714
NC	1–High Risk	$10,932,264	$21,678,824	$928,715	$2,219,828

Table 4-27 displays the county distribution of locations identified with a risk rating of medium-high to high in the future conditions, considering 3 feet of sea level rise. Understanding the spatial distribution of economic risk from coastal floods under existing and future sea level rise conditions can help inform communities about which potential actions should be implemented to mitigate the potential economic risks.

Table 4-27: Tier 2 Economic Risk Assessment Medium, Medium-High, and High-Risk Locations Categorized by County

County	Census Place	Existing EAD	Existing Risk Rating	Future EAD	Future Risk Rating	Percent Increase in EAD in Future Condition
Brunswick	Oak Island	$21,679,000	High	$42,549,000	High	96%
Brunswick	Holden Beach	$10,932,000	Med-High	$20,093,000	High	84%
Brunswick	Ocean Isle Beach	$8,063,000	Med-High	$19,565,000	High	143%
Brunswick	Sunset Beach	$3,546,000	Med	$8,158,000	Med-High	130%
Brunswick	Bald Head Island	$3,528,000	Med	$9,348,000	Med-High	165%
Brunswick	St. James	$2,175,000	Low-Med	$6,046,000	Med-High	178%
New Hanover	Wilmington	$14,578,000	High	$33,284,000	High	128%
New Hanover	Carolina Beach	$13,585,000	High	$30,299,000	High	123%
New Hanover	Wrightsville Beach	$14,642,000	High	$25,028,000	High	71%
New Hanover	Myrtle Grove	$4,526,000	Med	$7,125,000	Med-High	57%
New Hanover	Sea Breeze	$3,072,000	Med	$7,234,000	Med-High	135%
Onslow	North Topsail Beach	$3,294,000	Med	$6,097,000	Med-High	85%
Onslow	Jacksonville	$2,556,000	Low-Med	$5,930,000	Med-High	132%
Pender	Topsail Beach	$5,298,000	Med	$9,599,000	Med-High	81%
Pender	Surf City	$8,209,000	Med-High	$17,223,000	High	110%

Critical Erosion Risk Assessment

This study recognizes that there is significant erosion occurring in many back bay areas throughout Planning Reach NC_02, and that additional follow-on analysis is needed to further define this hazard in the back bay (see Recommendations).

Figure 4-51 identifies CEAs on the oceanfront shoreline within Planning Reach NC_02 that have elevated erosion rates (3 feet per year or greater) and a greater presence of exposed resources, which would be threatened by the erosion hazard. As indicated in **Figure 4-51**, SACS-identified CEAs within Planning Reach NC-02 are located at Holden Beach and at North Topsail Beach.

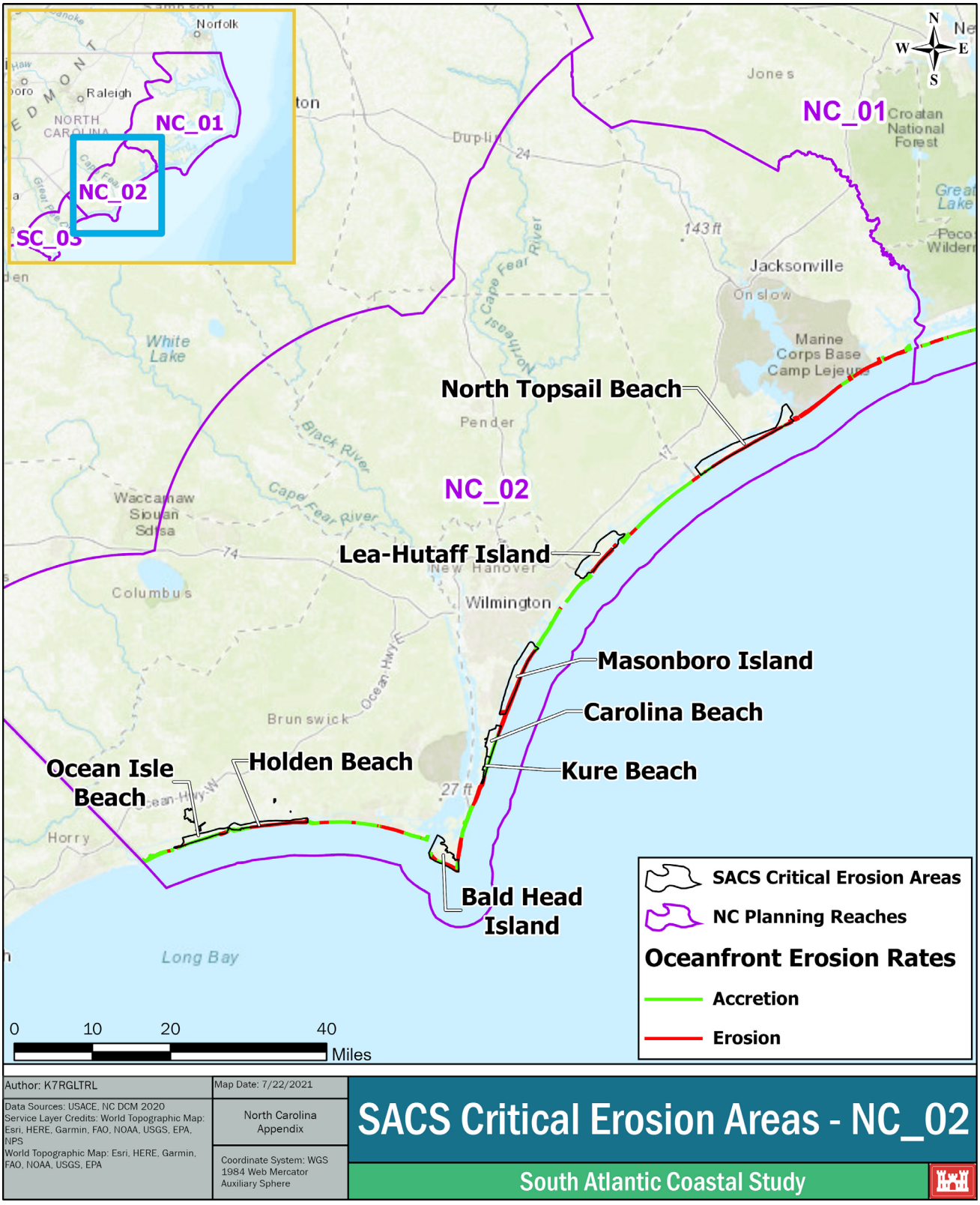


Figure 4-51: Critical Erosion Area in Planning Reach NC_02

Tier 2 Cultural Resources Risk Analysis

Based on qualitative assessment, there are multiple historic sites in Planning Reach NC_02 at risk of damage or loss due to coastal storm hazards and sea level rise. These resources are invaluable, and their loss would be an irreplaceable, tangible link to North Carolina and United States history. Especially in areas where erosion is already degrading site quality, such as at Brunswick Town/Fort Anderson on the west bank of the Cape Fear River, resource loss may be expected to continue without intervention. Damage to historic properties can sometimes be repaired, but this can be costly and may lack support if more essential recovery efforts are needed in the area to restore infrastructure. Archaeological sites are non-renewable resources that cannot be replaced once lost. Loss of historic properties and archaeological sites not only means a loss to the historical record that helps us to understand and explain the past, but it can also mean a loss to local tourism. Visitors are drawn, in part, to this planning reach due to the many historic districts, lighthouses, and colonial historical sites. Damage caused by storms may result in the complete loss of all or portions of historic properties. Years of costly repairs can close these sites indefinitely until the site can be restored and are deemed safe for visitors. The loss of archaeological sites could pose a significant hit to the academic community as well, limiting research into and interpretation of prehistoric and historic sites in this reach.

Tier 2 Environmental Resources Inundation Risk Analysis

Environmental risk is a product of exposure to coastal storm-related hazards and vulnerability to those hazards. Risk considers the ability of flora and fauna to endure the short- and long-term effects of coastal storms and the potential for habitat alteration. For example, lower elevation areas are more at risk to wave attack than are upland areas. Similarly, salt-intolerant habitats are more at risk to sea level rise than are salt-tolerant habitats. The risk areas in North Carolina were separated into categories of potential high, medium and low, as depicted in **Figure 4-31** and shown in the SACS Environmental Analysis Web-Mapping Tool.

PEAs are natural areas or features at medium to high risk to storm surge inundation and sea level rise. Stakeholders can consider these areas when looking for environmental resources to conserve and/or manage. PEAs found in Planning Reach NC_02 are shown in **Figure 4-52** and are listed below. All North Carolina PEAs are featured in Appendix C of the Environmental Technical Report (USACE 2022b), including selection justification and consequences of exposure to coastal storm damage and sea level rise. Additionally, a selection of PEAs is described further in each of North Carolina's three FAAS reports.

Priority Environmental Areas

- Carolina Beach State Park
- Fort Fisher State Recreation Area
- Green Swamp Preserve
- Lake Waccamaw Sunset Park
- Masonboro Island Reserve
- Sunset Beach Bird Island Coastal Reserve (Waties Island)

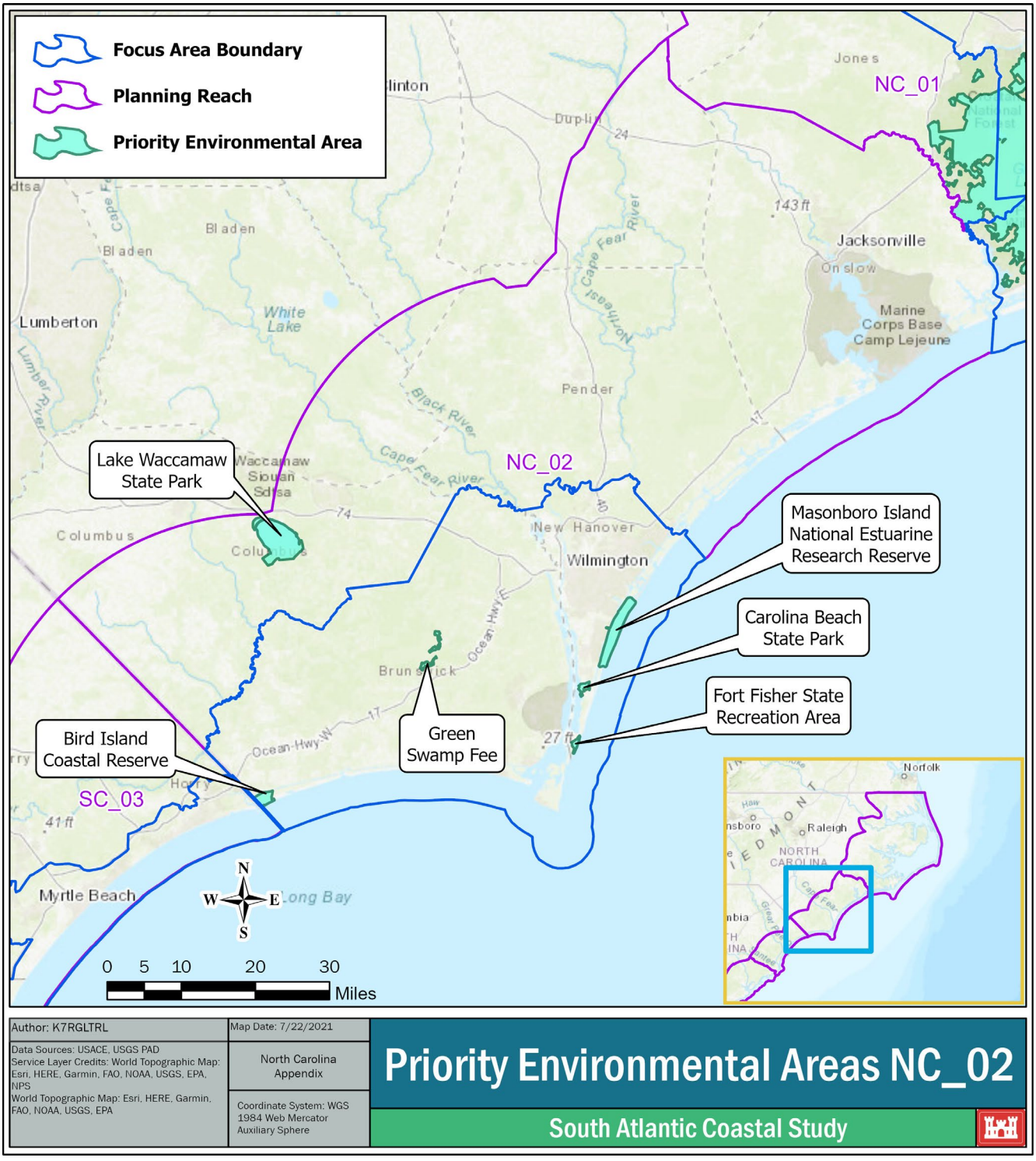


Figure 4-52: Priority Environmental Areas within Planning Reach NC_02

4.3.3 Planning Reach NC_02 Summary of High-Risk Locations

Additional high-risk areas in North Carolina were determined by census place and through a set of specific screening criteria. To be considered "high-risk," a location would need to meet one of the following criteria:

1. Medium-high to high-risk rating in the Tier 1 Risk Assessment
2. Medium-high to high Hazus inundation damage rating
3. Meet SACS CEA threshold for North Carolina (see Erosion Section 4.1.4.3 for details)
4. Seasonal Population (assumed for all shorefront communities based on comparative data)
5. PEA or cultural resource identified with significant risk

Although other risks were identified for Planning Reach NC_02, the aforementioned risks were considered the significant factors for determining higher risk to population and infrastructure and environmental, cultural, and habitat resources.

High-risk areas for Planning Reach NC_02 for Tier 1 and Tier 2 are shown in **Table 4-28.**

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Table 4-28: Planning Reach NC_02 Tier 1 and Tier 2 High-Risk Areas

Planning Reach NC_02		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate			At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk	Seasonal Population[1]	Identified as area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as area with PEA or Resource At-Risk	Environmental Resource Name	
Brunswick	Oak Island	X	X	$21,679,000	High	$42,549,000	High			X	X	Oak Island Life Saving Station (BW0259), Oak Island Lighthouse (BW0260), Fort Caswell Rifle Range (BW0640)			6
Brunswick	Holden Beach	X	X	$10,932,000	Med-High	$20,093,000	High		X	X					6
Brunswick	Ocean Isle Beach			$8,063,000	Med-High	$19,565,000	High			X					3
Brunswick	Sunset Beach	X	X	$3,546,000	Med	$8,158,000	Med-High			X			X	Sunset Beach Bird Island Coastal Reserve	6
Brunswick	Bald Head Island			$3,528,000	Med	$9,348,000	Med-High			X	X	Old Baldy Lighthouse (BW0001), Cape Fear Lighthouse Complex (BW0003), Battery Holmes (DOE) (BW0261)			4
Brunswick	St. James			$2,175,000	Low-Med	$6,046,000	Med-High								1
Brunswick	Calabash	X	X	$224,000	Low	$568,000	Low								2
Brunswick	Caswell Beach	X	X	$1,395,000	Low-Med	$2,713,000	Med			X					4
Brunswick	none (directly abuts Caswell Beach	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Fort Caswell Historic District (BW0230)			1

Planning Reach NC_02		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as area with PEA or Resource At-Risk	Environmental Resource Name	
	census place)														
Brunswick	Leland	X	X	$1,091,000	Low-Med	$2,461,000	Low-Med								2
Brunswick	none (closest community is Leland census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Clarendon Plantation (BW0227)			1
Brunswick	Shallotte	X	X	$772,000	Low	$1,617,000	Low-Med								2
Brunswick	Southport	X	X	$760,000	Low	$1,573,000	Low-Med				X	Southport NRHD (BW0008)			3
Brunswick	none (closest community is Southport census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Price's Creek Lighthouse (BW0573)			1
Brunswick	Navassa	X	X	$133,000	Low	$321,000	Low								2
Brunswick	Varnamtown		X	$116,000	Low	$198,000	Low								1
Brunswick	Belville	X	X	$53,000	Low	$148,000	Low								2
Brunswick	Bolivia			$0	Low	$0	Low						X	Green Swamp Preserve	1
Brunswick	Kendall Chapel (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Brunswick Town/Fort Anderson (BW0002)			1
Brunswick	New Hope (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Green Swamp Preserve	1
Brunswick	Piney Grove (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Green Swamp Preserve	1
Brunswick	Prospect (non-census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Green Swamp Preserve	1
Columbus	Riegelwood		X	$1,000	Low	$3,000	Low								1

Planning Reach NC_02		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as area with PEA or Resource At-Risk	Environmental Resource Name	
Columbus	Lake Waccamaw (census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Lake Waccamaw State Park	1
New Hanover	Wilmington	X	X	$14,578,000	High	$33,284,000	High				X	Cape Fear Memorial Bridge (NH2326), NRHP Historic Districts in Wilmington and Masonboro Sound	X	Masonboro Island Reserve	6
New Hanover	none (closest community is Wilmington census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	*USS North Carolina (NH0004)*			1
New Hanover	Carolina Beach	X	X	$13,585,000	High	$30,299,000	High			X	X	Joy Lee Apartment Building and Annex, Carolina Beach (NH 0628)	X	Masonboro Island Reserve	7
New Hanover	none (directly abuts Caswell Beach census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			X	Carolina Beach State Park	1

Planning Reach NC_02		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as area with PEA or Resource At-Risk	Environmental Resource Name	
New Hanover	Wrightsville Beach			$14,642,000	High	$25,028,000	High			X	X	James and Frances Sprunt Cottage, Wrightsville Beach (NH 0683), Trask Memorial Bridge, Wrightsville Beach (DOE) (NH 3471), Locally Designated cottages in Wrightsville Beach	X	Masonboro Island Reserve	5
New Hanover	Myrtle Grove	X	X	$4,526,000	Med	$7,125,000	Med-High						X	Masonboro Island Reserve	5
New Hanover	Sea Breeze	X	X	$3,072,000	Med	$7,234,000	Med-High						X	Masonboro Island Reserve	5
New Hanover	Kings Grant	X	X	$961,000	Low-Med	$2,072,000	Low-Med								2
New Hanover	Silver Lake	X	X	$368,000	Low	$1,523,000	Low-Med								2
New Hanover	Wrightsboro	X	X	$364,000	Low	$475,000	Low								2
New Hanover	Hightsville	X	X	$337,000	Low	$573,000	Low								2
New Hanover	Skippers Corner	X	X	$132,000	Low	$354,000	Low								2
New Hanover	Castle Hayne	X	X	$131,000	Low	$515,000	Low								2
New Hanover	Kure Beach			$235,000	Low	$1,459,000	Low-Med			X	X	*Fort Fisher (NH 0562)*			2

Planning Reach NC_02		Tier 1		Tier 2											Total High-Risk Factors (Qualifying factors indicated by an "x" or ERA Rating of "Med" or higher)
		Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)				Shoreline Erosion Rate		Seasonal Population[1]	At-Risk Cultural Resources		At-Risk Environmental Resources		
County	Census Place or Location Name	Identified as Existing High-Risk Location	Identified as Future High-Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Average long term oceanfront shoreline erosion rate	Above average erosion rate (>3ft.per year) plus Tier 1 med-high to high risk		Identified as area with Cultural Resource At-Risk	Cultural Resource Name *(Italics indicate National Historic Landmarks)*	Identified as area with PEA or Resource At-Risk	Environmental Resource Name	
New Hanover	none (closest community is Kure Beach census place)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	Battery Buchanan (NH1473) – part of Fort Fisher, The Rocks (BW0248)	X	Fort Fisher State Recreation Area	2
New Hanover	Bayshore		X	$0	Low	$0	Low								1
New Hanover	Ogden	X	X	$0	Low	$0	Low								2
New Hanover	Porters Neck	X	X	$0	Low	$0	Low								2
Onslow	North Topsail Beach	X	X	$3,294,000	Med	$6,097,000	Med-High		X	X					6
Onslow	Jacksonville	X	X	$2,556,000	Low-Med	$5,930,000	Med-High								3
Onslow	Sneads Ferry			$1,851,000	Low-Med	$3,335,000	Med								1
Onslow	Half Moon	X	X	$748,000	Low	$1,403,000	Low-Med								2
Onslow	Piney Green	X	X	$616,000	Low	$1,411,000	Low-Med								2
Pender	Topsail Beach			$5,298,000	Med	$9,599,000	Med-High			X					3
Pender	Hampstead	X	X	$0	Low	$1,000	Low								2
Pender	Surf City	X	X	$8,209,000	Med-High	$17,223,000	High			X					5

[1] Assumptions based on data from 8 beach communities across study area, assumes applicability to all barrier island communities. Study acknowledged there are likely other locations where increased seasonal population also exists.

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4.4 Summary of North Carolina High-Risk Locations

Results of the Tier 1 and Tier 2 analyses have resulted in more than 160 high-risk locations in North Carolina, which accounts for over two-thirds of the census places and environmental areas being assessed. Increased population and development, without planning for resilience and adaptation to sea level rise, will further increase the substantial risk. Throughout the state there is potential for significant increase in risk from sea level rise due to the large number of bays and relatively large number of counties along the state's northern coastline. The problems identified in Section 3.2 are the most pronounced in the locations identified below.

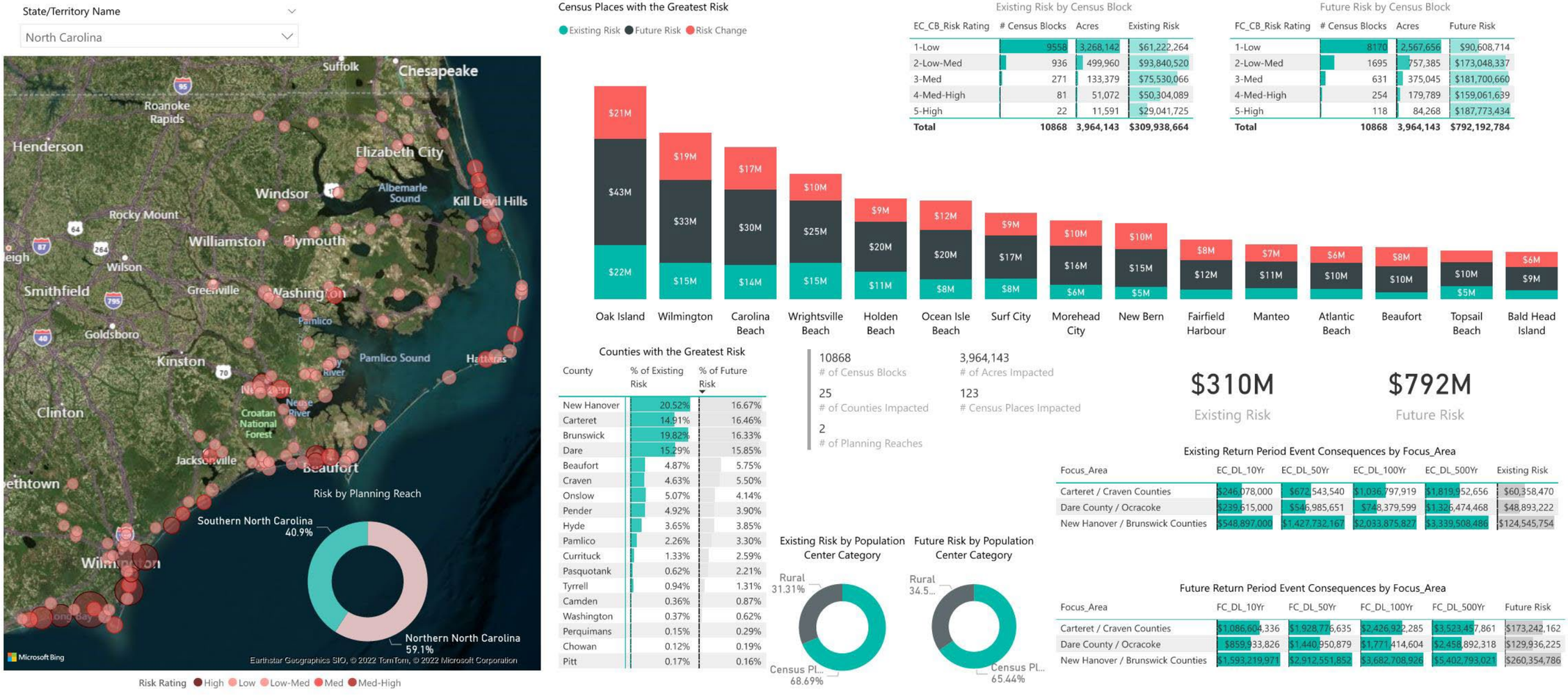
Within Planning Reach NC_01, the census places with the greatest economic risk are Morehead City in Carteret County ($5,602,000 EAD in existing conditions / $15,671,000 EAD in future conditions) followed by New Bern in Craven County ($4,935,000 EAD in existing conditions / $15,032,000 EAD in future conditions). On a county-wide basis, Carteret ($45,510,000 existing / $129,480,000 future) and Dare ($46,800,000 EAD in existing conditions / $124,870,000 EAD in future conditions) Counties project the most risk, with economic damage projections nearly tripling between existing and future conditions. This significant jump in future risk can be attributed to the extensive low-lying topography in those areas that will be exposed to future sea level rise. Pasquotank County, in particular, has the most significant increase in future risk relative to current risk. Pasquotank County is estimated to see an increase in economic risk by a factor of 10, from approximately $1,700,000 to $17,000,000 when factoring in sea level rise.

Within Planning Reach NC_02, the census places with the greatest economic risk are Oak Island in Brunswick County ($21,679,000 EAD in existing conditions / $42,549,000 EAD in future conditions), Wilmington in New Hanover County ($14,578,000 EAD in existing conditions / $33,284,000 EAD in future conditions), and Carolina Beach in New Hanover County ($13,585,000 EAD in existing conditions / $30,299,000 EAD in future conditions).

Figure 4-53 provides a snapshot of the Tier 2 Economic Risk Assessment for North Carolina. Each red circle on the map denotes separate census places. The map included in **Figure 4-53** displays the distribution of economic risk from low to high by census place. Bar charts highlight the census places with the greatest economic risk in North Carolina, with quantifications of the existing (green shading) and future risks, including sea level rise (black shading) and the change (i.e., delta) between the two (red shading). Economic risks displayed are not cumulative. The distribution of existing and future economic risks is further broken down by census block, counties with the greatest risk, population center category (i.e., rural, census place, or estate), and focus areas. Nearly two-thirds of the risk within the study area is in New Hanover, Carteret, Brunswick, and Dare Counties. However, risk tends to be more dispersed throughout moderately developed areas. More than 31 percent of the risk is anticipated outside of a census place and increases to nearly 35 percent in the future.

The Environmental Technical Report (USAE 2022b) identified 14 PEAs within North Carolina. For purposes of SACS, the North Carolina habitat types most at risk to the effects of coastal storms and sea level rise are beach/dune communities, floodplain forests, mesic forests, tidal swamp forests, and wetlands. Each of these habitat types is particularly sensitive to the effects of storm surge, saltwater intrusion, and sea level rise. For this reason, and because these habitat types are not known to readily migrate inland or adapt to increasingly saline conditions, they are considered to be most at risk. For beach/dune communities in particular, direct seaward exposure to erosion, wave attack, storm surge, and sea level rise increase risk.

Other habitat types, such as estuarine communities, are also vulnerable to the effects of sea level rise. However, estuarine communities are considered more inclined to adapt to increased salinity exposure due to regular tidal exposure under current conditions, relative ease of reproduction and propagation, and ability to migrate to higher elevations if no physical barriers preclude it.



Census Places with the Greatest Risk

Existing Risk by Census Block

EC_CB_Risk Rating	# Census Blocks	Acres	Existing Risk
1-Low	9558	3,268,142	$61,222,264
2-Low-Med	936	499,960	$93,840,520
3-Med	271	133,379	$75,530,066
4-Med-High	81	51,072	$50,304,089
5-High	22	11,591	$29,041,725
Total	**10868**	**3,964,143**	**$309,938,664**

Future Risk by Census Block

FC_CB_Risk Rating	# Census Blocks	Acres	Future Risk
1-Low	8170	2,567,656	$90,608,714
2-Low-Med	1695	757,385	$173,048,337
3-Med	631	375,045	$181,700,660
4-Med-High	254	179,789	$159,061,639
5-High	118	84,268	$187,773,434
Total	**10868**	**3,964,143**	**$792,192,784**

Counties with the Greatest Risk

County	% of Existing Risk	% of Future Risk
New Hanover	20.52%	16.67%
Carteret	14.91%	16.46%
Brunswick	19.82%	16.33%
Dare	15.29%	15.85%
Beaufort	4.87%	5.75%
Craven	4.63%	5.50%
Onslow	5.07%	4.14%
Pender	4.92%	3.90%
Hyde	3.65%	3.85%
Pamlico	2.26%	3.30%
Currituck	1.33%	2.59%
Pasquotank	0.62%	2.21%
Tyrrell	0.94%	1.31%
Camden	0.36%	0.87%
Washington	0.37%	0.62%
Perquimans	0.15%	0.29%
Chowan	0.12%	0.19%
Pitt	0.17%	0.16%

10868
# of Census Blocks

3,964,143
# of Acres Impacted

25
# of Counties Impacted

123
Census Places Impacted

2
# of Planning Reaches

$310M
Existing Risk

$792M
Future Risk

Existing Risk by Population Center Category

Future Risk by Population Center Category

Existing Return Period Event Consequences by Focus_Area

Focus_Area	EC_DL_10Yr	EC_DL_50Yr	EC_DL_100Yr	EC_DL_500Yr	Existing Risk
Carteret / Craven Counties	$246,078,000	$672,543,540	$1,036,797,919	$1,819,952,656	$60,358,470
Dare County / Ocracoke	$239,615,000	$546,985,651	$748,379,599	$1,326,474,468	$48,893,222
New Hanover / Brunswick Counties	$548,897,000	$1,427,732,167	$2,033,875,827	$3,339,508,486	$124,545,754

Future Return Period Event Consequences by Focus_Area

Focus_Area	FC_DL_10Yr	FC_DL_50Yr	FC_DL_100Yr	FC_DL_500Yr	Future Risk
Carteret / Craven Counties	$1,086,604,336	$1,928,776,635	$2,426,922,285	$3,523,457,861	$173,242,162
Dare County / Ocracoke	$859,933,826	$1,440,950,879	$1,771,414,604	$2,458,892,318	$129,936,225
New Hanover / Brunswick Counties	$1,593,219,971	$2,912,551,852	$3,682,708,926	$5,402,793,021	$260,354,786

Figure 4-53: North Carolina Overview of Existing and Future Risk

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SECTION 5
Managing Risk

5.1 Coastal Program Guide – North Carolina

The *SACS Coastal Program Guide* (USACE 2022a) provides information on federal directives, resources, and funding opportunities to help communities better leverage resources needed on a disaster-wide, state-/territory-wide, or community-wide basis. Many states/territories have additional resources available for local projects. Resources specific to North Carolina are described below and can be found in the *SACS Coastal Program Guide*.

- **North Carolina Department of Public Safety** provides information about available federal funding opportunities for local and state partners to prevent, protect, respond to, or recover from a natural or human-made disaster. https://www.ncdps.gov/our-organization/emergency-management/grants
- **Volunteer or Voluntary Non-profit Agencies or Organizations Active or Assisting in or with Disasters** is administered by the North Carolina Division of Emergency Management to provide shelters, housing repairs, and other emergency and disaster recovery services. https://www.ncdps.gov/VOADgrant
- **Recovery State/Rural Grants, North Carolina Department of Commerce**, administers grants through the North Carolina Department of Commerce to support recovery from hurricanes or other natural disasters. https://www.nccommerce.com/grants-incentives/disaster-recovery
- **North Carolina Community Foundation Disaster Relief Fund** allocates funding to programs supporting long-term recovery efforts and meeting unmet needs in communities. Funding is given to specific counties, and to regional and statewide nonprofits. https://www.nccommunityfoundation.org/apply/grants/nccf-disaster-relief-fund
- **Golden LEAF Disaster Recovery Grant Program** provides funds for governmental entities and 501(c)(3) to repair and replace infrastructure and equipment damaged or destroyed by Hurricanes Matthew, Florence, Michael, and Dorian. This includes publicly owned assets and buildings. Projects that construct new infrastructure for hazard mitigation and increased resilience receive higher priority for grant funding. This grant program focuses on meeting needs not served by other federal grant opportunities and insurance claims. https://www.goldenleaf.org/grant-seekers/disaster-recovery-grant-program/

- **Planning and Managements Grants, North Carolina Department of Environmental Quality**, managed by the Division of Coastal Management of the NCDEQ provides financial support to local governments for projects in the 20 coastal counties of North Carolina. The amount of grant funding available annually varies. https://deq.nc.gov/about/divisions/coastal-management/coastal-management-land-use-planning/grants

- **Coastal Adaptation Types and Examples, North Carolina Department of Environmental Quality**, provides many great tools, documents, and studies to help communities understand adaptation and how to practice it. https://deq.nc.gov/about/divisions/coastal-management/coastal-adaptation-and-resiliency/adaptation-types-and-examples#ocean-shoreline-management

- **North Carolina Sea Grant** works with coastal communities across the United States, Puerto Rico, the Virgin Islands, and Caribbean regions to improve community resilience to coastal storms. Sea Grant projects include vulnerability assessments, resilience planning, and social science initiatives to learn from previous storms and prepare for future storms. https://ncseagrant.ncsu.edu/

- **North Carolina Coastal Land Trust** is an accredited land trust that acquires easements for the preservation of critical lands for conservation efforts. https://coastallandtrust.org/

- **North Carolina Land and Water Fund Acquisition** offers land acquisition grants that provide funding for the acquisition of land in fee or conservation easements. Conserved lands offer ecological diversity, protecting/conserving surface waters, and protecting/conserving riparian buffers for the purpose of environmental protection. https://nclwf.nc.gov/

- **Donated Property Minigrant, North Carolina Land and Water Fund**, provides up to $25,000, or the value of conservation donation, whichever is less, to pay transaction costs associated with the donation of property in fee simple or a permanent conservation agreement as stated on the program website. To be eligible, the donation must be for protection of surface water quality, protection of a riparian buffer, to buffer military installations, preservation and conservation of ecological diversity, or development of a balanced state historic properties program. https://cwmtf.nc.gov/grants/apply-grant/apply-donated-property-minigrant

- **Planning Grant, North Carolina Land and Water Fund**, is available for planning projects that enhance or restore degraded waters, protect unpolluted waters, contribute toward a network of riparian buffers and greenways for environmental, educational, and recreational benefits, provide buffers around military bases to protect the military mission, acquire land that represents the ecological diversity of North Carolina, acquire land that contributes to the development of a balanced state program of historic properties, or facilitate innovative efforts to improve stormwater treatment. https://cwmtf.nc.gov/grants/apply-grant/apply-planning-grant

- **North Carolina Silver Jackets** is an intergovernmental team of federal, state, and local agencies that collaborate on flood management issues and share information and resources related to flooding and mitigation, integrating mitigation and recovery efforts, and leveraging available resources. https://silverjackets.nfrmp.us/State-Teams/North-Carolina

- **Water Resources Development Grant Program, North Carolina Department of Environmental Quality**, provides cost-share grants and technical assistance to local governments for eligible project types including water management, stream restoration, and feasibility/engineering studies. https://deq.nc.gov/about/divisions/water-resources/water-resources-grants/financial-assistance

- **Southeast Sustainable Communities Fund, Southeast Sustainability Directors Network**, accelerates the adoption of sustainable best practices in southeast communities, including aid to mitigate and adapt to climate change through sustainable water initiatives. https://www.southeastsdn.org/programs/southeast-sustainable-communities-fund-sscf/

- **North Carolina Department of Environmental Quality Division of Coastal Management** works to protect, conserve, and manage North Carolina's coastal resources through an integrated program of planning, permitting, education, and research. The office of Coastal Adaptation and Resiliency hosts a number of tools for coastal adaptation and resiliency from a variety of stakeholder partners. Information concerning hazards, risk, vulnerability, community planning, shoreline management, data, and tools can be found within the NC DEQ DCM. The NCDEQ Funding and Assistance for Coastal Resilience provides information to assist local communities in leveraging those funding resources available.

  - https://deq.nc.gov/about/divisions/coastal-management
  - https://deq.nc.gov/about/divisions/coastal-management/coastal-adaptation-and-resiliency/tools-coastal-adaptation
  - https://deq.nc.gov/about/divisions/coastal-management/coastal-adaptation-and-resiliency/data-support-coastal-adaptation
  - https://deq.nc.gov/about/divisions/coastal-management/coastal-adaptation-and-resiliency/funding-assistance-coastal

- **North Carolina Office of Recovery and Resiliency (NCORR)**, in the wake of Hurricane Florence, was established by Governor Roy Cooper to lead the state's efforts to rebuild smarter and stronger. At that time, many eastern North Carolina counties had been hit hard by two devastating storms in just two years. NCORR manages nearly a billion dollars in U.S. Department of Housing and Urban Development (HUD) funding in two grant types, Community Development Block Grant – Disaster Recovery (CDBG-DR) funds and Community Development Block Grant – Mitigation (CDBG-MIT) funds,

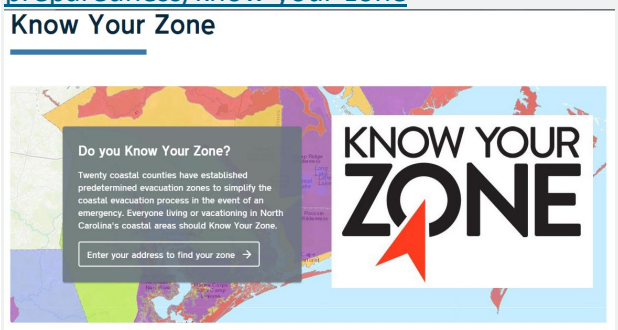
meant to make North Carolina communities safer and more resilient from future storms. Additional funding is provided through the State Disaster Recovery Acts of 2017 and 2018, and the Storm Recovery Act of 2019. https://www.rebuild.nc.gov/resiliency

5.2 Hurricane Evacuation Planning

Under the National Hurricane Program, a Hurricane Evacuation Study (HES) was completed for North Carolina in 2016. The purpose of the North Carolina HES was to provide emergency management officials with sound data that would inform them in hurricane evacuation planning and decision-making. The study was a partnership between FEMA, USACE, and the National Hurricane Center and was conducted in coordination with North Carolina Emergency Management and the coastal counties. Products included evacuation clearance times and the development of evacuation zones to assist with local evacuation decisions.

In 2020, North Carolina Emergency Management, in coordination with the coastal counties, developed updated evacuation zones and launched the Know Your Zone public outreach initiative (North Carolina Department of Public Safety [NCDPS] n.d.). Know Your Zone includes a public lookup tool with a color-coded interactive map that residents and visitors can use to determine the evacuation zone where they live, work, or are visiting based on a street address. Know Your Zone is intended to streamline the evacuation process by supporting personal readiness in preparation for hazardous weather events. When a storm is approaching, local officials will determine the zones that are most threatened to assess which residents should evacuate.

NC Department of Public Safety - Know Your Zone: https://www.ncdps.gov/our-organization/emergency-management/emergency-preparedness/know-your-zone



Components of the HES such as evacuation clearance times are typically updated periodically through the National Hurricane Program.

HURREVAC, short for hurricane evacuation, is a web-based decision support tool developed by the NHP for use by local, state, and federal agencies. Emergency management officials use the tool to translate forecast data to chart the progress of a storm. HURREVAC provides real-time analysis of potential consequences of current storms to help emergency management officials make the difficult decisions when to issue evacuation orders based on clearance times from the onset of tropical storm force winds. The clearance time developed in the transportation analysis is the time is takes for every person to evacuate safely before the arrival of tropical storm force winds. HURREVAC provides "earliest likely" and "most reasonable" arrival time of tropical storm force winds, giving a range of

times for emergency managers to plan and make decisions. HURREVAC also predicts wind arrival times.

HURREVAC can also predict the MOM of the hurricane and the Maximum Envelope of Water (MEOW) for multiple scenarios of the approaching storm based on hurricane category and direction of approach. These factors greatly influence the consequences of a hurricane event and the storm surge communities can expect. In addition to current storms, HURREVAC also houses information from past storms for post-storm evaluations and lessons learned.

5.3 Existing Beach Nourishment Programs

The State of North Carolina, along with local, regional, and federal partners, has been addressing coastal storm risk for decades with a robust coastal resiliency program already in place across the state. Early efforts focused on "hardened structures" as solutions to reduce erosion, such as jetties, groins, and revetments. While these types of structures can be an essential part of risk management, their design and placement must be carefully considered on North Carolina's coast given the potential to cause unwanted impacts such as erosion of adjacent shorelines. Beach nourishment is now the best practice to address coastal erosion, provide recreation, enhance critical habitat, and protect infrastructure.

SACS includes several sand management components including the Sand Availability and Needs Determination, SAND (USACE 2020c), the 2020 RSM Optimization Update (USACE 2020a), and the DMMA Offloading and Sediment Exchange (USACE 2020d). These products were used in the following sections as well as in the focus area action strategies to provide more detailed information concerning sand management in North Carolina.

5.3.1 Sand Needs and Resources

Table 5-1 provides a list of federal and non-federal CSRM and risk management projects within the State of North Carolina (USACE 2020c). The criteria for inclusion in the table is a beach that is nourished with a minimum of 100,000 cubic yards per single nourishment in the past 10 years or RSM projects used for nourishment that dredge more than 50,000 cubic yards per dredge event with a maintenance cycle of less than five years where the dredged sand is placed for beach. The sand needs analysis identified 21 federal and five non-federal beach nourishment projects in SAW.

Table 5-1: Existing Coastal Storm Risk Management Projects in North Carolina (USACE 2020c)

Project Name	County	Agency/Organization	Estimated 50-Year Sand Need (cubic yards)
Bald Head Island	Brunswick	USACE, FEMA, Village of Bald Head Island	25,704,000
Caswell Beach	Brunswick	USACE	4,160,000
Holden Beach	Brunswick	USACE, FEMA, Town of Holden Beach	12,903,000
Oak Island	Brunswick	USACE, FEMA, Town of Oak Island	9,639,000
Ocean Isle Beach	Brunswick	USACE, Town of Ocean Isle Beach	10,353,000

Project Name	County	Agency/Organization	Estimated 50-Year Sand Need (cubic yards)
Atlantic Beach/Ft. Macon	Carteret	USACE	14,575,000
Emerald Isle	Carteret	USACE, FEMA, Town of Emerald Isle	8,619,000
Indian Beach	Carteret	USACE, FEMA, Carteret County, Town of Indian Beach	2,907,000
Pine Knoll Shores	Carteret	USACE, Carteret County, Town of Pine Knoll Shores	7,410,000
Duck	Dare	Dare County, Town of Duck	2,480,400
Hatteras Island- Buxton	Dare	USACE	8,996,000
Kill Devil Hills	Dare	USACE, Dare County	3,445,000
Kitty Hawk	Dare	USACE, Dare County	6,837,000
Mirlo Beach/Rodanthe	Dare	NCDOT	94,700
Nags Head	Dare	USACE, Town of Nags Head, Dare County, FEMA	25,500,000
Pea Island	Dare	USACE	19,437,000
Southern Shores	Dare	Dare County	2,465,000
Carolina Beach	New Hanover	USACE, Town of Carolina Beach	16,677,000
Figure Eight Island	New Hanover	New Hanover County, Figure "8" Beach HOA	15,276,000
Kure Beach	New Hanover	USACE	18,513,000
Masonboro Island	New Hanover	USACE	6,420,000
Wrightsville Beach	New Hanover	USACE	9,204,000
Surf City/North Topsail Beach	Onslow & Pender	USACE, North Topsail Beach	26,210,000
North Topsail Beach	Onslow	USACE, North Topsail Beach	15,660,000
Onslow	Onslow	USACE	2,610,000
Topsail Beach	Pender	Town of Topsail Beach	11,679,000

Figure 5-1 summarizes the 50-year sand needs and availability of counties with coastal North Carolina. The sand needs component evaluates the 50-year sand needs for each beach nourishment project using documented sand volume requirements and historic nourishment placement volumes combined with local and regional stakeholder inputs. The “percentage of sand need available” in the tables illustrates the ratio of sand available compared to the sand needs for each county. If this percentage is greater than 100 percent, it indicates a sand surplus; if less than 100 percent, a sand deficit is identified. The 50-year sand needs are multiplied by a 55 percent contingency based off assumptions such as borrow area inefficiencies (sand left in the borrow area), other dredging losses (dig-to-place loss), and future project performance including sea level rise impacts.

The offshore sand source component quantified the volume of available sediment from offshore sand and beneficial use sources within the region and provides polygon shapes for these areas categorized according to the extent of available data and characteristics of the material. These categories, with confidence factors (percent), include Proven (90 percent), Potential (70 percent), Unverified Plus (5-30 percent), Unverified (0 percent), and Unusable (0 percent). The Beneficial Use portion of the sand source component incorporates federal and non-federal RSM sources such as dredging from

navigational channels, inlets, flood shoals, and ebb shoals utilizing the USACE 2020a for federal sources. The offshore borrow areas do not account for hardbottom habitat, cultural resources, unexploded ordnance, and dredge location constraints. Tables and figures are available in the SAND report by district at the county level. While the SAND report displays sand availability per county, it is emphasized that the majority of sand sources exist in state or federal waters and not within the jurisdiction of any particular county.

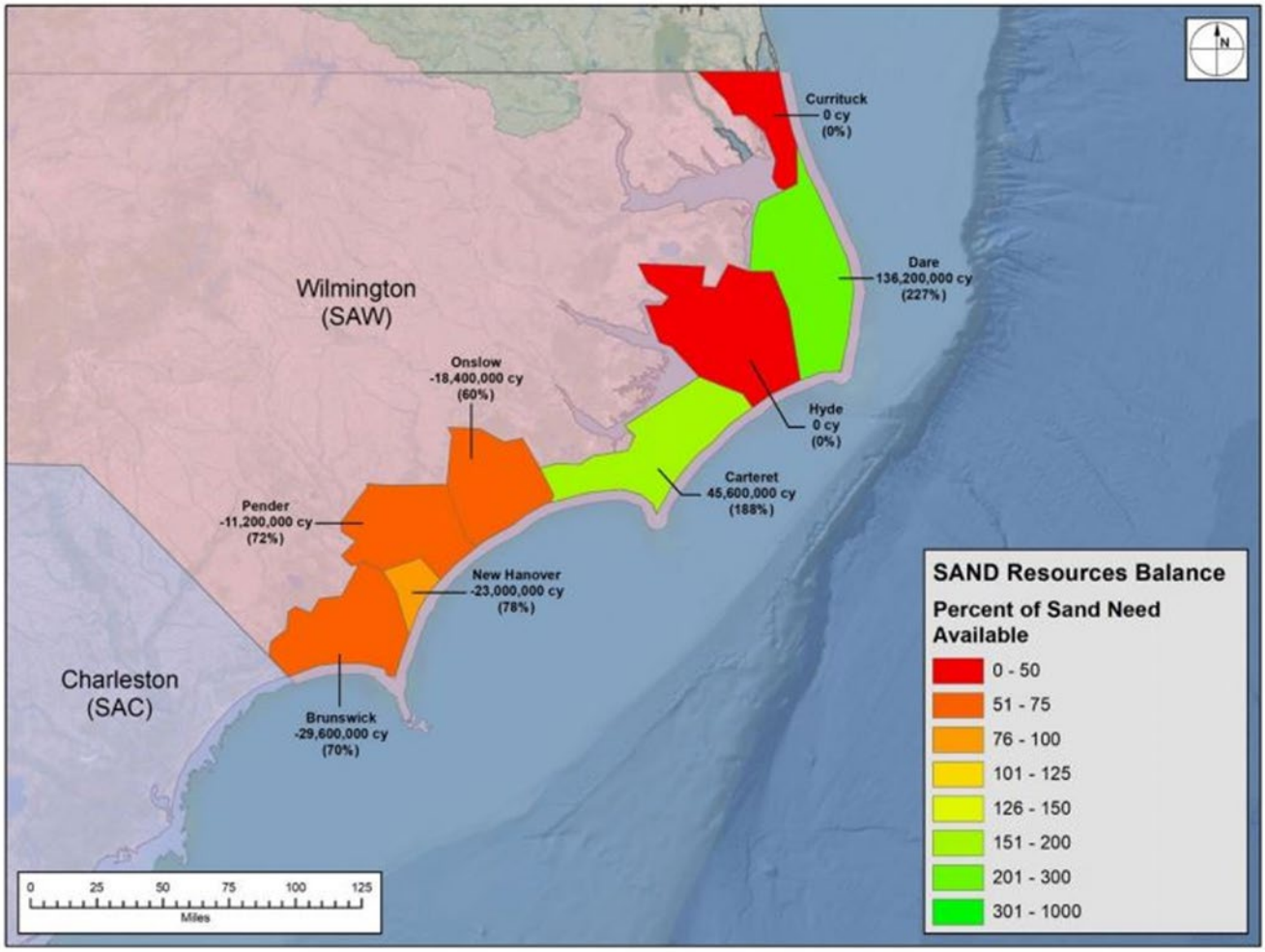


Figure 5-1: Sand Resources Balance Showing the Percent of 50-year Sand Needs Available by County for the State of North Carolina (USACE 2020c)

It is important to note that Hyde and Currituck counties are designated as zero (red) due to a lack of project needs reported for those counties. The SAND report identified the 50-year sand need and availability for all counties in North Carolina with beach nourishment projects. Dare and Carteret counties were found to have a surplus of available sands to meet the current project needs with a surplus of 127 percent in Dare County and a surplus of 88 percent in Carteret County. All counties in the southern portion of the state were found to have sand deficits. This is not surprising given the underlying geological controls e.g., rocky coast with more active inlet dynamics and significantly smaller marsh and back bay areas. Onslow County had the lowest percentage of available sand

resources at 60 percent of the projected 50-year need. Pender, New Hanover, and Brunswick counties have identified 72, 78, and 70 percent of needed sand resources, respectively.

Many project updates have occurred since the publication of SAND (USACE 2020c). Any pertinent project updates are provided below in addition to existing living shoreline projects.

Federal

- Surf City – Authorized, Funded, Active
- North Topsail Beach – Authorized, Funded, Inactive
- Wrightsville Beach – Constructed, Active
- Carolina Beach & Vicinity (Kure Beach) – Constructed, Active
- Brunswick County Beaches, Ocean Isle Portion – Constructed, Active
- Holden Beach – General Reevaluation Report Funded in 2021
- Fort Macon – Active
- Dare County – Authorized, now locally funded, Individual portions listed below
- Fort Fisher Revetment – Constructed
- Jockey's Ridge State Park Living Shoreline – NOAA
- Nags Head Living Shoreline – NOAA
- Alligator River NWR Living Shoreline – NOAA
- Festival Park Living Shoreline – Manteo, North Carolina
- Chaney Creek Urban Living Shoreline – NOAA
- Bradley Oaks Living Shoreline Demonstration – NOAA
- Airlie Gardens Marsh Creation and Living Shoreline – NOAA

Non-federal

- Nags Head – Constructed, Last nourished in 2019 (Dare County Project)
- Kill Devil Hills – Constructed, Last nourished in 2017 (Dare County Project)
- Kitty Hawk – Constructed, Last nourished in 2017 (Dare County Project)
- Rodanthe – Constructed (Dare County Project)
- Bogue Banks

- Topsail Beach
- North Topsail Beach
- Rock Revetment Protection fronting the Lost Colony Amphitheatre – Constructed

North Carolina beaches produce millions of dollars for the state's economy each year and the coastal areas also provide important habitats for a variety of species. Identifying potential sand deficits can aid in prioritizing further offshore sand investigations and coastal management planning.

5.3.2 Other Coastal Storm Risk Management Projects

In addition to beach nourishment projects, several other efforts are underway within the state to address CSRM needs. **Table 5-2** lists example efforts throughout North Carolina, including extensive community planning efforts, public outreach, and studies. Nonstructural, planning and policy efforts contribute to the overall success of CSRM projects by identifying critical areas for future projects, monitoring project efficacy, and creating public awareness of the need for and importance of CSRM.

Table 5-2: Summary of Existing/Ongoing Federal and Non-federal Efforts to Support Coastal Storm Risk Reduction within North Carolina

Project	Planning Reach	Project Area	Agency/ Organization	Comments
Risk Communication (Annual Public Hurricane Workshop)	NC_01	Nags Head	Dare County Emergency Medical Services	Dare County Emergency Medical Services holds an annual public workshop in Nags Head for hurricane awareness.
National Park Service (NPS) Erosion Assessment from Nags Head to Ocracoke Island	NC_01	Dare County, Ocracoke Island	NPS	NPS is completing an oceanfront erosion assessment from Nags Head to Ocracoke Island. This assessment looks at erosion from 1953 to 2020, with transects every 100 meters. It also forecasts 10, 20, and 30 years into the future and identifies which structures are at risk with and without sea level rise.
Structure Vulnerability Assessment (Historic Structures and NPS Structures)	NC_01	Dare County	NPS, Old Dominion University, Western Carolina University	This assessment will use Sea, Lake, and Overland Surges from Hurricanes (SLOSH) modeling to assess vulnerability of all historic and NPS structures to identify which ones need adaptive management measures. This will identify costs of adaptive measures for NPS structures.
North Carolina Coastal Community Resiliency Guide	NC_01	North Carolina Coastal Counties	North Carolina Division of Coastal Management	This online interactive North Carolina Coastal Communities Resilience Guide is designed to walk users through some of the key steps and questions required for effective community-level resiliency planning while pointing to relevant tools, resources, and examples.
Inclusion of 3 feet of freeboard for new construction	NC_01	Dare County	Dare County	Dare County adds 3 feet of freeboard (the height of a ship's side between the waterline and the deck) to their base flood elevations for new construction, which is above the minimum requirement.

Project	Planning Reach	Project Area	Agency/ Organization	Comments
Analysis and Incorporation of Coastal Hazards Planning into Policy and Comprehensive Plan	NC_01	Town of Nags Head	North Carolina Sea Grant, Town of Nags Head	North Carolina Sea Grant identified opportunities for the Town of Nags Head, North Carolina to incorporate coastal hazards planning into policy. The team led workshops to help community members better understand the scope of coastal hazard consequences and develop adaptation strategies. The team also secured funding through a Southeast Sea Grant Regional Resilience grant to conduct a law and policy analysis of issues affecting the adaptation options identified and to conduct GIS-based assessments. The Vulnerability, Consequences, Adaptation, Planning Scenarios (VCAPS) workshops led to formation of a Climate Adaptation and Sea Level Rise Committee that prioritized adaptation options and compiled them into a report. In September 2017, the Nags Head Board of Commissioners accepted the report, which provides guidance as the Town considers shoreline, stormwater, and wastewater management plan proposals. The Town has also included a Sea Grant written sea level rise science synthesis in its comprehensive plan, which was adopted in August 2017, making the Town of Nags Head the state's first northeastern municipality to include sea level rise in its comprehensive plan.
Neuse River Basin Flood Risk Management Study	NC_01	Entire Neuse River Basin, including Craven County	USACE, North Carolina Department of Environmental Quality	This is a congressionally authorized study to investigate and formulate measures to address flood risk in the Neuse River Basin. The study area includes Craven County. Potential flood risk management measures could include structural, nonstructural and/or natural and nature-based features (NNBF) that contribute to the reduction of flood damage and life safety risk.
Down East Community – Building a New Digital (BAND) Economy in North Carolina	NC_01	Carteret County – Down East Communities	Carteret County Economic Development Foundation	Reliable internet and broadband is a necessity that affects all aspects of life and communication in the Down East communities in Carteret County. There are currently plans through the BAND effort to expand broadband infrastructure.
New Bern Flood Resiliency Study	NC_01	City of New Bern (Craven County)	City of New Bern	The City of New Bern is engaged in a process to develop a resiliency and hazard mitigation plan to enhance overall community resilience, better understand flood risk within the community, and identify potential flood mitigation solutions. The purpose of this effort is to create a more resilient New Bern.
Establishment of Hurricane Evacuation Zones	NC_01 and NC_02	State of North Carolina	North Carolina Emergency Management (NCEM), Dare County, Hyde County	In coordination with a recent initiative implemented in 2019, 20 coastal counties, including Dare and Hyde, have established predetermined evacuation zones to simplify the coastal evacuation process in the event of an emergency. The initiative is titled "Know Your Zone." North Carolina Know Your Zone is a tiered evacuation system that highlights areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards.

Project	Planning Reach	Project Area	Agency/ Organization	Comments
Environmental Impact Statements (EIS) for NPS lands in Dare County, Ocracoke Island, and Outer Banks	NC_01 and NC_02	All NPS lands on the Outer Banks	NPS	The purpose of the EIS is to develop a streamlined framework for permitting sediment management at all NPS managed lands in Dare County and Ocracoke Island areas of the Outer Banks including the method, locations, and frequency for sediment management actions that may be permitted over the next 20 years. In this context, the EIS will address certain sediment management activities that may be implemented by the NPS, local jurisdictions, state agencies, and other federal agencies
HMGP Residential Home Acquisitions and Elevations	NC_01 and NC_02	Statewide	FEMA, State of North Carolina	This is a FEMA program to help homeowners through the Hazard Mitigation Grant Program.
ReBUILD NC Homeowner Recovery Program	NC_01 and NC_02	Areas damaged by Florence/ Matthew	North Carolina Office of Recovery and Resiliency (NCORR)	The Homeowner Recovery Program helps repair, reconstruct, replace, or elevate homes or reimburse residents for completed repairs to homes that were damaged by Hurricanes Florence or Matthew.
ReBUILD NC Strategic Buyout Program	NC_01 and NC_02	Statewide	NCORR	This program enables eligible property owners, located in areas that are prone to repeated flooding, to relocate to safer land. NCORR provides financial incentives to homeowners to remain in communities. The affordable housing program focuses on constructing affordable and safe housing.
Working Lands Climate & Salinization Study - Guidebooks	NC_01 and NC_02	State of North Carolina and Working Lands	US Department of Agriculture (USDA)	Guidebooks being produced as part of research on sustainability of working/agricultural lands in the face of saltwater intrusion and inundation. These are intended to be used as a tool to help farmers adapt to changes occurring due to sea level rise and coastal storms.
Saltwater Inundation and Intrusion Research	NC_01 and NC_02	Various	USDA, North Carolina State University (NCSU), East Carolina University, Duke University	Conduct scientific research to further document and understand the sea level rise-related phenomena of saltwater intrusion and inundation, and its impacts in coastal North Carolina. Research may help identify adaptive measures.

Project	Planning Reach	Project Area	Agency/ Organization	Comments
Collaboratory for Coastal Adaptation over Space and Time (C-CoAST)	NC_01 and NC_02	North Carolina Coastal Counties	–	The Collaboratory for Coastal Adaptation over Space and Time (C-CoAST) is funded by the National Science Foundation to address grand challenges in coastal resilience. Developed coastal environments are shaped by interactions between human activities and natural processes. Mitigation and recovery strategies that promote adaptation at the time scale of storm events can be counterproductive over longer timescales. A series of collaborative activities will integrate coastal researcher, stakeholder, and practitioner expertise, building capacity for a comprehensive understanding of the human-natural coastal system. This will enable the potential for steering away from future outcomes that communities may want to avoid, and toward outcomes they deem more desirable.
Completed Living Shorelines	NC_02	Bradley Oaks and Airlie Gardens	–	There are two completed living shorelines in the area.
Holden Beach CSRM Study	NC_02	Town of Holden Beach	USACE, Town of Holden Beach	USACE is studying the feasibility and justification of Federal partnership for coastal storm risk management measures at the Town of Holden Beach for a 50-year period.
Transportation/ Evacuation Route Improvements	NC_02	Brunswick County	North Carolina Department of Transportation (NCDOT), Brunswick County, Metropolitan Planning Organization, Grand Strand Area Transportation	Highway 211 is a major transportation/evacuation route in Brunswick County, which has been inundated by past coastal storm events. Impacts include life safety and prevention of ingress/egress. The North Carolina Department of Transportation (NCDOT), in collaboration with Brunswick County, the local Metropolitan Planning Organization, and the Grand Strand Area Transportation have included Highway 211 in NCDOT's State Transportation Improvement Program. The State Transportation Improvement Program identified improvements to Highways 211 and 906 as a multi-phase project to start in 2022 with final completion more than 10 years out. Improvements would include road widening extending to Highway 17, as well as elevation in sections.

5.3.3 Federal Project Performance Evaluation

USACE district staff completed PPEs to evaluate the effectiveness of SAD's federal CSRM projects, to recommend improvements and identify barriers to such improvements. PPEs were completed for four federal projects within the State of North Carolina. PPEs use a rating system to assess overall performance (rating of one to three shown in **Table 5-3**) as well as performance during significant storm events (rating of one to 10 shown in **Table 5-4**). Higher scores indicate better performance. North Carolina's PPEs are summarized in **Table 5-5**. Even if a project is performing well and providing authorized benefits, there may still be ways to increase the overall performance, including decreasing costs, increasing benefits from beneficial use, and improving consideration of co-benefits to storm risk management such as habitat maintenance for threatened and endangered species.

Table 5-3: Overall Project Performance Rating System

Ranking	Description
1: Failure	No or minimal storm damage reduction benefits derived.
2: Average or Above Average Design Performance	Acceptable amount of expected storm damage reduction benefits derived; an example of acceptable or above average project design and performance.
3: Well Above Average Design Performance	Majority of expected storm damage reduction benefits derived; an example of exceptional project design and performance.

Table 5-4: Project Performance Rating System During a Significant Storm Event

Ranking	Description
1-2: Failure	No or minimal storm damage reduction benefits derived; hard structures damaged due to design deficiency.
3-4: Below Average Performance	Minimal expected storm damage reduction benefits derived; considerable-to-some damage to hard structures.
5: Average Performance	Acceptable amount of expected storm damaged reduction benefits derived; some damage to hard structures.
6-7: Above Average Performance	Acceptable amount of expected storm damage reduction benefits derived; some to minimal damage to hard structures; an example of acceptable performance.
8-9: Well Above Average Performance	Majority of expected storm damage reduction benefits derived; minimal damage to hard structures; project provided incidental damage reduction.
10: Exceptional	Total expected storm damage reduction benefits derived; minimal or no damage to hard structures; project provided incidental damage reduction; an example of exceptional project performance.

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Table 5-5: Summary of Project Performance Evaluations

Project Name (County)	SACS Planning Reach	USACE District	Non-federal Project Sponsor	Initial Completion Date	Estimated 50 Year Sand Need (CY)	Project Performance Rating (1-3)	Project Performance during Low-Frequency Major Storms (1-10)	Additional Benefits (quantified/not quantified)	Does Project use or benefit from RSM practices? (yes/no)	RSM Federal Projects Coordination	Annual RSM Value	Potential RSM Actions to Sustain or Enhance Project Performance	Cited Institutional and Other Barriers to Providing Comprehensive Protection	Performance Improvement Recommendations
Carolina Beach	NC_01	SAW	Town of Carolina Beach	1966	16,700,000	3 (Southern 10,000) 1 (Northern 2,050)	Rating – 6 Hurricane Fran Category 3 1996	Environmental (not quantified) for Southern 10,000 Recreation (quantified) for Northern 2,050	Yes	USACE Navigation sands from Carolina Beach Inlet and the AIWW are periodically placed on Carolina Beach.	$1.3 million	–	Delayed nourishments due to funding limitations. Dredge availability. Project Timing and current Coastal Barrier Resources Act (CBRA) Coastal Barrier Resources System (CBRS) Unit guidance.	Re-evaluation of northern end template to limit/prevent flooding along the rock revetment. Consider dune alternatives. Future nourishments will require use of an offshore borrow area due to current CBRA guidance. Use of the existing borrow area for both Kure and Carolina Beach is feasible; however, it must be properly managed in order to avoid exhausting it prior to the end of project lifespan.
Kure Beach	NC_01	SAW	Town of Kure Beach	1998	18,500,000	2	Rating - 3 Hurricane Florence Category 1 2018	Environmental (not quantified)	No	–	–	–	Offshore borrow area management with Carolina Beach under current CBRA guidance.	Current CBRA guidance has resulted in both the Carolina Beach and Kure Beach projects being resourced by the same offshore borrow area. It is imperative that this borrow area be properly managed in order to avoid exhausting it prior to the end of project lifespan.
Ocean Isle Beach	NC_01	SAW	Town of Ocean Isle Beach	2001 - 2050	10,400,000	2	Rating -10 Hurricane Florence Category 1 2018	Environmental (not quantified)	Yes	USACE Navigation sands from Shallotte Inlet and the AIWW Inlet and the AIWW are periodically placed at Ocean Isle.	$0-Although not quantified for RSM value, management strategy represents the cheapest cost and best option.	–	Delayed nourishments due to funding limitations. Project Timing.	–
Wrightsville Beach	NC_01	SAW	Town of Wrightsville Beach	1965 Completely restored 1980-1981.	9,200,000	6	Rating -10 Hurricane Florence Category 1 2018	Environmental (not quantified)	Yes	USACE management of the Masonboro Inlet NAV project and the Wrightsville Beach CSRM	$1.7 million	–	Inlet borrow area within USFWS CBRS Unit L09 will no longer be authorized for use under current CBRA guidance. Project Timing. Economic justification for pushing the extent of the northern end of the project.	Redrawing of the USFWS CBRS Unit L09 boundary out of the inlet, south to Masonboro Island, would allow Federal CSRM projects, which contribute to resiliency, to be implemented more efficiently. Revaluation of the storm berm elevation to reduce scarping. Evaluate extending the project footprint to the north.

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5.4 Regional Sediment Management Strategies

RSM is a systems approach to manage sediments in a manner that maximizes natural and economic efficiencies to contribute to sustainable water resource projects, environments, and communities. Sediments can be used effectively in coastal, estuarine, and inland environments. The 2020 RSM Optimization Update (USACE 2020a) and the SAND report (USACE 2020c) are key SACS products that look at regional sediment principles throughout the entire SACS study area.

2020 South Atlantic Division Regional Sediment Management Optimization Update

The 2020 RSM Optimization Update (USACE 2020a) documents placement strategies for all routine Navigation (NAV) and Flood Risk Management (FRM) projects throughout the SAD, including costs. Economic value is demonstrated by integrating FRM and NAV projects (e.g., when a NAV project uses the FRM project as a dredged material placement area or when a FRM project uses a NAV project's channel[s] as a sediment source). Estimated value was calculated by multiplying the total volume of navigation dredging material placed on the beaches by typical costs per cubic yard for the individual projects. There are 11 federal projects throughout North Carolina; seven of the projects are NAV projects and four are FRM (CSRM) projects. Future efforts could include RSM actions to restore habitat function, under the USACE Ecosystem Restoration mission, and restore and increase environmental resource resilience, utilizing other stakeholders' efforts.

As described in the 2020 RSM Optimization Update (USACE 2020a), the USACE FRM mission encompasses CSRM. The document also details the benefits of linking projects through an RSM approach. Benefits include a reduced number of dredge mobilizations, conservation of sediment sources and capacity in dredged material placement areas, potential maintenance of low-priority channels, advanced maintenance of navigation channels, project lifecycle value, enhanced partnerships with stakeholders, and more resilient projects and coastal communities. The 2020 RSM Optimization Update provides details on RSM strategies that have been implemented in the USACE's SAD and recommendations to advance RSM throughout the SACS study area (USACE 2020a). Wilmington District dredges 9.9 million cubic yards of material to maintain its authorized navigation and flood risk management projects. Through RSM, approximately 43 percent of this material is utilized or repurposed (versus traditional disposal) for beneficial use purposes, resulting in an estimated $11 million annual valuation to the Wilmington District (**Table 5-6**). An overview and summary of recommendations for each of these projects is included in each FAAS. Recommendations include optimization of ongoing strategies, coastal wetland enhancement or creation, and other potential beneficial use opportunities, but each recommendation comes with its own set of challenges that may require a coordinated multi-agency effort.

Table 5-6: Total Dredge Volume and Value of Regional Sediment Management Implemented Wilmington District Navigation and Flood Risk Management Projects (USACE 2020a)

Project	Total Dredge Volume (cubic yards)[1]	% Managed Using RSM Strategies	Annual RSM Value ($M)
Wilmington District Total	**9,900,000**	**43%**	**$11.0**
Morehead City Harbor	3,900,000	28%	$2.8
Manteo (Shallowbag) Bay, Rollinson, Silver Lake	1,100,000	100%	$0.3
AIWW	300,000	60%[2]	$1.1
Masonboro Inlet-Wrightsville Beach	800,000	100%	$1.7
Wilmington Harbor	3,800,000	26%	$3.8
Carolina Beach-Kure Beach	–	38%	$1.3
Ocean Isle Beach	–	100%	$0.0

[1]Total dredge volume is calculated as the sum of all material dredged from navigation projects per dredge cycle

[2]AIWW dredging includes upland placement of material every few cycles

In addition to the economic benefits provided in the RSM Optimization Update, the Atlantic Intracoastal Waterway Association has reported on the economic benefits as it relates to recreational boating. The AIWW provides more than 4,000 jobs, $57 million in state and federal taxes and fees, $124 million in wages, and $257 million in annual sales for North Carolina (Atlantic Intracoastal Waterway Association n.d.). Although this study did not include a comprehensive evaluation of the economic impacts and benefits of the AIWW, it demonstrates the economic importance of a waterway (Herstine et al. 2007). Similarly, there are several uninhabited islands along the coast of North Carolina that provide benefits that are not captured in any known economic analysis. The SACS Tier 2 Economic Risk Assessment Viewer demonstrates this well at Masonboro Island, as shown in **Figure 5-2**. Although an uninhabited protected preserve, Masonboro Island provides a buffer for the mainland from coastal storm damage, erosion, wave action, and other hazards. For those areas located directly behind Masonboro Island and along the AIWW, there is an estimated $6.411 million in expected annual damages for existing conditions. Although no economic risks were directly associated with Masonboro Island, it provides unquantifiable infrastructure protection benefits to the mainland.

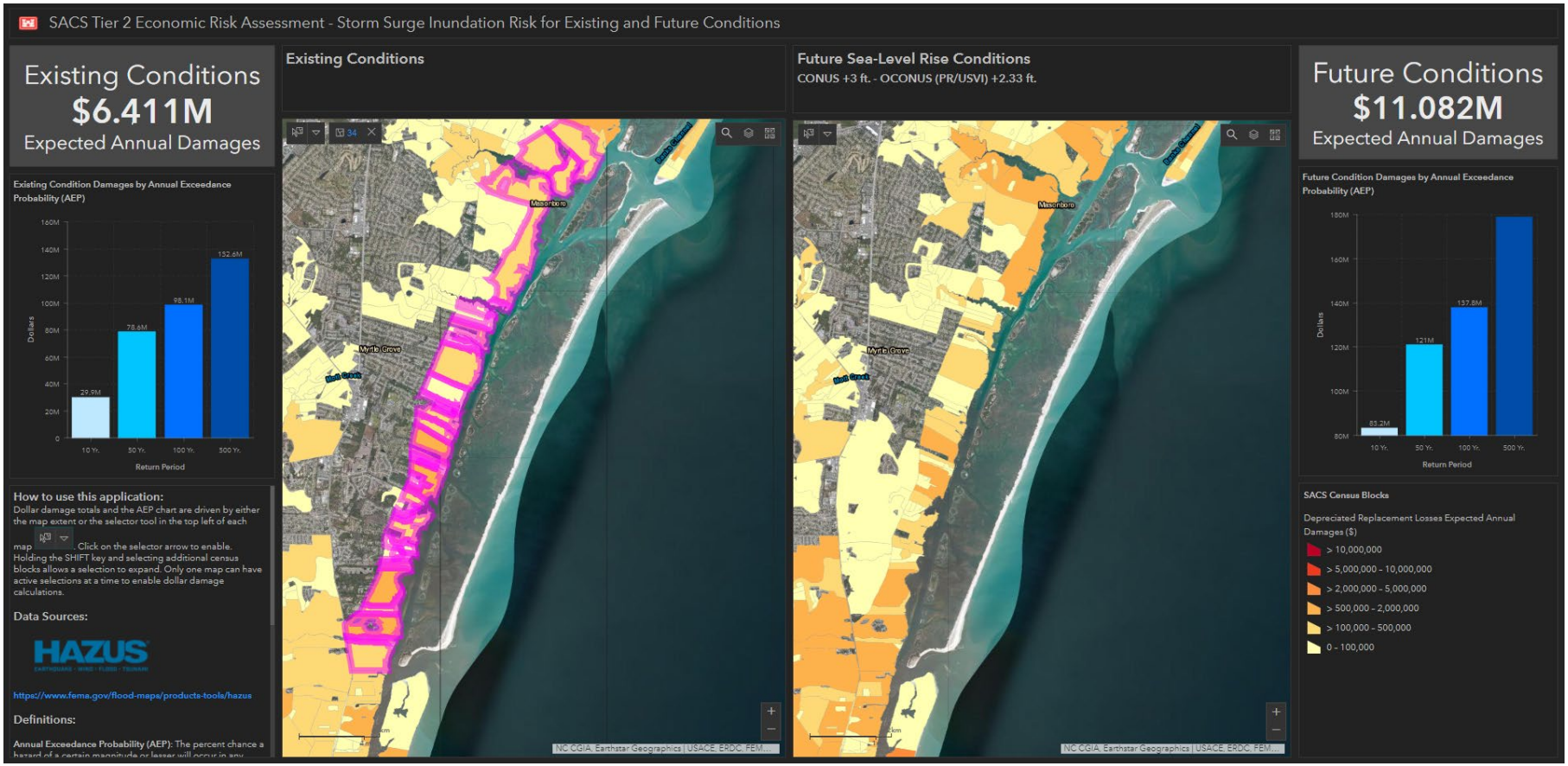

Figure 5-2: Tier 2 Economic Risk Assessment Dashboard Depicting Expected Annual Damages Near Masonboro Island

Opportunities for Action

The Wilmington District identified an opportunity for a research proposal that includes an analysis of non-beach-quality material in key project areas to determine the volume and value of sediment that could be placed beneficially if the state's percent-fines regulations were modified or exempted. The proposal could include stakeholder meetings with state regulators and local sponsors. Other districts, including Mobile, execute strategies for placing similar material to this non-beach-quality material. These strategies include open water placement, thin-layer placement and wetland creation. These strategies, as well as other potential opportunities such as filling of relict dredge holes and coastal and wetland habitat restoration projects, could be explored by the Wilmington District.

Dredged Material Management Areas Offloading and Sediment Exchange Study

The USACE DMMA Offloading, and Sediment Exchange Study is a subcomponent of SACS that seeks to identify best practices in the storage, handling, and re-use of dredged materials. A major portion of this study was developing an inventory of all DMMA's across SAD that could viably provide material for beneficial second use, versus permanent placement within a management area. Offloading of material stored in these DMMAs presents opportunities to construct or replenish coastal and estuarine environments, while extending the service life of DMMAs through beneficial placement of the stored material. Wilmington District dredges an estimated 1.9 to 2.0 million cubic yards of sediment each year from North Carolina's ports, harbors, and waterways, and approximately 57 percent of this material is placed in upland or offshore dredged material disposal areas. **Figure 5-3** displays the existing dredge material placement throughout the North Carolina Study Area. Through RSM, this material can and should be considered a valuable resource to be reclaimed where it is economically feasible. The DMMA Offloading and Sediment Exchange Study identified several upland placement areas within North Carolina that may be suitable for sediment offloading and reclamation based upon proximity to current projects, potential end-use, material type, and prior history of use.

Offloading of sediment in DMMAs presents RSM opportunities to support coastal resilience, such as beach, nearshore, or littoral zone placement, back bay, marsh, or wetland habitat creation, building levees, or augmenting agriculture, infrastructure, and residential or commercial development. The key to successful implementation of sediment offloading and exchange is active and robust federal and public-private partnerships to ensure handling and processing is conducted economically and efficiently, with net benefit to all. Coordinating the use of DMMA stored material into state and local construction projects, or other federal agency efforts, can provide a number of benefits, such as prolonged DMMA service life, additional shore protection/storm risk management or additional habitat for future mitigation purposes.

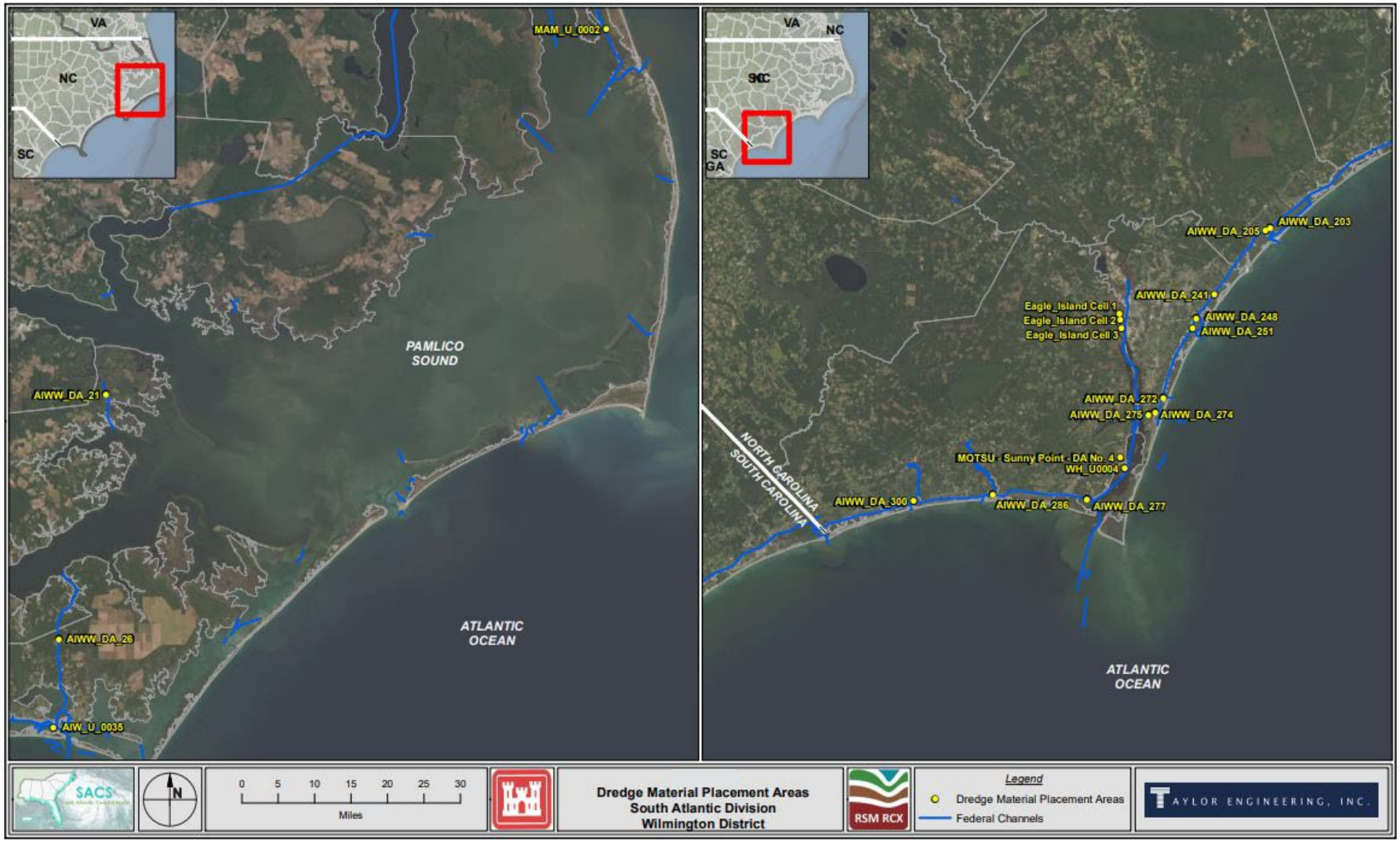

Figure 5-3: Dredged Material Placement Areas in North Carolina (USACE 2020d)

5.5 Coastal Storm Risk Management Measures and Costs

A management measure is a feature or activity at a site that addresses one or more of the planning objectives. A wide variety of measures may be considered in CSRM project planning, as depicted in **Figure 5-4**. The management measures are generally broken into the categories as follows:

1. Nonstructural: Various nonstructural alternatives, including buyouts/relocations, elevating structures, flood-proofing, evacuation planning and signage, floodplain management and community education are all considered viable measures for the coast of North Carolina.

2. Structural: Measures such a beach fills, breakwaters, groins, seawalls, and dikes may be appropriate CSRM measures. Construction of a structural feature serves to prevent waters from reaching residential property, businesses, and roads.

3. NNBF: Natural and nature-based features refer to the intentional use of natural and engineered features to produce engineering functions in combination with ecosystem services and social benefits. Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands dunes, berms, beaches, wetlands, and maritime forests such as mangroves.

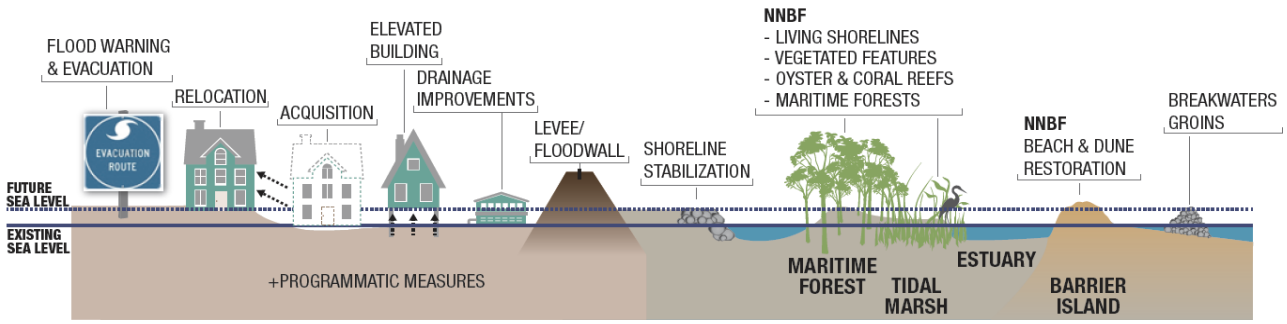

Figure 5-4: Measures to Improve Resilience and Sustainability in the Coastal Environment (USACE 2015)

The SACS Measures and Cost Library (MCL) provides a suite of specific risk management measures that exemplify the categories outlined above. It provides users with the associated costs of these measures, considering the risk management category, risk management function, shoreline applicability, regional location, cost components, and uncertainty. The MCL also provides rough-order-of-magnitude (ROM) cost data specific to each planning reach within the SACS study area. **Table 5-6** displays general ROM cost ranges throughout the SACS study area for nonstructural, structural, and NNBF, respectively. Descriptions of each measure are located in the Measures & Cost Library Report. CSRM projects can combine multiple measures (i.e., alternatives) to gain additional risk management. The location of each measure type must match the wave energy environment based on the hazard causing the problem. The SACS Measures & Cost Library Report describes planning considerations to be made when estimating ROM costs for measures and alternatives.

Table 5-7: Measures and Cost Library Tool Measure Types for North Carolina

Measures & Categories				Mobilization/Demobilization Cost		Total Cost/Unit	
Measure Code	Measure Category	Measure Group Name	Measure Unit	Mobilization/ Demobilization Low	Mobilization/ Demobilization High	Total Cost/Unit Low	Total Cost/Unit High
S-1	Structural	Groins	$/Linear Foot (LF)	$150,000	$400,000	$1,976	$10,450
S-2	Structural	Seawall	$/LF	$500,000	$750,000	$7,668	$16,097
S-3	Structural	Revetment	$/LF	$180,000	$430,000	$6,541	$18,635
S-4	Structural	Bulkhead	$/LF	$160,000	$185,000	$1,580	$4,234
S-5	Structural	Breakwaters	$/LF	$400,000	$1,200,000	$5,494	$24,762
S-6	Structural	Floodwalls	$/LF	$500,000	$500,000	$5,473	$8,828
S-7	Structural	Deployable Floodwalls	$/LF	$13,768	$17,000	$2,070	$2,796
S-8	Structural	Levees / Dikes	$/LF	$181,000	$226,150	$1,260	$3,989
S-9	Structural	Surge Barrier	$/LF	$2,000,000	$187,500,000	$181,250	$285,183
S-10	Structural	Beach Nourishment (Initial)	$/LF	$2,500,000	$6,000,000	$1,258	$7,050
S-10	Structural	Beach Nourishment (Renourishment)	$/LF	$2,500,000	$6,000,000	$628	$3,375
S-11	Structural	Nearshore Nourishment	$/LF	$450,000	$450,000	$455	$2,329
S-12	Structural	Road Elevation	$/LF	$10,000	$150,000	$7,565	$13,909
S-13	Structural	Ringwalls	$/LF	$10,000	$150,000	$2,064	$2,437
NNBF-1	NNBF	Barrier Island	$/AC	$4,500,000	$10,400,000	$231,105	$1,131,163
NNBF-2	NNBF	Tidal Flats	$/Square Foot (SF)	$400,000	$500,000	$96	$235
NNBF-3	NNBF	Wetland	$/Acre (AC)	$400,000	$1,500,000	$198,002	$1,276,032
NNBF-4	NNBF	Maritime Forest	$/AC	$10,000	$100,000	$2,075	$11,175
NNBF-5	NNBF	Wet Pine Savannah	$/AC	$10,000	$100,000	$2,075	$11,175
NNBF-6	NNBF	Mangroves	$/LF	$10,000	$150,000	$1,895	$3,088
NNBF-7	NNBF	Living Shoreline Vegetation	$/LF	$10,000	$150,000	$22	$2,234
NNBF-8	NNBF	Submerged Aquatic Vegetation	$/AC	$100,000	$300,000	$173,000	$585,500
NNBF-9	NNBF	Coral Reef Breakwater	$/LF	$400,000	$1,200,000	$2,703	$8,074

Measures & Categories				Mobilization/Demobilization Cost		Total Cost/Unit	
Measure Code	Measure Category	Measure Group Name	Measure Unit	Mobilization/ Demobilization Low	Mobilization/ Demobilization High	Total Cost/Unit Low	Total Cost/Unit High
NNBF-10	NNBF	Oyster Reef Breakwater	$/LF	$100,000	$300,000	$973	$4,063
NNBF-11	NNBF	Living Shoreline Reefs	$/LF	$250,000	$1,200,000	$6,125	$19,313
NNBF-12	NNBF	Living Shoreline Sills	$/LF	$250,000	$1,200,000	$1,805	$8,530
NS-1	Nonstructural	Buyout & Acquisition	$/Asset	–	–	$324,210	$745,880
NS-2	Nonstructural	Building Elevation	$/Asset	–	–	$131,650	$307,263
NS-3	Nonstructural	Dry Floodproofing	$/Asset	–	–	$38,353	$101,871
NS-4	Nonstructural	Wet Floodproofing	$/Asset	–	–	$10,323	$14,494
NS-5	Nonstructural	Relocation	$/Asset	–	–	$214,163	$316,397
NS-6	Nonstructural	Flood Warning Systems	No Cost Included	–	–	–	–
NS-7	Nonstructural	Flood Insurance	No Cost Included	–	–	–	–
NS-8	Nonstructural	Floodplain Mapping	No Cost Included	–	–	–	–
NS-9	Nonstructural	Flood Emergency Preparedness Plan	No Cost Included	–	–	–	–
NS-10	Nonstructural	Land Use Regulations	No Cost Included	–	–	–	–
NS-11	Nonstructural	Zoning	No Cost Included	–	–	–	–
NS-12	Nonstructural	Evacuation Plans	No Cost Included	–	–	–	–
NS-13	Nonstructural	Risk Communication	No Cost Included	–	–	–	–
NS-14	Nonstructural	Risk Analysis	$/Study	–	–	–	–
NS-15	Nonstructural	Land Conservation	No Cost Included	–	–	–	–

5.6 Focus Area Selection

The SACS focus areas are geographic areas that are highly vulnerable to storm damages as a result of sea level rise. These focus areas serve as examples of how to develop strategies to reduce risk in populated areas, areas of concentrated economic development, and areas with vulnerable environmental and cultural resources. The focus areas were selected based on Tier 1 high-risk areas and stakeholder feedback, as shown in **Figure 5-5**.

Stakeholders were engaged throughout the focus area selection process to maximize local knowledge in the area and to promote collaboration toward achieving coastal storm risk resilience. The focus area action strategies (summarized in Section 5.7) use a "watershed approach" to address risk using USACE Watershed Planning Guidance: PB 2019-01, EC 1105-2-411 (USACE 2010).

There were three focus areas selected in North Carolina—Dare County and Ocracoke Island; Carteret and Craven Counties; and Brunswick and New Hanover Counties. Each were selected based on factors including risk and stakeholder input.

Dare County and Ocracoke

This focus area is unique across the SACS study area. It is delineated by the approximate political boundaries of Dare County, North Carolina, which includes the Albemarle-Pamlico Peninsula, Roanoke Island, with approximately 85 miles of continuous ocean shoreline on the barrier islands of the Outer Banks, plus extensive back barrier shoreline. Additionally, Ocracoke Island to the immediate south is incorporated into the focus area due to its inclusion as part of the Outer Banks. There are several resources that could be leveraged for strategy recommendations, including state, county, and stakeholder resources. This region has high economic importance.

Carteret and Craven Counties

This focus area in the mid-portion of coastal North Carolina spans a portion of two counties: Carteret and Craven. It consists of several significant population centers including New Bern, Morehead City, Beaufort, and Newport. It also includes over a dozen very low-lying unincorporated communities such as Sea Level, Atlantic, and Merritt. This focus area also contains the Bogue Banks, which is a 21-mile-long barrier island that includes Fort Macon State Park, Atlantic Beach, and several other island communities.

Brunswick and New Hanover Counties

Brunswick and New Hanover Counties are divided by the Cape Fear River and represent the most populated area in Coastal North Carolina. Together, these are the two most southeastern counties in the state. There is significant infrastructure and population density around the Cape Fear River. Infrastructure of note includes a major port, rail infrastructure, a nuclear power plant, Military Ocean Terminal Sunny Point (MOTSU), and downtown Wilmington. A variety of environmental and cultural resources are also at risk.

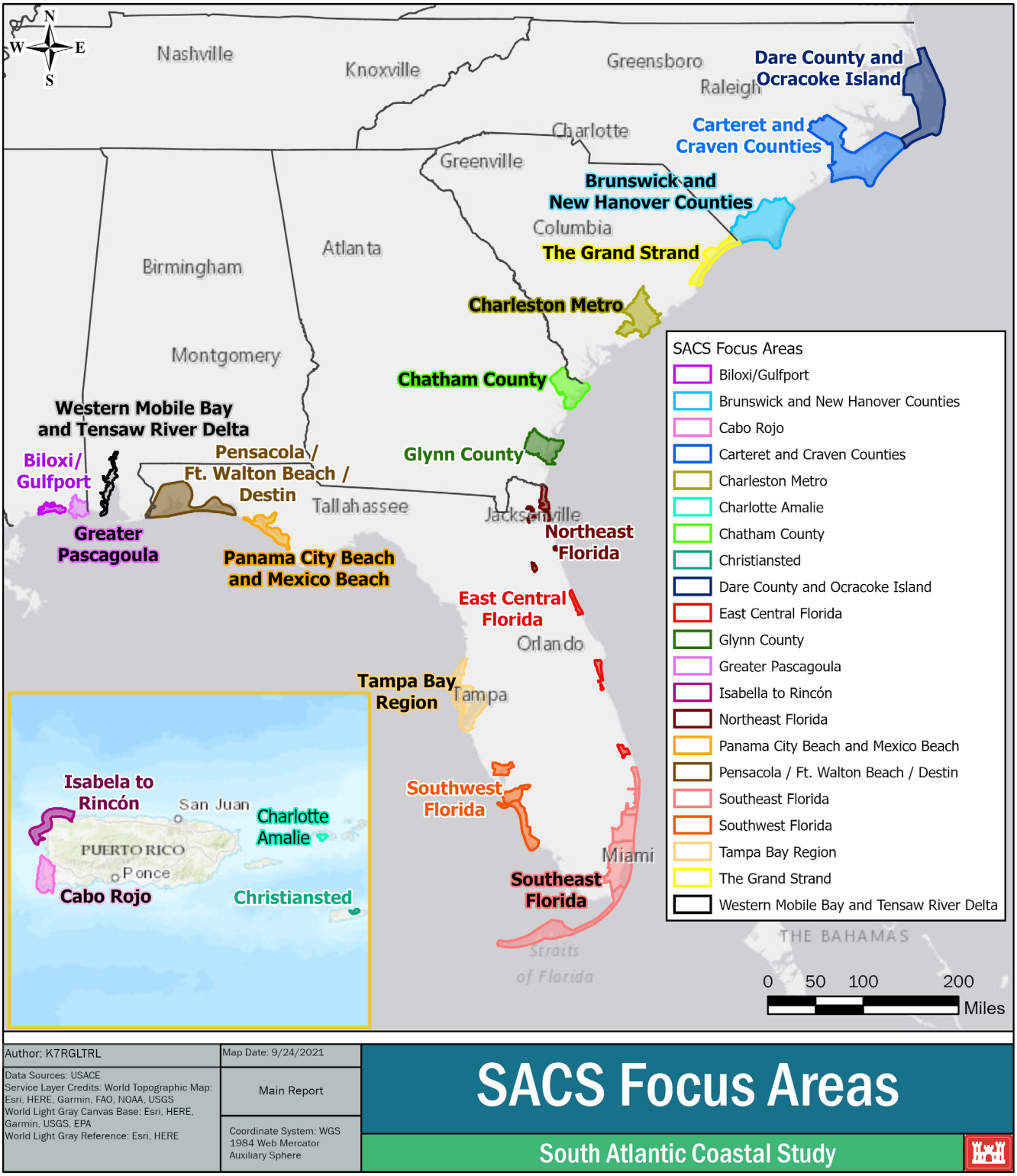

Figure 5-5: SACS Focus Areas

5.7 Focus Area Action Strategies (FAAS)

North Carolina's three focus areas are briefly described. Detailed FAAS are included as attachments to this appendix.

5.7.1 Dare County and Ocracoke Island Focus Area

The Dare County and Ocracoke focus area faces many challenges as it is situated on both a dynamic chain of barrier islands and a very low-lying mainland peninsula. There is only one primary transportation corridor on the Outer Banks which has been repeatedly damaged and closed in multiple locations due to coastal storms. With a naturally migrating shoreline in the face of stationary development, erosion is a key hazard. There are population centers, critical environmental resources, and historical cultural resources at risk throughout the area. The strategy captures extensive resiliency efforts already active within the area, including those being actioned by Dare County and the National Parks Service, who manages a large segment of the Focus Area. Additional actions are also identified to further the goals of the shared vision developed by the stakeholders.

5.7.2 Carteret and Craven Counties Focus Area

The Carteret and Craven County focus area is located at about the midpoint of the North Carolina coastline and contains a large number of high-risk areas in the SACS study area. The City of New Bern in Craven County, which is susceptible to both riverine and coastal storm surge, is developing their New Bern Flood Resiliency Study. Within Carteret County there are many small unincorporated communities which are located in extremely low-lying area vulnerable to storm surge. Loss of salt marsh habitat in the back bay areas from erosion and sea level rise is an identified problem, but more detailed research is needed to better understand the problem. Similar to the other focus areas, there are many planned resiliency efforts within the focus area, and opportunities for additional actions which further the goals of the stakeholders' shared vision.

5.7.3 Brunswick and New Hanover Counties

Located in the most populated and developed area in the North Carolina coast, this focus area includes multiple barrier island communities which are at risk from frequent coastal storms, as well as erosion. The use of sand placement is part of an overall strategy to add resiliency to these communities. However, analysis within the SACS indicates that there is a deficit in the 50-year budget of know viable sand quantities. Masonboro Island, part of the National Estuarine Research Reserve, is one of the rare undeveloped barrier islands in the region, but also has the highest erosion rate in the area. The City of Wilmington and other communities along the lower Cape Fear River are at high risk from inundation due to coastal storm surge, as well as the potential from compound flooding. The strategy captures the extensive ongoing efforts in the area and identifies additional actions which contribute to the stakeholders' shared vision.

5.8 Strategies to Address Remaining High-Risk Areas

As part of the Governor's Executive Order 80, the State's Climate Risk Assessment and Resiliency Plan is recognized as the overarching resiliency strategy for North Carolina. This plan builds upon North Carolina's ongoing work in resiliency and establishes the North Carolina Resilience Strategy, which includes four elements:

1. North Carolina Climate Science Report
2. State Agency Resilience Strategy
3. Statewide Vulnerability Assessment and Resiliency Strategies
4. North Carolina Enhanced Hazard Mitigation Plan

The scope of the SACS ties into several critical sectors of study within the State Plan, including coastal resources, ecosystems, housing, building, and support services, public safety, and transportation.

Additionally, North Carolina residents and visitors within the SACS study area are encouraged to be familiar with the Hurricane Evacuation Zone established for their area by visiting KNOWYOURZONE.NC.GOV. North Carolina Know Your Zone is a tiered evacuation system that highlights areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards. The Know Your Zone lookup tool is a color-coded interactive map residents and visitors can use to determine the evacuation zone where they live, work, or are visiting based upon a street address. Evacuation zones highlight areas most at risk to storm surge and flooding. Know Your Zone is intended to streamline the evacuation process by supporting personal readiness in preparation for hazardous weather events. When a storm is approaching, local officials in that area will determine the zones that are most threatened to assess which residents should evacuate.

The SACS products and tools are designed to benefit the entire coastal area of North Carolina. Through the FAAS process, opportunities for collaboration have been identified that extend beyond the boundaries of the SACS focus areas. Section 5.8.1 describes some of those opportunities.

5.8.1 Identification of Further Study Efforts

The following identified actions are applicable to high-risk areas outside of the North Carolina SACS focus areas:

Back bay Erosion and Marsh Restoration Study – Albemarle-Pamlico Estuary System (APES) (USACE)

A study to evaluate erosion trends, habitat loss, and potential mitigation measures in the APES is needed to gain a better understanding of changes that coastal North Carolina is facing so that natural resources can be managed appropriately. The APES has been designated as an estuary of National Significance and is at continued risk of damage as a result of coastal storms and sea level rise, as indicated by analysis within the SACS and other studies. A scope of work and associated cost estimate

should be developed through stakeholder coordination which may be pursued through the USACE Section 22 Planning Assistance to States program.

Silver Jackets Proposal – Coastal Hazards System Training Workshop

Conduct training workshops for potential users of the SACS CHS wave and water-level modeling data who are located in the focus area, and in other coastal areas of North Carolina, to maximize future use of the SACS data and tools where applicable.

Offshore Sand Management Strategy Discussions (Bureau of Ocean Energy Management, USACE, North Carolina Division of Coastal Management)

Build from the South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report) effort in North Carolina by continuing dialogue between BOEM, USACE, and NCDCM to consider and plan for an offshore resources management strategy in North Carolina, to get ahead of future multiuser conflicts.

Headquarters-level Discussion for Potential Barrier Removal – Federal Emergency Management Agency Floodplain Maps (FEMA, USACE)

SACS coordination indicates there is widespread perception at the local level that updated FEMA flood mapping has created an unintentional barrier to preventing development in higher-risk areas. Discussions should determine the source and validity of these perceptions and, if valid, consider paths forward for removing the barrier.

Leverage Coastal Hazards System directly to North Carolina Office of Recovery and Resiliency Strategic Buyout Program

USACE should directly coordinate and share SACS CHS data as the information becomes available with the NCORR in support of planning and investment decisions conducted as part of the RebuildNC Strategic Buyout Program

Enhanced Building-level Risk Assessments (North Carolina Division of Emergency Management, University of North Carolina Wilmington, USACE)

The Enhanced Building Level Risk Assessment provides building level footprints that can be used for a variety of coastal research topics. Combined with the wave and water levels from the Coastal Hazards System, this could allow for a more targeted and strategic approach to coastal storm management, including improved cost benefit ratios to assist with economic justification or elevations, buyouts, and relocations and could identify potential suitable locations for infrastructure management actions like breakwaters or shoreline stabilization. UNCW has worked with the NC light detection and ranging (LiDAR) building footprints on other projects and expressed interest in working with stakeholders to facilitate this process when CHS becomes available. The SAW District team facilitated communication between those stakeholder groups interested in pursuing this action and will continue to foster collaboration.

RSM Opportunities

Includes working with local and state stakeholder groups on placement opportunities.

Compound Flooding Modeling Effort (National Hurricane Center and National Weather Center)

Recommendation for North Carolina-focused coupled model. Key stakeholders include the NHC and NWC. North Carolina has experienced significant compound flooding from Hurricanes Floyd, Matthew, and Florence.

Cape Fear River Basin – Flood Risk Management Study (USACE)

The Cape Fear River Basin area sustained significant damage from Hurricane Florence. This study was previously identified as a need, but it was not funded in the FY19 Emergency Supplemental. SACS presents an opportunity to add support for its future funding.

SECTION 6
Institutional and Other Barriers

The SACS *Institutional and Other Barriers Report* (USACE 2022c) identifies barriers to providing comprehensive coastal protection and documents policies or improvements that could potentially counter these barriers, thus increasing collaborative capabilities to reduce risk more effectively. Barriers were identified through SACS outreach coordination with stakeholders and assessing existing CSRM projects under the SACS PPE.

6.1 Institutional and Other Barriers

Institutional barriers are defined as barriers posed by agency silos and overlapping or competing missions that inhibit necessary coordination among agencies/levels of government, and/or that otherwise impede the attainment of SACS goals. Other barriers include laws, regulations, agency guidance and programs at federal, state, or local levels that: (1) contribute to the vulnerability of coastal populations, ecosystems, and/or infrastructure, (2) work at cross purposes with policies and measures that reduce risk and/or increase resilience, (3) increase flood risk in the coastal zone (tidally influenced), (4) conflict with the goals to improve coastal resilience or reduce risk, (5) expose federal investments or increase financial exposure of federal taxpayers, and (6) impede the ability of decision makers—at all levels of community and political governance—to support or make hard decisions, pursue innovative solutions, or lead change supporting SACS goals.

Two stakeholder outreach field workshops were held in North Carolina: (1) September 19, 2019, in the Outer Banks and (2) September 24, 2019, in Wilmington. Additional virtual workshops were held during the summer and fall of 2020, with North Carolina showing an increase in stakeholder participation despite the challenges of the COVID-19 pandemic (USACE 2022c). The following sections provide a high-level summary of the *SACS Institutional and Other Barriers Report* and those findings relative to North Carolina.

Section 1204 of the Water Resources Development Act (WRDA) 2016 directs that SACS, “identify . . . institutional and other barriers to providing protection to the vulnerable coastal populations.” Modeled after the NACCS *Institutional and Other Barriers Report*, the SACS *Institutional and Other Barriers Report* (USACE 2022c) summarized stakeholder input from fall 2019 Field Workshops into six themes:

- Theme 1: Risk and Resilience Standards
- Theme 2: Risk Communication
- Theme 3: Risk Management

- Theme 4: Science, Engineering, and Technology
- Theme 5: Leadership and Institutional Coordination
- Theme 6: Local Planning and Financing

Over 1,000 pieces of feedback were then categorized further into subthemes based on specific key barriers provided within each theme. Subthemes unique to SACS were created to identify additional trends in the feedback and capture differences between the two studies. Under Theme 1, inflexible agency rules and ineffective standards comprised over 50 percent of stakeholder feedback. Examples included difficulties in modifying maintenance agreements or past authorities, gaps in regulations regarding the protection of wetlands and other environmental habitats, and other federal funding requirements and restrictions. The institutional barrier noted most often by SACS stakeholders was a need for increased coordination and leadership across all levels of government.

Lack of funding was the next most noted barrier. Cost-share requirements to access federal funding were also noted as limiting, especially in smaller and more rural communities.

6.2 Barriers to Coastal Storm Risk Management Projects

USACE executed PPEs and evaluated how effective federal CSRM projects were for recommending improvements and identifying barriers to such improvements. For North Carolina, this includes the following projects: Wrightsville Beach, Carolina Beach, Kure Beach, and Ocean Isle Beach (Section 5.3.1).

All projects identified limited sand sources and referenced the Coastal Barrier Resources Act (CBRA) of 1982 as a barrier to meeting project sand needs. The CBRA was initiated to disincentivize development on coastal barriers—the interface of land and sea —that protect landward areas from coastal storm impacts. Coastal Barrier Resource System (CBRS) units for North Carolina include most inlet waterways, which provide the least-cost source for beach quality sand, and dredging helps maintain the channel for safe navigation and recreational use (USACE 2020a). Current guidance and interpretation of the CBRA of 1982 from USFWS does not allow for the use of material from a CBRA zone outside of that CBRA zone. This interpretation will continue to be seen as a barrier to project performance (cost/time) for Wrightsville Beach, Carolina Beach, and Kure Beach.

The Carolina Beach CSRM project reported barriers to sand source availability and has been impacted by environmental or permitting restrictions and construction or operations considerations. Dredge availability is a continual consideration and has sometimes impacted USACE's ability to successfully award dredging/renourishment contracts. In addition, current CBRA guidance will require an offshore borrow source—although one exists, it is mainly reserved for the Kure Beach project, includes a higher pumping cost, and must be properly managed to avoid exhausting this resource before the end of the project lifespan.

Kure Beach also reported that dredge availability has impacted the project cost, which may impact the long-term project viability. The southern portion of the project terminates in a coquina rock formation, erodes rapidly, and is difficult to maintain for the three-year project cycle. North Carolina currently has restrictions on hardened structures on the beach, which prevents USACE from considering terminal groin or groin structures as alternatives to stabilize the southern end of the project.

The Ocean Isle CSRM project was recently funded with no noted implementation barriers; the next periodic renourishment is scheduled for fiscal year 2022. Kure Beach also has no implementation barriers, and the next planned renourishment of Kure Beach, which will use a previously approved offshore borrow site, is in fiscal year2022. The Carolina Beach CSRM project will be renourished in fiscal year 2022 using the same offshore borrow site approved for Kure Beach. This will avoid borrowing sand from Carolina Beach Inlet, which is located in CBRS Unit L09. Previously, the Wrightsville Beach CSRM project was renourished using sand from Masonboro Inlet, which is also in CBRS Unit L09; however, there is no approved offshore borrow site close to Wrightsville Beach. Therefore, efforts are underway to complete an Environmental Assessment and obtain approvals for use of an offshore borrow site for future Wrightsville Beach renourishments. It is currently planned to renourish Wrightsville Beach in fiscal year 2023.

6.3 Barriers to Regional Sediment Management

Section 1204 of WRDA (2016) specifically directs that the SACS will “conduct a comprehensive analysis of current hurricane and storm damage reduction measures with an emphasis on regional sediment management practices to sustainably maintain or enhance current levels of storm protection.” Districts and regional stakeholders have noted that financial, institutional, and other barriers often prevent implementation of RSM strategies.

The 2020 RSM Optimization Update (USACE 2020a) identified four existing projects where less than 100 percent of dredge was managed using RSM strategies: Morehead City (28 percent managed using RSM), the AIWW (60 percent managed using RSM), Carolina-Kure Beach (38 percent managed using RSM), and Wilmington Harbor (26 percent managed using RSM). RSM is being implemented for the Carolina Beach project through placement of dredged material from the AIWW. Additionally, shallow draft dredging practices have been modified to retain sediment within the system rather than removing and placing it in an ocean dredged material disposal site. The Morehead City project places 1.6 million cubic yards in the nearshore, which was not captured in the 2020 RSM Optimization Update Report (USACE 2020a), but advancements in placement technology could allow for placement closer to shore, which would keep more material within the littoral system. Sediments not being used for RSM purposes are usually of non-beach-quality material and barriers such as environmental and permitting restrictions, sand quality requirements (<10% fines), and benefit-cost ratios have impacted the project’s ability to use more sediments for RSM strategies.

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SECTION 7
Recommendations

The following recommendations (**Table 7-1**) result from the analyses detailed within this appendix and from coordination with stakeholders throughout North Carolina. As part of the Tier 2 analysis, efforts were made to develop specific and detailed recommendations to address coastal storm risk within the selected focus areas as described in each FAAS. Importantly, several recommendations initially developed for focus areas are also applicable throughout all coastal areas of North Carolina. Other high-risk areas not located within a focus area may also have had recommendations developed.

All recommendations for North Carolina are shown in **Table 7-1** and represent important components of an overall regional strategy for the full SACS study area. As described in the Main Report, the SACS regional strategy focuses on maintaining and adapting projects and programs that are successfully addressing coastal storm risk while advancing emerging methods. The regional strategy also emphasizes the importance of advancing coordination and collaboration on complex issues, such as land use and development practices, to manage increased coastal storm risk as a result of sea level rise throughout the SACS study area. Recommendations are made for either multiagency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and from coordination with stakeholders.

Recommendations are organized into six categories, as shown in **Figure 7-1,** and three implementation time frames (near-, mid-, and long-term). Importantly, follow-on study efforts should incorporate an integrated approach to the maximum extent practicable, including consideration of structural, nonstructural, and NNBF measures, as well as the shared responsibility of all stakeholders to contribute to coastal storm risk management. Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation time frames include:

Figure 7-1: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.

- **Mid-Term Implementation (5–10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance ongoing and emerging efforts to address coastal storm risk.

- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination and—from technical, political, or social perspectives—may be the most challenging to implement on a regional scale. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term time frame is reflective of the time to implementation based on lead time needed to advance these recommendations, which include complex issues such as land use, zoning, and building codes. Given the uncertainty surrounding impacts from sea level rise and other factors (e.g., development trends), long-term recommendations may require reconsideration prior to implementation.

Based on its shoreline length relative to other states and territories in the SACS study area, ten priority recommendations were made for North Carolina. Priority recommendations can manage a significant amount of risk and have a high implementation potential based on stakeholder interest and other factors. State and territory prioritization was heavily based on stakeholder coordination, assigning higher priority to recommendations that leveraged ongoing or planned actions to manage coastal storm risk, were supported by stakeholder consensus, and/or had an overall higher potential for implementation within North Carolina.

Table 7-1: Recommendations for North Carolina (Priority Recommendations in Yellow)

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Activities and Areas Warranting Further Analysis	Near-Term (<5 years)	USACE	FPMS Special Study – CHS Training Workshop	*This recommendation is applicable throughout all coastal counties within the planning reach.	Funding
Activities and Areas Warranting Further Analysis	Mid-Term (5-10 years)	Multi-Agency Action	Compound Flooding Modeling Effort (NHC and NWC)	Recommendation for North Carolina-focused coupled model – key stakeholder being the National Hurricane Center and National Water Center. North Carolina has experienced significant compound flooding from Hurricanes Floyd, Matthew, and Florence.	Stakeholder Collaboration
Activities and Areas Warranting Further Analysis	Mid-Term (5-10 years)	Multi-Agency Action	Enhanced Building-level Risk Assessments (NCEM, UNCW, USACE)	The Enhanced Building Level Risk Assessment action was brought to our attention by Dare County. North Carolina was the first to complete the USGS 3d Elevation program giving us building level footprints that can be used for a variety of coastal research topics. This combined with the wave and water levels from the Coastal Hazards System could provide a more targeted and strategic approach to coastal storm management, including improved cost benefit ratios to assist with economic justification or elevations, buyouts, and relocations and could potentially identify suitable locations for infrastructure management actions like breakwaters or shoreline stabilization. UNCW has worked with the North Carolina LiDAR building footprints on other projects and expressed interest in working with stakeholders to facilitate this process as CHS data becomes available.	Stakeholder Collaboration

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Activities and Areas Warranting Further Analysis	Mid-Term (5-10 years)	USACE	Leverage CHS directly to NCORR Strategic Buyout Program	USACE should directly coordinate and share SACS Coastal Hazards System (CHS) data as it becomes available with the North Carolina Office of Recovery and Resiliency (NCORR) in support of planning and investment decisions conducted as part of the RebuildNC Strategic Buyout Program.	Stakeholder Collaboration
Activities and Areas Warranting Further Analysis	Mid-Term (5-10 years)	USACE	Community Interest Night - Down East Community (FPMS Special Study)	The USACE should coordinate with the Down East Council in Carteret County to develop and facilitate a community-based education event (or events) for the Down East communities built around SACS data and tools for practical risk assessments. The intent of the outreach and education events would be to bridge the gap between what information and tools the SACS effort has produced, and what the local community can use to help inform ways in which to live more safely in the years and decades ahead in this low-lying coastal area. This would be conducted by development of an interagency proposal and funding request through the Silver Jackets Non-structural Flood Risk Management (FPMS) program.	Stakeholder Collaboration
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	USACE	Masonboro Inlet Jetty project	Fund prior commitment for mitigation of Masonboro Inlet Jetty project (periodic sand by-pass) based on previous Continuing Authorities Program (CAP) 111 report.	Funding

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Design and Construction Efforts	Near-Term (<5 years)	Multi-Agency Action	City of New Bern Flood Resiliency Study Recommendations	Fund recommendations which result from the current City of New Bern Flood Resiliency Study.	Funding
Design and Construction Efforts	Near-Term (<5 years)	Congress	Neuse River Basin and Tar-Pamlico Flood Risk Management Feasibility Study Recommendations	Fund recommendations which result from the current Neuse River Basin and Tar-Pamlico River Basin Flood Risk Management studies, which overlap with the SACS study footprint.	Funding

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Regional Sediment Management Practices	Mid-Term (5-10 years)	USACE	SAD-RSM-RCX coordination with SAW on applicable District projects identified in the 2020 RSM Optimization Update	SAD-RSM-RCX coordination for applicable District projects, working with state and local stakeholder groups on placement opportunities, and promoting the advancement of industry technologies that allow for more effective BU placement. For example, the RSM 2020 Optimization Report indicated that Morehead City Harbor could gain >$1M in annual value for shore protection benefits if the material currently placed in the nearshore could be placed closer to the beach in the nearshore.	Stakeholder Collaboration
Regional Sediment Management Practices	Long-Term (>10 years)	Multi-Agency Action	Offshore Sand Management Strategy Discussions (BOEM, USACE, NCDCM)	Build off the SACS Sand Availability and Needs Determination (SAND) effort in North Carolina with continued dialogue between the Bureau of Ocean Energy Management (BOEM), the U.S. Army Corps of Engineers (USACE) and the North Carolina Division of Coastal Management for considerations for an offshore resources management strategy in North Carolina – to get ahead of future multi-user conflicts.	Stakeholder Collaboration
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Cape Fear River Basin – FRM study (USACE)	This area sustained significant damage from Hurricane Florence. A flood risk management study was previously identified as a need but was not funded. SACS presents an opportunity to add support for future funding. A new congressional authorization would be needed.	New Study Authority

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Masonboro Island - Beach, Dune and Back-barrier Ecosystem Restoration (USACE)	A new congressional authorization is needed for a comprehensive study for the purpose of ecosystem restoration for Masonboro Island in New Hanover County. As part of the National Estuary Research Reserve and one of the few undeveloped barriers islands in North Carolina, Masonboro provides critical habitat to a variety of species as well as ancillary natural protective services to mainland infrastructure directly behind the island. This recommendation aligns with strategies outlined in the North Carolina Resilience Strategy sectors of Coastal Resources & Infrastructure, and Ecosystems.	New Study Authority
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Oak Island CSRM feasibility study	A coastal storm risk management study for the Town of Oak Island is needed to reduce future risk of damages associated with hurricanes and other coastal storms. Current significant risks are expected to increase with sea level rise. Congressional authority for the project exists under Section 203 of the Flood Control Act of 1966 (PL 89 - 789).	Funding

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Study Efforts (follow-on USACE Planning Assistance to States (PAS) study)	Near-Term (<5 years)	Multi-Agency Action	Back Bay Erosion/Marsh Restoration Study – Albemarle-Pamlico Estuary System (APES) (USACE)	A study evaluating erosion trends, habitat loss and potential mitigation measures in the Albemarle-Pamlico Estuary System (APES) is needed to gain a better understanding of changes that coastal North Carolina is facing so that natural resources can be managed appropriately. The APES has been designated as an estuary of National Significance and is at continued risk of damage as a result of coastal storms and sea level rise as indicated by analysis within the SACS and other studies. This would be pursued under the USACE Planning Assistance to States (PAS) program.	Identify Non-Federal Sponsor (USACE Study)
Study Efforts (Activities under CAP)	Near-Term (<5 years)	USACE	Lola Road - Emergency Streambank and Shoreline Erosion Protection	An analysis to evaluate suitable shoreline stabilization adjacent to Lola Road in Carteret County is needed to prevent undermining of the only transportation route for residents in a portion of eastern Carteret County. Section 14 of the USACE Continuing Authorities Program could be pursued to meet this need through a partnership between USACE and an eligible non-federal entity.	Identify Non-Federal Sponsor (USACE Study)

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Study Efforts (Activities under CAP)	Mid-Term (5-10 years)	USACE	NC Battleship Memorial - CAP 205	The USS Battleship North Carolina Memorial Park is impacted by flooding which significantly impacts safety, park operations, and the economics of the Park. These impacts will increase with sea level rise. The USS Battleship North Carolina Memorial is located on the west bank of the Cape Fear River across from the downtown Wilmington waterfront. It is owned by the State of North Carolina and operated by State employees. The park serves as a memorial to North Carolinians who gave their lives during World War II, as well as an education center and top tourist destination in the State of North Carolina.	Stakeholder Collaboration
Study Efforts (Activities under CAP)	Mid-Term (5-10 years)	USACE	Wanchese (south of Harbor) - CAP 204	Conduct a beneficial use of dredged material project in the area immediately south of Wanchese Harbor under the USACE Continuing Authorities Program Section 204 for the purposes of aquatic ecosystem restoration. This recommendation aligns with strategies outlined in the North Carolina Resilience Strategy sectors of Coastal Resources & Infrastructure, and Ecosystems.	Funding

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SECTION 8
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SOUTH ATLANTIC COASTAL STUDY (SACS)

Dare County and Ocracoke Island Focus Area

FINAL REPORT

AUGUST 2022

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1. Introduction

This Focus Area Action Strategy (FAAS) identifies action strategies to reduce risk to coastal storms and increase resilience in the Dare County and Ocracoke Island area of North Carolina. The South Atlantic Coastal Study (SACS) key products and analyses were leveraged to assess existing and future conditions and quantify existing and potential risks. Stakeholders were engaged throughout the development of the Dare County and Ocracoke Island FAAS to elicit feedback on problems and opportunities, identify and prioritize specific institutional and other barriers, and identify potential action strategies to improve resilience. Agencies invited to participate included the U.S. Army Corps of Engineers (USACE), the U.S. Coast Guard, the National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), the United States Department of the Interior National Park Service (NPS), the Bureau of Ocean Energy Management (BOEM), the Town of Duck, Dare County, and other local county and city officials. State agencies include the North Carolina Department of Environmental Quality (NCDEQ) Division of Coastal Management (DCM), the NCDEQ Coastal Resources Commission, the North Carolina National Estuarine Research Reserve System, the North Carolina Coastal Federation (NCCF), North Carolina Sea Grant, the North Carolina Wildlife Resources Commission, the North Carolina Department of Public Safety, the North Carolina Department of Transportation's (NCDOT) Ferry Division, and the NC Office of Recovery and Resiliency (NCORR). Research and academic institutions include University of North Carolina Wilmington (UNCW) and North Carolina State University.

The FAAS was developed according to the Coastal Storm Risk Management (CSRM) Framework, an iterative process that gains resolution each time it is implemented. Under the Tier 1 analysis, national datasets were utilized to assess potential risk across the entire SACS study area, as documented in the SACS Main Report. For the Tier 2 analysis, more refined data, and analyses unique to each individual state or territory were incorporated. The Tier 2 analysis for the Dare County and Ocracoke Island Focus Area is documented within the North Carolina Appendix. The FAAS is a third iteration of the SACS study framework, incorporating data and knowledge unique to the local area to identify risks to coastal storm events and develop potential strategies to address the identified risks.

This FAAS is carried out as part of SACS, which was authorized by Section 1204 of the Water Resources Development Act of 2016 as described in the Main Report. The FAAS refers to ongoing, planned, and needed actions to manage coastal storm risk based on stakeholder coordination conducted during Focus Area Vision Meetings, a series of interactive webinars held between July and December 2020. The status and description of actions provided in this report represents a snapshot in time, and specific actions may have been modified or the status may have been changed from the description provided. However, final recommendations resulting from stakeholder coordination on specific actions were updated to represent the most recent information as of June 2022.

Figure 1 shows the three focus areas within North Carolina selected for the SACS focus area action strategy development. Section 0 of this report discusses the study area for the Dare County and Ocracoke Island Focus Area.

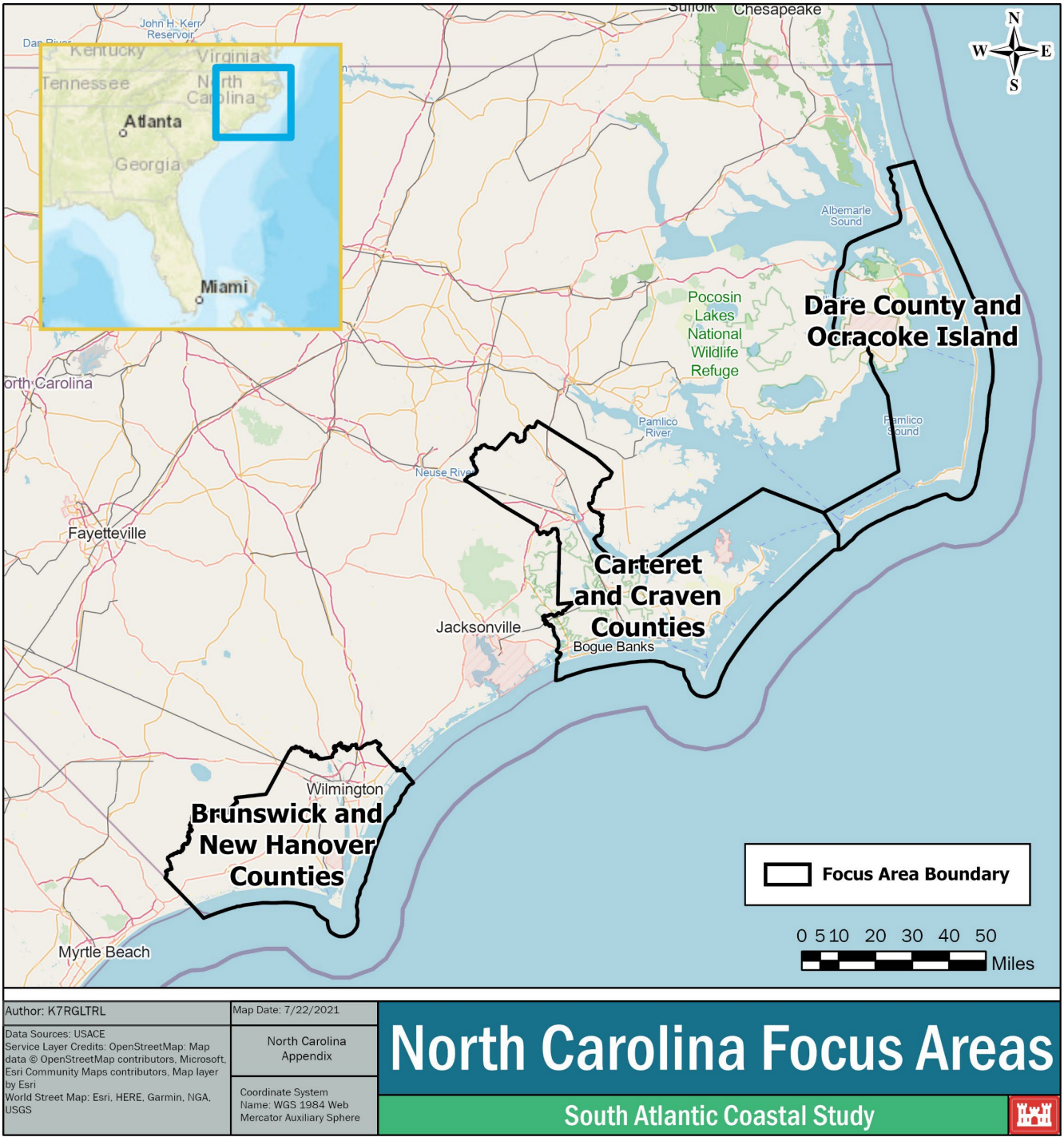


Figure 1: SACS Focus Areas in North Carolina

1.1 Study Area

This focus area is delineated by the political boundaries of Dare County, North Carolina, which includes the Albemarle-Pamlico Peninsula, Roanoke Island, and approximately 85 miles of continuous ocean shoreline on the barrier islands of the Outer Banks, plus extensive back bay shoreline (**Figure 2**). Additionally, the Ocracoke Island portion of Hyde County to the immediate south is incorporated because of inclusion as part of the Outer Banks and recent significant impacts from Hurricane Dorian in 2019. Municipalities within the Dare County and Ocracoke Island Focus Area include the following communities: Manteo, Duck, Kitty Hawk, Kill Devil Hills, Nags Head, Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, Hatteras, and Ocracoke. The boundaries of the focus area can be seen in **Figure 2**.

The Dare County and Ocracoke Island Focus Area is a distinctive region with national significance and high economic impacts. Dare County includes the following sites with national significance: (1) three lighthouses—Roanoke Marshes, Bodie Island, and Cape Hatteras; (2) Wright Brothers National Memorial; (3) Fort Raleigh National Historic Site; (4) The Lost Colony; (5) Cape Hatteras National Seashore; (6) Alligator River National Wildlife Refuge; and (7) a portion of the Albemarle-Pamlico Estuary System.

This focus area is extremely exposed to storms because of its location jutting out into the Atlantic Ocean. Since 1960, 23 hurricane and tropical storm centers have passed within 50 miles of this focus area. On average, a storm event occurs every 2.5 years (NOAA n.d.).

The Dare County and Ocracoke Island Focus Area currently totals almost $50 million in economic risk to structures alone—a figure that triples when projecting future conditions with sea level rise. This area also contains three priority environmental areas (PEAs), making this region both highly valuable and highly vulnerable to coastal storm hazards.

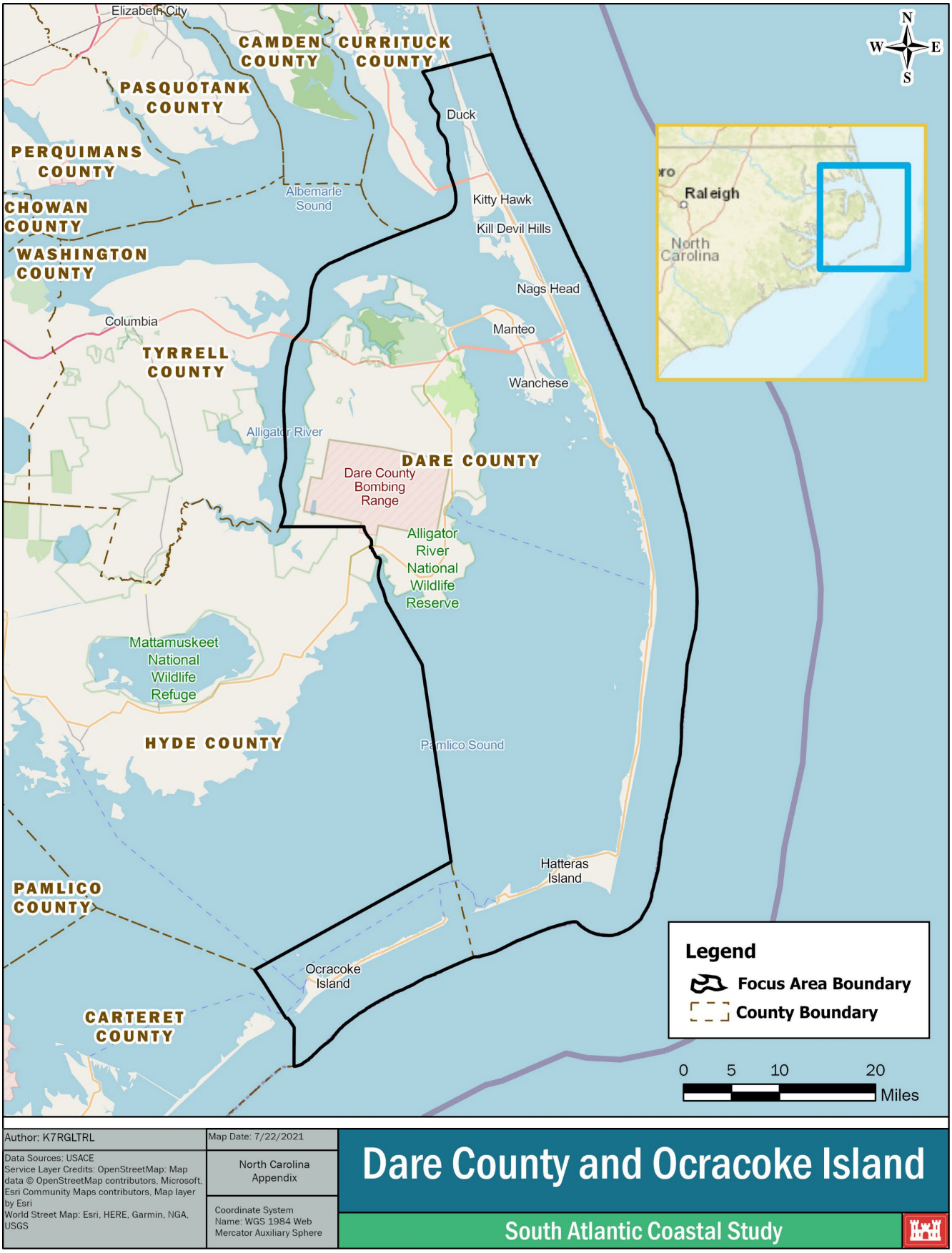


Figure 2: Boundary of the Dare County and Ocracoke Island Focus Area

1.2 Prior Reports and Efforts by Stakeholders within the Focus Area

Prior and ongoing stakeholder efforts within the Dare County and Ocracoke Island Focus Area related to coastal storm risks and impacts from sea level rise are listed in **Table 1**.

Table 1: Stakeholder Reports and Efforts in the Focus Area

Agency/Stakeholder	Report/Tool/Project	Year Completed
NPS	Addressing Climate Change Options for Cultural Resources Along the Cape Hatteras and Cape Lookout National Seashore	In-development
NCCF	Living Shoreline Projects Map	2020
NCDEQ	North Carolina Climate Risk Assessment and Resilience Plan	2020
NCDEQ	North Carolina Coastal Community Resilience Guide	2020
NCDEQ	Tools for Coastal Adaptation and Resiliency	2020
NCORR	ReBUILD NC Homeowner Recovery Program	2020
North Carolina Department of Public Safety	Know Your Zone Hurricane Evacuation Information	2020
North Carolina Flood Risk Information System (FRIS)	Web map	2020
North Carolina Forest Service	Water-Focused Forestry Research Requested for North Carolina	2020
The Nature Conservancy	Coastal Resilience Apps	2020
The Nature Conservancy	Coastal Resilience Map	2020
Town of Duck, North Carolina	Coastal Hazards Infrastructure Vulnerability Assessment	2020
Town of Kill Devil Hills, North Carolina	Outer Banks Regional Hazard Mitigation Plan	2020
Town of Nags Head, North Carolina	Comprehensive Plan	2020
United States Department of Agriculture (USDA)	Saltwater Intrusion and Salinization on Coastal Forests and Farms	2020
University of Georgia, Marine Extension and Georgia Sea Grant	Coastal Resilience Funding Glossary Available to Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina	2019
United States Department of Defense	Readiness and Environmental Protection Integration (REPI) Date County Bombing Range	2019
NCDEQ	Resilience Evaluation and Needs Assessment Reports (Duck, Hatteras Village)	2018
United States Geological Survey	Optimizing Historical Preservation Under Climate Change	2018
NOAA	Ecological Effects of Sea Level Rise in North Carolina: Maps, Marshes, and Management Applications	2017
USACE	Dare County Beaches (Bodie Island Portion), North Carolina Final Feasibility Report and EIS	2000

Existing Sand Needs Projects

As detailed in the North Carolina Appendix, several beach nourishment projects are present in the focus area, including Nags Head, Kitty Hawk, Kill Devil Hills, Duck, and Southern Shores. CSRM projects provide significant value to the region by reducing coastal storm damages. To ensure the longevity of these benefits, periodic nourishments of sand are required. Nourishments for Nags Head were completed in 2019 and both Kitty Hawk and Kill Devil Hills were nourished in 2017. As detailed in the South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report), Dare County has a surplus in their 50-year sand budget of 127 percent with a 55-percent contingency factor (USACE 2020c). Estimated 50-year sand requirements in Dare County are summarized in **Table 2**. Hyde County was not addressed because there are no reported nourishment projects located on Ocracoke Island at this time.

Table 2: Estimated 50-Year Sand Need in Dare County (USACE 2020c)

Name	Federally Sponsored	Project Sponsor	Federal Authority	Nourishment Interval (Years)	Estimated 50-Year Sand (2020-2070) Requirement (cubic yards)
Nags Head	Yes	USACE, Town of Nags Head, Dare County, FEMA	2001	–	25,500,000
Kitty Hawk	Yes	USACE, Dare County	2004	–	6,837,000
Kill Devil Hills	Yes	USACE, Dare County	2004	–	3,445,000
Duck	No	Dare County, Town of Duck		–	2,480,400
Southern Shores	No	Dare County	2017	–	2,465,000
Hatteras Island-Buxton	Yes	USACE	1974	–	8,996,000
Mirlo Beach/ Rodanthe	No	NCDOT	2014	1	94,700
Pea Island	Yes	USACE	1990	1	19,437,000

Existing Regional Sediment Management Projects

The 2020 South Atlantic Division Regional Sediment Management (RSM) Optimization Update provided detailed information for existing RSM strategies in place for the Dare County and Ocracoke Island Focus Area (USACE 2020b). Maintenance dredging of Manteo (Shallowbag Bay), Rollinson, and Silver Lake navigation channels produces approximately 1.1 million cubic yards of material every dredging cycle. This material is all repurposed through beneficial use for beach and nearshore placement on Pea Island and to maintain upland migratory bird habitat islands adjacent to the navigation channels. These practices efficiently use 100 percent of the dredged material at no additional cost to the federal government and provide $0.3 million in economic (maintenance efficiency) benefits. Additional RSM actions in this focus area are taken in the Hatteras ferry channel and Buxton. Currently, there are no dredged material management areas (DMMA) located in Dare County or near Ocracoke Island.

Other Existing Risk Management Strategies

The Dare County and Ocracoke Island Focus Area also includes other risk management strategies such as living shorelines, rock revetments, and marsh restoration projects. Living shoreline development and education has been supported through a partnership between NOAA and the NCCF through community-based restoration, which has helped restore and protect more than 6,200 feet of shoreline (NOAA 2020a). Existing risk management projects include:

- Living shorelines at Jockey's Ridge State Park, Festival Park at Manteo, Nags Head, Moor Shore Road at Kitty Hawk, Wanchese Marine Industrial Park, and Alligator River National Wildlife Refuge (NOAA)
- Rock revetment protection at the Lost Colony Amphitheatre in Roanoke Island in Dare County
- Hydrologic restoration of coastal wetlands bordering North Carolina's Albemarle-Pamlico estuary in Hyde County

1.3 Shared Vision

The shared vision provides an overall goal for the focus area. Actions identified in this report incrementally contribute to the shared vision by achieving objectives to address problems and realize opportunities identified in the focus area. The Dare County and Ocracoke Island Focus Area shared vision was developed with stakeholder input provided in the Focus Area Visioning Meetings described in the Main Report. The shared vision is:

Our vision is to develop a stakeholder-led, science-based cohesive actionable strategy to address coastal storm risk and sea level rise while strengthening the economic, environmental, and social resilience of the Dare County and Ocracoke Island Focus Area for current and future generations.

2. Problems and Opportunities

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

2.1 Problems

The following problems were identified as the most significant throughout the focus area and may include all problems. These problems will increase in both intensity and extent as sea levels rise depending on the vulnerability and resiliency of the exposed population, infrastructure, and environmental resources. Problems 1, 2, and 3 were the most often cited during stakeholder coordination. Each problem is given an abbreviated label (e.g., P3 for problem 3) for cross reference in Section 5.2 of this report.

Problem (P)1: Oceanfront and back bay shoreline inundation from coastal storms damages infrastructure and is projected to increase with sea level rise.

- Most of the population within Dare County and Ocracoke Island is vulnerable to coastal storm surge based on the location of residential structures. Dare County has over a dozen communities that are at high risk to damages from coastal storms, which will increase with sea level rise. The towns of Manteo, Kitty Hawk, and Hatteras have the most expected annual damages (EAD).

P2: The economy is negatively impacted by the increasing effects of coastal storms as a result of sea level rise.

- Of the 100 counties in North Carolina, Dare County ranked fourth in tourism dollar expenditures in 2016, with $1.1 billion (U.S. Travel Association 2017). Coastal storms can impact the Dare County and Ocracoke Island tourism industry by disrupting transportation flows with closed roads and bridges and cancelled ferry services, by changing the width of beaches, and by damaging infrastructure (e.g., hotels, vacation homes, restaurants, piers). EAD to infrastructure within the focus area are expected to more than double in future conditions with sea level rise, from about $50 million to $130 million.

P3: North Carolina Highway 12 (N.C. 12) road closures impact life safety and economics.

- N.C. 12 is the only roadway and evacuation route that runs through the Outer Banks. This critical artery has been breached or buried in sand on many occasions over the last 20 years because of severe dune loss and overwash from coastal storms. Hot spots have included Pea Island National Wildlife Refuge, the reach just north of Rodanthe, and on Ocracoke Island between the NPS pony pens and the Ferry Terminal.

P4: Insufficient data on erosion rates and impacts along the back bay shoreline prevent finding meaningful erosion and back bay solutions.

- Extensive data have been collected on the oceanfront shorelines. Fewer data exist along the extensive mileage of back bay shorelines on potential impacts of erosion rates, which could be used to identify and plan for possible mitigation measures, including marsh restoration and thin-layer placement. Stakeholders indicate a surplus of dredged material available for beneficial use but that a lack of data regarding placement needs has limited implementation.

P5: Saltwater inundation and intrusion are negatively impacting sensitive habitats.

- The entirety of mainland Dare County on the Albemarle-Pamlico Peninsula has an elevation of under 1.5 meters above sea level. Although this is an emerging field of research, there are indications that 10 percent of the forested wetland within the Alligator River National Wildlife Refuge has been lost over the last 35 years (Ury 2021).

P6: Coastal storms are impacting natural infrastructure. Impacts will increase with sea level rise, resulting in loss of protective value and economic services.

P7: There is a lack of detailed data on large areas of offshore sand resources, which prevents their potential use for future residency projects to mitigate the impacts of coastal storms.

- The SAND Report indicates a surplus in available sand versus need for Dare County. However, less than 50 percent of the available sand in this calculation is "proven" with a 90-percent or more confidence rating of its suitability. The remaining majority of sand sources in this calculation have "potential" with a 70-percent or more confidence rating but will require more analysis to determine suitability of use on beaches. Additionally, the sand needs of the focus area are projected to increase if more communities begin to pursue beach sand placement projects as part of their mitigation strategy.

P8: Oceanfront shoreline migration (erosion) is threatening stationary development.

- Dare County and Ocracoke Island have some of the highest ocean shoreline erosion rates in North Carolina. Structures have been lost to the moving shoreline on Seagull Drive in Nags Head and at homes in northern Rodanthe. The main transportation corridor, N.C. 12, has been repeatedly breached or inundated along various locations within the focus area.

P9: Several challenges are associated with habitat and threatened and endangered species management (e.g., erosion and inundation as a result of wave attack, coastal storms, and sea level rise).

- Important ecological habitats on both the barrier islands and mainland of the focus area provide nesting habitat and protective services to threatened and endangered species. These areas encompass the Pea Island National Wildlife Refuge and Cape Hatteras National Seashore along the barrier islands, and the Alligator River National Wildlife Refuge in mainland Dare County. Much of this habitat has very low elevations and thus is at an elevated risk to the negative impacts of coastal hazards.

P10: Flood maps and most infrastructure investments do not account for future conditions.

- Federal Emergency Management Agency (FEMA) flood maps do not consider the future risk of sea level rise. They only consider current risk.

P11: Existing SACS data and tools, including Coastal Hazards System (CHS) data, need to be easier to access and more frequently used.

P12: Existing risk communication techniques may not be reaching all required individuals.

- Television, internet, radio, print, and other media may be under- or inefficiently utilized in reaching the public.

2.1.1 Institutional and Other Barriers

As described in the SACS Institutional and Other Barriers Report, "Institutional and other barriers" impede the attainment of SACS goals and limit the ability to provide comprehensive CSRM (USACE 2022a). Several institutional and other barriers (IOBs) were identified within the Dare County and Ocracoke Island Focus Area by stakeholders:

- **IOB 1:** Regulatory policy may restrict implementation of risk management measures to not include living shorelines.

- **IOB 2:** Federal and state aid allotment processes to help recovery are not timely.
- **IOB 3:** Current coastal modeling communicating flood risk on Flood Insurance Rate Maps does not capture all risk hazards, including rainfall and surge.
- **IOB 4:** Updated FEMA flood maps which became effective in June 2020 show less properties at risk than in previous maps. Specifically, in Dare County many properties were reclassified out of the flood hazard areas category and into the lower risk "shaded x" or "x" categories. According to the County, many of these properties have been flooded previously, sometimes repeatedly. There is concern about the logic of this reclassification and the risk-message it sends to new residents moving into the area.
- **IOB 5:** National Flood Insurance Program reforms are needed.
- **IOB 6:** There are limited tax base and funds to support local-scale resiliency efforts.
- **IOB 7:** There is societal resistance to adapt to living in a dynamic environment.

2.2 Opportunities

Stakeholders identified several opportunities that include conditions, resources, and factors that could contribute favorably to the Dare County and Ocracoke Island Focus Area:

- **Opportunity (O)1:** Increase understanding of coastal wetland trends and restoration strategies.
- **O2:** Use natural and nature-based features (NNBF) to address erosion.
- **O3:** Improve risk communication to development groups and the public.
- **O4:** Integrate CHS data and other modeling efforts focused on probabilistic coastal hazard assessment to analyze future beach erosion, barrier island lowering or breaching, and/or marsh loss.
- **O5:** Maximize sand characterization and borrow usage by collaborating with neighboring beach projects.
- **O6:** Delineate offshore sand resources and further characterize resources for beach-compatible sand.

3. Objectives and Constraints

Objectives are specific outcomes meant to alleviate the identified problems and take advantage of opportunities within a project. Constraints are conditions that limit the extent a project can meet its objectives, address the identified problems, and/or take advantage of opportunities. The final strategy formulated during this study is intended to meet the project's objectives while working within the constraints. Objects and goals of the FAAS are included in this section.

3.1 Objectives

Overall objectives were developed for the focus area, generally focused on reducing coastal storm risks. Objectives and goals of the focus area include:

Objectives:

- **Objective (OBJ) 1:** Reduce coastal storm inundation risk to population and infrastructure within both the oceanfront and back bay vulnerable areas of Dare County and Ocracoke.
- **OBJ 2:** Reduce the risk to environmental and cultural resources due to inundation, wave attack, and erosion as a result of coastal storms.

Goal:

- **Goal (G) 1:** Identify potential federal involvement in specific resiliency actions that can begin implementation within 2 to 10 years.

3.2 Constraints

A constraint may limit the planning process. To the maximum extent practicable, the SACS analysis will minimize information, observations, and recommendations that may be inconsistent with coastal storm risk management plans developed by other federal and applicable state and local agencies and tribes within the study area.

4. Existing and Future Conditions

4.1 Hazards

In a general sense, a hazard is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014). For a full list of hazards information relevant to the focus area, see Sections 4.1, 4.2.1.1, and 4.2.2.1 of the North Carolina Appendix. For the FAAS, hazards were divided into two categories: primary hazards and secondary hazards. Primary hazards are those directly addressed within the scope of the SACS and secondary hazards are those not directly addressed but still relevant and important to the focus area.

4.1.1 Primary Hazards

Primary hazards for the Dare County and Ocracoke Island Focus Area include inundation, wave attack, and erosion. Coastal erosion can be hazardous to natural shorelines such as marshes and sandy beaches and can increase vulnerability of cultural and environmental resources and infrastructure. Coastal erosion poses a major hazard within this focus area.

4.1.1.1 Inundation

Inundation from both coastal storm surge and sea level rise is a significant hazard for the Dare County and Ocracoke Island Focus Area. The area has a frequent history of coastal storms, and there are high sea level rise projections compared with areas in the southern portion of the state. The areas that are subject to more frequent occurrences of the inundation hazard are:

The Barrier Islands. A predominant feature of this focus area is the string of islands that are separated from the mainland by the expansive Pamlico Sound. These barrier islands, which include Hyde County's Ocracoke Island, are at a low elevation and will be inundated from coastal storm surge more frequently. Their position jutting out into the Atlantic Ocean contributes to their long history of impacts from coastal storms. Based on the Tier 1 analysis, most barrier islands within the focus area will experience more frequent inundation with sea level rise.

Roanoke Island. Between the Outer Banks and mainland Dare County, Roanoke Island has an area of approximately 18 square miles. While much of the northern extent of the island is on higher ground and subject to only extreme storm surges, most of the island is very low-lying with inundation occurring more frequently.

Albemarle-Pamlico Peninsula (mainland Dare County). This large area of land is extremely low in elevation, with 100-percent of the area being exposed to coastal storm surge inundation in the future condition.

Table 3 provides surge levels vs. storm frequency for Dare County and Ocracoke Island (Hyde County) generated by the FEMA Hazus Flood Model (Hazus) using the FEMA Flood Insurance Study (FEMA 2020a, 2020b). The storm surge levels presented include the effects of astronomical high tide and wave setup. For the future condition damages, add 3 feet of relative sea level rise to these events.

Table 3: Dare County and Ocracoke Island Storm Tide Elevations from the Federal Emergency Management Agency Flood Insurance Study (FEMA 2020a, 2020b)

Shorelines	10-Percent Annual Exceedance Probability (AEP) (feet NAVD88)	2-Percent AEP (feet NAVD88)	1-Percent AEP (feet NAVD88)	0.2-Percent AEP (feet NAVD88)
Dare-North Outer Banks	5.1	7.0	7.9	9.7
Dare-South Outer Banks	5.9	8.1	9.2	11.3
Dare-Roanoke Island	5.2	7.2	8.2	10.1
Dare-Inland Mainland	2.9	4.0	4.6	5.7
Hyde	3.3	4.5	5.1	6.3

Figure 3 provides a map of relative inundation risk for the focus area, showing the likelihood of flooding based on three different probability events with an added 3 feet of sea level rise. Areas that may flood during a 10-percent AEP event are shaded in dark blue; 1-percent AEP events are shaded in medium blue; and Category 5 Hurricane Maximum of Maximum (Category 5 MOM) areas represent flooding in a worst-case scenario and are shaded in light blue (Zachry et al. 2015).

CHS develops AEP water levels throughout the South Atlantic region, including Dare County and Ocracoke Island, under existing and future sea levels (USACE 2020a). **Table 4** shows stillwater levels under the existing sea level for various AEPs, where the AEP represents the probability of exceeding each stillwater elevation in one given year. The highest stillwater levels are seen at oceanfront locations: Duck, Rodanthe, and Ocracoke.

Table 5 shows stillwater levels under the USACE High Scenario (7.35 feet of sea level rise). Under this scenario, stillwater levels are around 11 to 13 feet NAVD88 for the 1-percent AEP throughout the focus area. Nonlinear effects, which are changes to stillwater levels due to sea level rise that are not a simple addition of the sea level rise value (in this case, 7.35 feet), are evident in this focus area. Nonlinear effects occur primarily in the back bay regions, while minimal nonlinear effects exist in ocean regions. In addition to 7.35 feet of sea level rise, these effects led to an increase in 2.30 feet for the 1-percent AEP in the back bay region of Ocracoke Island but led to a 0.24-foot decrease on the ocean side of Ocracoke Island. This means that, rather than the future 1-percent AEP value being equal to the present 1-percent AEP plus 7.35 feet of SLR, the future AEP value is 0.24 feet lower than the additional 7.35 feet.

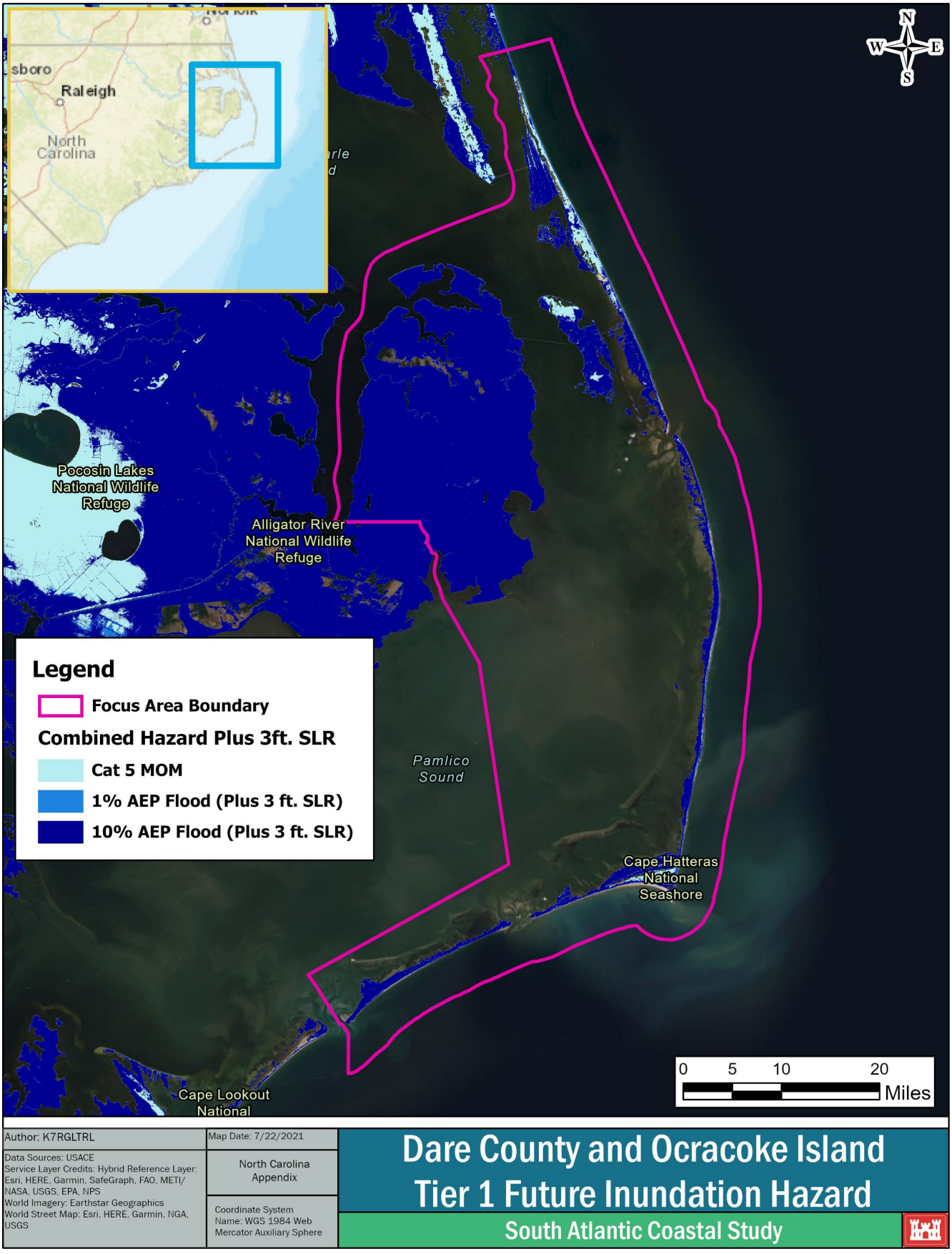


Figure 3: Combined Hazards plus 3 Feet of Sea Level Rise

Table 4: Dare County and Ocracoke Island Stillwater Elevations from the USACE Coastal Hazards System – Existing Sea Level

Location	10-Percent AEP (feet NAVD88)	5-Percent AEP (feet NAVD88)	2-Percent AEP (feet NAVD88)	1-Percent AEP (feet NAVD88)	0.2-Percent AEP (feet NAVD88)
Duck	4.60	5.08	5.59	5.91	6.58
Albemarle Sound	2.11	2.56	3.00	3.25	3.72
Alligator River	2.00	2.28	2.64	2.89	3.41
Pamlico Sound, Near Oregon Inlet	2.79	3.18	3.57	3.87	4.55
Rodanthe	3.87	4.13	4.39	4.56	5.34
Pamlico Sound – Near Hatteras	1.88	2.08	2.27	2.39	2.85
Ocracoke –Ocean	3.78	4.04	4.44	4.76	5.49
Ocracoke – Pamlico Sound	1.75	1.93	2.09	2.19	2.65

Table 5: Dare County and Ocracoke Island Stillwater Elevations from the USACE Coastal Hazards System – High Scenario (7.35 feet)

Location	10-Percent AEP (feet NAVD88)	5-Percent AEP (feet NAVD88)	2-Percent AEP (feet NAVD88)	1-Percent AEP (feet NAVD88)	0.2-Percent AEP (feet NAVD88)
Duck	11.85	12.31	12.79	13.08	13.67
Albemarle Sound	10.31	10.79	11.38	11.79	12.55
Alligator River	10.02	10.36	10.74	10.99	11.54
Pamlico Sound – Near Oregon Inlet	10.64	11.25	12.00	12.46	13.26
Rodanthe	11.15	11.38	11.61	11.75	12.31
Pamlico Sound – Near Hatteras	10.28	10.60	11.08	11.41	12.01
Ocracoke – Ocean	11.08	11.29	11.62	11.87	12.47
Ocracoke – Pamlico Sound	10.36	10.83	11.45	11.84	12.52

4.1.1.2 Wave Attack

Waves cause damage through the force that they impart directly on structures, habitats, and shorelines. Waves also generate alongshore and cross-shore currents at shorelines that can mobilize and erode sediments. In the context of the SACS, wave attack refers to the process of destructive waves impacting a shoreline and leading to increase erosion along that shoreline. Erosion is addressed in Section 4.1.1.3.

The wave climate for Dare County can be described using data from USACE Wave Information Studies (WIS) station 63225, which is located approximately 10 miles from Pea Island National Wildlife Refuge (north of Rodanthe) at a depth of 85 feet. WIS stations are output locations for a series of coastal wave hindcast model estimates for a 35-year period from 1980 to 2014. The average significant wave height at this station is 4.4 feet, with a period of 8.7 seconds. The estimated significant wave height for a 1-percent AEP event based on the hindcast data at this location is 35.0 feet.

Similarly, the wave climate for Ocracoke Island and portions of Dare County south of Cape Hatteras can be described using WIS station 63263, which is located approximately 17 miles from Ocracoke at a depth of 92 feet. At this location, the average significant wave height over the 35-year span is 4.2 feet, with a period of 8.3 seconds (time between wave peaks). The estimated significant wave height for a 1-percent AEP event is 39.9 feet.

The CHS analysis developed by USACE models wave heights for a range of storm events. While WIS data can describe offshore wave heights using hindcast model estimates, CHS describes wave heights at a range of AEPs throughout the region for current and future conditions. For example, a wave height of 22.60 ft at 10-percent AEP means that there is a 10-percent chance of wave heights higher than 22.60 ft in any one given year.

Table 6 shows modeled wave heights at various AEP throughout the focus area for the existing sea level, while

Table 7 shows modeled wave heights for the future, high sea level rise estimates from CHS (7.35 feet). Points representing ocean waves were chosen at locations roughly 5 miles offshore and are much larger than waves in back bay regions. For example, the 1-percent AEP wave height on the ocean side of Ocracoke Island is 47.85 feet, while the 1-percent AEP wave height in Pamlico Sound near the same island is 11.01 feet.

Wave heights correlate to fetch (length over which wind stress is applied), duration of the wind stress, and water depth. Therefore, waves in deep ocean water can become much larger than waves in back bay regions. Because of the size of the Pamlico Sound, waves in this region can become much larger than waves in other back bay areas but are not as large as ocean waves. This also applies to sea level rise—as the sea level increases, the depth at which the wave develops increases, enabling larger waves.

Table 6: Dare County and Ocracoke Island Wave Heights from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Duck	22.60	25.62	28.84	30.76	34.22
Albemarle Sound	3.85	4.17	4.49	4.75	5.36
Alligator River	2.98	3.30	3.66	3.93	4.58
Pamlico Sound – Near Oregon Inlet	5.08	5.58	5.99	6.25	6.67
Rodanthe	25.96	29.83	34.02	36.16	39.48
Pamlico Sound – Near Hatteras	6.34	7.20	7.96	8.41	9.17
Ocracoke – Ocean	35.68	41.22	45.59	47.85	51.50
Ocracoke – Pamlico Sound	8.08	9.21	10.43	11.01	12.15

Table 7: Dare County and Ocracoke Island Wave Heights from the USACE Coastal Hazards System – High Scenario (7.35 feet)

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Duck	23.27	26.63	30.16	32.19	35.76
Albemarle Sound	5.37	6.01	6.57	6.90	7.55
Alligator River	2.80	3.01	3.46	3.85	4.66
Pamlico Sound – Near Oregon Inlet	7.09	8.06	8.84	9.25	9.97
Rodanthe	26.69	31.43	36.43	38.98	42.97
Pamlico Sound – Near Hatteras	8.25	9.38	10.30	10.82	11.74
Ocracoke – Ocean	36.38	42.40	47.48	50.07	54.31
Ocracoke – Pamlico Sound	9.64	11.08	12.45	13.19	14.49

4.1.1.3 Erosion

As shorelines erode, natural storm protection barriers, such as the dune and berm, become less effective and large amounts of erosion can encroach upon important infrastructure. The NCDEQ DCM 2019 shoreline change rates discussed in the Tier 2 Risk Assessment reported that nearly all coastal shorelines of Dare County and Ocracoke Island were experiencing erosion, with smaller areas of accretion often near sediment nourishment projects, such as in Kill Devil Hills, Pea Island, and Oregon Inlet. For eroding beaches, average shoreline changes rates varied between -0.49 feet per year at Southern Shores and -6.69 feet per year at Bodie Island (**Table 8**). The NCDEQ DCM Web Map Viewer 2020 update of shoreline erosion rates indicated that areas with more erosion include portions of Ocracoke Island, with over 10 feet per year; Hatteras and Oregon Inlets, with over 15 feet per year; Cape Hatteras, with over 11 feet per year; Rodanthe, with up to 13 feet per year; and Pea Island, with up to 12 feet per year (NCDEQ DCM 2020e).

Erosion is also a hazard in the back bay shorelines; however, limited data were available for back bay erosion in this focus area. Additional shoreline erosion data from Riggs and Ames (2003) included an average of -2.7 feet per year for the northeastern North Carolina estuarine shoreline region and an estimated 25-year land loss of 49 square meters from 1975 to 2000. Additional average erosion rates were reported for the Albemarle-Pamlico Estuary System region (Riggs and Ames 2003):

- Inner Pamlico River: -1.1 feet per year
- Outer Pamlico River: -3.8 feet per year
- Albemarle and Pamlico Sounds: -2.2 feet per year
- Back Barrier Northern Outer Banks: -2.7 feet per year

This hazard presents a significant risk to infrastructure, including homes, businesses, and N.C. 12—the only transportation corridor that runs through the Outer Banks. Erosion also presents significant risk to the environmental and cultural resources of Cape Hatteras National Seashore. Additionally, the Tier 2 analysis identified nine critical erosion areas: Kitty Hawk, Kill Devil Hills, Nags Head, Rodanthe, Waves, Avon, Buxton, Hatteras, and Ocracoke.

NPS developed an Environmental Impact Statement (EIS) (NPS 2021) for oceanfront shorelines within the focus area, which provides a sediment management framework for procuring special use permits for nourishments in protected areas. The Cape Hatteras National Seashore served as the pilot with reserved areas designated for additional long-term habitat monitoring and research. Although erosion rates are well documented for the coastal side, no existing literature could be located for erosion rates in the back bay of the Albemarle-Pamlico Estuary System north of Cedar Island. The portions of the Albemarle-Pamlico Estuary System that are included as part of this focus area are the sound side of the coastal islands from Ocracoke to Duck, Roanoke Island, and the inland peninsula, which includes four reserve areas and Stumpy Point. Stakeholder feedback supported the conclusion that erosion in the back bay represents a data gap for the regional Outer Banks estuary.

Table 8: Oceanfront Shoreline Change Rates in the Dare County and Ocracoke Island Focus Area

Location	2020 Rate	Average (feet/year)
Ocracoke	Erosion	-3.22
Outer Banks–Bodie Island	Erosion	-6.69
Outer Banks–Cape Hatteras	Erosion	-0.93
Outer Banks–Cape Hatteras to Oregon Inlet	Erosion	-3.89
Outer Banks–Kill Devil Hills	Erosion	-0.85
Outer Banks–Kitty Hawk	Erosion	-2.24
Outer Banks–Nags Head	Erosion	-2.99

4.1.2 Secondary Hazards

For the Dare County and Ocracoke Island Focus Area, secondary hazards include wind and saltwater inundation and intrusion. While SACS does not specifically address these hazards, they are important because they can impact the focus area.

4.1.2.1 Wind

In Dare County and Ocracoke Island, high wind speeds can damage roofs, mobile homes, and, if strong enough, can destroy entire buildings. Flying debris can also cause additional damage to resources. High winds can destroy environmental resources by downing and defoliating large patches of trees and other vegetation. Typical hourly winds at NOAA station 8654467 at Oregon Inlet Marina, North Carolina are 10.7 miles per hour. Speeds reached 32.9 miles per hour on September 14, 2018, during Hurricane Florence (NOAA 2021a). Wind directions are generally from the north during colder months and from the south during warmer months (Cedar Lake Ventures, Inc. n.d.). This difference in wind direction creates changes in approach patterns of wind-blown waves, thus creating a different angle of wave attack that drives sediment transport and causes property damage. Similarly, extratropical cyclones (e.g., nor'easters) typically approach this focus area from the north during colder months and tropical cyclones (e.g., hurricanes and tropical storms) typically approach this focus area from the south during warmer months, creating different angles of approach for wind-induced damages. See Section 4.1.4.4 of the North Carolina Appendix for additional details on wind hazard.

4.1.2.2 Compound Flooding

Compound flooding is a combination of hazards that create a greater flooding risk. These can be a combination of storm surge, precipitation, nuisance flooding, and higher groundwater elevations. Hurricane Florence in 2018 and Hurricane Matthew in 2016 caused catastrophic damages due to a combination of storm surge and heavy inland rainfall exceeding 30 inches in some areas of North Carolina (Stewart and Berg 2019). Compound flooding can contribute significantly to increased runoff volumes, the elevation of the ocean, river, and groundwater levels above banks, containment structures and drainage systems, and the overwhelming of outflow systems (Gori et al. 2020).

4.1.2.3 Saltwater Intrusion and Inundation

Saltwater inundation and intrusion (North Carolina Appendix Sections 4.1.4.6) has significant consequences to both the environment and the economy in eastern North Carolina, including upland forest retreat, crop yield decline, marsh migration, eutrophication, degradation of habitat by invasive species, coastal forest loss, and decreased ecosystem service benefits (Weston et al. 2011; Tully et al. 2019; Ury et al. 2019). The USDA Southeast Climate Hub, using the NOAA Sea Level Rise Viewer, projects that the Albemarle-Pamlico Peninsula will lose half of its land mass to open water with 3 feet of sea level rise by the end of the century. With over half of its landmass less than 1 meter above sea level; a large rural population dependent on agriculture, timber, and fisheries; and a limited adaptive capacity, areas in mainland Dare County are more susceptible to saltwater inundation and intrusion. Saltwater intrusion as a hazard could affect potentially all the barrier islands within this focus area, approximately half of the Albemarle-Pamlico Peninsula, the surrounding estuary, back bay sound, and tidal creeks. In addition, dead stands of coastal forest, or ghost forests, are a result of the combination of increased flooding and saltwater inundation and have been identified within Dare and Hyde counties by the North Carolina Sea Grant, North Carolina State University, University of North Carolina at Chapel Hill, and East Carolina University.

Current efforts are focused on sustainability and mitigation strategies. Jurjonas and Seekamp (2018) developed a framework for rural coastal community resilience for the rural population of the Albemarle-Pamlico Peninsula. Lerner et al. (2013), in conjunction with the Conservation Fund in Arlington, Virginia and the Audubon Maryland-DC in Baltimore, Maryland, determined that at the current rate of transition—either from marsh to open water or from forest to marsh, and with predictions for sea level rise—bolstering existing marshes in the Blackwater National Wildlife Refuge of Chesapeake Bay would not be enough to maintain the existing marsh habitat. Lerner et al. suggests that mapping marsh movement corridors could identify the most supportive route for continued marsh development along the Atlantic Coast. In 2019, North Carolina State University, in conjunction with the USDA Natural Resources Conservation Service 2019 Soil Science Collaborative Research Projects, began a 2-year study into the spatial distribution of North Carolina areas impacted by salinization with the goal to inform predictions about future changes within the transition zone and identify risks to water and septic infrastructure through the next 100 years (Howard 2019). Other adaptive strategies include planting salt-tolerant crops, implementing greater conservation efforts, and installing saltwater management controls (Myers 2019). Current research efforts imply that saltwater intrusion constitutes a serious risk to many coastal communities of North Carolina and is expected to increase in both area and potential negative impacts with rising sea level.

4.1.3 Sea Level Rise Effects on Coastal Hazards

At NOAA National Ocean Service (NOS) gauge no. 8651370 in Duck, North Carolina, the mean sea level trend is 0.0157 feet per year, with a 95-percent confidence interval of 0.002 feet per year, based on monthly mean sea level data from 1978 to 2020 (**Figure 4**), which is equivalent to a change of 1.57 feet over 100 years. At NOS gauge no. 8652587 at Oregon Inlet, North Carolina, the mean sea level trend is 0.017 feet per year, with a 95-percent confidence interval of 0.004 feet per year, based on monthly mean sea level data from 1977 to 2020, which is equivalent to a change of 1.75 feet over 100 years (**Figure 5**). Although trends were slightly higher at Oregon Inlet than Duck, this projection has a higher variability for the 95-percent confidence interval. Because of gaps in data shown in **Figure 5**, NOS gauge no. 8652587 at Oregon Inlet is not compliant with USACE guidance for estimating long-term sea level change. Relative sea level rise between 2020 and 2120 is shown graphically in **Figure 6** and numerically in **Table 9.** The USACE Sea Level Change Curve Calculator shows the change in height between 2020 and 2120 (USACE 2021).

As sea levels rise in this focus area, as projected, the hazards of inundation (flooding), wave attack, and erosion will have increased negative impacts. The NOAA Sea Level Rise Viewer was used to simulate an inundation footprint due to a given water level rise (NOAA 2021a).

Figure 7 shows a portion of the Dare County and Ocracoke Island Focus Area with 3 feet of relative sea level rise, a probable value for the study area for the next 50 to 100 years roughly corresponding to the USACE Intermediate Scenario for 2120 and USACE High Scenario for 2070 in North Carolina. References to these tools can be found in North Carolina Appendix Section 3.6.3.

3 feet of relative sea level rise would result in extensive loss of wetlands and wildlife refuge areas; overflowing drainage creeks; inundation of barrier islands; widening of Hatteras and Ocracoke inlets; loss of Ocracoke; and inundation of N.C. 12, including the span on Ocracoke Island, parts of Hatteras, Frisco, Buxton, and Avon, and nearly all the highway from Salvo to Bodie Island. Sea level rise can enhance the effects of other hazards and reduce resiliency. This pattern is seen throughout the focus area, including those communities on barrier islands and the peninsula. Additionally, Roanoke Island could experience increasing inundation between Wanchese and Manteo, potentially separating them from one another. Rising surface water would further exacerbate the risks of inundation and the rising water table could lead to drainage and wastewater management issues. Saltwater intrusion and salinity regime changes would be expected, as are damaged coastal shorelines, coastal and back bay erosion, and reduced efficiency of the natural buffer that provides ecosystem services to infrastructure.

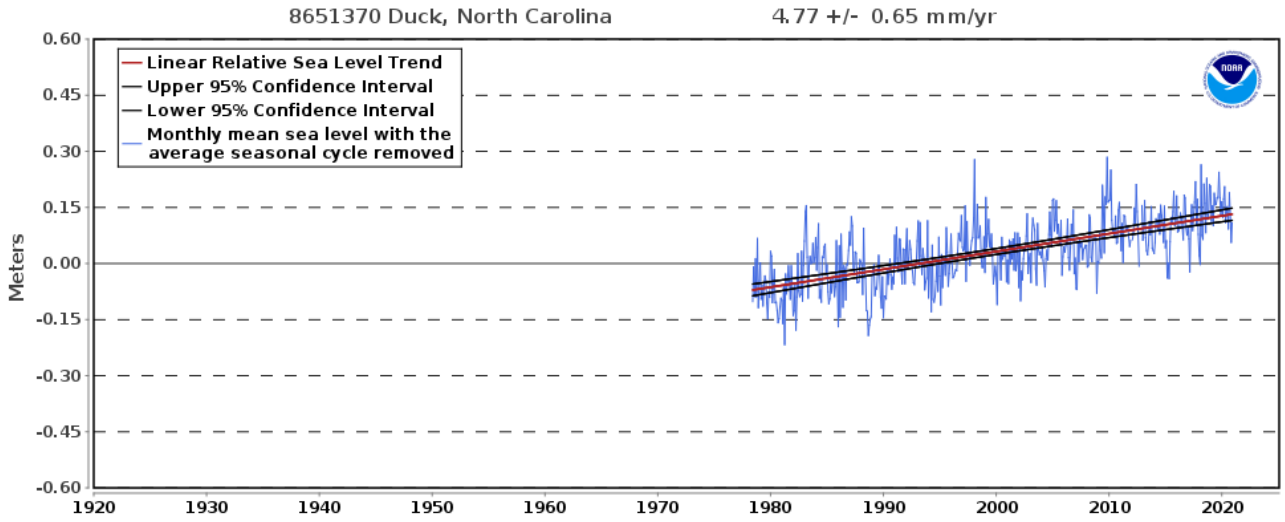


Figure 4: Relative Sea Level Trend, National Ocean Service Gauge 8651370 – Duck, North Carolina

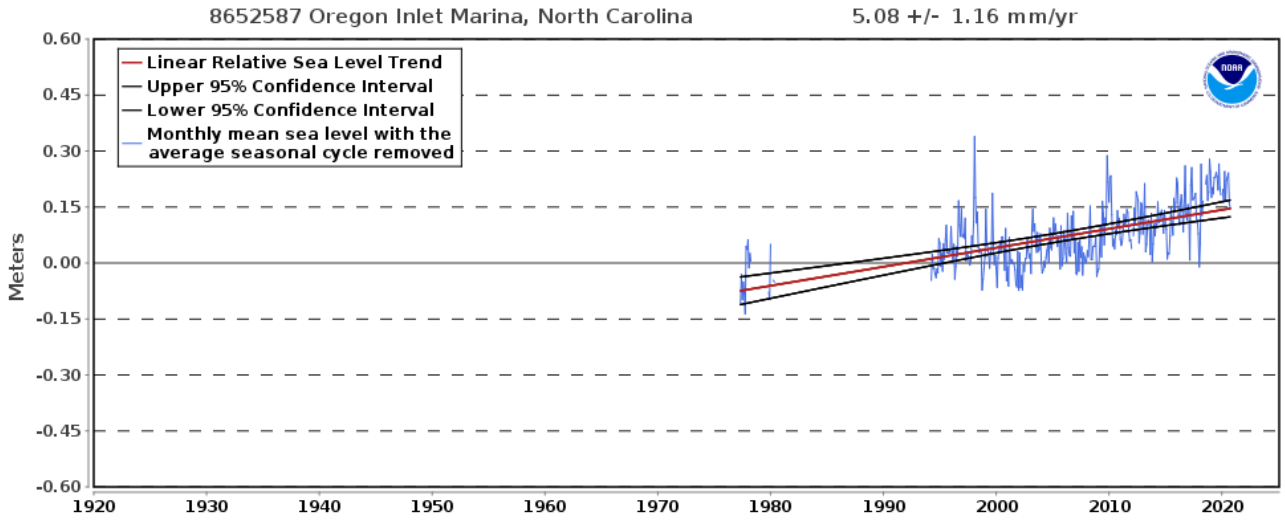


Figure 5: Relative Sea Level Trend, National Ocean Service Gauge 8652587 – Oregon Inlet Marina, North Carolina

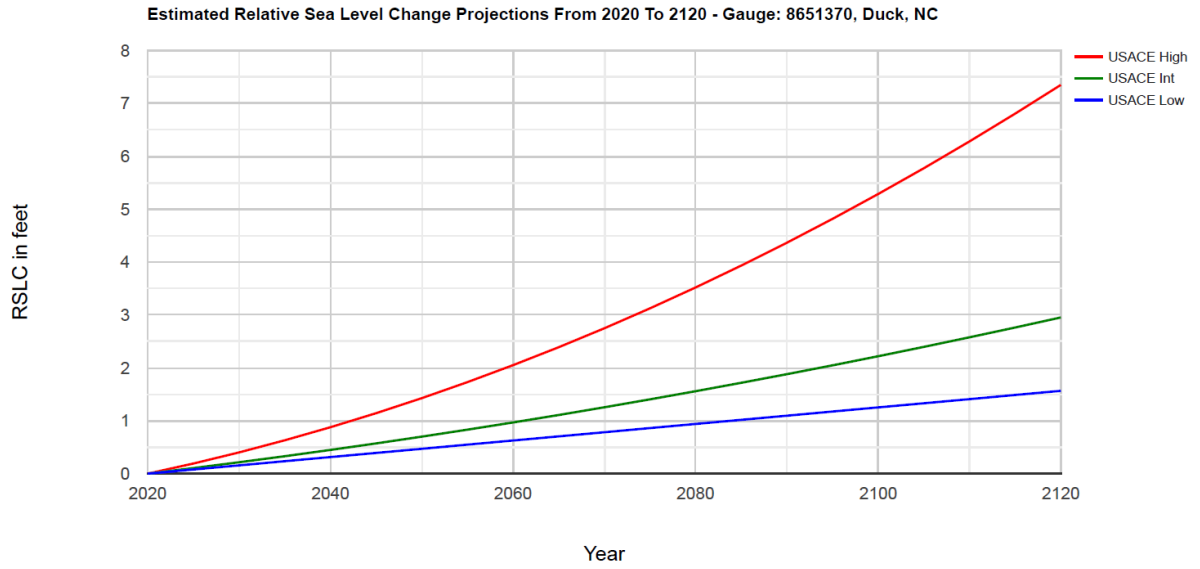


Figure 6: Estimated Relative Sea Level Change Projections Relative to 1992 from 2020 to 2120 – Duck, North Carolina

Table 9: Estimated Relative Sea Level Change from 2020 to 2120 for Various USACE Projections – Duck, North Carolina

Location	USACE Low Scenario (feet)	USACE Intermediate Scenario (feet)	USACE High Scenario (feet)
Duck, NC	1.57	2.95	7.35

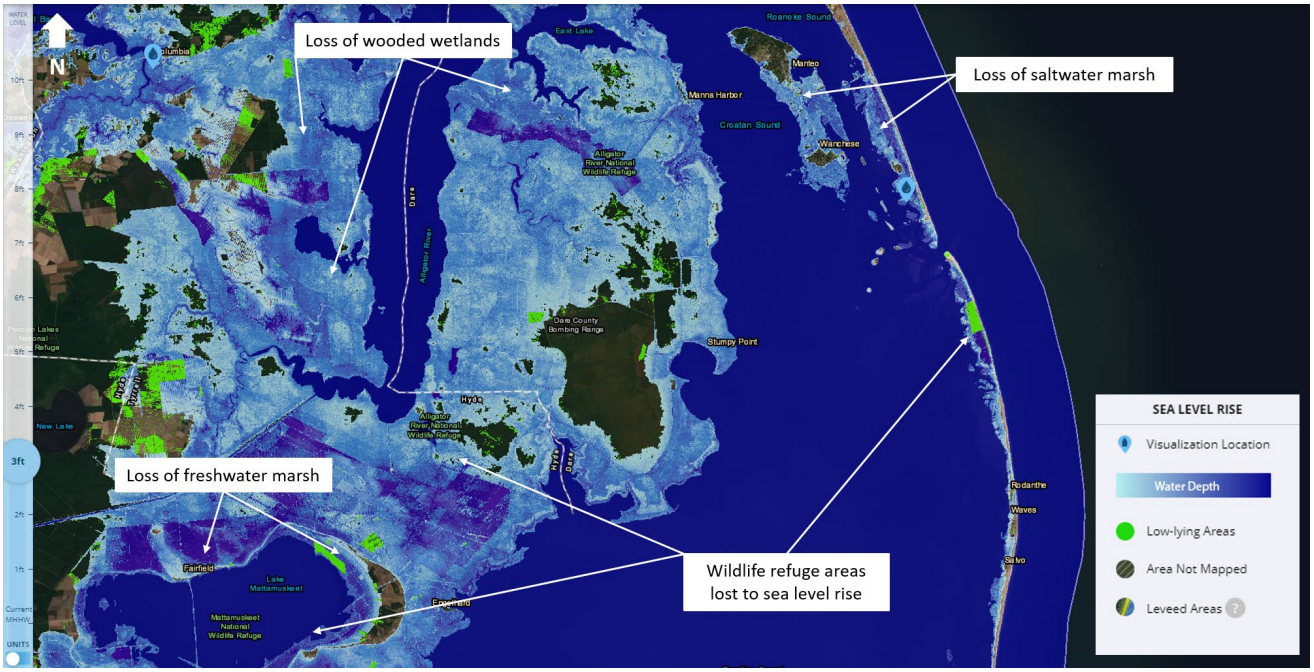


Figure 7: Projected 3 Feet of Relative Sea Level Rise Using the National Oceanic and Atmospheric Administration Sea Level Rise Viewer (NOAA 2022a)

4.2 System Performance

The focus area contains a range of risk management measures. These include a combination of natural features, constructed components, policy initiatives, and other factors that influence how the overall system within the focus area performs in response to coastal hazards. Generally, constructed measures have been developed and implemented individually rather than holistically. As sea level rises, the coastal storm risk footprint is expanding to encompass multiple areas that have previously been managed separately. For example, beach nourishment projects have significantly reduced risk to infrastructure on the oceanfront sides of barrier islands. However, as sea level rises, infrastructure is at increasing risk of inundation from the back bay side of islands.

Beach nourishment projects reduce damages to oceanfront infrastructure, anchor the coastal system, and serve as a first line of defense to storm damages on the back bay side. Natural resources, such as salt marsh and offshore barrier islands, serve as a first line of defense, and their preservation is important for environmental and risk management purposes.

System components in the focus area include:

- Coastal land use plans in accordance with the North Carolina Coastal Area Management Act. The land use plans for both Dare and Hyde Counties outline policies and regulations that guide development.
- Oceanfront construction setback regulations
- First floor elevation standards for new development
- Structure elevation, relocation, and buyout measures
- Beach nourishment projects at various population centers within Dare County
- Numerous hardened structures along points of the back bay shoreline to reduce erosion and inundation
- Preservation of vast natural areas of the barrier islands as managed by the NPS
- Past (1999) relocation of the Cape Hatteras Lighthouse
- Post-storm island breach repair measures
- Critical evacuation/transportation routes vital to ingress and egress of thousands of people and emergency services before, during, and after hurricanes or other significant coastal storms. N.C. 12 is the only roadway that spans the Outer Banks.

The area also contains significant environmental resources that naturally function as a system to reduce and adapt to storm impacts and sea level rise. However, these resources and their natural functions are increasingly fragmented and constrained because of development and other factors. Examples of these resources include:

- Natural dune systems providing storm damage reduction
- Extensive salt marsh habitat in back bay areas

Within the focus area, holistic management of the coastal system is increasingly necessary. This includes continued efforts for collaboration and coordination between federal, state, local, and all stakeholders to better understand each other's role in risk management and work effectively to combine authorities and activities to holistically assess and address coastal storm risk.

The South Atlantic Division Sand Availability and Needs Determination Summary Report (USACE 2020c) reported a surplus of 127 percent for the current 50-year sand budget with a 55-percent contingency for Dare County. Hyde County was not addressed because there were no reported nourishment projects located on Ocracoke Island at the time. The northern sections of Dare County, from Duck to Oregon Inlet, are near several proven borrow sources, which could be used for beach nourishment. Those projects south of Oregon Inlet are near potential or unverified borrow sources, which would require additional geotechnical analysis before they could be used for sediment placement. Although Ocracoke Island has not reported any local nourishment projects, there are several unverified borrow sources offshore and one potential borrow source near Hatteras Inlet that could be used for future needs.

The RSM Optimization Update provided a detailed review of the existing actions in place as well as recommendations for actionable strategies. Maintenance dredging of Manteo (Shallowbag Bay), Rollinson, and Silver Lake navigation channels produces approximately 1.1 million cubic yards of material every dredging cycle. This material is beneficially repurposed for beach and nearshore placement on Pea Island and maintaining upland migratory bird habitat islands adjacent to the navigation channels. These practices result in the efficient use of 100 percent of the dredged material at no additional cost to the federal government, along with $0.3 million in economic (maintenance efficiency) benefits. Additional placement areas for dredged material from Hatteras Inlet and Rollinson Channel are needed to accommodate channel maintenance needs.

4.3 Exposure

Tier 1 and Tier 2 analyses described in the Main Report and North Carolina Appendix describe exposure of populations, infrastructure, and environmental resources in SACS Planning Reach NC_01, which includes the focus area. Exposure describes who and what may be harmed by the hazard. Details on exposure related to this focus area are found in the following sections related to population, infrastructure, and environmental and cultural resources.

4.3.1 Exposed Population

4.3.1.1 Current Population

Dare County has a permanent population of about 37,000 people, while Ocracoke Island has a fluctuating population of between 500 and 1,000 people. Everyone on Ocracoke Island is exposed to storm surge inundation and almost 90 percent of residents in Dare County are exposed.

In Dare County, the northern communities from Nags Head to Duck have more high ground with most inundation exposure only from extreme events. Essentially all communities south from southern Nags Head to Hatteras Village are frequently exposed to inundation hazard from surge in existing conditions. These communities include Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, and Hatteras. The town of Manteo on Roanoke Island is completely in the surge zone, as is Manns Harbor on the eastern edge of the mainland. With future conditions considering projected sea level rise, the level of exposure increases. The entire population on Ocracoke Island is currently exposed to higher probability surge inundation events.

4.3.1.2 Seasonal Population

Seasonal population increases during the high-risk months of May through September. During these high-risk months, the exposure to hazards is significantly greater than originally assessed in the Tier 1 analysis.

The year-round permanent population within the focus area is approximately 38,000 people. However, the seasonal population increases exponentially during the warmer months, which coincides with hurricane season. For example, the town of Nags Head within Dare County has a permanent population of 2,800, which increases to a seasonal population of 40,000 (Nags Head Guide 2021). In late spring, summer, and early fall, Dare County may be populated by several hundred thousand people on any given day, many of which are occupying seasonal homes, rental structures, or hotels. Therefore, during these higher-risk months, the exposure to hazards in tourism-heavy areas is significantly greater than originally assessed in the Tier 1 analysis.

Dare County will see a population increase of nearly 50 percent by 2100. Most of the growth and development is expected to occur along the Outer Banks barrier island system, which is largely classified as a potential medium- to medium/high-risk area.

4.3.2 Exposed Infrastructure

Assets exposed to risk include residential, commercial, industrial, public, and transportation infrastructure. Information from the 2016 North Carolina Hurricane Evacuation Study (FEMA 2016) identifies how many critical facilities are in Dare County and whether they are exposed to specific storm surge categories (**Table 10**). Most critical facilities in Dare County are exposed to inundation from storm surge. Because the entire island of Ocracoke is exposed to storm surge, all of its critical facilities are also exposed.

N.C. 12 is a key piece of exposed infrastructure. It is the only transportation corridor that connects the entire Outer Banks and is a critical evacuation route. Over the last 20 years, this highway has been undermined and breached in multiple locations, as well as buried in deep sand from overwash.

Table 10: Dare County Critical Facility Exposure to Coastal Storm Surge Inundation (FEMA 2016)

Facility Type	CAT 1 MOM	CAT 2 MOM	CAT 3 MOM	CAT 4 MOM	CAT 5 MOM	Outside of Surge Risk Area	In 1% Annual Chance Flood Event	Total
Emergency Operations Centers	0	0	1	1	1	0	0	1
EMS Locations	3	5	7	7	8	0	3	8
Fire Stations	10	14	18	19	20	0	11	20
Police Stations	4	11	12	13	13	2	8	15
Shelters	2	3	3	3	3	0	2	3
Airport	0	1	2	2	3	0	1	3
Total	19	34	43	45	48	2	25	50

4.3.3 Exposed Environmental and Cultural Resources

The Dare County and Ocracoke Island Focus Area is rich with significant and unique environmental and cultural resources. Because of factors including plentiful food sources, multiple habitat types, tidal influence, and ocean access, man and nature have inhabited coastal North Carolina for ages. Coastal storms and sea level rise continue to expose vulnerable environmental and cultural resources to risk of alteration or loss. To offer additional protection to at-risk environmental and cultural resources, where actionable and practicable, several potential structural and nonstructural measures have been identified. Sections 4.3.3.1 and 4.3.3.2 summarize environmental and cultural resources priority areas/sites within the focus area. For additional information concerning exposed environmental and cultural resources in this focus area and in other North Carolina areas included in the SACS, please refer to the North Carolina Appendix.

4.3.3.1 Environmental Resources

Most exposed environmental resources were identified in the Tier 1 Risk Assessment. Tier 2 analyses refined our Tier 1 understanding of environmental exposure by incorporating state-level data. As seen in **Figure 8,** which depicts the SACS Tier 1 Risk Assessment Viewer's Environmental and Cultural Resources Exposure Index, North Carolina's areas of highest exposure are concentrated in low-lying areas on barrier islands and back bay areas. This is because of their proximity to the hazards of sea level rise and coastal storm damage. Areas directly adjacent to water bodies are relatively more exposed than landward areas. Similarly, species that require these exposed habitats are also exposed. For example, shorebirds and sea turtles that use beaches as nesting habitat may experience a higher degree of exposure to hazards as compared to species that nest inland or at higher elevations.

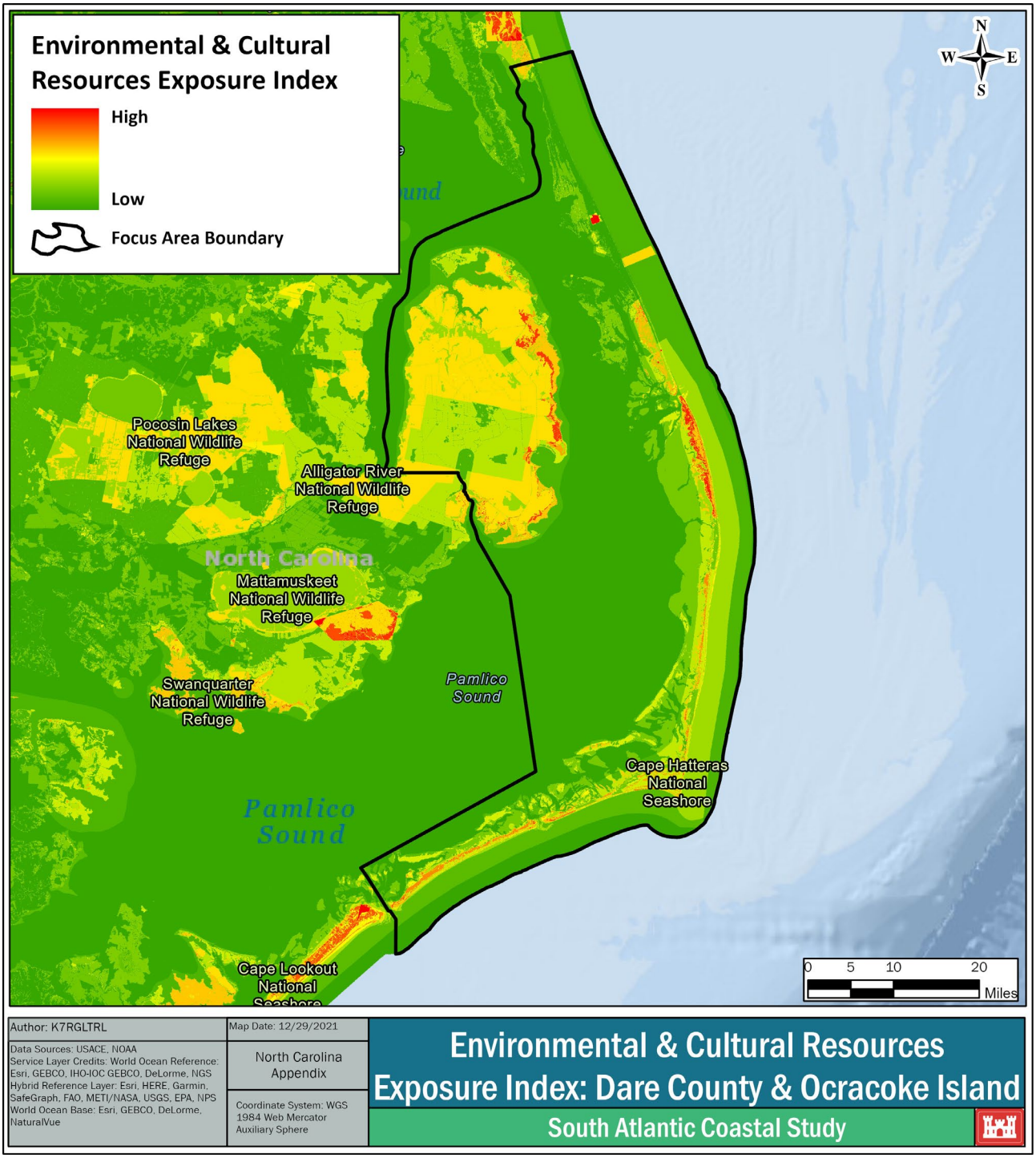


Figure 8: Tier 1 Risk Assessment Viewer (Environmental and Cultural Resources Exposure Index)

The primary data source used in Tier 2 analysis was the North Carolina Natural Heritage Data Explorer online tool curated by the North Carolina Natural Heritage Program (2020). This tool identifies natural areas with high ecological value, existing managed areas, and other areas of environmental significance within the state's boundaries. Natural areas in this focus area exposed to storm surge inundation include upland forests, coastal plain early successional habitats, scrub shrub habitats, beaches and dunes, forested wetlands, shrub and herbaceous wetlands, wet pine savanna, pocosins,

and submerged aquatic vegetation. Beaches and dunes and other areas abutting water bodies are particularly exposed to erosion. For additional information regarding the Tier 2 Environmental Resources Vulnerability and Risk Analysis, please refer to the South Atlantic Coastal Study Environmental Technical Report, Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification.

4.3.3.2 Cultural Resources

Fourteen at-risk cultural resource sites and historic districts are identified within, or partially within, the Dare County and Ocracoke Island Focus Area. These cultural resources were identified through collaborative discussions with the North Carolina Office of State Archaeology and the North Carolina State Historic Preservation Office.

- **Cape Hatteras Lighthouse (DR0004):** Listed on the National Register of Historic Places (NRHP) in 1978, the lighthouse abuts the Buxton census-designated place community in Dare County. The lighthouse was constructed in 1870, is 208 feet tall, wears a spiral daymark pattern, and is also a National Historic Landmark.
- **Wright Brothers National Memorial (DR0014):** Listed on the NRHP in 1966, the memorial is located within the Kill Devil Hills census place in Dare County. The memorial was constructed in 1932 of grey granite and is an obelisk shape.
- **Wright Brothers National Memorial Visitor Center (DR0273):** Listed on the NRHP in 1996, the visitor center is located within the Kill Devil Hills census place in Dare County. The visitor center was originally constructed in 1960 by Mitchell/Giurgola, is a modernist style, and is also a National Historic Landmark.
- **Fort Raleigh (DR0008):** Listed on the NRHP in 1966, Fort Raleigh is located near the Manteo census place in Dare County. Fort Raleigh is the 1585 site of early attempted English settlement.
- **Bodie Island Lighthouse (DR0001):** Listed on the NRHP in 2003, the lighthouse is located near the Nags Head census place community in Dare County. The lighthouse was constructed in 1872 of brick and is 164 feet tall.
- **Oregon Inlet Coast Guard Station (DR0012):** Listed on the NRHP in 1975, the station is located near the Nags Head census place in Dare County. The station was originally constructed in 1987, with subsequent construction events occurring in 1933 and 1970.
- **Chicamacomico Life Saving Station (DR0006):** Listed on the NRHP in 1976, the station is in the Rodanthe census place in Dare County. The shingle-style 1-1/2 story office/residence was originally constructed in 1887, with subsequent construction occurring in 1911.
- **First Colony Inn (DR0022):** Listed on the NRHP in 2003, the inn is in the Nags Head census place in Dare County. The 2.5-story inn was constructed in 1932.
- **Hatteras Weather Bureau Station (DR0009):** Listed on the NRHP in 1978, the station is in the Hatteras census place in Dare County. The 1.5-story frame office/residence was constructed in 1901.

- **Mattie Midgett Store and House (DR0574):** Listed on the NRHP in 2004, the store and house are located in the Nags Head census place community in Dare County. The 2-story shingled store was constructed in 1914 and the 2-story shingled house was constructed in 1933.
- **Nags Head Beach Cottage Row Historic District (DR0011):** Listed on the NRHP in 1977, the district is in the Nags Head census place in Dare County. The district consists of multiple early twentieth century shingled beach cottages.
- **Salvo Post Office (DR0023):** Listed on the NRHP in 1993, the small 1-story building is located in the Salvo census place in Dare County.
- **Ocracoke Historic District (HY0634):** Listed on the NRHP in 1990, the district is in the Ocracoke census place in Hyde County. The district is a maritime community of structures constructed between 1823 and 1959.
- **Ocracoke Light Station (HY0004):** Listed on the NRHP in 1977, the light station is in the Ocracoke census place in Hyde County. The conical brick light station was constructed in 1823 and is 75 feet tall.

Potential strategies and measures to protect vulnerable areas of identified cultural resources include elevating or relocating structures, excavating and studying sites in eroding areas, constructing living shorelines or other breakwater structures to protect resources from wave action and erosion, and using dredged material beneficially to buffer the effects of wave attack.

4.3.3.3 Environmental and Cultural Resource Uncertainty

At this time, no certain effects of climate change on tropical cyclone activity in terms of frequency, intensity, and rainfall across all global basins have been identified because the current sciences related to climate effects on tropical cyclone activity have not reached the standard consensus necessary to change storm analysis baselines. Similarly, the rate of sea level rise in North Carolina is unknown, although some models suggest that sea level will continue to rise, threatening natural and human environments. If protective measures are not implemented, habitat types with limited tolerance to salinity may migrate inland, be displaced, or be lost because of inundation or erosion. Similarly, cultural resources may be subjected to increased erosive forces, increased saline conditions, and potential inundation due to coastal storm damage and sea level rise.

4.4 Vulnerability

Vulnerability is the susceptibility of harm to human beings, property, and the environment when exposed to a hazard (USACE 2017). Regarding environmental vulnerability to the effects of coastal storms and sea level rise, pocosin vegetation systems are highly susceptible to increased salinity impacts. According to the North Carolina Forest Service (2020), intense wildfires in the Alligator River National Wildlife Refuge over the past 12 years eliminated the root mat of some pocosin/bay forest areas, preventing recovery and increasing remaining pocosin/bay forests' importance due to loss of the root mat. Furthermore, the deep organic soils found in the refuge and elsewhere in the region may release additional carbon dioxide and methane if exposed to increasingly saline conditions, which may contribute to climate change and atmospheric warming.

Additionally, salinity changes within this focus area may alter habitats bordering Pamlico Sound, behind barrier islands. Coastal storms could change existing barrier island habitats through erosion and storm surge. Coastal storms may also redistribute sand such that capes are expanded or reduced and inlets are created or closed. Sand redistribution may significantly change available habitat types and associated acreage.

The Dare County and Ocracoke Island Focus Area is highly vulnerable to coastal storms and sea level rise in part due to the following:

- Habitat Conversion: **Figure 9** illustrates the significant increase in acreages vulnerable to inundation between existing conditions and future conditions with sea level rise. Storm surge and sea level rise hazards may inundate currently upland natural communities and/or introduce increased localized salinity which may force habitat conversion.

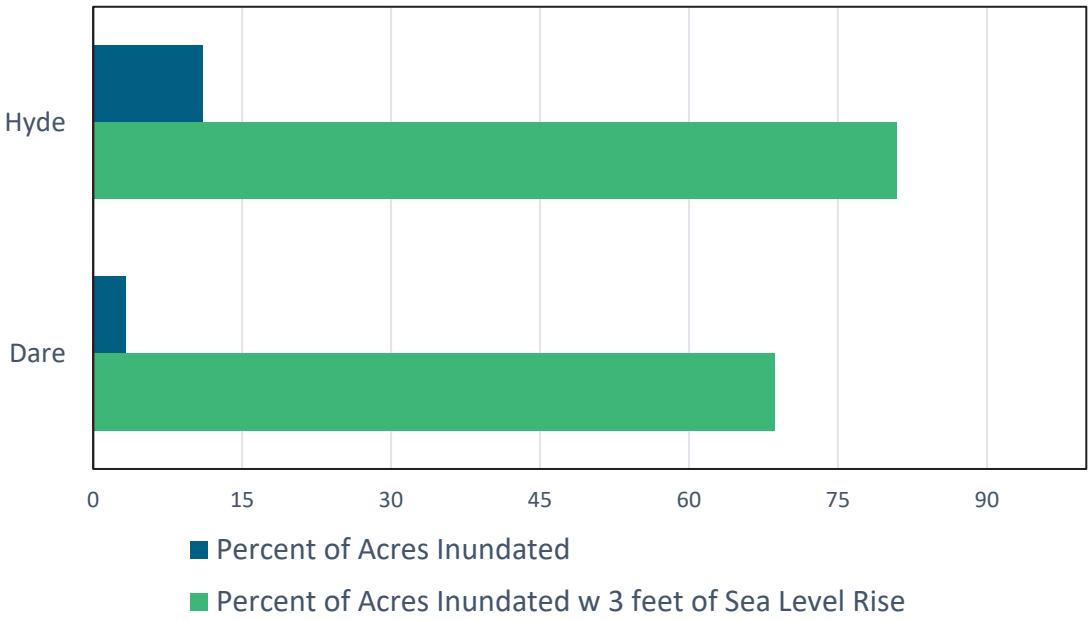


Figure 9: Comparison of Land Currently Vulnerable to Inundation and in Future Conditions with Sea Level Rise

- Naturally dynamic barrier islands: The barrier island portions of the Dare County and Ocracoke Island Focus Area have historically migrated west via natural processes such as overwash as the islands slowly roll back up the continental shelf as sea levels rise. Static human development conflicts with this natural migratory process, creating vulnerability for people, property, and the islands.
- High seasonal population: During the spring, summer, and fall, the Outer Banks population exponentially increases because of tourism and seasonal residents. Much of this time coincides with hurricane season.
- Limited evacuation routes: Other than limited ferry service, N.C. 12 is the only evacuation route that spans the Outer Banks.

The 2016 North Carolina Hurricane Evacuation Study (FEMA 2016) used NOAA surge modeling, land surveying, and photography to visualize the vulnerability of landmark structure for potential surge height and depth of water for all hurricane categories. **Figure 10** through **Figure 12** from the Hurricane Evacuation Study (FEMA 2016) illustrate the vulnerability of specific landmark locations within the focus area to storm surge inundation for a Category 3 MOM hurricane. Although these images would not represent the inundation levels of all Category 3 hurricanes, they do represent the possibilities in a worst-case scenario for a Category 3 MOM hurricane, based on the modeling.

Figure 10: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Rodanthe Emergency Management Services Station 6, Dare County (FEMA 2016)

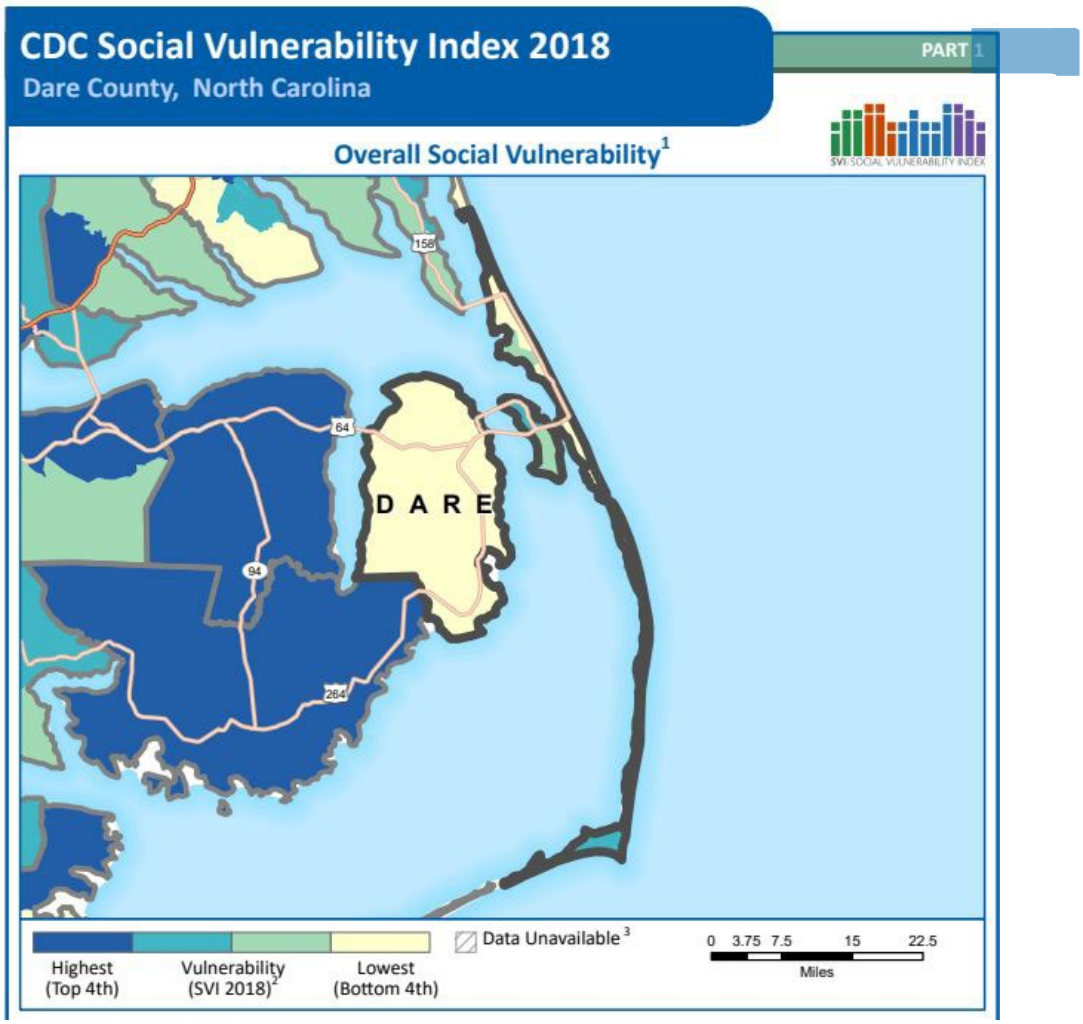
Figure 11: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at Cape Hatteras High School, Dare County (FEMA 2016)

Figure 12: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Ocracoke Fire Department, Ocracoke Island (FEMA 2016)

4.4.1 Social Vulnerability

Social Vulnerability Index

The Centers for Disease Control and Prevention Social Vulnerability Index (CDC SVI) was used to further evaluate social vulnerability within the focus area by assessing overall SVI percentile rankings at the census tract scale. The CDC SVI depicts the social vulnerability of communities by assigning an SVI percentile ranking that ranges from 0 (lowest vulnerability) to 1.0 (highest vulnerability) based on national comparisons. The overall CDC SVI ranking for Dare County is in the 0 to 0.25 quartile, which indicates a low level of vulnerability within the focus area. At a more refined scale, census tracts south of Oregon Inlet and on Roanoke Island have the highest CDC SVI rankings in Dare County (0.5 to 0.75), indicating a higher level of social vulnerability (**Figure 13**). Ocracoke Island has the highest level of social vulnerability with a ranking of 0.75 to 1.0 (**Figure 14**). The North Carolina Appendix provides additional detail about the CDC SVI.



[1]*Overall Social Vulnerability: All 15 variables.*
[2]*Data Sources: CDC/ATSDR/GRASP, U.S. Census Bureau, Esri StreetMap TM Premium.*
[3]*Census tracts with 0 population.*

Figure 13: Dare County Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)

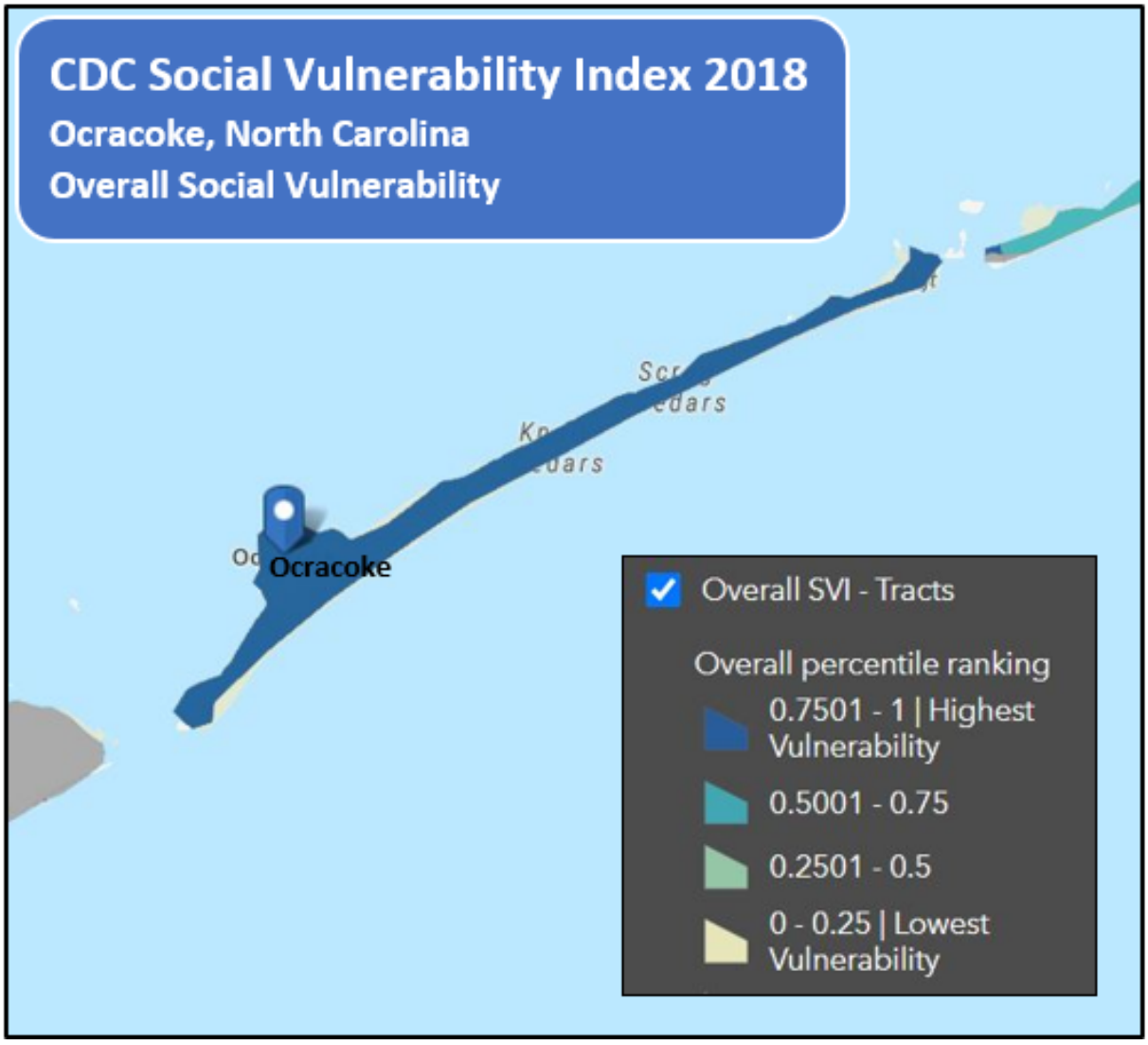


Figure 14: Ocracoke Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)

Environmental Justice

USACE conducted an evaluation of environmental justice (EJ) by determining whether the study area contains a concentration of minority and/or low-income populations.

As defined in Executive Order 12898 and the Council on Environmental Quality (CEQ) guidance, a minority population occurs where one or both of the following conditions are met within a given geographic area:

- American Indian, Alaskan Native, Asian, Pacific Islander, Black, or Hispanic population of the affected area exceeds 50 percent.
- Minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis.

An affected geographic area consists of a low-income population where the percentage of low-income persons:

- is at least 50 percent of the total population, or
- is meaningfully greater than the low-income population percentage in the general population or other appropriate unit of geographic analysis.

The Environmental Protection Agency EJScreen is an EJ mapping and screening tool that provides the EPA with a nationally consistent dataset and approach for combining environmental and demographic indicators (EPA 2020). EJScreen users choose a geographic area; the tool then provides demographic and environmental information for that area. For the purposes of this evaluation, only demographic information was applied for the area.

The low-income population is the percentage of a block group's population in households where the household income is less than or equal to twice the federal "poverty level."

The minority population is the percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino (i.e., all people other than non-Hispanic, white-alone individuals). The word "alone" in this case indicates that the person is of a single race, not multiracial.

Using the EJScreen tool, the study area was user-defined *(***Figure 15**) to calculate the average percentages for EJ criteria. The result is a population-weighted average, which equals the block group indicator values averaged over all residents estimated to be inside the study area. **Table 11** compares the average percentages for the study area, the State of North Carolina, and the United States.

Based on the information provided by the EJScreen tool, for Dare County, the average minority population is approximately 13 percent of the total population, and approximately 28 percent of the population are considered low-income. When assessed at a county-level geographic scale, Dare County does not meet the EJ community minimum threshold because the minority population and low-income percentages are below 50 percent. While these are overall county estimates, 2019 Census Bureau estimates show projections varying from one census tract to another. Ocracoke Island, which is part of Hyde County, has a minority population of approximately 29 percent and a low-income population of approximately 50 percent. Therefore, Ocracoke is considered a low-income population.

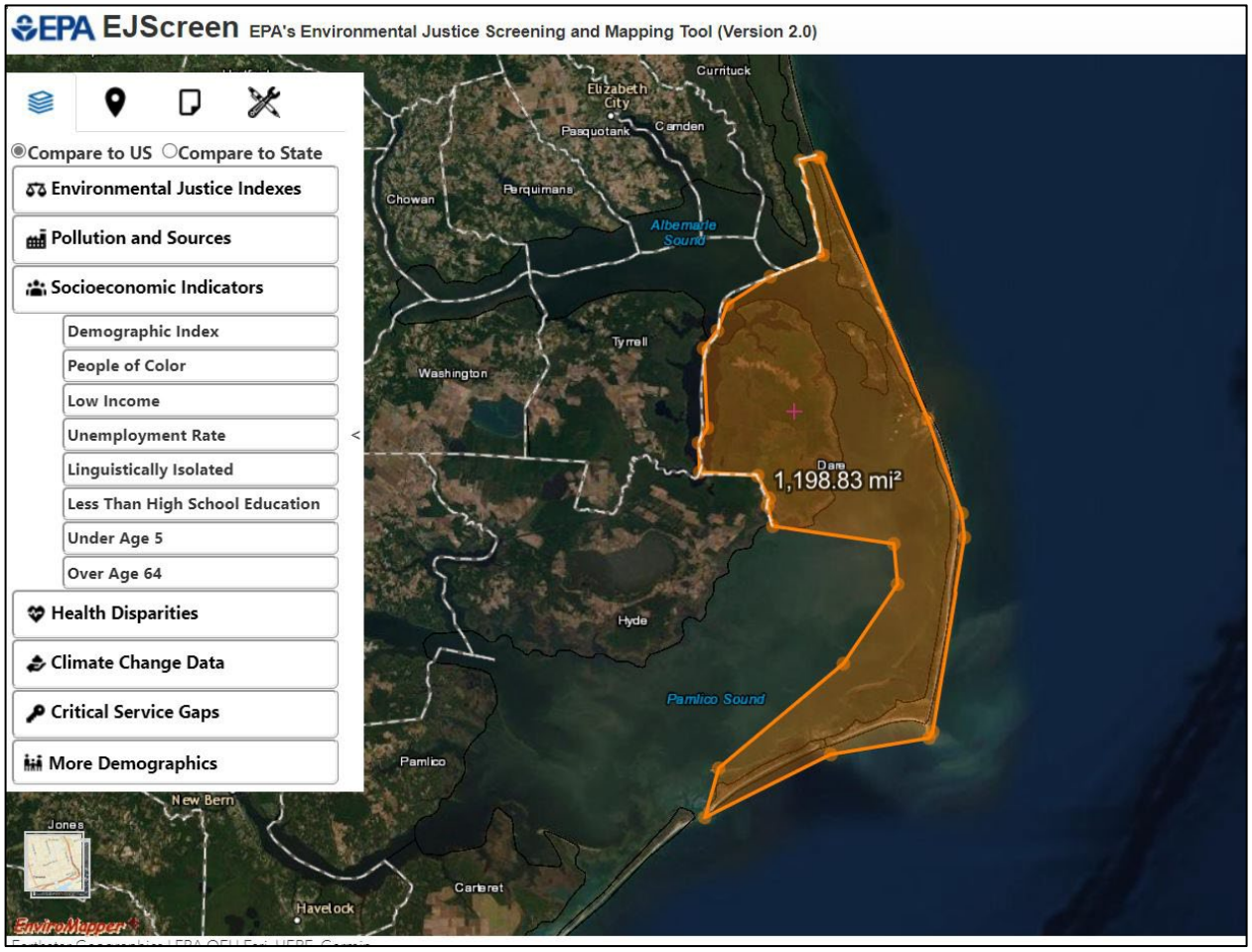


Figure 15: User-Defined Environmental Protection Agency EJScreen Tool Analysis Boundary (EPA 2020)

Table 11: Environmental Protection Agency EJScreen Tool Environmental Justice Criteria Percentages (EPA 2020)

Population Type	User-Defined Project Area % Dare/Ocracoke	North Carolina Average %	U.S. Average %
Minority Population	13/29	47	39
Low Income Population	28/50	36	33

4.4.2 Environmental Vulnerability

An environmental resources vulnerability analysis was conducted for the Dare County and Ocracoke Island Focus Area to determine the degree to which natural areas are susceptible to loss or degradation when exposed to coastal storm hazards and sea level rise. A table was created from this analysis to assess the numerical level of vulnerability of natural habitats, which are assigned by the NOAA Coastal Change Analysis Program (C-CAP), against the hazards of sea level rise, storm surge inundation, saltwater intrusion, erosion, and wind damage. Based on the results of this assessment, a weighted formula was developed to assign a vulnerability rating of each C-CAP class (low, medium, or high) for each state and territory in the SACS study area (**Table 12**). **Figure 16** reflects the results of the vulnerability scoring for each C-CAP habitat found within Planning Reach NC_01, which includes all of the focus area.

Table 12: Coastal Change Analysis Program Classes Vulnerability Rating

Coastal Change Analysis Program (C-CAP) Habitat	Vulnerability Rating
Evergreen Forest	Medium
Grassland	Medium
Deciduous Forest	Medium
Mixed Forest	High
Unconsolidated Shore	Medium
Estuarine Forested Wetland	Low
Estuarine Emergent Wetland	Low
Palustrine Emergent Wetland (Persistent)	Medium
Palustrine Scrub/Shrub Wetland	Medium
Palustrine Forested Wetland	Medium
Palustrine Aquatic Bed	Medium
Scrub/Shrub	Medium
Estuarine Scrub/Shrub Wetland	Low
Open Water	Medium
Estuarine Aquatic Bed	Low

In addition to rating the vulnerability of the natural habitats to the hazards identified above, the ability for the natural habitat to adapt to these conditions was also assessed. Low tolerances of certain habitats to water and soil chemistry changes caused by saltwater inundation, intrusion, and impediments to migration were identified as important vulnerability considerations. Anthropogenic activities, such as increased residential and commercial development in the coastal plain and the construction of structural coastal storm risk management infrastructure (e.g., sea walls), can produce barriers that impede inland migration of natural resources.

Please see Appendix B of the Environmental Technical Report for a more detailed summary of the resource vulnerability table and scoring criteria.

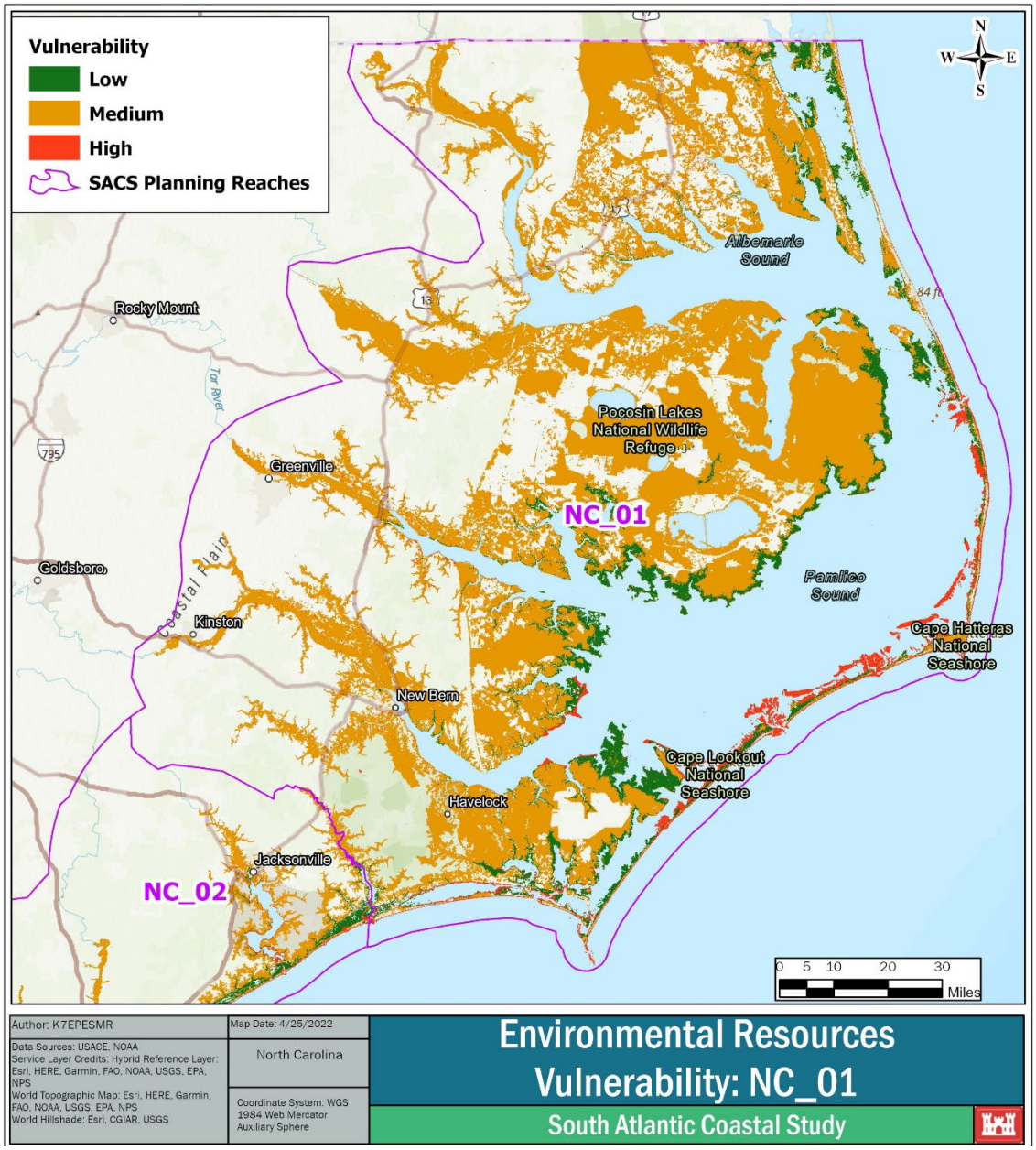


Figure 16: Dare County and Ocracoke Vulnerability Rating for Coastal Change Analysis Program Habitats

4.5 Consequences

The Dare County and Ocracoke Island Focus Area is frequently impacted by coastal storms, historically about every 2.5 years. Because of its isolated location, vulnerable single evacuation route, and high populations during hurricane season, the consequences of coastal storm impacts can be significant. These consequences include destroyed infrastructure and loss of nesting habitat for threatened and endangered species from erosion and wave attack, and potentially tens of millions of dollars in direct economic damage to infrastructure, which is spread throughout all the communities in the focus area from storm surge inundation. The consequences will continue to increase with sea level rise.

Consequences are measured in terms of metrics such as economic damage, acreage of habitat lost, value of crop damage, and potential loss of life. The Tier 1 and Tier 2 analyses incorporated both vulnerability and consequence in the overall risk assessment. Hazus uses damage functions to represent the vulnerability of different types of infrastructure to flood hazards. The consequences of infrastructure impacts are represented in dollar-damages through the Tier 2 Economic Risk Assessment.

As described in the Environmental Technical Report, the Tier 2 Environmental Resources Vulnerability Analysis assigned vulnerability scores to NOAA's Coastal Change Analysis Program (C-CAP) land cover classifications based on potential exposure to hazards. Vulnerability scores were assigned based on adaptive capacity of the natural resources to inundation. Environmental consequences include resources disturbed, lost, or permanently altered because of the hazard. Social vulnerability was assessed during the Tier 1 Risk Assessment with consequences including life loss and relocation of vulnerable populations.

4.6 Risk Assessment

Population, infrastructure, environmental, and cultural resources are at risk within the Dare County and Ocracoke Island Focus Area. The risk is driven by a combination of factors, including wave attack, erosion, and inundation from coastal storms. This risk will increase as sea level rises.

4.6.1 Priority Environmental Areas

Regarding environmental factors, three PEAs are identified within, or partially within, the Dare County and Ocracoke Island Focus Area. These areas were identified through collaboration with multiple state and federal stakeholders.

Alligator River National Wildlife Refuge

Located in the Manns Harbor census place community and the Mashoes, East Lake, Buffalo City, and Stumpy Point non-census place communities in Dare County, the Alligator River National Wildlife Refuge contains approximately 153,000 acres of Atlantic white cedar forest, bay forest, brackish marsh, cropland, cypress-gum forest, freshwater lakes and ponds, freshwater marsh, high shrub pocosin, loblolly pine forest, low shrub pocosin, managed wetlands, mixed hard swamp, mixed pine/hardwood forest, non-alluvial hardwood forest, pond pine cane pocosin, pond pine shrub pocosin, and shrub/marsh transition.

Managed by the FWS, the Alligator River National Wildlife Refuge is home to one of the largest concentrations of black bear found in the southeastern United States and provides habitat for threatened and endangered species, including red wolves, red-cockaded woodpeckers, and American alligators. Additionally, the refuge provides habitat and management opportunities for waterfowl and other migratory birds.

Cape Hatteras National Seashore

Located in the Hatteras, Avon, Frisco, Nags Head, Buxton, Salvo, Waves, and Rodanthe census places in Dare County and the Ocracoke census place in Hyde County, the Cape Hatteras National Seashore contains approximately 24,400 acres and 70 miles of ocean beach, sand dunes, shrub thicket, deciduous/evergreen/mixed forest, brackish and freshwater marshes, tidal flats, and tidal wetlands.

Managed by the NPS, the seashore contains habitat for a variety of animals, including reptiles, birds, and mammals. The seashore contains critical habitats for beach-nesting birds, such as the endangered piping plover. Multiple endangered sea turtle species also use the seashore's beaches for nesting.

Pea Island National Wildlife Refuge

Located near (abutting) the Rodanthe census place community in Dare County, the Pea Island National Wildlife Refuge contains approximately 5,800 acres of ocean beach, dune, brackish ponds, and marsh communities dissected by tidal creeks containing submerged aquatic vegetation.

Managed by the FWS, the refuge was established in 1938 to protect and conserve migratory birds and other wildlife resources through the protection of wetlands, in accordance with Executive Order 7864 (National Archives 2021). The refuge also provides nesting habitat and protection for endangered and threatened species including multiple sea turtles.

Potential strategies and measures to protect vulnerable parts of identified PEAs include building a comprehensive actionable plan for stormwater management in unincorporated areas overlapping with managed lands, constructing living shorelines to protect habitats and marshes from wave action and erosion, using dredged material beneficially to support marsh or beach resiliency, implementing sediment management strategies to support beach nourishment and island breach repairs, and studying and monitoring benchmark surface elevation in wetlands to better understand the effects of sea level rise in terms of habitat inundation.

Risk to life safety is increased when considering there is only one narrow evacuation route, which has a history of closures due to coastal hazards and must be used to accommodate a substantially greater seasonal population during hurricane season.

4.6.2 Population and Infrastructure Risk

As shown in the SACS Tier 2 Economic Risk Assessment, North Carolina ranks third in terms of economic risk among the states and territories within the SACS area, behind South Carolina and Florida. This is likely in part due to existing strategies to limit high-density development in vulnerable coastal areas, including preserving large amounts of natural shoreline along Dare County and Ocracoke Island. However, analysis also shows that North Carolina has the highest increase in future economic risk among all states when accounting for sea level rise. This is due to the large extent of North Carolina's low-lying areas—many of which are in back bay areas such as mainland Dare County. Additionally, North Carolina is a top five destination state for people to relocate to (News and Observer 2020), and many people will continue to move into coastal areas like Dare County while the coastal storm risk increases (**Figure 17**). This further illustrates the importance of existing strategies such as the North Carolina Climate Risk Assessment and Resilience Plan, which is further discussed in Section 5 of this report.

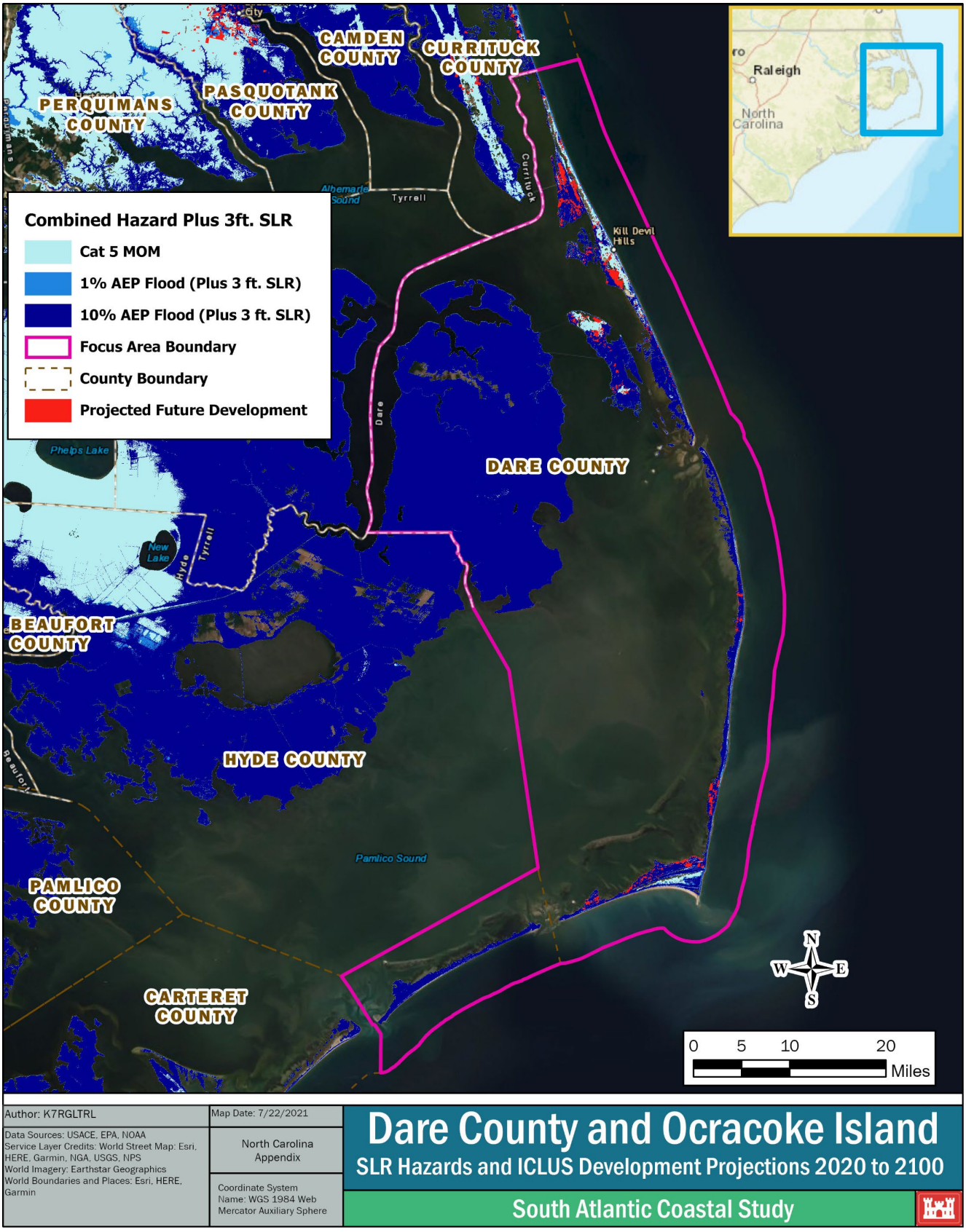


Figure 17: Future Development Projections (Red) Through 2100 in Dare County and Ocracoke Island Overlaid with Future Sea Level Rise Hazard Data

Figure 18 provides a snapshot of the Tier 2 Economic Risk Assessment for the focus area. Each circle on the map denotes separate census places and displays the distribution of economic risk from low to high. Bar charts on the figure highlight the census places with the greatest economic risk, with quantifications of the existing (green shading) and future risks, including sea level rise (black shading). Economic risks displayed are not cumulative. The distribution of existing and future economic risks is further broken down by county. The analysis includes National Economic Development risk and consequences of events. EAD for the Dare County and Ocracoke Island Focus Area is $48.9 million in the existing condition, and $129.9 million in the future conditions, an increase of 166 percent with 3 feet of sea level rise. The total accumulated all damages in the focus area. Manteo, Kitty Hawk, Hatteras, Southern Shores, Wanchese, Duck, Avon, Frisco, Kill Devil Hills, Ocracoke, Nags Head, and Buxton are all areas within the Dare County and Ocracoke Island Focus Area.

A problem in this area is the damage to structures due to coastal storm-driven inundation and erosion. Under existing conditions, a 2-percent AEP (50-year) event will cause $0.55 billion of damages and under future conditions, it would cause $1.4 billion of damages. The consequences are almost tripled for the future conditions. The census places with the greatest risk include Manteo, Kitty Hawk, and Hatteras.

Data derived from the Tier 2 Economic Risk Assessment realize the opportunity to gather additional data on coastal hazards and vulnerability to refine current and future CSRM efforts. High-risk locations identified above are directly correlated with problems within the focus area identified in Section 2. This information, in conjunction with the suite of SACS products and tools, was used to develop draft action strategies.

Focus Area

Dare County / Ocracoke

Dare County / Ocracoke

$48,893,222
Existing Risk ($EAD)

$129,936,225
Future Risk ($EAD)

Focus Area Risk by County

County	Existing Risk ($)	Future Risk ($)
Dare	$47,225,793	$125,107,590
Hyde	$1,667,429	$4,828,635
Total	**$48,893,222**	**$129,936,225**

Existing Consequences by Return Interval Event

Future Consequences by Return Interval Event

Existing Risk ($EAD) & Future Risk ($EAD) by Census Places in Focus Area

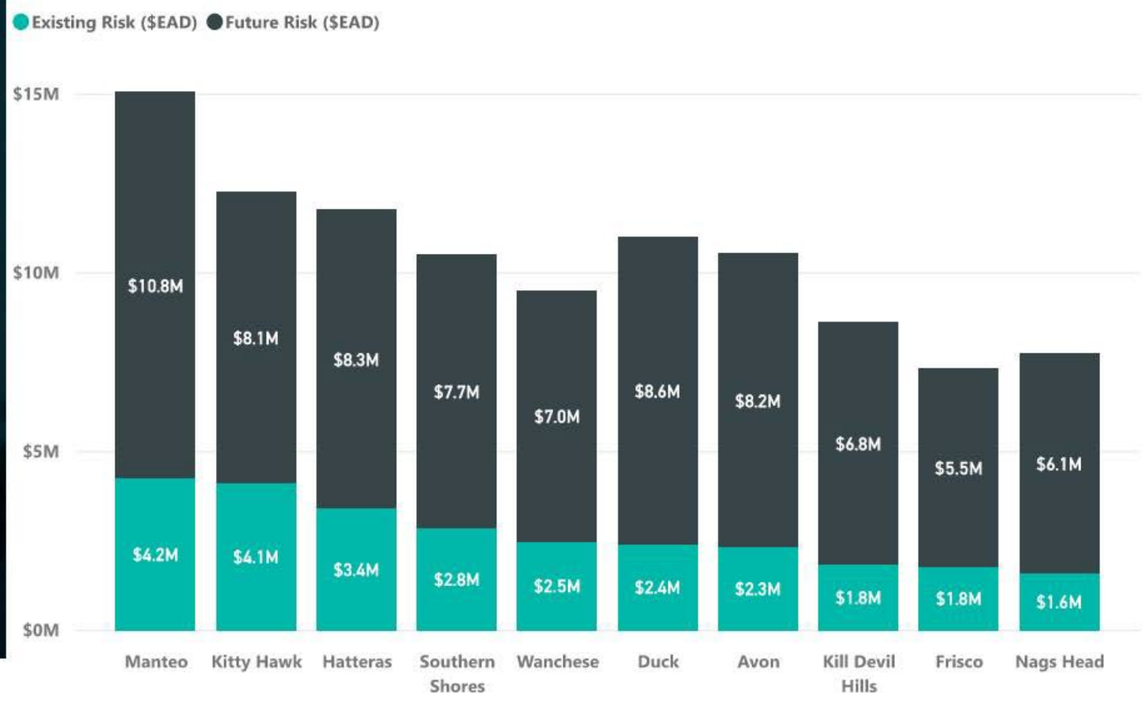


Figure 18: Existing and Future Economic Risk in Dare County and Ocracoke Island due to Storm Surge

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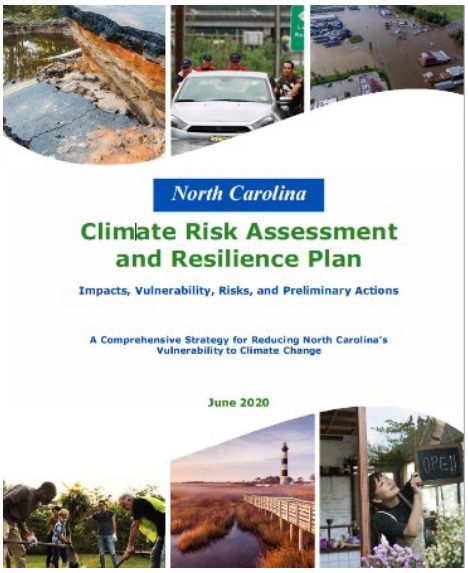
5. Action Strategy Development

North Carolina continues to be proactive with resiliency efforts along the coastline, and initiatives have been implemented or are planned throughout all levels of government, as well as by non-governmental entities. This FAAS for the Dare County and Ocracoke Island Focus Area within the scope of the SACS was developed in support of the significant ongoing efforts within the region. One major existing strategy in North Carolina falls under the governor's Executive Order 80 (North Carolina Office of the Governor 2018), which is a commitment to address climate change and transition to a clean energy economy. Within Executive Order 80 is the North Carolina Climate Risk Assessment and Resiliency Plan (NCDEQ 2020). This existing plan builds upon North Carolina's ongoing work in this area and establishes the North Carolina Resilience Strategy, which includes four elements:

1. North Carolina Climate Science Report
2. State Agency Resilience Strategy
3. Statewide Vulnerability Assessment and Resiliency Strategies
4. North Carolina Enhanced Hazard Mitigation Plan



Accordingly, the Dare County and Ocracoke Island FAAS does not seek to create a strategy separate from significant and ongoing efforts, but to support those of the region and develop additional considerations for future federal and non-federal efforts. The scope of the SACS ties into several critical sectors of study within the North Carolina Climate Risk Assessment and Resiliency Plan, including coastal resources, ecosystems, housing, building and support services, public safety, and transportation. Where possible, the Dare County and Ocracoke FAAS seeks to contribute to the overall North Carolina Climate Risk Assessment and Resiliency Plan while supporting the SACS Shared Vision statement as created by the stakeholders of Dare County and Ocracoke Island.

5.1 Identify Possible Solutions

A series of workshops were held with focus area stakeholders to identify ongoing, planned, and needed actions to address problems and realize opportunities identified earlier in this report. Proposed actions were evaluated based on their ability to address those problems, realize opportunities, and ultimately contribute to the objectives. Actions were grouped into categories of *Infrastructure and Mitigation, Sediment Management,* and *Education and Outreach.*

There are several SACS key products that can be used to help identify measures and possible solutions. The SACS Measures and Cost Library (MCL) can be used to identify suitable measures based on wave energy (USACE 2022b). Planning-level rough order of magnitude cost estimates and the Tier 2 Economic Risk Assessment can be used to identify potential economic benefits. The 2020 RSM Optimization Update and SAND Report can be used to identify opportunities for RSM strategies and suitable sand sources. Measures are organized into structural, nonstructural, and NNBF categories.

- **Structural measure**: Structural measures consist of human-made structures designed to reduce the occurrence and/or severity of an event that leads to harm.
- **Nonstructural measure**: Nonstructural measures reduce risk by either removing the item of concern from the exposure or reducing the item's degree of vulnerability to the harm.
- **NNBF**: The use of natural features or the human design of features that mimic or work in concert with natural processes to meet a planning objective. NNBF can include policy, and may be considered a structural or nonstructural measure, depending on the feature.

The broad measures identified in **Table 13** (structural, nonstructural, and NNBF) could be further developed to target specific areas for CSRM. The goal of developing alternatives is to achieve the objectives by combining one or more measures while avoiding constraints. Measures identified will be further evaluated, screened, and used in combination (as appropriate) to determine area-specific project viability to meet the planning objectives.

Table 13: General Dare County and Ocracoke Island Focus Area Issues and Potential Measures

Issues Identified in Focus Area	Potential Measures		
	Structural	Nonstructural	NNBF
Damage to infrastructure from storm surge and erosion	• Build seawall/revetment • Build detached breakwaters • Build floodwalls and bulkheads • Perform beach nourishment	• Relocate utilities and critical infrastructure • Implement building codes and zoning • Elevate structures • Retreat the shoreline	• Build dunes • Create living shorelines (oyster sills, vegetation) • Restore wetland/ marsh
Loss of environmental resources due to storm surge and erosion	• Perform beach nourishment (habitat protection and expansion)	• Conduct stormwater management • Implement preservation measures • Conduct local permitting	• Create living shorelines • Restore wetland/ marsh • Conduct RSM (thin-layer placement; marsh resilience)
Road closures that impact life safety	• Build seawalls/revetments • Elevate roads	• Relocate infrastructure	• Create living shoreline sill
Risk communication	• N/A	• Implement early warning systems • Educate and engage the public • Prepare emergency plans/hazard mitigation plans	• N/A
Cultural resource protection	• Build breakwater structures • Conduct RSM (erosional areas)	• Elevate or relocate structures • Conduct study/site excavations	• Create living shorelines

Each of the following identified actions have been organized as existing, planned, or needed actions. They are also identified as either actions led by USACE or actions led by others. More detailed information on each action is available in **Table 17** in Section 5.3.

5.1.1 Existing or Ongoing Actions

The following are actions that have already been implemented or are currently being implemented:

USACE Actions

- Conduct RSM for Manteo (Shallowbag Bay, Pea Island, and migratory bird habitat) and Rollinson Channel and Silver Lake Harbor (upland bird habitat in Ocracoke and Hatteras).

Actions by Others

- Establish hurricane evacuation zones in Dare and Hyde Counties.
- Conduct CSRM and beach fill placement for Duck, Kitty Hawk, Kill Devil Hills, Nags Head, Buxton.
- Prepare an environmental impact statement on sediment management for NPS lands.
- Perform an oceanfront erosion assessment from Nags Head to Ocracoke Island.
- Perform a vulnerability assessment for all historic and NPS structures.
- Restore living shorelines/marshes at Jockey's Ridge State Park, Alligator River National Wildlife Refuge, Festival Park (Manteo), and Nags Head back bay.
- Pursue FEMA Hazard Mitigation Grant Program opportunities enabling Dare County and Ocracoke Island to assist local permanent residents in seeking funds to repair seriously damaged homes as a result of hurricanes and tidal storm events, as well as elevating them above current base flood levels.
- Implement Dare County zoning regulations for elevation.
- Form working groups, coalitions, and councils:
  - Dare County Waterways Commission
  - North Carolina Beach, Inlet, and Waterway Association
  - The Collaboratory for Coastal Adaptation over Space and Time (C-CoAST)
- North Carolina Coastal Community Resilience Guide, which is applicable to Dare and Hyde Counties.
- Continue Natural and Working Lands initiatives applicable to coastal farmlands in North Carolina, including mainland Dare County.
- Use the Vulnerability, Consequences, and Adaptive Planning Scenario (VCAPS) to assist with planning. VCAPS is a Town of Nags Head and North Carolina Sea Grant initiative to incorporate sea level rise into comprehensive planning.
- Conduct saltwater inundation and intrusion research.

5.1.2 Planned Actions

The following actions are planned to be implemented:

USACE Actions

- Conduct RSM, including Rollinson Channel nearshore placement (Hatteras).
- Develop statewide non-federal dredged material management plan with stakeholder input.

Actions by Others

- Support Resilient Coastal Communities Program, which is applicable to all 20 coastal counties, including Dare and Hyde Counties.
- Develop actionable comprehensive Stormwater Management Plan for unincorporated areas of Dare County, which includes realigning the Ocracoke Island ferry terminal.

5.1.3 Needed Actions

The following actions were identified as potentially needed:

- Discuss an offshore resources sediment management strategy.
- Identify locations for new DMMAs, upland placement, thin-layer placement, and/or marsh restoration, all of which allow for efficient use of dredged materials to mitigate the effects of erosion and sea level rise in various environments and could alleviate the need for additional placement areas and strategies needed to accommodate dredged material and reduce capacity constraints on current placement areas.
- Beneficially use dredged material at Wanchese Harbor southside.
- Conduct an Albemarle-Pamlico Estuary back bay erosion/marsh restoration study.
- Conduct an enhanced building-level risk assessment.
- Hold stakeholder training workshops of CHS data.
- Saltwater Marsh Habitat Mitigation at Durant Point near Rollinson Channel.

5.2 Evaluation of Actions

The potential actions listed in Section 5.1 were compared with the identified problems, opportunities, and the overall study objectives, which were developed through the stakeholder engagement process to align with the overarching goals of the shared vision statement. Potential actions that contribute to at least one study objective were included in the FAAS. Any measures not directly contributing to an objective were screened out for the purposes of the SACS FAAS. However, these screened actions may be valuable efforts through a separate application. The following evaluation reveals how specific actions are contributing to the objectives of the strategy (**Table 14**).

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Table 14: Connecting Actions to Identified Problems, Opportunities, and Objectives in the Dare County and Ocracoke Island Focus Area

Action Type	Recommended Action	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	IOB 1	IOB 2	IOB 3	IOB 4	IOB 5	IOB 6	IOB 7	O1	O2	O3	O4	O5	O6	OBJ 1	OBJ 2	G1
Infrastructure and Mitigation	Structure Vulnerability Assessments (NPS)	X							X																		X		
Infrastructure and Mitigation	Resilient Coastal Communities Program (NCDEQ DCM)	X	X						X				X														X		
Infrastructure and Mitigation	Refuge Management Planning (USFWS)						X			X											x	X						X	
Infrastructure and Mitigation	Vulnerability, Consequences, and Adaptive Planning Scenarios (Nags Head)	X	X	X			X		X				X										X				X		
Infrastructure and Mitigation	Aggressive Zoning/Elevation Requirements (Dare County)	X	X																								X		
Infrastructure and Mitigation	Home Elevations/Buyouts (FEMA Hazard Mitigation Grant Program)	X	X																								X		
Infrastructure and Mitigation	ReBUILD NC Strategic Buyout Program (NCORR)	X	X																								X		
Sediment Management	Statewide Non-Federal Dredged Material Management Plan (USACE/NCDEQ)																					X							
Sediment Management	Beneficial Use of Dredged Material (Hatteras Inlet/Rollinson Channel/Chicamacomico Channel)	X					X															X						X	X
Sediment Management	Environmental Impact Statement for Sediment Management (NPS)		X	X					X																		X		
Sediment Management	Erosion Assessment (NPS)								X														X				X		
Sediment Management	Non-Federal CSRM Projects (Dare County)	X	X						X													X						X	
Education and Outreach	Establishment of Hurricane Evacuation Zones (NCDPS)			X									X										X						X
Education and Outreach	North Carolina Coastal Community Resilience Guide (NCDEQ DCM)	X	X										X								X	X	X			X	X	
Education and Outreach	Identification, Mitigation, and Adaptation to Salinization on Working Lands in the U.S. Southeast – Guidebooks (USDA)					X																					X	
Other Needed Actions	Albemarle-Pamlico Estuary Back Bay Erosion/Marsh Restoration Study (USACE)	X			X		X			X												X					X	X
Other Needed Actions	Continuing Authorities Program 204 – South of Wanchese Harbor (USACE)	X			X																	X					X	X
Other Needed Actions	Silver Jackets Nonstructural Flood Risk Management Program – CHS Training Workshop (USACE, State Hazard Mitigation Advisory Group)											X												X		X		
Other Needed Actions	Offshore Sand Management Strategy Discussions (BOEM, USACE, NCDEQ DCM)							X																	X	X		X
Other Needed Actions	Headquarter-level Discussion for Potential Barrier Removal – FEMA Floodplain Maps (FEMA, USACE)										X		X				X											X
Other Needed Actions	Enhanced Building-level Risk Assessments (North Carolina Emergency Management, UNCW, USACE)	X	X									X														X		
Other Needed Actions	RSM Optimization Update Opportunities Strategy (USACE)	X					X															X					X	X
Other Needed Actions	Apply CHS to ReBUILD Strategic Buyout Program (NCORR)	X	X									X													X	X		

Note: Orange shaded row denotes an action that was screened from the FAAS.

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5.2.1 Evaluation of Needed Actions

The following section discusses future needed actions in more detail:

5.2.1.1 Needed USACE Actions

Offshore Resources Sediment Management Strategy Discussion

Purpose and need: The SACS funded the SAND Report and the RSM Optimization Update. While Section 3.1 of the SAND Report identified areas of sand surplus in Dare County, deficiencies were reported in the southern portion of the state. The RSM Optimization Update reported 100-percent optimization of dredged material in this focus area while stakeholders indicated that additional placement areas were needed for navigation material from Hatteras Inlet and Rollinson Channel. Additionally, many of the offshore sources available in Dare and Hyde Counties will need further geotechnical investigation before they can be used for beach nourishments. Institutional barriers prevent local utilization of federal dredged material placement areas. Further coordination between federal, state, and local partners is needed to:

- Develop strategies to systematically assess resources in areas of prioritized needs
- Identify areas to increase efficiencies to maximize use of available resources
- Identify new DMMAs, upland placement areas, and/or marsh restoration areas

Information obtained from the SAND Report and RSM Optimization Update should be used to work with federal, state, and local partners to identify best sediment management strategies in support of multiple project needs. Discussion topics may include strategies to find new sand sources and manage finite resources. Although this action may be more critical for areas south of Dare County and Ocracoke Island, there may be valuable long-term outcomes for this focus area as well.

Potential benefits and impacts of action: This action could result in the development of a strategy to manage offshore sand resources, and the implementation of actions specific to that strategy. This will include updating the SACS Geoportal database with offshore sand resources and coordinating stakeholder/USACE workshops to address sediment budget needs, considering optimization opportunities, and potentially establishing a framework for statewide sediment resource management. If approved, this work will begin in 2022.

Saltwater Marsh Habitat Mitigation at Durant Point near Rollinson Channel

Purpose and need: There is significant saltwater marsh habitat that could be inundated from erosion and sea level rise over the coming years. Stakeholders want to protect the integrity of the marsh through a beneficial use of dredged material such as *thin-layer placement*. These projects are often constructed using fine-grained material from navigation channels deposited as a thin layer and considered beneficial use. Researchers with the National Estuarine Research Reserve recently published *Guidance for Thin-Layer Placement as a Strategy to Enhance Tidal Marshes* (Raposa et al. 2020). National Estuarine Research Reserve researchers established the following purpose statements: (1) Increasing tidal marsh resilience in the face of sea level rise will require implementation of climate adaptation strategies; (2) One emerging climate adaptation strategy for tidal marshes is thin-layer sediment placement; and (3) Thin-layer sediment placement emulates

natural depositional processes in tidal marshes. At Durant Point, approximately 122 acres of marsh located between the Hatteras boat basin and Durant Point may be suitable for thin-layer placement. Material dredged from the Rollinson Channel project may be compatible for this type of application. Assuming a sediment thickness of 6 inches, the volume that could be placed within 122 acres would be approximately 98,000 cubic yards.

Potential benefits and impacts of action: This type of action would preserve or restore important environmental resources (122 acres of saltwater marsh) while accommodating beneficial placement of dredged material from a nearby navigation channel (**Figure 19**).

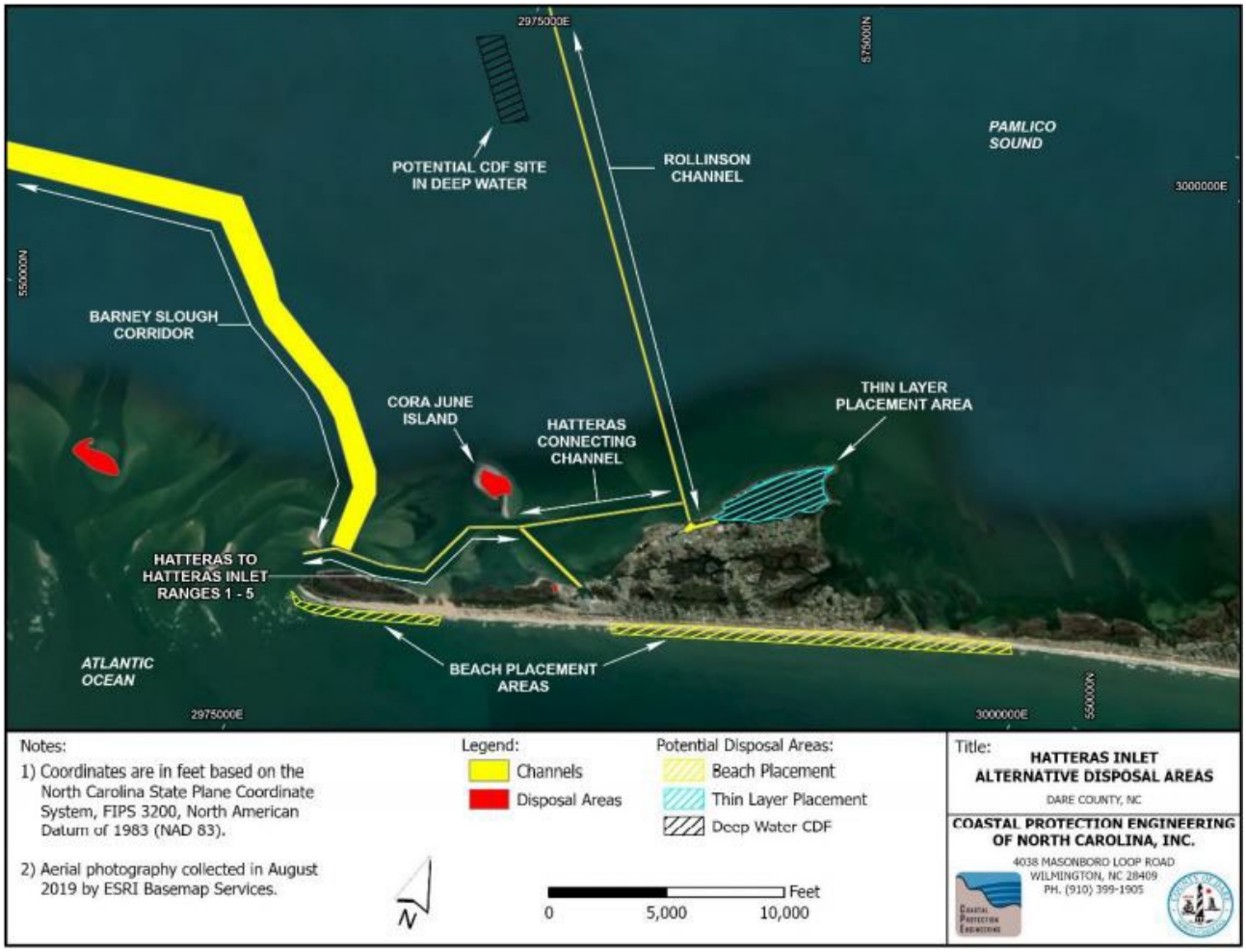

Figure 19: Location of Rollinson Channel and Potential Beneficial Use of Dredged Material Site at Durant Point (Figure Courtesy of Dare County)

The SACS MCL tool and data from the CHS were used to evaluate potential measures that could be implemented for this problem. After identifying the problem and assessing potential risk using SACS tools and stakeholder input, potential structural, nonstructural, and NNBF measures were identified (**Table 15**).

Table 15: Initial Measures for Durant Point (Hatteras Island) in Dare County

Location 2 Durant Point (Hatteras Island) in Dare County
1. No Action (without project condition) 2. NNBF a. Nearshore Nourishment b. Wetland Restoration

The SACS MCL tool provides a rough order of magnitude cost estimate range for the selected measures, including high and low values, equivalent annual costs (EAC), and the total first construction cost (**Table 16**). EAC is the annual cost range based over a 50-year analysis period. The SACS MCL tool is useful in the preliminary stages of planning to efficiently identify a variety of possible solutions and obtain rough order of magnitude costs for early comparison of measures.

Table 16: Measures and Cost Library -Derived Costs for Durant Point (Hatteras Island) in Dare County

Measure	Unit(s)		Rough Order of Magnitude Cost Range (EAC)	ROM Total First Construction Cost
Nearshore Nourishment	Linear Feet	1,000	$34,000–$103,000	$905,000–$2,779,000
Wetland Restoration	Acres	122	$910,000–$822,000	$24,556,000–$157,176,000

Albemarle-Pamlico Estuary Back Bay Erosion/Marsh Restoration Study

Purpose and need: The SACS indicates significant economic and environmental damage occurring in northeast North Carolina in the Albemarle-Pamlico Estuary System that will increase with sea level rise. This estuary system has been designated as an estuary of national significance by the U.S. Environmental Protection Agency. The North Carolina Climate Assessment and Resilience Plan identifies the need to "Increase understanding of sea level rise implications and resilience opportunities for reserve site and coastal and estuarine systems by participating in local, state and regional initiatives (NCDEQ 2020)." Authorization for a back bay study is needed to address coastal storm and sea level rise impacts to reduce economic and environmental damage.

Although there has been much focus on the changes along the oceanfront shoreline, shoreline dynamics along more sheltered estuaries, like those along the Albemarle-Pamlico Estuary System are an increasing concern. These boundary resources serve as critical habitat for a variety of ecosystem goods and services. It is vital to understand continued changes that coastal North Carolina will soon face so natural resources can be appropriately managed. Likewise, salt marsh forms critical habitats along these same estuarine shorelines. Research conducted by agencies such as NOAA and other stakeholders indicates marsh loss as an ongoing problem and supports the need for subsequent analysis to identify areas of concern and potential management factors that could be implemented at these locations. Given the size of the peninsula system, it could require a multi-agency strategy, and effort should be made to maximize potential partnerships.

Potential benefits and impacts of action: This action would address a significant data gap in the back bay of an area of national significance, which would help to understand of erosion rates, identify critical areas of habitat loss, and identify site-specific locations where ecosystem restoration measures could be implemented. This action would also identify risk areas for population and infrastructure in the back bay.

Wanchese Harbor Southside – Beneficial Use of Dredged Material

Purpose and need: Erosion and loss of habitat directly south of Wanchese Harbor is a concern of Dare County (**Figure 20**). Dredged material from Manteo (Shallowbag Bay) could be diverted from traditional placement facilities toward beneficial use south of Wanchese Harbor.

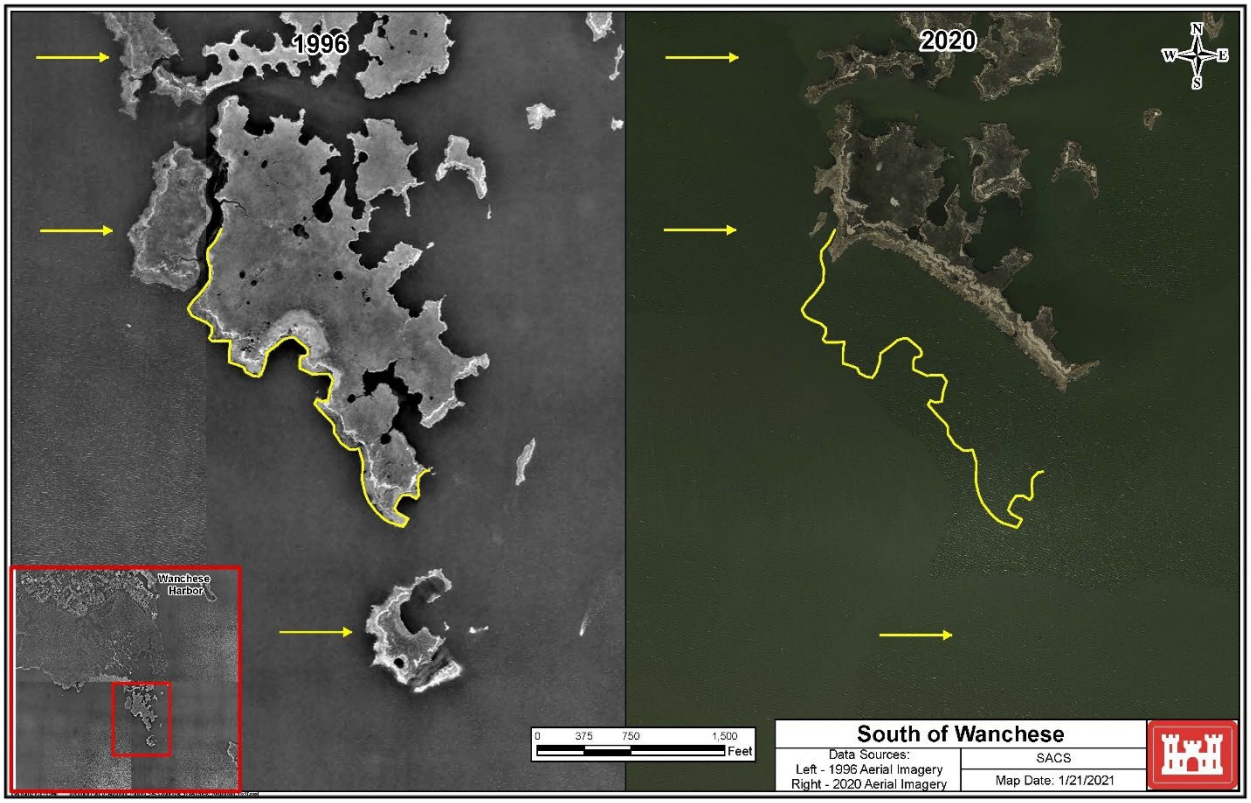

Figure 20: A Marsh Erosion in the Albemarle-Pamlico Estuary System

Potential benefits and impacts of action: This action could prevent further loss of marsh habitat by beneficially using dredged material while simultaneously alleviating traditional placement islands that are currently near capacity.

Enhanced Building-Level Risk Assessment

Purpose and need: This action would include using CHS data and North Carolina Emergency Management building footprints to perform an enhanced building-level risk assessment for more targeted nonstructural measure evaluation. Stakeholder coordination has indicated that Dare County may be good candidates for initial use of this approach. The North Carolina Climate Assessment and Resilience Plan—within the sector of housing, buildings and support services—identified that the resilience strategy had detailed, quantified risk assessments at a local level (NCDEQ 2020).

Potential benefits and impacts of action: Because several significant hurricanes recently impacted North Carolina, there have been significant efforts toward structural mitigation, such as elevations and buyouts. An enhanced building-level risk assessment may be an important next step to identify additional future structural mitigation needs. A potential benefit of conducting building-level risk assessments instead of census block assessments is obtaining refined costs, which could ultimately improve benefit-cost ratios with the use of targeted buyouts. Improved benefit-cost ratios could help justify these nonstructural projects such as building buyouts.

Stakeholder Training Workshops of Coastal Hazards System Data

Purpose and need: This action would provide training as a workshop or series of workshops where potential users of the CHS wave and water level modeling data could learn about and be trained on the application of the data and related tools.

Potential benefits and impacts of action: This initiative would help ensure that stakeholders who may benefit from using CHS data are aware of its availability and application methods. The goal of the workshops would be to maximize use of the data where it would provide value for risk assessment, planning decisions, or coastal project designs.

5.2.2 Impacts of Sea Level Rise and Climate Change

As discussed in Section 4.1.3, sea level rise and climate change will increase exposure to hazards for low-lying coastal areas, including this focus area. The SACS uses a 3-foot sea level rise scenario, which is consistent with the USACE Intermediate Scenario for a 100-year projection and the USACE High Scenario for a 50-year projection. Sea level rise and climate change are fundamentally incorporated into the FAAS and were considered carefully by stakeholders when identifying specific problems and needs. Sea level rise scenarios were modeled throughout the SACS using Hazus, the CHS, and the NOAA Sea Level Rise Viewer to estimate the severity of hazards due to sea level rise throughout the study area. Site-specific considerations for each project area beyond those already addressed in the SACS would likely be addressed during Tier 3 analysis follow-on activities with stakeholders.

5.2.3 Potential Benefits and Impacts

The FAAS includes a focused array of problems and needs, potential lead stakeholders, potential solutions, a summary of needed actions, a time frame for implementation, and potential funding sources. These elements are essential to make actionable recommendations and were coordinated closely with stakeholders. Potential benefits of the FAAS can be evaluated either individually as specific solutions to identified problems, or collectively as a system of solutions that address the shared vision. This report does not prioritize individual actions that make up the FAAS, although these actions could be prioritized to maximize finite resources. Prioritization could be based on several factors, including benefit-cost, time frame of incurring negative effects, or availability of authorities and funding. The FAAS provides a consistent platform to evaluate stakeholder-identified problems and needs in the focus area.

5.3 Focus Area Action Strategy

The Dare County and Ocracoke Island FAAS captures existing efforts identifies needs and opportunities for future actions in Dare County and Ocracoke Island. This focus area includes the well-known Outer Banks and attracts millions of visitors every year. It is also home to tens of thousands of permanent residents, as well as a national seashore and many significant environmental and cultural resources. The data from the SACS and many other studies provide consensus that this area is highly vulnerable and will increase in risk and vulnerability with continued hazards such as coastal storms, erosion, and sea level rise. Erosion and inundation will likely occur to the point where certain locations may no longer be livable, and important fringe or terrestrial habitat will be inundated. As identified during stakeholder workshops, social change and adaptation to these circumstances is a challenge and will require continued outreach and education. The shared vision statement developed by the stakeholder group reflects the economic and environmental importance of the area, as well as the social resilience of the communities that have lived there for generations. The vision strives toward a balance of those values with a goal to continue that balance to benefit future generations.

The actions identified within the FAAS work to address the identified problems and realize opportunities. Specific components of the strategy that translate into future needed actions are also documented as recommendations in Section 6 Actions have been organized into three themes: sediment management, infrastructure and mitigation, and education and outreach. These components are outlined in Section 5.1 and discussed in Section 5.3. **Table 17** includes details for each action and paths to implement future needed actions.

Table 17: Actions to Address Identified Problems and Realize Opportunities

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority	Potential Funding Source
Done	NNBF	Completed Living Shorelines	Projects	There are four completed living shorelines in the area.	Jockey's Ridge State Park, Alligator River National Wildlife Refuge, Festival Park (Manteo), and Nags Head Back Bay	Various federal/non-federal entities and NGOs	–	–	–	–
Ongoing	Nonstructural	Establishment of Hurricane Evacuation Zones	Policy	In coordination with a recent initiative implemented in 2019, 20 coastal counties, including Dare and Hyde, have established predetermined evacuation zones to simplify the coastal evacuation process in the event of an emergency. The initiative is titled "Know Your Zone." North Carolina Know Your Zone is a tiered evacuation system that highlights areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards. The Know Your Zone lookup tool is a color-coded interactive map residents and visitors can use to determine the evacuation zone where they live, work, or are visiting based upon a street address. Evacuation zones highlight areas most at risk to storm surge and flooding. Know Your Zone is intended to streamline the evacuation process by supporting personal readiness in preparation for hazardous weather events. When a storm is approaching, local officials in Dare and Hyde Counties will determine the zones that are most threatened to assess which residents should evacuate.	Dare County and Hyde County (Ocracoke Island)	North Carolina Emergency Management (NCEM), Dare County, Hyde County	Implemented. Public outreach is ongoing.	–	–	–
Ongoing	Nonstructural	Risk Communication (Annual Public Hurricane Workshop)	Outreach/Education	Dare County Emergency Medical Services holds an annual public workshop in Nags Head for hurricane awareness.	Nags Head	Dare County Emergency Medical Services	Implemented.	–	–	–
Ongoing	Nonstructural	EIS	Policy	The purpose of the EIS is to develop a streamlined framework for permitting sediment management at all NPS managed lands in Dare County and Ocracoke Island areas of the Outer Banks including the method, locations, and frequency for sediment management actions that may be permitted over the next 20 years. In this context, the EIS will address certain sediment management activities that may be implemented by the NPS, local jurisdictions, state agencies, and other federal agencies.	All NPS lands on the Outer Banks	NPS	–	Short	High	NPS
Ongoing	Nonstructural	Erosion Assessment	Study	NPS is completing an oceanfront erosion assessment from Nags Head to Ocracoke Island. This assessment looks at erosion from 1953 to 2020, with transects every 100 meters. It also forecasts 10, 20, and 30 years into the future and identifies which structures are at risk with and without sea level rise.	Dare County, Ocracoke Island	NPS	–	Short	High	–
Ongoing	Nonstructural	Structure Vulnerability Assessment (Historic Structures and NPS Structures)	Study	This assessment will use Sea, Lake, and Overland Surges from Hurricanes (SLOSH) modeling to assess vulnerability of all historic and NPS structures to identify which ones need adaptive management measures. This will identify costs of adaptive measures for NPS structures.	Dare County	NPS, Old Dominion University, Western Carolina University	–	Short	Medium	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority	Potential Funding Source
Done, updates ongoing	Nonstructural	North Carolina Coastal Community Resiliency Guide	Outreach/Education	This online interactive North Carolina Coastal Communities Resilience Guide is designed to walk users through some of the key steps and questions required for effective community- level resiliency planning while pointing to relevant tools, resources, and examples. The guide outlines a process for building resilience and climate change considerations into existing efforts such as comprehensive land use, hazard mitigation, or capital improvement planning while also focusing on other co-beneficial strategies to reduce risk in the community. The primary audience for this guide is local government staff and officials in the coastal region of North Carolina. NCDEQ DCM's goal is to update and adapt this online tool over time.	Applicable for all coastal counties	North Carolina Division of Coastal Management	–	–	–	State
Ongoing	Nonstructural	Land Use/Zoning	Policy	Dare County adds 3 feet of freeboard (the height of a ship's side between the waterline and the deck) to their base flood elevations for new construction, which is above the minimum requirement.	Dare County	Dare County	–	–	–	–
Ongoing	Nonstructural	Home Elevations/Buyouts	Outreach/Education	This is a FEMA program to help homeowners through the Hazard Mitigation Grant Program.	Statewide	FEMA/State	Engage with FEMA Hazard Mitigation Grant Program.	Mid	–	FEMA
Ongoing	Nonstructural	ReBUILD NC Homeowner Recovery Program	Outreach/Education	The Homeowner Recovery Program helps repair, reconstruct, replace, or elevate homes or reimburse residents for completed repairs to homes that were damaged by Hurricanes Florence or Matthew.	Areas damaged by Florence/Matthew	NCORR	Engage with Housing and Affordable Rental Program.	Short	High	–
Ongoing	Nonstructural	ReBUILD NC Strategic Buyout Program	Outreach/Education	This program enables eligible property owners, located in areas that are prone to repeated flooding, to relocate to safer land. NCORR provides financial incentives to homeowners to remain in communities. The affordable housing program focuses on constructing affordable and safe housing.	Statewide	NCORR	Engage with Strategic Buyout Program.	Short	High	–
Done, updates ongoing	Nonstructural	Working Lands Climate & Salinization Study - Guidebooks	Outreach/Education	Guidebooks being produced as part of research on sustainability of working/agricultural lands in the face of saltwater intrusion and inundation. These are intended to be used as a tool to help farmers adapt to changes occurring due to sea level rise and coastal storms.	Applicable statewide to include working lands in mainland Dare County	USDA	–	Short	–	USDA
Ongoing	Nonstructural	Saltwater Inundation and Intrusion Research	Study	Conduct scientific research to further document and understand the sea level rise-related phenomena of saltwater intrusion and inundation, and its impacts in coastal North Carolina. Research may help identify adaptive measures.	Various	USDA, North Carolina State University (NCSU), East Carolina University, others	–	Long	Low	–
Ongoing	Nonstructural	VCAPS	Study	North Carolina Sea Grant identified opportunities for the Town of Nags Head, North Carolina to incorporate coastal hazards planning into policy. The team led workshops to help community members better understand the scope of coastal hazard consequences and develop adaptation strategies. The team also secured funding through a Southeast Sea Grant Regional Resilience grant to conduct a law and policy analysis of issues affecting the adaptation options identified and to conduct GIS-based assessments. The VCAPS workshops led to formation of a Climate Adaptation and Sea Level Rise Committee that prioritized adaptation options and compiled them into a report. In September 2017, the Nags Head Board of Commissioners accepted the report, which provides guidance as the Town considers shoreline, stormwater, and wastewater management plan proposals. The Town has also included a Sea Grant-written sea level rise science synthesis in its comprehensive plan, which was adopted in August 2017, making the Town of Nags Head the state's first northeastern municipality to include sea level rise in its comprehensive plan.	Town of Nags Head	North Carolina Sea Grant, Town of Nags Head	–	–	Medium	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority	Potential Funding Source
Ongoing	Nonstructural	C-CoAST	Outreach	The Collaboratory for Coastal Adaptation over Space and Time (C-CoAST) is funded by the National Science Foundation to address grand challenges in coastal resilience. Developed coastal environments are shaped by interactions between human activities and natural processes. Mitigation and recovery strategies that promote adaptation at the time scale of storm events can be counterproductive over longer timescales. A series of collaborative activities will integrate coastal researcher, stakeholder, and practitioner expertise, building capacity for a comprehensive understanding of the human-natural coastal system. This will enable the potential for steering away from future outcomes that communities may want to avoid, and toward outcomes they deem more desirable.	Dare County, Carteret County, New Hanover County	–	–	Long	Medium	National Science Foundation
Ongoing	Structural	Non-federal Beach Nourishment Projects	Project	Conduct large-scale beach nourishment projects in Dare County in Duck, Kitty Hawk, Kill Devil Hills, Nags Head, and Buxton from 2017 to 2019.	Dare County	Dare County	Continued budgeting.	Recurring	High	Dare County
Planned	NNBF	Beneficial Use of Dredged Material	Project	This project provides additional beneficial use options for Hatteras Inlet/Rollinson Channel for near-shore placement of beach-compatible sand on the southern end of the oceanside of Hatteras Island.	Hatteras Inlet/Hatteras Island	USACE	Completion of Environmental Assessment.	Short	Low	–
Planned	Nonstructural	Statewide Non-Federal Coastal Dredged Material Management Plan Study	Study	The North Carolina Division of Water Resources and USACE are partnering to develop a statewide non-federal dredged material management plan. Coastal dredged material placement facilities will be evaluated to identify current non-federal conditions, capacities, and placement needs of each site. This information will be essential for the State of North Carolina to determine future dredge material capacity needs, capacity restoration efforts at current sites, and to determine what new placement sites must be developed or acquired, including for beneficial use. This Planning Assistance to States (PAS) study will only assess the non-federal components of a dredged material management plan. The study will focus on dredged material placement facilities owned, operated, or managed by the State of North Carolina, local municipalities, private marinas, conservation groups, and other non-federal stakeholders that are located along or adjacent to the Atlantic Intracoastal Waterway.	Atlantic Intercoastal Waterway (statewide)	USACE, North Carolina Division of Water Resources	Study initiated in January 2021.	Short	High	USACE Planning Assistance to States Program, NCDEQ
Planned	All	Resilient Coastal Communities Program	Study/Projects	The North Carolina Resilient Coastal Communities Program aims to facilitate a community-driven process for setting coastal resilience goals, assessing existing and needed local capacity, and identifying and prioritizing projects to enhance community resilience to coastal hazards. Participating communities will walk through a framework leading to the development of “shovel-ready” projects. Local governments throughout the 20 coastal counties will be eligible to apply for direct technical assistance to complete a community engagement process, risk and vulnerability assessment, and develop a resilience project portfolio. The four phases of the program include: Phase 1: Community Engagement and Risk and Vulnerability Assessment Phase 2: Planning, Project Selection, and Prioritization Phase 3: Engineering and Design Phase 4: Implementation	To be determined. All 20 coastal counties eligible to apply.	North Carolina Division of Coastal Management	–	Mid	High	State
Planned	Structural	Stormwater Management	Planning and Construction	This effort is to build a comprehensive actionable plan for stormwater management in the unincorporated areas of Dare County.	Dare County	Dare County	–	–	–	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority	Potential Funding Source
Needed	NNBF	Beneficial Use of Dredged Material	Project	Potential thin-layer placement of dredged material at Durant Point to mitigate wetland loss.	Durant Point, near Village of Hatteras	USACE, Dare County	1. Identify mechanism for implementation. 2. Follow Process to obtain funding.	Mid	Low	North Carolina Shallow Draft Navigation Funds, BRIC, WRDA, USACE CAP 204
Needed	NNBF	Beneficial Use of Dredged Material	Study/Project	Disposal capacity is limited in the vicinity of Wanchese Harbor. This study would identify appropriate beneficial use of material from the nearby navigation channel to address erosion concerns and habitat loss on the southside of Wanchese Harbor. Implementation would follow in conjunction with the next federal dredging event.	South Side of Wanchese Harbor	USACE, Dare County	1. Submit Study Initiation Report. 2. Initiate feasibility phase once Federal funding is obtained.	Mid	Medium	USACE Continuing Authorities Program – Section 204
Needed	Nonstructural	Statewide Offshore Sand Management Strategy Discussions	Coordination	Section 3.1 of the SACS-funded SAND Report identifies areas of sand deficiencies in North Carolina. The SAND Report indicates future discussions may be needed to move forward. Information from the SAND Report should be used to work with federal and state partners to identify management strategies to support multiple berm and dune project needs. Discussion topics may include strategies for finding new sand sources and strategies to manage finite resources.	Applicable statewide	USACE, BOEM, State of North Carolina	1. Establish agency POCs. 2. Coordinate kickoff discussion.	Short	Med	Collaborate Funding (e.g., for USACE - RSM or PAS)
Needed	Nonstructural	Training	Workshop	This action would provide training as a workshop or series of workshops where potential users of the SACS CHS wave and water level modeling data could learn about and be trained on the application of the data and related tools.	TBD	USACE	1. Wilmington District develop and submit proposal for funding through appropriate program. 2. Coordinate workshop invite with stakeholders.	Short	Medium	USACE FPMS Special Study/ FPMS Interagency proposal
Needed	Nonstructural	Back Bay Erosion Study Authorization for Albemarle-Pamlico Sound	Study	The SACS indicates significant economic and environmental damage occurring in northeast North Carolina in the Albemarle-Pamlico and Currituck Sounds that will increase with sea level rise. The Albemarle-Pamlico Estuary System is designated as an estuary of national significance. A back bay study is needed to identify erosion trends and areas of concern for future efforts.	Albemarle and Pamlico Sounds	USACE	1. Draft scope of work for PAS study. 2. Identify non-federal partner. 3. Finalize scope and sign cost-sharing agreement. 4. Obtain Federal and non-Federal funds to begin work.	Mid	Medium	USACE Planning Assistance to States

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority	Potential Funding Source
Needed	Nonstructural	Enhanced Building-Level Risk Assessment – Proof of Concept Exercise	Study	Use CHS data and NCEM building footprints to perform an enhanced building-level risk assessment for more targeted nonstructural measure evaluation. Long-term goals of conducting building-level risk assessments vs. by census block risk assessments would be to obtain enhanced/updated costs and ultimately improve benefit-cost with use of targeted buyouts. Improved benefit-cost ratios help justify projects. Building-level risk assessments helps target areas and refine costs. It significantly improves cost benefit analyses and a provides a more targeted strategy and improves building buyouts.	Potentially applicable in any coastal county	NCEM, UNCW, NCORR, USACE	–	Mid	Medium	UNCW; NCORR
Needed	Non-structural/ NNBF	Wetland/Fisheries Analysis	Study	Use cross-agency partnerships to identify the areas most appropriate for marsh restoration projects. Stakeholders from NOAA and BOEM have indicated the potential benefits of marsh restoration on the oceanfront and that more coordination with the FWS would be required to address fisheries habitat. To increase beneficial use of dredged material, appropriate locations would need to be identified for dredge material disposal.	–	NOAA, FWS, BOEM, USACE, National Fish and Wildlife Foundation (NFWF)	–	Mid	Low	–
Needed	Structural	Federal Beach Nourishment Projects	Project	Under existing Authorization, updating the prior USACE Dare County Beaches coastal storm risk management study for potential implementation.	Dare County	USACE, Dare County	1. Obtain non-federal support for update. 2. Obtain funding to conduct update of study. 3. Complete update.	Mid	Low	–
Needed	NNBF	Refuge Management Planning	Study	Conduct refuge management planning for all refuges within the Albemarle-Pamlico Estuary System (APES) region. Includes shoreline and estuarine habitat management goals for listed species and other trust resources.	APES, including Alligator River National Wildlife Refuge	USFWS	–	Mid	Medium	USFWS

[1]Timeframe: short = <2 years; mid = 2–10 years; long = >10 year

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6. Recommendations

The focus area action strategy was developed to advance the shared vision and manage increased coastal storm risk as a result of sea level rise in the Dare County and Ocracoke Island Focus Area as shown in **Figure 21**. The shared vision is the overarching goal of the FAAS, broadly representing problems and opportunities stakeholders wish to address in the focus area. Resultingly, FAAS goals and objectives support the shared vision. SACS key products and other stakeholders' shared tools and data were used to support FAAS goals and objectives by assessing risk and identifying ongoing, planned, and needed actions to communicate and address the risk.

Figure 21: Focus Area Action Strategy Supports the Focus Area's Shared Vision

Recommendations are made for either multi-agency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and coordination with stakeholders throughout the focus area. Recommendations are organized into six categories, as shown **Figure 22,** and three implementation timeframes (near-, mid-, and long-term). Importantly, follow-on study efforts should incorporate an integrated approach to the maximum extent practicable, including consideration of structural, nonstructural, and NNBF measures, as well as the shared responsibility of all stakeholders to contribute to coastal storm risk management. Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation timeframes include:

Figure 22: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.
- **Mid-Term Implementation (5-10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance emerging efforts to address coastal storm risk.
- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination before implementation and may be the most challenging to implement on regional scales from technical, political, or social perspectives. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term timeframe is reflective of the time to implementation based on immediate action to advance these recommendations which include complex issues such as land-use, zoning, and building codes. Given the uncertainty surrounding impacts from sea level rise and other factors (e.g., development trends), long-term recommendations may require reconsideration prior to implementation.

Table 18 provides the recommendations for the Dare County and Ocracoke Island Focus rea.

Table 18: Recommendations for the Dare County and Ocracoke Island Focus Area

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Study Efforts (follow-on USACE Planning Assistance to States (PAS) study)	Near-Term (<5 years)	Multi-Agency Action	Back Bay Erosion/Marsh Restoration Study – Albemarle-Pamlico Estuary System (APES) (USACE)	A study evaluating erosion trends, habitat loss and potential mitigation measures in the Albemarle-Pamlico Estuary System (APES) is needed to gain a better understanding of changes that coastal North Carolina is facing so that natural resources can be managed appropriately. The APES has been designated as an estuary of National Significance and is at continued risk of damage as a result of coastal storms and sea level rise as indicated by analysis within the SACS and other studies. This would be pursued under the USACE Planning Assistance to States (PAS) program.	Identify Non-Federal Sponsor (USACE Study)
Study Efforts (Activities under CAP)	Mid-Term (5-10 years)	USACE	Wanchese (south of Harbor) - CAP 204	Conduct a beneficial use of dredged material project in the area immediately south of Wanchese Harbor under the USACE Continuing Authorities Program Section 204 for the purposes of aquatic ecosystem restoration. This recommendation aligns with strategies outlined in the North Carolina Resilience Strategy sectors of Coastal Resources & Infrastructure, and Ecosystems.	Funding

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SOUTH ATLANTIC COASTAL STUDY (SACS)

Carteret and Craven Counties Focus Area

FINAL REPORT

AUGUST 2022

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1. Introduction

This Focus Area Action Strategy (FAAS) identifies action strategies to reduce risk to coastal storms and increase resilience in the Carteret and Craven Counties of North Carolina. The South Atlantic Coastal Study (SACS) key products and analyses were leveraged to assess existing and future conditions and quantify existing and potential risks. Stakeholders were engaged throughout the development of the Carteret and Craven Counties FAAS to elicit feedback on problems and opportunities, identify and prioritize specific institutional and other barriers, and identify potential action strategies to improve resilience. Agencies invited to participate included the U.S. Army Corps of Engineers (USACE), the U.S. Coast Guard, the National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), Morehead City, City of New Bern, Emerald Isle, the Town of Newport, the Town of Pine Knoll Shores, Carteret County, Craven County, and other local county and city officials. State agencies include the North Carolina Department of Environmental Quality and Division of Coastal Management (NCDEQ DCM), the North Carolina Department of Transportation's (NCDOT) Ferry Division, North Carolina State Ports Authority, and the North Carolina Department of Public Safety, as well as one non-profit agency, Learn Ethos.

The FAAS was developed according to the Coastal Storm Risk Management (CSRM) Framework, an iterative process that gains resolution each time it is implemented. Under the Tier 1 analysis, national datasets were utilized to assess potential risk across the entire SACS study area, as documented in the SACS Main Report. For the Tier 2 analysis, more refined data, and analyses unique to each individual state or territory were incorporated. The Tier 2 analysis for the Carteret and Craven Counties Focus Area is documented within the North Carolina Appendix. The FAAS is a third iteration of the SACS study framework, incorporating data and knowledge unique to the local area to identify risks to coastal storm events and develop potential strategies to address the identified risks.

This FAAS is carried out as part of SACS, which was authorized by Section 1204 of the Water Resources Development Act of 2016 as described in the Main Report. The FAAS refers to ongoing, planned, and needed actions to manage coastal storm risk based on stakeholder coordination conducted during Focus Area Vision Meetings, a series of interactive webinars held between July and December 2020. The status and description of actions provided in this report represents a snapshot in time, and specific actions may have been modified or the status may have been changed from the description provided. However, final recommendations resulting from stakeholder coordination on specific actions were updated to represent the most recent information as of June 2022.

Figure 1 shows the three focus areas selected within North Carolina for the SACS focus area action strategy development. Section 1.1 of this report discusses the study area for the Carteret and Craven Counties Focus Area.

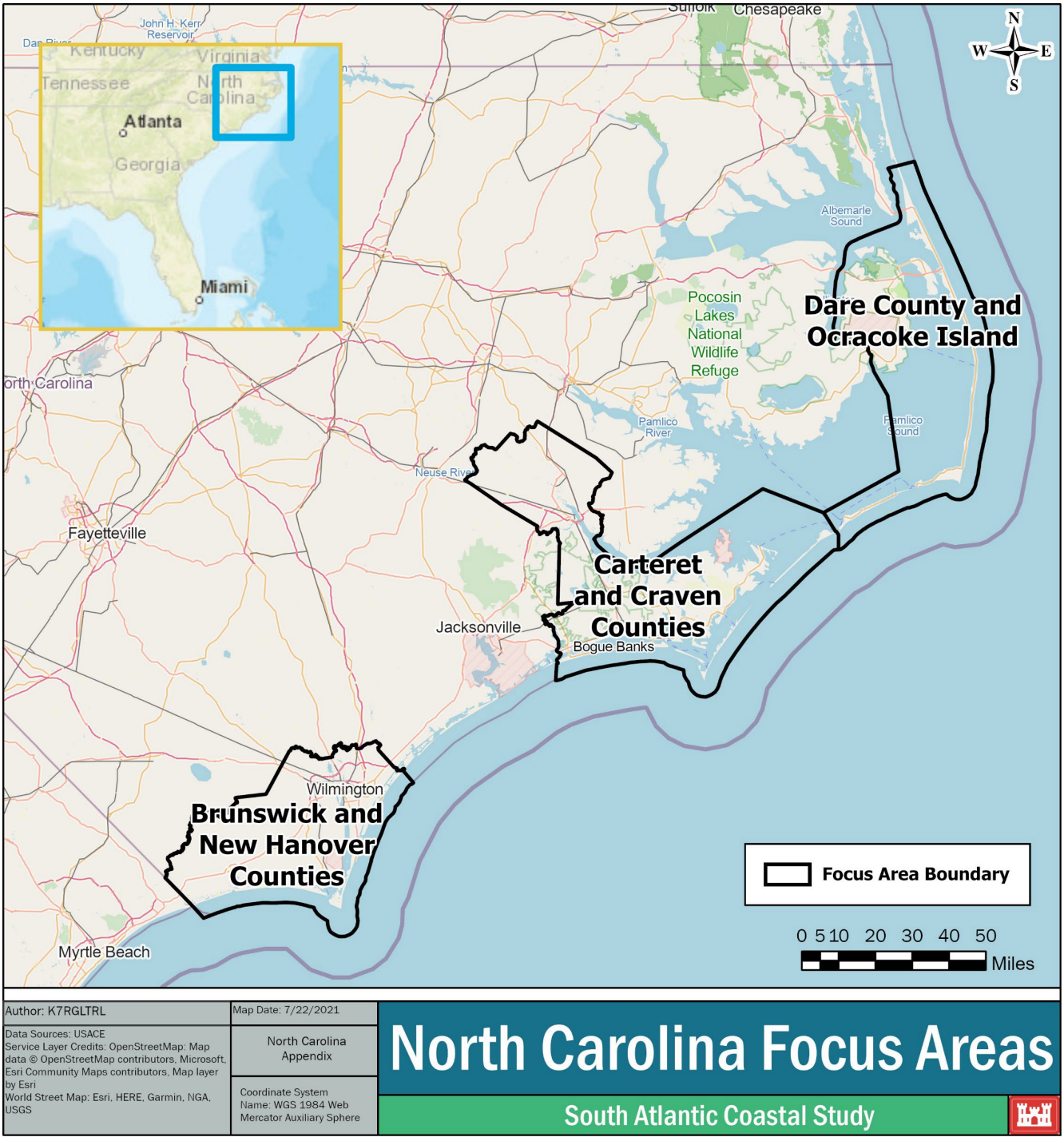


Figure 1: SACS Focus Areas in North Carolina

1.1 Study Area

This geographic area in the mid-portion of coastal North Carolina spans two counties: Carteret and Craven (**Figure 2**). According to the U.S. Census Bureau QuickFacts data, Carteret County's estimated population on July 1, 2019, was 69,473, a 4.5-percent change since the 2010 Census, and 102,139 for Craven County, a -1.3-percent change since the 2010 Census (U.S. Census Bureau n.d.). Together, these counties have a year-round population of approximately 170,000 (US Census Bureau). The Carteret and Craven Counties Focus Area consists of several significant population centers: New Bern, Morehead City, Beaufort, and Newport, as well as over a dozen small very low-lying mainland communities such as Sea Level, Atlantic, and Merritt. Additionally, this focus area contains the Bogue Banks, a 21-mile-long barrier island that includes Fort Macon State Park, Atlantic Beach, and several other island communities.

The area has a mix of population and infrastructure, critical environmental resources and habitat, and social vulnerability. The eastern portion of Carteret County includes the Cedar Island National Wildlife Refuge, Cape Lookout National Seashore, and the Rachel Carson National Research Estuarine Reserve. Beaufort Inlet serves the North Carolina Ports Authority and the Marine Corps Air Station Cherry Point. Farther inland in Craven County, communities situated along the Neuse and Trent Rivers have flood risk that is influenced by both the coastal storm surge and inland riverine flood from freshwater rainfall. Twenty-five hurricanes and tropical storm centers have passed within 50 miles of this focus area since 1960—an average of one every 2.4 years.

The Carteret and Craven Counties Focus Area contains census places that are the most economically at risk to coastal storms in the northern half of the State of North Carolina. This area also contains highly vulnerable social populations, as well as four priority environmental areas (PEAs), making this region both highly valuable and highly vulnerable to coastal storm hazards.

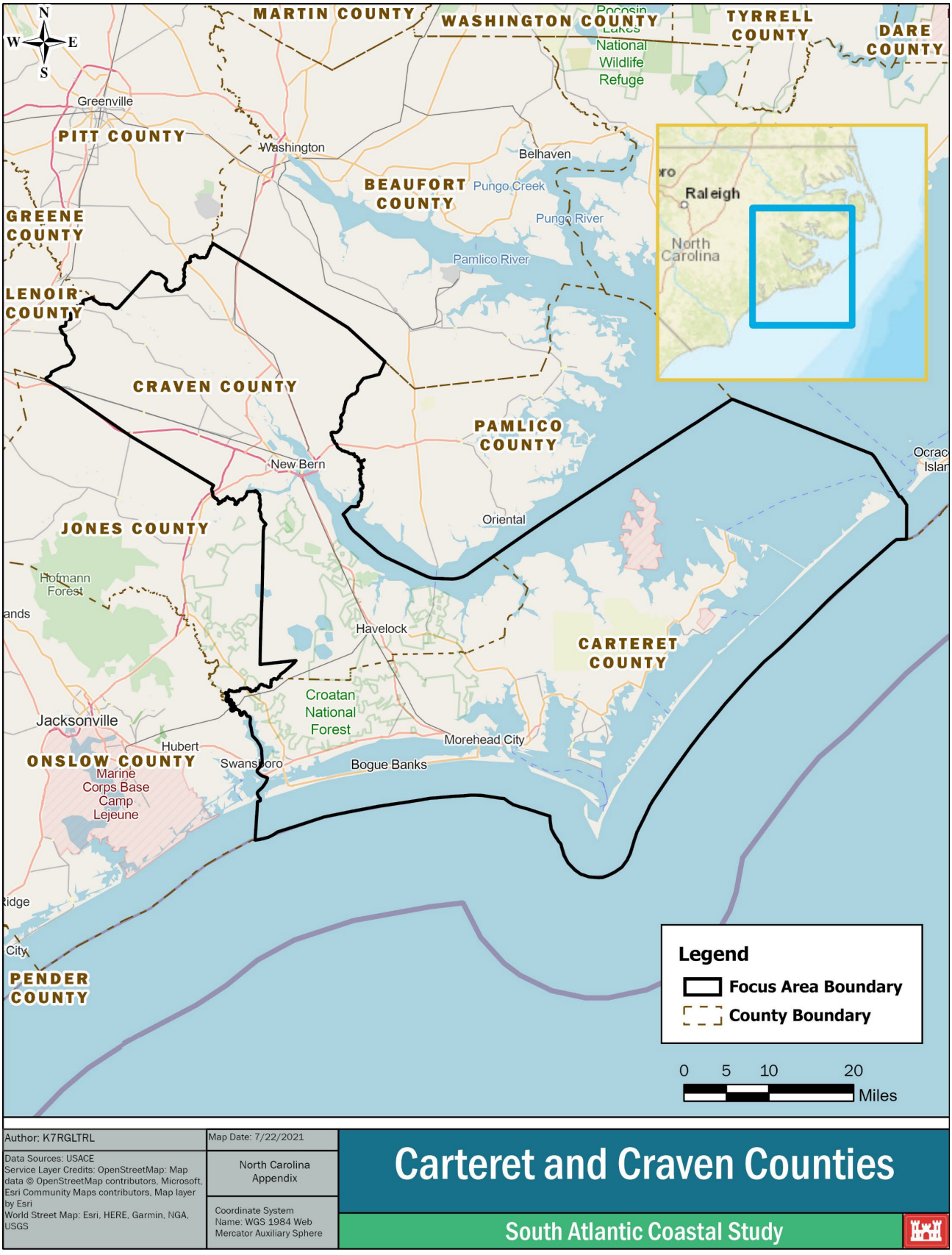


Figure 2: Carteret and Craven Counties Focus Area

1.2 Prior Reports and Efforts by Stakeholders within the Focus Area

Prior and ongoing stakeholder efforts within the Carteret and Craven Counties Focus Area related to coastal storm risks and impacts from sea level rise are listed in **Table 1**. Of particular note is the North Carolina Department of Environmental Quality's (NCDEQ) *North Carolina Climate Risk Assessment and Resilience Plan*. This plan is the most comprehensive effort to date addressing North Carolina's vulnerability to climate change. It provides a framework to guide state action and engage policy-makers and stakeholders. Furthermore, the plan aims to inform climate resilience actions based on underlying stressors such as aging infrastructure, socio-economic disparities, and competing development priorities. The plan builds upon existing work and establishes the North Carolina Resilience Strategy, which includes four elements:

- The North Carolina Climate Science Report
- State Agency Resilience Strategies
- Statewide Vulnerability Assessment and Resilience Strategies
- The North Carolina Enhanced Hazard Mitigation Plan

Table 1: Stakeholder Reports and Efforts in the Focus Area

Agency/Stakeholder	Report/Tool/Project	Year Completed
National Fish and Wildlife Foundation	Coastal Resilience Evaluation and Siting Tool (CREST)	2020
National Oceanic and Atmospheric Administration (NOAA)	Ecological Effects of Sea Level Rise in North Carolina	2017
NOAA	National Estuarine Research Reserve System	2020
NOAA	Climate at a Glance: Global Mapping	2020
NOAA	Climate Central's Surging Seas: Risk Zone Map	2020
NOAA	Coastal Emergency Risks Assessment	2020
NOAA	Living Shorelines Project Map	2020
NOAA	National Estuarine Research Reserve System-Wide Monitoring Program Data	2020
NOAA	New Interactive Mapping Tool, Reports Help Understand Coastal Resilience	2020
NOAA	New OceanReports Tool Brings Ocean Data to Your Fingertips	2020
NOAA	Sea Level Rise Viewer	2020
NOAA	U.S. Climate Resilience Toolkit	2020
North Carolina Climate Office	Weather and Climate Database – North Carolina Climate Retrieval and Observations Network of the Southeast Database (CRONOS)	2020
North Carolina Department of Environmental Quality (NCDEQ)	North Carolina Climate Risk Assessment and Resilience Plan	2020
NCDEQ	Rachel Carson Reserve	2020
NCDEQ	Resources for Homeowners and Professionals	2020

Agency/Stakeholder	Report/Tool/Project	Year Completed
North Carolina Department of Public Safety	Flood.NC.gov	2020
North Carolina Department of Public Safety	North Carolina Flood Inundation Mapping and Alert Network	2020
North Carolina Department of Public Safety	North Carolina Flood Risk Information System	2020
North Carolina Department of Public Safety	North Carolina Spatial Data Download	2020
Town of Morehead City, North Carolina	Floodplain Management Plan	2017
University of Georgia, Marine Extension and Georgia Sea Grant	Coastal Resilience Funding Glossary Available to Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina	2019
USACE Wilmington District	Bogue Banks Coastal Storm Risk Management Project (Locally funded in 2020.)	Not Constructed
USACE Wilmington District	Neuse River Basin Flood Risk Management Study	–
Carteret County	Bogue Banks Master Renourishment Plan	–

Existing Sand Needs Projects

As detailed in the SACS North Carolina State Appendix, several beach nourishment projects exist in the focus area, including Emerald Isle/Indian Beach/Salter Path, Pine Knoll Shores, Atlantic Beach/Fort Macon, and the Bogue Banks CSRM project, which included Indian Beach, Pine Knoll Shores, and the remaining footprint across Bogue Island. USACE Wilmington District completed the Bogue Banks Feasibility Study which indicated that a CSRM project was needed. The Bogue Banks CSRM project was authorized and funded; however, due to funding constraints in 2020, the local sponsor opted out of the federal partnership and locally funded smaller footprints of this project. CSRM projects provide significant value to the region through reductions in coastal storm damages. To ensure the longevity of these benefits, periodic nourishments of sand are required. The South Atlantic Division Sand Availability and Needs Determination Summary Report (USACE 2020c) reported a surplus of over 45 million cubic yards (MCY) for the current 50-yr sand budget with a 55-percent contingency for Carteret County. The current 50-year budget includes 51.9 MCY needed with 40.9 MCY available from offshore borrow sources. Estimated 50-year Sand Requirements in Carteret County are summarized in **Table 2**.

Table 2: Estimated 50-Year Sand Need in Carteret County (USACE 2020c)

Feature	Federally Sponsored	Project Sponsor	Federal Authority	Nourishment Interval (Years)	Estimated 50-Year Sand (2020-2070) Requirement (cy)
Atlantic Beach/ Ft. Macon	Yes	USACE	1958	3	14,575,000
Pine Knoll Shores	Yes	USACE, Carteret County, Town of Pine Knoll Shores	2002	3	7,410,000
Indian Beach	Yes	USACE, FEMA, Carteret County, Town of Indian Beach	2002	3	2,907,000
Emerald Isle	Yes	USACE, FEMA, Town of Emerald Isle	1984	3	8,619,000

Existing Regional Sediment Management Projects

The 2020 South Atlantic Division Regional Sediment Management (RSM) Optimization Update provided a detailed review of the existing actions in place (**Table 3**) as well as recommendations for actionable strategies (USACE 2020b). Maintenance dredging of Morehead City Harbor produces 3.9 MCY of material every dredging cycle, from which 1.2 MCY of beach-suitable sand is diverted for near-shore placement, providing coastal flood risk management benefits evaluated at $2.8 million. The Atlantic Intracoastal Waterways (AIWW) Bogue Inlet Crossing provides approximately 100,000 CY of sediment to Emerald Isle every three years. Over the next 50 years, it is estimated that 56.7 MCY of RSM sediment contributions will be placed at Atlantic Beach/Fort Macon, Indian Beach, Emerald Isle, Pine Knoll Shores, and nearshore placement areas.

Table 3: Regional Sediment Management Actions in Carteret County (USACE 2020b)

RSM Source	Federally Sponsored?	Placement Area	Total Dredge Volume (CY)	Average Dredge Interval (Years)	Average Volume Per Project (CY)	Average Annualized Dredge Volume (CY)	50 Year Source Volume (CY)
Morehead City Harbor	Yes	Atlantic Beach/Ft. Macon	1,100,000	1	1,100,000	1,100,000	55,000,000
Bogue Inlet AIWW Crossing	Yes	Emerald Isle	100,000	3	100,000	33,333	1,666,667
Bogue Inlet	Yes	Emerald Isle	–	–	–	–	0

Other Existing Risk Management Strategies

The Carteret and Craven Counties Focus Area includes other risk management strategies such as living shorelines and restoration projects. More than 20 living shoreline projects have been constructed from Bogue Inlet to the Cape Lookout National Seashore, and one shoreline restoration project was completed in the Bogue Sound. Living shoreline projects have been and are supported by NOAA, North Carolina Coastal Federation (NCCF), Cedar Island National Wildlife Refuge, Cape Lookout National Seashore, and the Duke Marine Lab as well as by other agencies, local governments, and communities. In addition, three structures were removed from the floodplain at New Bern by the State of NC and federal Emergency Management Agency (FEMA).

1.3 Shared Vision

The shared vision provides an overall goal for the focus area. Actions identified in this report incrementally contribute to the shared vision by achieving objectives to address problems and realize opportunities identified in the focus area. The Carteret and Craven Counties Focus Area shared vision was developed with stakeholder input provided in the Focus Area Visioning Meetings described in the Main Report. The shared vision is:

Our vision is to develop a stakeholder led, science-based cohesive actionable strategy to address coastal storm risk and sea level rise while strengthening the economic, environmental, and social resilience of the Carteret and Craven Counties Focus Area for current and future generations.

2. Problems and Opportunities

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

2.1 Problems

The following problems were identified as the most significant throughout the focus area and may not be exhaustive of all problems. These problems will increase in both intensity and extent as sea levels rise depending on the vulnerability and resiliency of the exposed population, infrastructure, and environmental resources. Problems 1, 2, and 3 were the most often cited during stakeholder coordination. Each problem is given an abbreviated label (e.g., P3 for problem 3) for cross reference in **Table 16** in Section 5.2 of this report.

- **Problem (P)1:** The economy is negatively impacted by the effects of coastal storms which will increase with sea level rise. These negative impacts include loss of business income and the displacement of people.
- **P2:** There are numerous vulnerable low-lying communities (e.g., Sea Level, Atlantic, Merritt, and Cedar Island) that are at significant risk from storm surge.
- **P3:** Erosion and inundation threaten critical habitats (i.e., marshes and beaches).
- **P4:** Road closures are impacting life safety and economics.
    - *Thirty-nine percent of roads in Carteret County are located in special flood hazard areas (SFHAs). Specific road closures due to erosion and flooding from coastal storms include Lola Road and Cedar Island Road in the Down East Community.*
- **P5**: Storm surge and precipitation from coastal storms and elevated groundwater levels cause compound flooding, which damages public and private infrastructure.
    - *The City of New Bern, which is on the Neuse River, was devastated by Hurricane Florence from a combination of coastal storm surge and riverine flooding.*
- **P6:** Coastal storm and sea level rise impacts to habitat are affecting shrimp and crabbing industries.

- *Coastal storms, such as Hurricane Florence in 2018, disrupt the presence of fisheries species such as shrimp and directly damage the fishing communities' boats, gear, docks, and packing houses, as well as the communities. The central North Carolina coast, much of which is in the focus area, brings an estimated annual economic impact of $50 million through commercial fishing alone (North Carolina SeaGrant 2021).*

- **P7:** Lack of proficiency or understanding of existing SACS data, tools, and their applications, including Coastal Hazards System (CHS) data.

2.1.1 Institutional and Other Barriers

As described in the SACS Institutional and Other Barriers Report, "Institutional and other barriers" impede the attainment of SACS goals and limit the ability to provide comprehensive coastal storm risk management (USACE 2022a). Several institutional and other barriers (IOBs) were identified within the Carteret and Craven Counties Focus Area by stakeholders:

- **IOB 1:** Recovery actions are focused on speed rather than resiliency.
- **IOB 2:** Current coastal modeling communicating flood risk on Flood Insurance Rate Maps does not capture all risk hazards, including rainfall.
- **IOB 3:** Federal and state aid allotment processes to help recovery are not timely.
- **IOB 4:** There is insufficient consideration for future conditions in land-use planning.
- **IOB 5:** Updated FEMA flood maps show less properties at risk than in previous maps. There is concern about the logic of this reclassification and the risk-message it sends to new residents moving into the area.
- **IOB 6:** National Flood Insurance Program reforms are needed.
- **IOB 7:** There are limited tax base and funds to support local-scale resiliency efforts at a local level.
- **IOB 8:** Local elevation standards at county or town levels are needed.
- **IOB 9:** There is insufficient data on erosion rates and impacts along the back bay shoreline that prevents the development of meaningful solutions.
    - *Extensive data have been collected on the oceanfront shorelines. Much less data on the potential impact of erosion rates exist along the extensive mileage of back bay shorelines, which could be used to identify and plan for possible mitigation measures.*
- **IOB 10:** There is a lack of comprehensive data about coastal wetland status and trends, which prevents the identification of areas of concern and the development of mitigation measures.
    - *Much of the existing data available is dated and is only a snapshot in time*

2.2 Opportunities

Stakeholders identified several opportunities that include conditions, resources, and factors that could contribute favorably to the Carteret and Craven Counties Focus Area:

- **Opportunity (O)1**: Partially base flood maps and infrastructure plans on future condition projections.
- **O2:** Improve utilization of natural and nature-based features (NNBF) to address back bay erosion.
- **O3:** Increase understanding of coastal wetland trends and restoration strategies.
- **O4:** Use CHS data and other modeling efforts focused on probabilistic coastal hazard assessment to analyze future beach erosion, barrier island lowering or breaching, and/or marsh loss.
- **O5:** Increase knowledge of offshore sand resources to maximize efficiency and maintain 88 percent surplus in 50-year sand budget.
- **O6:** Increase risk awareness to vulnerable communities

3. Objectives and Constraints

Planning objectives are statements that describe the desired results of the planning process by solving the problems and taking advantage of the opportunities identified within the planning process. Constraints are conditions that limit the planning process. The final strategy formulated during this study is intended to meet the planning process objectives while working within the constraints.

3.1 Objectives

Overall objectives were developed for the focus area, generally focused on reducing coastal storm risks. Objectives and goals of the focus area include:

Objectives:

- **Objective (OBJ) 1:** Reduce coastal storm inundation risk to population and infrastructure within both the oceanfront and back bay vulnerable areas of Carteret and Craven Counties.
- **OBJ2:** Reduce the risk to environmental and cultural resources due to inundation, wave attack, and erosion as a result of coastal storms.

Goals:

- **Goal(G1):** Identify potential federal involvement in specific resiliency actions that can begin implementation within 2 to 10 years.
- **G2:** Improve interagency communication to address institutional barriers to coastal resiliency.

3.2 Constraints

A constraint may limit the planning process. To the maximum extent practicable, the SACS analysis will minimize information, observations, and recommendations that may be inconsistent with coastal storm risk management plans developed by other federal and applicable state and local agencies and tribes within the study area.

4. Existing and Future Conditions

4.1 Hazards

In a general sense, a hazard is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014). For a full list of hazards information relevant to the focus area, see Sections 4.1.1, 4.2.1.1, and 4.2.2.1 of the North Carolina Appendix. For the FAAS, hazards were divided into two categories: primary hazards and secondary hazards. Primary hazards are those directly addressed within the scope of the SACS and secondary hazards are those not directly addressed but still relevant and important to the focus area.

4.1.1 Primary Hazards

For the Carteret and Craven County Focus Area, primary hazards include inundation, wave attack, and erosion. Coastal erosion can be hazardous to natural shorelines such as marshes and sandy beaches and can lead to increased vulnerability of cultural and environmental resources and infrastructure. Coastal erosion poses a major hazard within this focus area.

4.1.1.1 Inundation

Inundation is a significant hazard within the focus area due to the extensive areas of low elevation within Carteret and Craven Counties. The areas that are subject to more frequent occurrences of the inundation hazard are as follows:

The Barrier Islands. Both the southern-facing Bogue Banks and the eastern-facing Cape Lookout National Seashore have low elevations and will be inundated from coastal storm surge on a more frequent basis.

Eastern Carteret County. East of Core Creek and Adams Creek in Carteret County, the topography is consistently low in elevation. Particularly along the eastern edge of the county in the vicinity of Highway 70 there is a frequent history of coastal storms, and many areas of low elevation. As with the barrier islands, these locations in eastern Carteret will be inundated from coastal storm surge on a more frequent basis than other locations in the area.

Lower Neuse River. Areas along the lower Neuse River in Craven County are susceptible to both inundation from coastal storm surge and from riverine flooding from inland rainfall that drains into the Neuse River. Coastal storms can be responsible for both types of flooding. When the right factors coincide, the flooding can be compounded from both hazards.

Table 4 provides stillwater elevations for various annual exceedance probability (AEP) events for Carteret and Craven Counties generated from the FEMA Flood Insurance Study. The storm surge levels presented include the effects of astronomical high tide and wave setup. For the future condition damages, add 3 feet of relative sea level rise to these events.

Table 4: Carteret and Craven Counties Storm Tide Elevations (FEMA 2020a; 2020b)

Shorelines	10% Annual Exceedance Probability (AEP) (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Craven	5.0	6.9	7.8	9.6
Carteret-Bogue Banks and Mainland	5.1	7.0	7.9	9.7
Carteret-Cape	3.8	5.3	6.0	7.4
Carteret-North Barrier	3.3	4.6	5.2	6.4

Figure 3 provides a map of the focus area showing the likelihood of flooding based on three probability events. Specifically, areas that may flood during a 10-percent AEP event are shaded in dark blue. One-percent AEP events are shaded in medium blue. Category 5 Maximum of Maximum (MOM) represents flooding in a worst-case Category 5 Hurricane scenario and is shaded in light blue (Zachry et al. 2015).

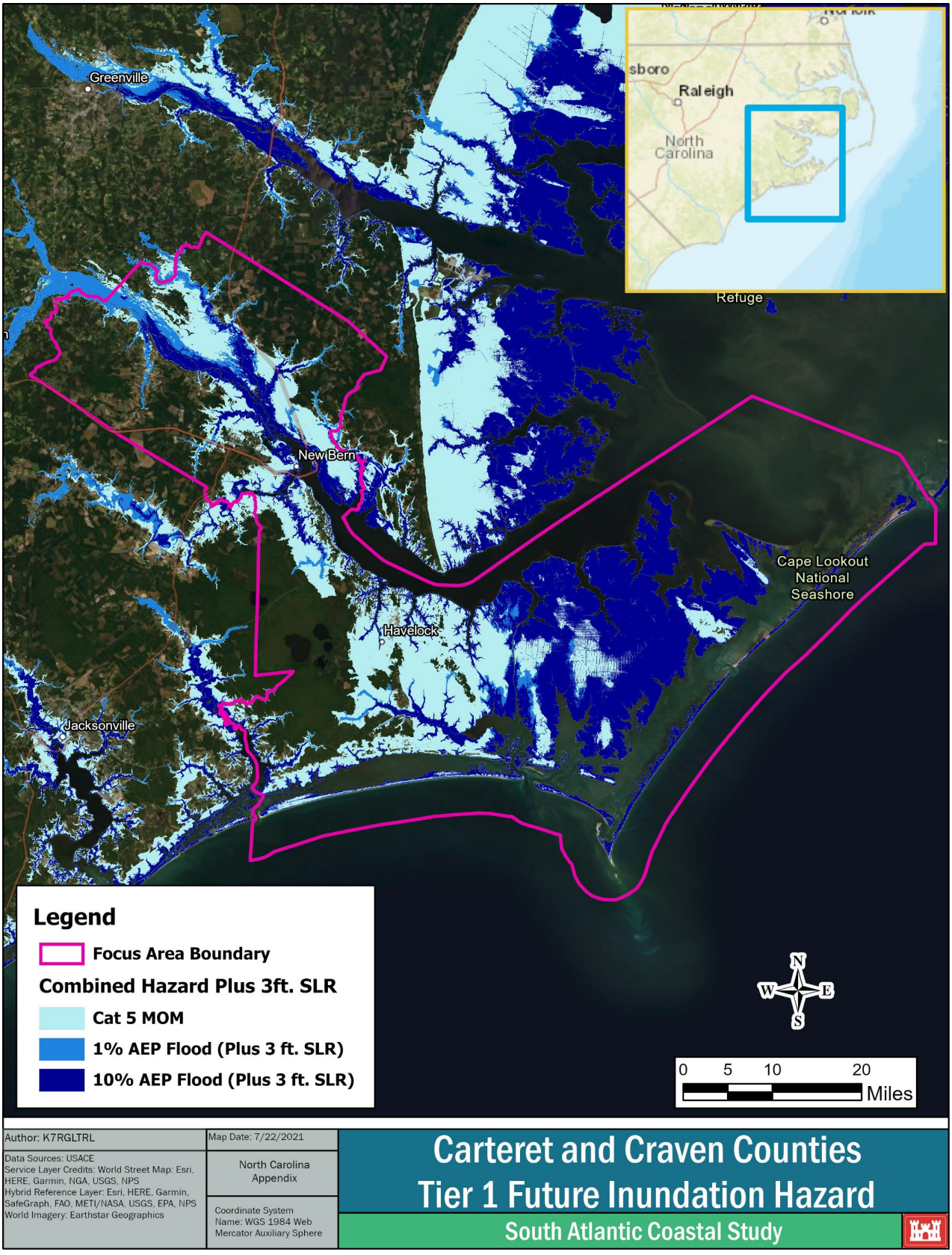


Figure 3: Combined Hazards plus 3 Feet of Relative Sea Level Rise for the 10-Percent Annual Exceedance Probability Storm Event (Darkest Blue), 1-Percent Annual Exceedance Probability Storm Event (Medium Blue), and Category 5 Hurricane Maximum of Maximum (Light Blue)

CHS develops AEP water levels throughout the South Atlantic region, including Carteret and Craven Counties, under existing and future sea levels (USACE 2020a). **Table 5** shows stillwater levels under the existing sea level for various AEP, where AEP represents the probability of exceeding each stillwater elevation in one given year. The highest stillwater levels for this region are seen along the Neuse River, with 1-percent AEP values of 9.08 feet NAVD88 at Marine Corps Air Station Cherry Point and 10.01 feet NAVD88 at New Bern. **Table 6** shows stillwater levels under the high sea level rise scenario (7.35 feet of sea level rise). Under this scenario, stillwater levels are between 12.49 and 17.72 feet NAVD88 for the 1-percent AEP throughout the focus area. Nonlinear effects, which are changes to stillwater levels due to sea level rise that are not a simple addition of the sea level rise value (in this case, 7.35 feet), are evident in this focus area. Nonlinear effects take place primarily in the back bay regions, while minimal nonlinear effects exist in ocean regions. In addition to 7.35 feet of sea level rise, these effects led to an increase in 1.33 feet for the 1-percent AEP in Core Sound but led to a 0.46 foot decrease on the ocean side at the Cape Lookout National Seashore. This means that, rather than the future 1-percent AEP value being equal to the present 1-percent AEP plus 7.35 feet of SLR, the future AEP value is 0.46 feet lower than the additional 7.35 feet.

Table 5: Carteret and Craven Counties Stillwater Elevations from the USACE Coastal Hazards System – Existing Sea Level

Location	10% Annual Exceedance Probability (AEP) (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Pamlico Sound - Cedar Island	3.08	3.68	4.43	4.94	6.02
Neuse River - MCAS Cherry Point	5.30	6.63	8.10	9.08	10.89
Neuse River - New Bern	6.09	7.55	9.04	10.01	11.65
Cape Lookout National Seashore	4.10	4.47	5.09	5.60	6.55
Core Sound - Davis	4.15	5.35	6.62	7.67	8.85
Morehead City	4.99	5.70	6.84	7.75	9.86
Emerald Isle	5.61	5.95	6.64	7.30	9.16
Bogue Sound - Emerald Isle	5.59	6.87	8.08	8.81	11.42
White Oak River	5.89	6.97	8.29	9.32	10.69

Table 6: Carteret and Craven Counties Stillwater Elevations from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% Annual Exceedance Probability (AEP) (feet-NAVD88)	5% AEP (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Pamlico Sound - Cedar Island	11.11	12.06	13.20	13.83	14.94
Neuse River - MCAS Cherry Point	13.08	14.65	16.19	17.16	18.95
Neuse River - New Bern	13.62	15.17	16.75	17.72	19.50
Cape Lookout National Seashore	11.37	11.67	12.11	12.49	13.24
Core Sound - Davis	12.65	14.18	15.58	16.35	17.69
Morehead City	12.34	13.20	14.44	15.43	17.65
Emerald Isle	12.90	13.20	13.73	14.27	15.90
Bogue Sound - Emerald Isle	12.66	14.02	15.49	16.40	19.19
White Oak River	12.89	14.15	15.71	16.76	18.54

4.1.1.2 Wave Attack

Waves cause damage through the force that they impart directly on structures, habitats, and shorelines. Waves also generate alongshore and cross-shore currents at shorelines that can mobilize and erode sediments. In the context of SACS, wave attack refers to the process of destructive waves impacting a shoreline and leading to increase erosion along that shoreline. Erosion is addressed in Section 4.1.1.3.

There is high wave energy within the focus area and the impact of waves on shorelines can be hazardous to both natural shorelines and engineered structures. Wave attack is a greater risk for areas with prominent infrastructure and population or cultural and environmental resources—all of which are present within this focus area.

The wave climate for coastal Carteret County can be described using data from USACE Wave Information Studies (WIS) station 63276, which is located approximately 16 miles from Emerald Isle at a depth of 69 feet. WIS stations are output locations for a series of coastal wave hindcast model estimates for a 35-year period from 1980 to 2014. The average significant wave height at this station is 3.6 feet, with a period (time between wave peaks) of 8.6 seconds. The estimated significant wave height for a 1-percent AEP flood event based on the hindcast data at this location is 33.0 feet. Data from WIS station 63270, located about 14 miles from the Core Banks at a depth of 82.0 feet, show that typical waves north of Cape Lookout are slightly larger. The average significant wave height at this location is 4.0 feet, with a period of 8.6 seconds and a 1-percent AEP flood event significant height of 35.9 feet.

Craven County, located primarily along the Neuse River, is at lower risk to wave attack. This county is protected from ocean waves by the barrier islands, so limited wind fetch (length over which wind stress is applied to the water surface) is available for wave development. Although Craven County is more protected from wave attack, waves can still create risk, especially during storms with added effects of storm surge and compound flooding.

The CHS analysis, developed by USACE, models wave heights for a range of storm events. While WIS data can describe offshore wave heights using hindcast model estimates, CHS describes wave heights at a range of AEP values throughout the region for current and future conditions. For example, a wave height of 7.32 ft at a 10-percent AEP means that there is a 10-percent chance of wave heights higher than 7.32 ft in any one given year. **Table 7** shows modeled wave heights at various AEP values throughout the focus area for the existing sea level, while **Table 8** shows modeled wave heights for the future, USACE High sea level rise scenario from CHS (7.35 feet). Points representing ocean waves were chosen at locations roughly 5 miles offshore and are much larger than waves in back bay regions. For example, the 1-percent AEP wave height on the ocean side of Emerald Isle is 32.52 feet, while the 1-percent AEP wave height in Bogue Sound near the same beach is 6.22 feet.

Wave heights correlate to fetch, duration of the wind stress, and water depth. Therefore, waves in deep ocean water can become much larger than waves in back bay regions. This also applies to sea level rise; as the sea level increases, the depth at which the wave develops increases, allowing for larger waves.

Table 7: Carteret and Craven Counties Wave Heights from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Pamlico Sound - Cedar Island	7.32	8.26	9.18	9.74	10.74
Neuse River - MCAS Cherry Point	4.35	5.25	6.18	6.72	7.71
Neuse River - New Bern	2.60	3.28	4.03	4.45	5.24
Cape Lookout National Seashore	28.04	32.87	36.75	38.96	42.21
Core Sound - Davis	3.15	3.77	4.38	4.74	5.33
Morehead City	2.97	3.65	4.30	4.66	5.35
Emerald Isle	23.11	27.00	30.48	32.52	36.52
Bogue Sound - Emerald Isle	3.76	4.75	5.78	6.22	7.40
White Oak River	1.75	2.33	3.00	3.36	4.06

Table 8: Carteret and Craven Counties Wave Heights from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Pamlico Sound - Cedar Island	8.60	9.94	11.25	11.98	13.24
Neuse River - MCAS Cherry Point	4.82	5.71	6.57	7.08	8.00
Neuse River - New Bern	3.44	4.24	5.11	5.63	6.55
Cape Lookout National Seashore	28.65	33.93	38.50	41.02	44.95
Core Sound - Davis	5.99	6.98	7.94	8.45	9.36
Morehead City	3.69	4.50	5.38	5.87	6.73
Emerald Isle	24.37	28.47	32.09	34.20	38.26
Bogue Sound - Emerald Isle	7.12	8.21	9.33	9.87	11.04
White Oak River	2.65	3.25	4.00	4.43	5.23

4.1.1.3 Erosion

The North Carolina Division of Coastal Management's (NCDCM) 2019 shoreline change rates discussed in the Tier 2 Risk Assessment reported that all coastal shorelines within this focus area were experiencing erosion except Emerald Isle and Fort Macon State Park (**Table 9**), which experienced accretion rates of 0.27 feet/year and 1.32 feet/year, respectively. The NCDCMs 2020 Web Map Viewer update of shoreline change and erosion rates indicated that Emerald Isle, Atlantic Beach, parts of Pine Knoll Shores, and Fort Macon were experiencing accretion (NCDCM 2020e). NCDCM reported in 2019 that both Atlantic Beach and Fort Macon State Park experienced a net accretion because of consistent nourishments from the Morehead City Harbor Navigation Project. Future performance of these projects depends on continued nourishments for existing projects, with shorelines exhibiting minimal erosion (<1 foot/year) or experiencing stability and/or net accretion (NCDCM, 2019). Average oceanfront shoreline change rates in this focus area ranged between -0.34 foot/year and -4.27 feet/year for eroding shorelines. The Tier 2 Risk Assessment did not identify any critical erosion areas within this focus area.

Table 9: Oceanfront Shoreline Change Rates in the Carteret and Craven Counties Focus Area

Location	2020 Rate	Average (feet/year)
Atlantic Beach	Erosion	-2.16
Core Banks–Cape Lookout to Drum Inlet	Erosion	-4.27
Core Banks–Drum Inlet to Ocracoke Inlet	Erosion	-5.26
Emerald Isle	Accretion	0.27
Fort Macon State Park	Accretion	1.32
Indian Beach	Erosion	-0.71
Pine Knoll Shores	Erosion	-0.34
Salter Path	Erosion	-2.56
Shackleford Banks	Erosion	-2.56

Nearly all the Cape Lookout National Seashore is experiencing erosion, from Beaufort Inlet to Ocracoke Inlet. The oceanfront shoreline has been designated as potential low risk while the estuary side is designated potential medium risk. Shackleford Banks to Barden Inlet experiences erosion rates of 2 to 7 feet per year. The eastern coast of Cape Lookout experiences erosion rates of 2 to 5 feet per year while the western coast experiences 2 to 13 feet per year. Erosion rates on the eastern side of Cape Lookout National Seashore increase northward from 5 to 25 feet per year and up to 43 feet per year at Drum Inlet. The opposite side of Drum Inlet at Ophelia Banks experiences erosion rates of 25 feet per year and decreases northward before exhibiting accretion at Old Drum Inlet.

This focus area includes shoreline change data within the back bay and estuary, specifically within the Neuse River Estuary (Cowart et al. 2011) and Cedar Island (Cowart et al. 2010). Cowart et al. (2011) reported a shoreline change rate of -1.9 feet/year (-0.58 meter/year), with 93 percent of the Neuse River Estuary eroding. Erosion rates are found to increase along the length of the estuary, which, when considered at the local scale, demonstrated correlation with increasing fetch and decreasing mean elevation. Cowart et al. (2010) reported a shoreline change rate of -0.79 feet/year (-0.24 m/year), with 88 percent of the Cedar Island shoreline eroding; shoreline composition was identified as an important control. As detailed in Section 4.1.4.3 of the North Carolina State Appendix, numerous variables influence estuarine erosion, and additional studies are needed to improve predictions of future shoreline change.

4.1.2 Secondary Hazards

For the Carteret and Craven Counties Focus Area, secondary hazards include wind, compound flooding, and saltwater inundation and intrusion. While SACS does not address these hazards in detail, they are important because they can impact the focus area.

4.1.2.1 Wind

In Carteret and Craven Counties, high wind speeds can damage roofs, mobile homes, and, if strong enough, can destroy entire buildings. Flying debris can also cause additional damage to resources. High winds can destroy environmental resources by downing and defoliating large patches of trees and other vegetation. Typical hourly winds at NOAA station 8656483 at Duke Marine Lab in Beaufort, North Carolina are 7.8 miles per hour. Speeds reached 53.9 miles per hour on September 14, 2018, during Hurricane Florence (Tides & Currents 2021). Wind directions are generally from the north

during colder months and from the south during warmer months (Cedar Lake Ventures, Inc. n.d.). This difference in wind direction creates changes in approach patterns of wind-blown waves, thus creating a different angle of wave attack that drives sediment transport and causes property damage. Similarly, extratropical cyclones (e.g., nor'easters) typically approach this focus area from the north during colder months and tropical cyclones (e.g., hurricanes and tropical storms) typically approach this focus area from the south during warmer months, creating different angles of approach for wind-induced damages. See Section 4.1.4.4 of the North Carolina Appendix for additional details on wind hazard.

4.1.2.2 Compound Flooding

Compound flooding creates a greater flood risk through the combination of hazards (North Carolina Appendix Sections 4.1.4.5 and 4.2.2.1). These can be a combination of storm surge, precipitation, nuisance flooding, and higher groundwater elevations. In 2018, Hurricane Florence caused catastrophic damage in the focus area due to a combination of storm surge and heavy inland rainfall exceeding 30 inches in some areas of North Carolina (Stewart and Berg 2018). Compound flooding can contribute significantly to increased runoff volumes, the elevation of the ocean, river and groundwater levels above banks, containment structures and drainage systems, and the overwhelming of outflow systems (Gori et al. 2020).

4.1.2.3 Saltwater Intrusion and Inundation

Saltwater intrusion and inundation due to coastal storms (North Carolina Appendix Sections 4.1.4.6 and 4.2.2.1) has significant consequences to both the environment and the economy in eastern North Carolina, including upland forest retreat, crop yield decline, marsh migration, eutrophication, degradation of habitat by invasive species, coastal forest loss, and decreased ecosystem service benefits (Weston et al. 2011; Tully et al., 2019; Ury et al. 2019). Saltwater inundation and intrusion are currently being studied within coastal North Carolina by several state and academic stakeholders to better understand the nature of the hazard and to identify strategies for addressing this emerging issue.

4.1.3 Sea Level Rise Effect on Hazards

At NOAA National Ocean Service (NOS) gauge number 8656483 at Beaufort, North Carolina, the mean sea level trend is 0.011 feet per year, with a 95-percent confidence interval of 0.0011 feet per year, based on monthly mean sea level data from 1953 to 2020 (**Figure 4**), which is equivalent to a change of 1.08 feet over 100 years. Relative sea level rise between 2020 and 2120 is shown graphically in **Figure 5.** These values are displayed numerically in **Table 10**. The USACE Sea Level Change Curve Calculator shows the change in height between 2020 and 2120 (USACE 2021). Tidal data and extreme water levels for NOS gage no. 8656483 are shown in **Figure 6**.

The NOAA Sea Level Rise Viewer (NOAA n.d.) was used to simulate an inundation footprint due to a given water level rise. **Figure 7** shows a portion of the Carteret and Craven Counties Focus Area with 3 feet of relative sea level rise, a probable value for the study area for the next 50 to 100 years based on the USACE Intermediate Scenario for 2120 and USACE High Scenario for 2070 in North Carolina. References to these tools can be found in North Carolina Appendix Section 3.6.3.

3 feet of relative sea level rise would result in extensive loss of marsh and wooded wetlands, loss of wildlife refuge areas, overflowing drainage creeks, inundation of barrier islands, widening of Drum, New Drum, Beaufort, and Bogue inlets, and complete inundation of the town of Davis. Rivers, creeks, and canals would be more vulnerable to flooding, including high-tide flooding, leading to less effective stormwater management systems and increased risk for adjacent communities, specifically, the Neuse River, Newport River, and White Oak River watershed communities. The Cedar Island National Wildlife Refuge would be inundated and split into two segments with Cedar Island becoming cut off from the Marine Corps Outlying Field Atlantic. Hundreds of miles of wetlands would be lost in the Pamlico and Core Banks sounds and drainage basins within the Morehead City Harbor complex. Changes to tidal regimes and flow velocity would also be expected, which could exacerbate saltwater intrusion and erosion of deltaic wetlands.

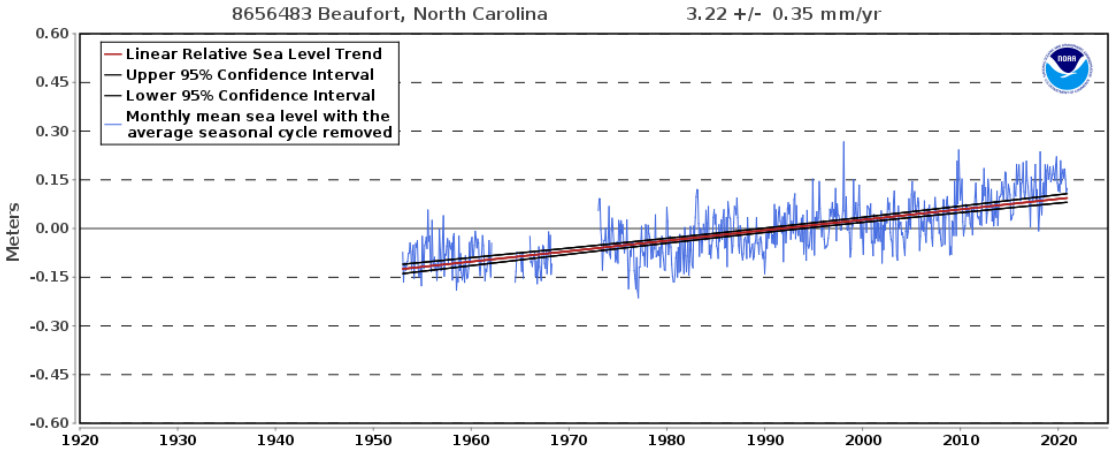


Figure 4: Relative Sea Level Trend, National Ocean Service Gauge 8656483 at Beaufort, North Carolina

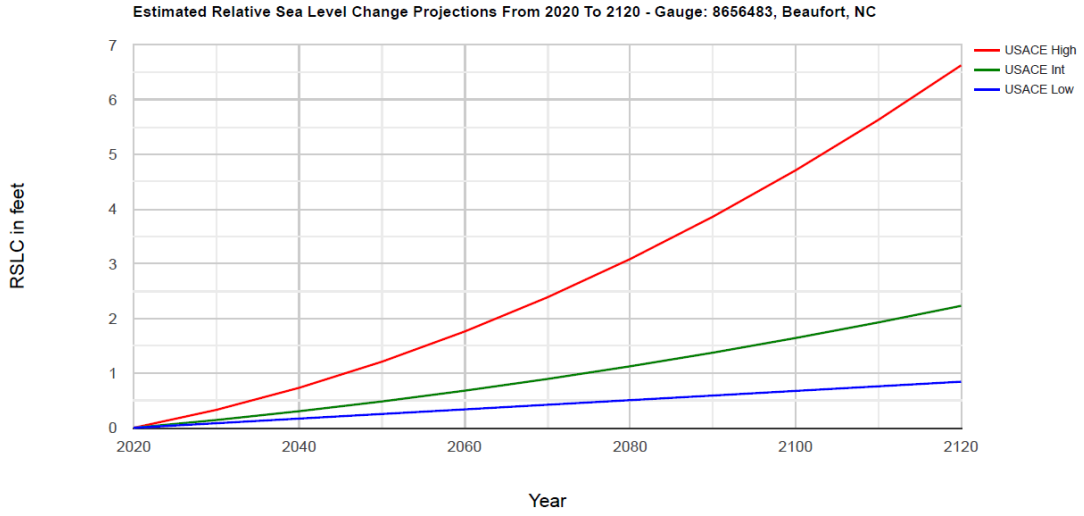
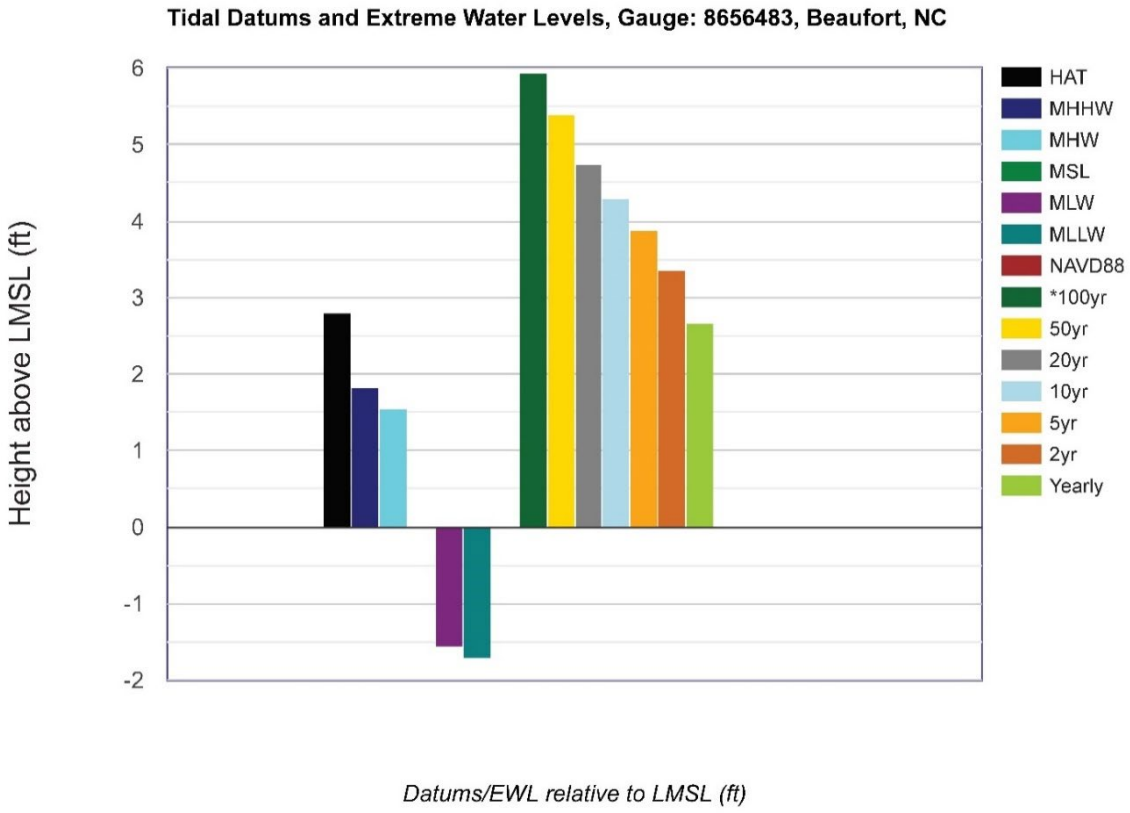


Figure 5: Estimated Relative Sea Level Change Projections Relative to 2020 from 2020 to 2120 – Beaufort, North Carolina

Table 10: Estimated Relative Sea Level Change from 2020 to 2120 for Various USACE Projections – Beaufort, North Carolina

Location	USACE Low (feet)	USACE Intermediate (feet)	USACE High (feet)
Beaufort, NC	0.843	2.23	6.63



EWL – Extreme Water Level
HAT – Highest Astronomical Tide
LMSL – Local Mean Sea Level
MHHW – Mean Higher High Water
MHW – Mean High Water
MSL – Mean Sea Level
MLW – Mean Low Water
MLLW – Mean Lower Low Water

Figure 6: Tidal Data and Extreme Water Levels

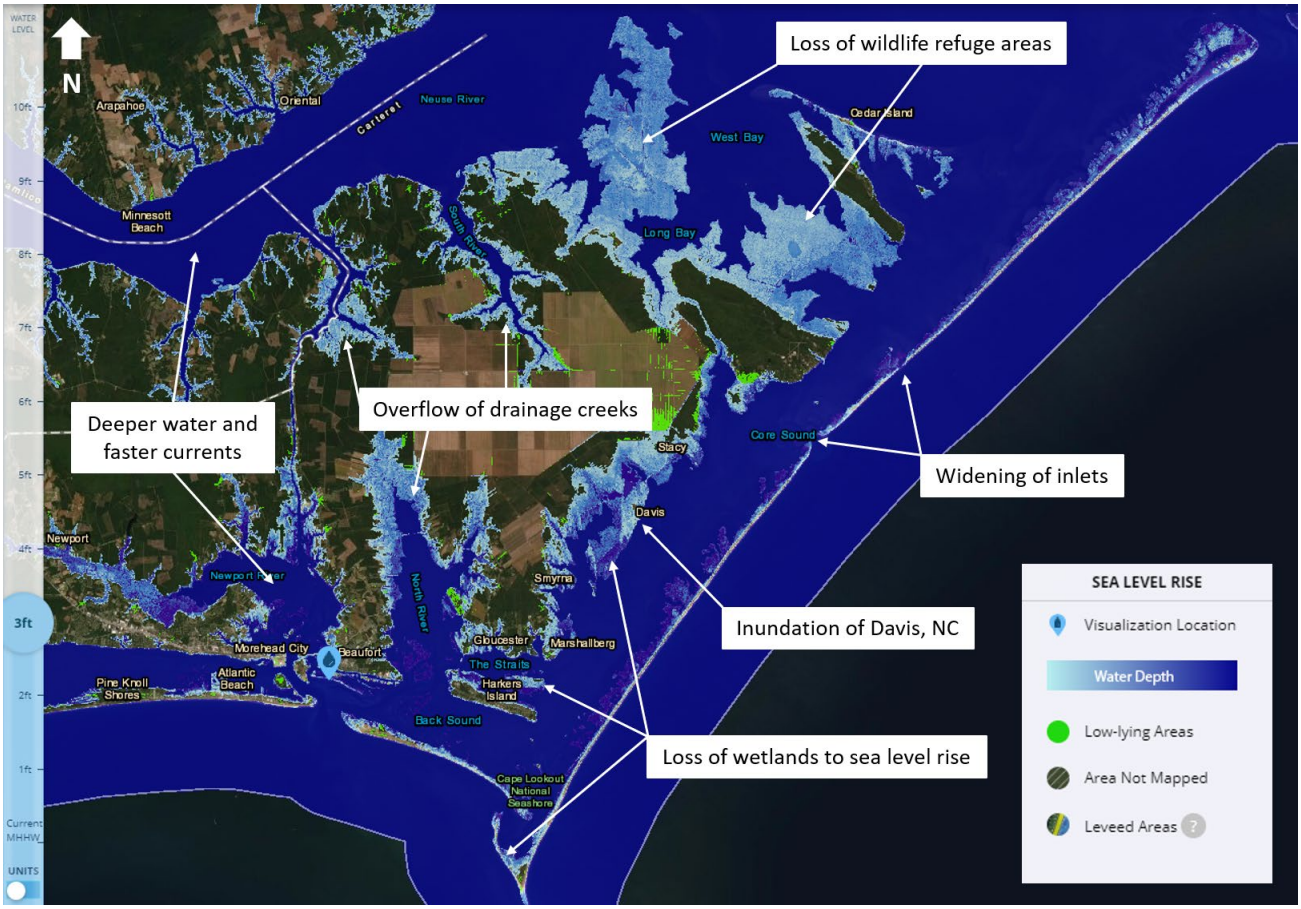


Figure 7: Projection of 3 Feet of Relative Sea Level Rise Using the National Oceanic and Atmospheric Administration Sea Level Rise Viewer

4.2 System Performance

The focus area contains a range of risk management measures. These include a combination of natural features, constructed components, policy initiatives, and other factors that influence how the overall system within the focus area performs in response to coastal hazards. Generally, constructed measures have been developed and implemented individually rather than holistically. As sea level rises, the coastal storm risk footprint is expanding to encompass multiple areas that have previously been managed separately. For example, beach nourishment projects have significantly reduced risk to infrastructure on the oceanfront sides of barrier islands. However, as sea level rises, infrastructure is at increasing risk of inundation from the back bay side of islands.

Beach nourishment projects reduce damages to oceanfront infrastructure, anchor the coastal system, and serve as a first line of defense to storm damages on the back bay side. Natural resources, such as salt marsh and offshore barrier islands, serve as a first line of defense, and their preservation is important for environmental and coastal storm risk management purposes.

System components in the focus area include:

- Coastal land use plans in accordance with the North Carolina Coastal Area Management Act. The land use plans for both Carteret and Craven Counties outline policies and regulations that guide development.
- Oceanfront construction setback regulations
- Structure elevation, relocation, and buyout measures
- Beach nourishment projects on the densely populated barrier island (Bogue Banks)
- Oceanfront sand placement as beneficial use from navigation projects
- Numerous hardened structures (e.g., bulkheads, revetments) along points of the back bay shoreline to reduce erosion and inundation
- Numerous living shoreline projects along points of the back bay shoreline to reduce erosion and inundation
- Preservation of undeveloped barrier islands (Shackleford Banks and Cape Lookout National Seashore)

The area also contains significant environmental resources that naturally function as a system to reduce and adapt to storm impacts and sea level rise. However, these resources and their natural functions are increasingly fragmented and constrained because of development and other factors. Examples of these resources include:

- Natural dune systems providing storm damage reduction
- Extensive saltmarsh habitat in back bay areas

Within the focus area, holistic management of the coastal system is increasingly necessary. This includes continued efforts for collaboration and coordination between federal, state, local, and all stakeholders to better understand each other's role in risk management and work effectively to combine authorities and activities to holistically assess and address coastal storm risk.

The SAND Report reported a surplus of over 45 million cubic yards (MCY) for the current 50-year sand budget with a 55-percent contingency for Carteret County. The current 50-year budget includes 51.9 MCY needed, 40.9 MCY available offshore, and another 56.7 MCY estimated from RSM contributions. For those locations on the Outer Banks and the Core Sound, no proven borrow sources were identified, meaning any nourishment activities on the east side of Carteret County would require additional geotechnical investigation before they could be considered for beach placement. For those locations near the Bogue Sound, several proven sources are available and ready for use offshore.

The RSM Optimization Update provided a detailed review of the existing actions in place as well as recommendations for actionable strategies. Maintenance dredging of Morehead City Harbor produces 3.9 MCY of material every dredging cycle of which 2.3MCY is used for coastal flood risk management benefits evaluated at $8.8 million. Approximately 1.2 MCY of beach-suitable sand is placed in the nearshore placement zones adjacent to Beaufort Inlet to ameliorate ebb shoal deflation

from the removal of sand from the inlet complex, and approximately 1.1 MCY is placed on the beach at Fort Macon State Park and the Town of Atlantic Beach, providing $2.8 million in annual shoreline protection benefits. An additional 1.6 MCY is diverted to upland placement. Future improvements to nearshore placement methods may provide additional benefits to coastal resiliency efforts. Additionally, the RSM Optimization Update recognized the potential for dredged material placed in upland sites to be beneficially used to enhance coastal and wetland habitats and maximizing upland site capacity.

4.3 Exposure

Tier 1 and Tier 2 analyses described in the Main Report and North Carolina Appendix describe exposure of populations, infrastructure, and environmental resources in SACS Planning Reach NC_01, which include this focus area. Exposure describes who and what may be harmed by the hazard. Details on exposure related to this focus area are found in the following sections related to population, infrastructure, and environmental and cultural resources.

4.3.1 Exposed Population

The focus area contains approximately 170,000 people, the majority of which are exposed to coastal storm hazards. Inundation is the primary threat to people. The most extreme cases of storm surge could flood a significant portion of the focus area.

In Carteret, populations exposed to more frequent, higher-probability events are located in portions of the barrier islands along the Bogue Banks (Cape Lookout is undeveloped) and the Down East communities in the eastern portion of the mainland. The Down East area covers about a dozen small unincorporated communities, many of which have their roots in commercial fishing, that are developed upon areas of extremely low elevation.

In Craven, areas exposed to inundation are along the lower Neuse River and include Fairfield Harbor and parts of New Bern, as well as areas along the lower Trent River. **Figure 8** shows the percentage of people in Carteret and Craven who are exposed to coastal storm surge by Hurricane Category.

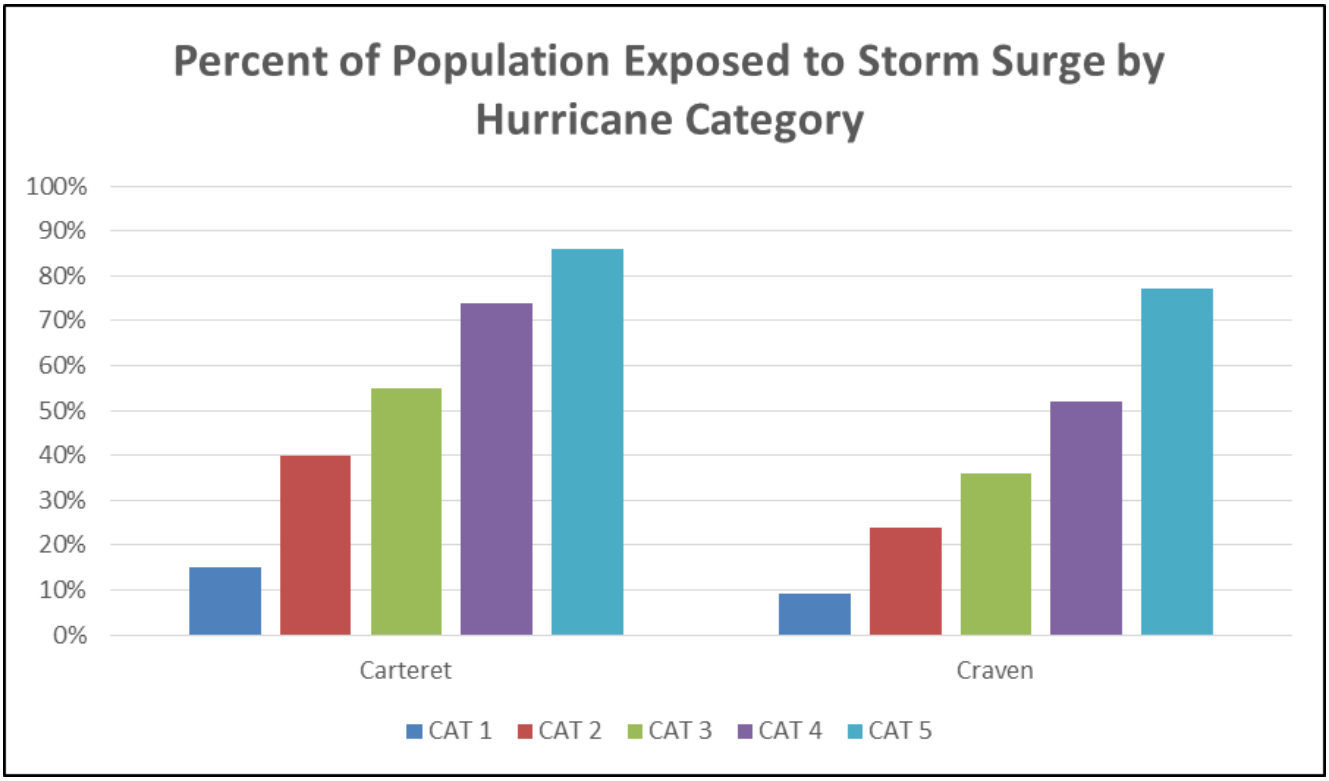


Figure 8: Percentage of Population Exposed to Storm Surge by Hurricane Category (FEMA 2016)

Although census data portray the number of people living in an area year-round, in many beachfront towns, the seasonal population increases during the high-risk months of May through September, which coincides with hurricane season. Thus, the exposure of people to hazards is significantly greater than originally assessed in the Tier 1 analysis, which was based on permanent population figures. These additional people include second-home owners and vacationers who may be staying in rental homes or hotels.

Bogue Banks is the only island on the Carteret County shore that has been developed with numerous housing communities. Second homeowners make up most of the property owners in the beach towns of Carteret County. **Figure 9** shows a comparison of the permanent population with the estimated seasonal population of two island communities on the Bogue Banks, Atlantic Beach, and Emerald Isle.

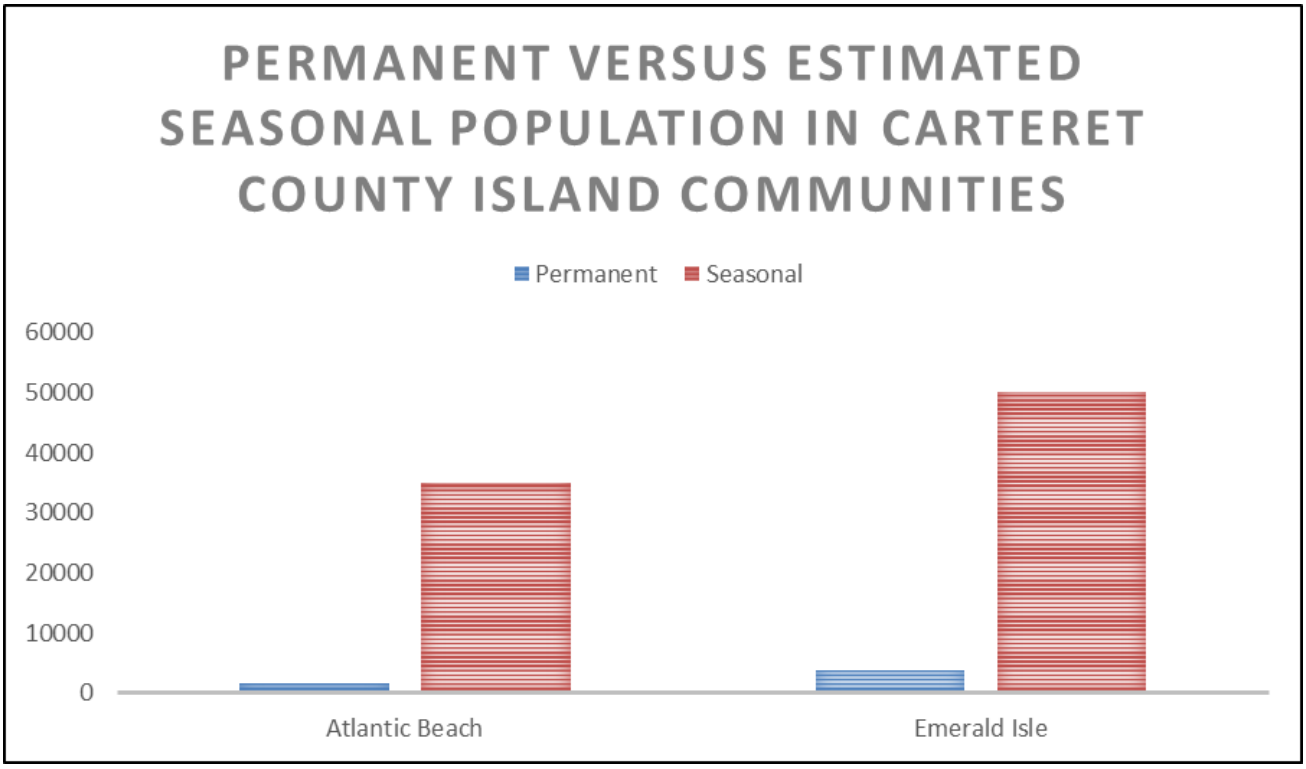


Figure 9: Permanent versus Estimated Seasonal Population in Atlantic Beach and Emerald Isle (Atlantic Beach, North Carolina Population 2021; Facts & Figures: Growth of the Town of Emerald Isle)

4.3.2 Exposed Infrastructure

Assets exposed to inundation include residential, commercial, industrial, public, and transportation infrastructure. Information from the 2016 North Carolina Hurricane Evacuation Study (HES) identifies numbers of critical facility types and whether they are exposed to specific categories of storm surge within Carteret and Craven Counties (FEMA 2016). **Table 11** represents Carteret County, while **Table 12** represents Craven County. Note that the majority of critical facilities in the focus area are exposed to inundation from storm surge.

Table 11: Carteret County Critical Facility Exposure to Coastal Storm Surge Inundation (FEMA 2016)

Facility Type	CAT 1 MOM	CAT 2 MOM	CAT 3 MOM	CAT 4 MOM	CAT 5 MOM	Outside of Surge Risk Area	In 1% Annual Chance Flood Event	Total
EMS Locations	1	1	2	2	2	0	1	2
Fire Stations	0	1	1	1	1	0	1	1
Government	2	10	13	16	19	4	3	23
Health Care Facilities	2	7	7	11	11	4	2	15
Police Stations	1	1	1	1	1	0	1	1
Shelters	2	7	9	15	21	3	4	24
Utilities	1	6	9	10	12	2	3	14
Total	9	33	42	56	67	13	15	80

Table 12: Craven County Critical Facility Exposure to Coastal Storm Surge Inundation (FEMA 2016)

Facility Type	CAT 1 MOM	CAT 2 MOM	CAT 3 MOM	CAT 4 MOM	CAT 5 MOM	Outside of Surge Risk Area	In 1% Annual Chance Flood Event	Total
Emergency Operations Centers	0	0	1	1	1	0	0	1
EMS Locations	0	1	3	3	4	7	0	11
Fire Stations	1	4	10	15	21	18	0	39
Prisons	0	0	0	0	0	1	0	1
Police Stations	0	1	3	5	7	3	0	10
Shelters	0	0	0	0	4	4	0	8
Airport	0	1	2	2	3	1	0	4
Total	1	7	19	26	40	34	0	74

4.3.3 Exposed Environmental and Cultural Resources

The Carteret and Craven Counties Focus Area is rich with significant and unique environmental and cultural resources. Because of factors including plentiful food sources, multiple habitat types, tidal influence, and ocean access, man and nature have inhabited coastal North Carolina for ages. Coastal storms and sea level rise continue to expose vulnerable environmental and cultural resources to risk of alteration or loss. To offer additional protection to at-risk environmental and cultural resources, where actionable and practicable, several potential structural and nonstructural measures have been identified. These measures are summarized in Sections 4.3.3.1 and 4.3.3.2 in addition to environmental and cultural resources priority areas/sites within the focus area. For additional information concerning exposed environmental and cultural resources in this focus area and in other North Carolina areas included in the SACS, please refer to the North Carolina Appendix.

4.3.3.1 Environmental Resources

The majority of exposed environmental resources were identified in the Tier 1 Risk Assessment, although Tier 2 analyses refined our Tier 1 understanding of environmental exposure by incorporating state-level data. As seen in **Figure 10**, which depicts the SACS Tier I Risk Assessment Viewer's Environmental and Cultural Resources Exposure Index, North Carolina's areas of highest exposure are concentrated in low-lying areas on barrier islands and back bay areas. The reasoning for this is proximity to the hazards of sea level rise and coastal storm damage. Areas directly adjacent to water bodies are more exposed than landward areas. Similarly, species that require these most exposed habitats are particularly exposed. As an example, shorebirds and sea turtles that use beaches as nesting habitat may experience a higher degree of exposure to hazards as compared to species that nest inland or at higher elevations.

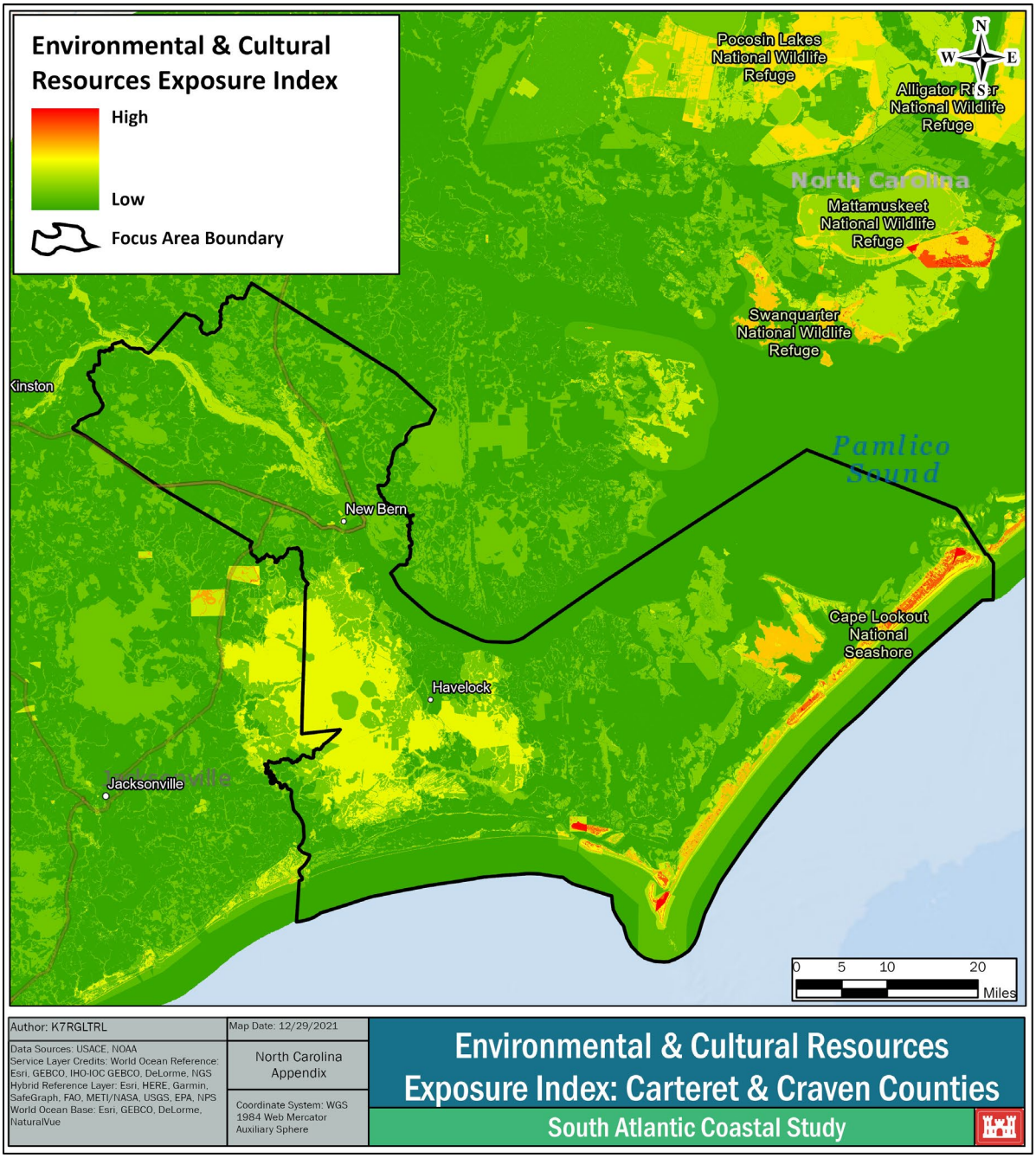


Figure 10: Tier 1 Risk Assessment Viewer (Environmental and Cultural Resources Exposure Index)

The primary data source used in Tier 2 analysis was the Data Explorer online tool curated by the North Carolina Natural Heritage Program (2020). This tool identifies natural areas with high ecological value, existing managed areas, and other areas of environmental significance within the state's boundaries. Natural areas in this focus area exposed to storm surge inundation include upland forests, coastal plain early successional habitats, scrub shrub habitats, beaches and dunes, forested wetlands, shrub and herbaceous wetlands, wet pine savanna, pocosins, and submerged aquatic vegetation. Beaches, dunes, and other areas abutting water bodies are particularly exposed to erosion. For additional information regarding Tier 2 Environmental Resources Vulnerability and Risk Analysis, please refer to the SACS Environmental Technical Report.

4.3.3.2 Cultural Resources

Seven at-risk cultural resource sites and historic districts are identified within, or partially within, the Craven and Carteret Counties Focus Area. These cultural resources were identified through collaborative discussions with the North Carolina Office of State Archaeology and the North Carolina State Historic Preservation Office.

- **New Bern Historic District (CV0028):** Listed on the National Register of Historic Places (NRHP) in 1973, the district is in the New Bern census place in Craven County. The district consists of numerous late eighteenth- to early twentieth-century Georgian style structures. New Bern served as the capital of the North Carolina colonial government, then as the state capital for a short time.
- **Clubfoot and Harlowe Creek Canal (CR0565):** Although not listed on the NRHP, this canal was state-listed as a significant resource in 1989 and is located near the Harlowe non-census place in Craven County. The canal was completed in 1827 and functioned with an associated lock at its northern end on Pamlico Sound to control tidal flow. Its dimensions are 14 feet wide and 4 to 5 feet deep and its physical footprint is in both Carteret and Craven Counties.
- **Beaufort Historic District (CR0001):** Listed on the NRHP in 1974, the district is located partially within the Beaufort census place in Carteret County. The district is comprised of 16 contributing structures, some dating back to 1710, including examples of Queen Anne, Greek Revival, and Gothic Revival style construction.
- **Portsmouth Village (CR0007):** Listed on the NRHP in 1979, the village abuts the Cape Hatteras National Seashore toward northeastern Carteret County; however, the nearest community is Ocracoke (census place) in Hyde County. Originally a maritime village and now only accessible by ferry, the village is comprised of multiple eighteenth- to early twentieth-century structures.
- **Fort Macon (CR0003):** Listed on the NRHP in 1970, the village is located near the Atlantic Beach census place in Carteret County. Constructed of brick and stone, the Battle of Fort Macon was fought here in 1862. Today, Fort Macon is the second most visited state park in North Carolina.
- **Cape Lookout Light Station (CR0002):** Listed on the NRHP in 1972, the light station is located near the Harkers Island census place in Carteret County. The brick lighthouse was constructed between 1857 and 1859 and stands 169 feet tall.
- **Cape Lookout Village Historic District (CR0266):** Listed on the NRHP in 2000, with eligibility reconfirmed in 2018, the district is located near the Harkers Island census place in Carteret County. The district is a maritime complex consisting of multiple structures constructed in the nineteenth and twentieth centuries.

Potential strategies and measures to protect vulnerable areas of identified cultural resources include elevating or relocating structures, excavating and studying sites in eroding areas, constructing living shorelines or other breakwater structures to provide protection from wave action and erosion, and using dredged material beneficially to buffer the effects of wave attack.

4.3.3.3 Environmental and Cultural Resource Uncertainty

At this time, no certain effects of climate change on tropical cyclone activity in terms of frequency, intensity, and rainfall across all global basins have been identified. Current science related to climate effects on tropical cyclone activity have not reached the point of standard consensus necessary to inform a change in storm analysis baselines. Similarly, the rate of sea level rise in North Carolina is unknown, although some models suggest that sea level will continue to rise, threatening natural and human environments. If protective measures are not implemented, habitat types with limited tolerance to salinity may migrate inland, be displaced, or be lost because of inundation or erosion. Similarly, cultural resources may be subjected to increased erosive forces, increased saline conditions, and potential inundation due to coastal storm damage and sea level rise.

4.4 Vulnerability

Vulnerability is the susceptibility of harm to human beings, property, and the environment when exposed to a hazard (USACE 2017). Regarding environmental vulnerability to the effects of coastal storms and sea level rise, salinity changes may alter habitats bordering Pamlico Sound, behind the barrier islands. Additionally, coastal storms may alter existing habitat through erosion and storm surge. Further, costal storms may redistribute sand such that capes are expanded or reduced, and inlets are created or closed. Sand redistribution may significantly change available habitat types and associated acreage. Additionally, the effects of coastal storms and sea level rise threaten to inundate/eliminate wetlands and introduce saline conditions in areas with salt-intolerant vegetation. Coastal storms may alter existing barrier island habitats through erosion, storm surge, and high winds.

The Carteret and Craven Counties Focus Area is highly vulnerable to coastal storms, which will increase with sea level rise in part due to the following:

- Habitat Conversion: **Figure 11** illustrates the significant increase in acreages vulnerable to inundation between existing conditions and future conditions with sea level rise. Storm surge and sea level rise hazards may inundate currently upland natural communities and/or introduce increased localized salinity which may force habitat conversion.

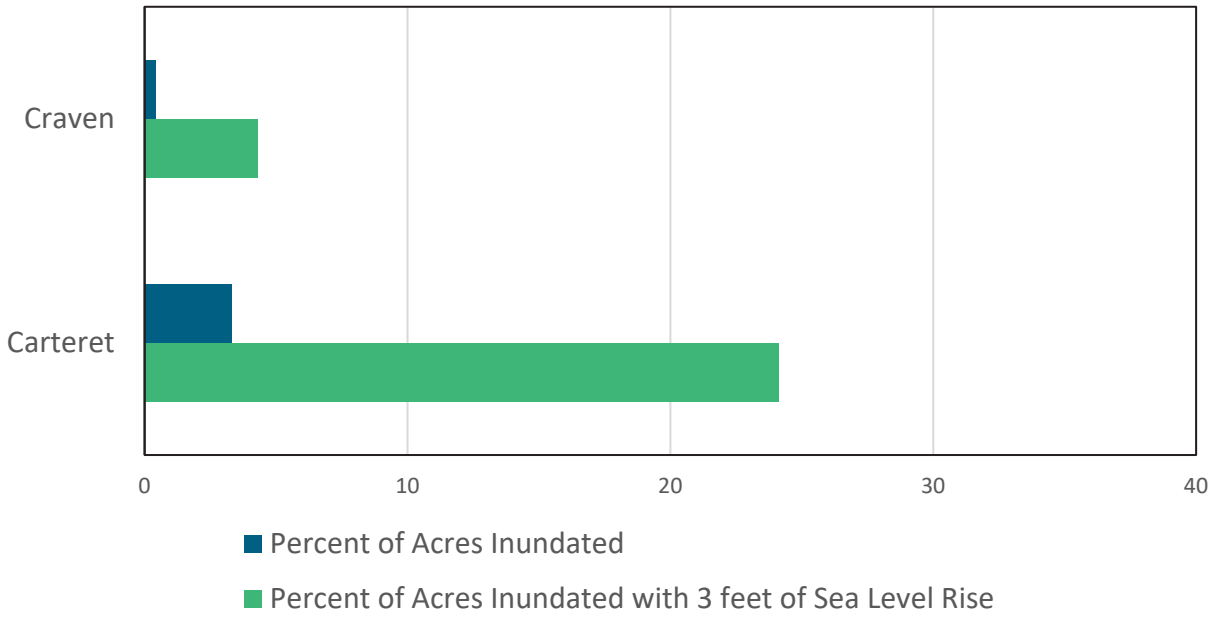


Figure 11: Comparison of the Land Currently Vulnerable to Inundation and in Future Conditions with Sea Level Rise

- Naturally dynamic barrier islands: The barrier island portions of Carteret County have historically migrated west via natural processes such as overwash as the islands slowly roll back up the continental shelf as sea levels rise. Static human development conflicts with this natural migratory process, creating vulnerability for people, property, and the islands.
- High seasonal population: During the spring, summer, and fall, the population of the island communities within the focus area exponentially increases because of tourism and seasonal residents. Much of this time coincides with hurricane season.

The 2016 North Carolina HES used NOAA surge modeling, land surveys, and photography to visualize the vulnerability of landmark structure for potential surge height and depth of water for all categories of hurricane. The following figures from the HES study illustrate the vulnerability of specific landmark locations within the focus area to storm surge inundation for a Hurricane Category 3 MOM. Although these images would not represent the inundation levels of all Category 3 hurricanes, they do represent what is possible in a worst-case scenario for a Category 3, based on the modeling (FEMA 2016).

Figure 12: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height represented by Pale Blue Line) at the Atlantic Beach Fire Department, Carteret County (FEMA 2016)

Figure 13: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height represented by Pale Blue Line) at the Carteret County Court House (FEMA 2016)

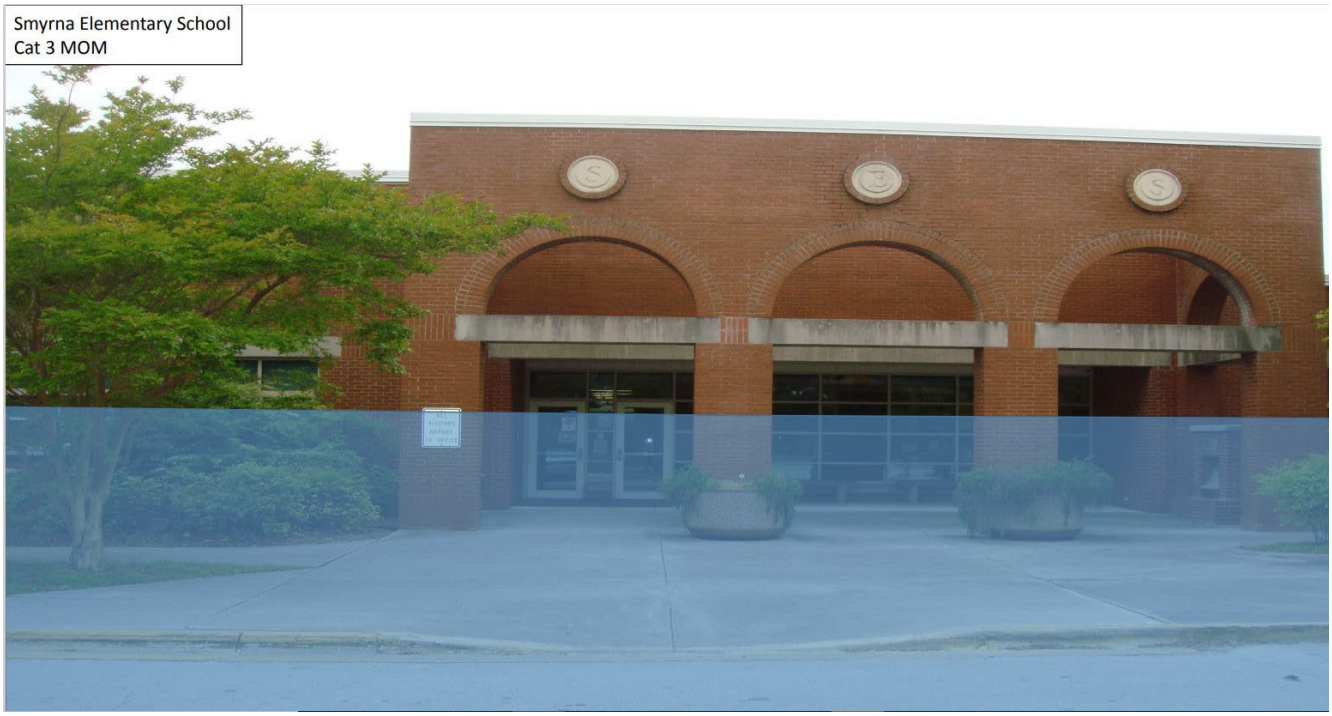


Figure 14: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height represented by Pale Blue Line) at the Smyrna Elementary School (Down East Region, Carteret County) (FEMA 2016)

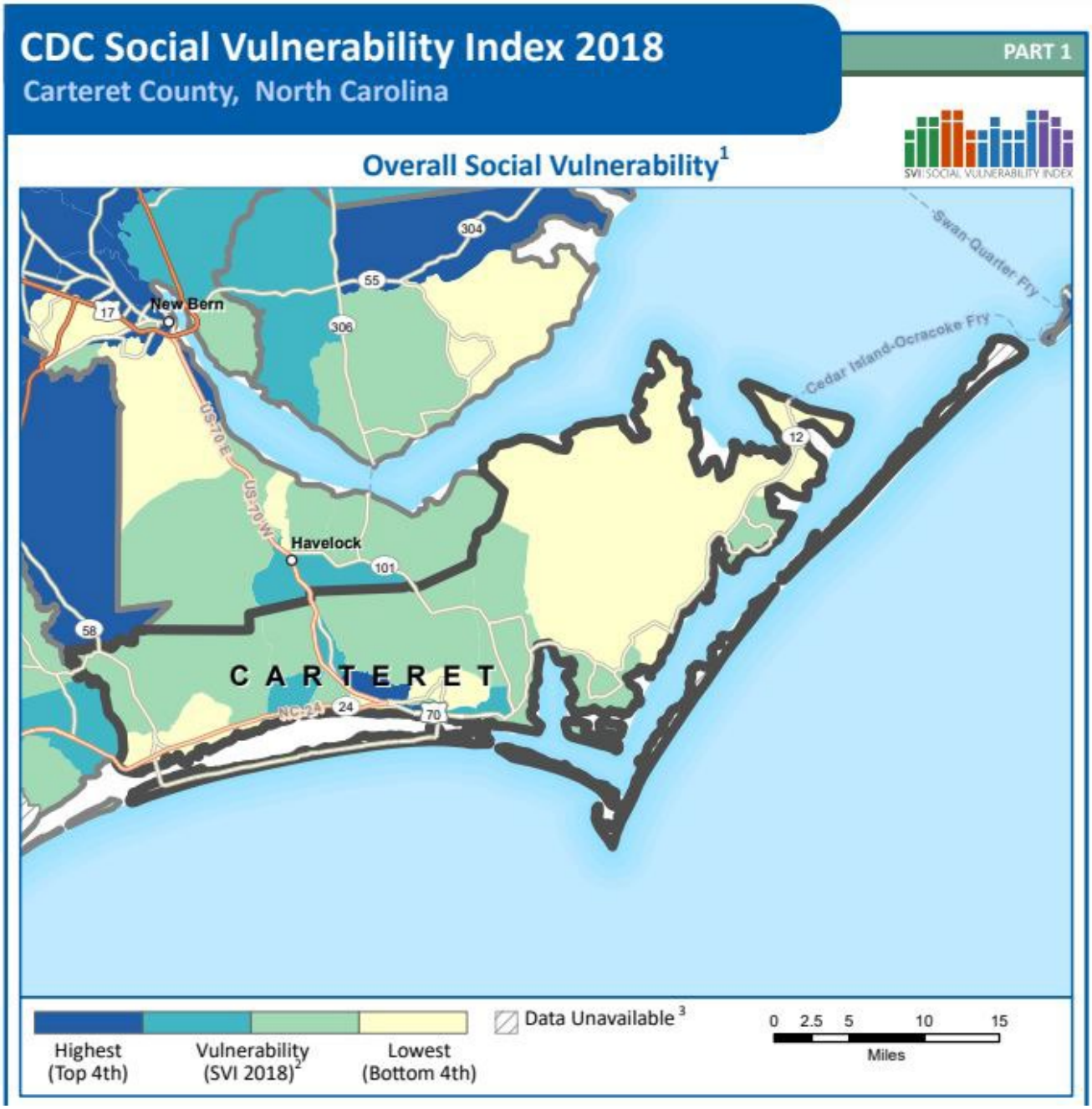
Figure 15: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height represented by Pale Blue Line) at New Bern Riverfront Convention Center, Craven County (FEMA 2016)

Figure 16: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height represented by Pale Blue Line) at Fairfield Harbor Property Owners Association, Craven County (FEMA 2016)

4.4.1 Social Vulnerability

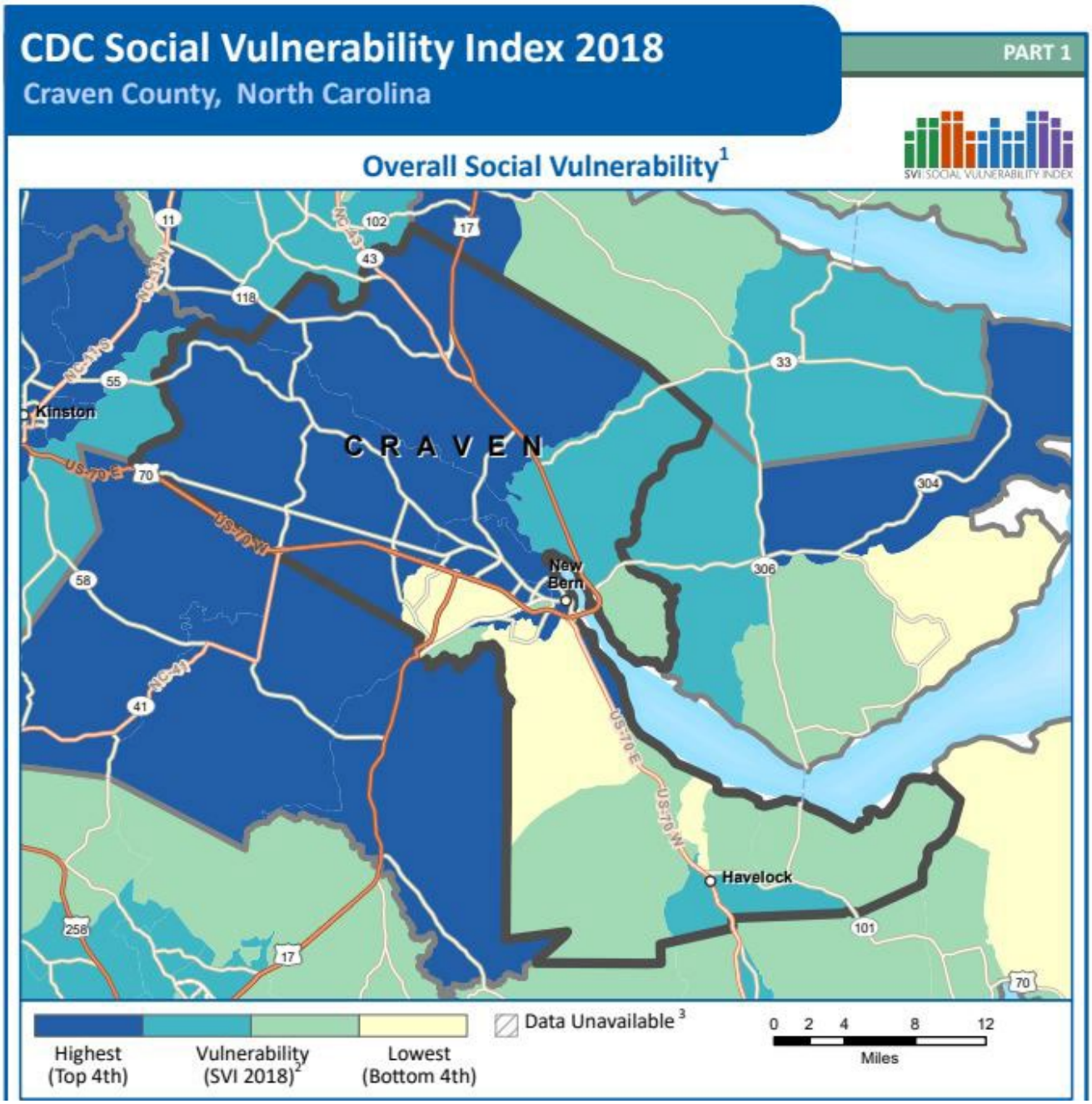
Social Vulnerability Index

The Centers for Disease Control and Prevention Social Vulnerability Index (CDC SVI) was used to further evaluate social vulnerability within the focus area by assessing overall SVI percentile rankings at the census tract scale. The CDC SVI depicts the social vulnerability of communities by assigning an SVI percentile ranking that ranges from 0 (lowest vulnerability) to 1.0 (highest vulnerability) based on national comparisons. The overall CDC SVI ranking for Carteret County ranges from 0.25 to 0.5, which indicates a moderate level of vulnerability within the focus area. At a more refined scale, census tracts within sections of Morehead City have higher CDC SVI rankings (>0.7501) as compared with the rest of the county, indicating a high level of social vulnerability (**Figure 17**). Craven County has an overall SVI ranking >0.75, indicating the highest level of social vulnerability as a county (**Figure 18**). The North Carolina Appendix provides additional detail about the CDC SVI.



[1]Overall Social Vulnerability: All 15 variables.
[2]Data Sources: CDC/ATSDR/GRASP, U.S. Census Bureau, Esri StreetMap TM Premium.
[3]Census tracts with 0 population.

Figure 17: Carteret County Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)



[1]*Overall Social Vulnerability: All 15 variables.*

[2]*Data Sources: CDC/ATSDR/GRASP, U.S. Census Bureau, Esri StreetMap TM Premium.*

[3]*Census tracts with 0 population.*

Figure 18: Craven County Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)

Environmental Justice

USACE conducted an evaluation of environmental justice (EJ) by determining whether the study area contains a concentration of minority and/or low-income populations.

As defined in Executive Order 12898 and the Council on Environmental Quality (CEQ) guidance, a minority population occurs where one or both of the following conditions are met within a given geographic area:

- American Indian, Alaskan Native, Asian, Pacific Islander, Black, or Hispanic population of the affected area exceeds 50 percent.
- Minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis.

An affected geographic area consists of a low-income population where the percentage of low-income persons:

- is at least 50 percent of the total population, or
- is meaningfully greater than the low-income population percentage in the general population or other appropriate unit of geographic analysis.

The Environmental Protection Agency EJScreen is an EJ mapping and screening tool that provides the EPA with a nationally consistent dataset and approach for combining environmental and demographic indicators (EPA 2020). EJScreen users choose a geographic area; the tool then provides demographic and environmental information for that area. For the purposes of this evaluation, only demographic information was applied to the area.

The low-income population is the percentage of a block group's population in households where the household income is less than or equal to twice the federal "poverty level."

The minority population is the percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino (i.e., all people other than non-Hispanic, white-alone individuals). The word "alone" in this case indicates that the person is of a single race, not multiracial.

Using the EJScreen tool, the study area was user-defined (**Figure 19** and **Figure 20**) to calculate the average percentages for EJ criteria. The result is a population-weighted average, which equals the block group indicator values averaged over all residents estimated to be inside the study area. **Table 13** compares the average percentages for the study area, the State of North Carolina, and the United States.

Based on the information provided by the EJScreen tool, for Carteret County, the average minority population is approximately 14 percent of the total population, and approximately 28 percent of the population are considered low-income. When assessed at a county-level geographic scale, Carteret County does not meet the EJ community minimum threshold because the minority population and low-income percentages are below 50 percent. For Craven County, the minority population and low-

income population are both approximately 34 percent of the total population. While these are overall county estimates, 2019 Census Bureau estimates show projections varying from one census tract to another. In Craven County, the New Bern area has a high percentage of minority population, and New Bern, Havelock, and the northwestern portion of the county have a high percentage of low-income residents.

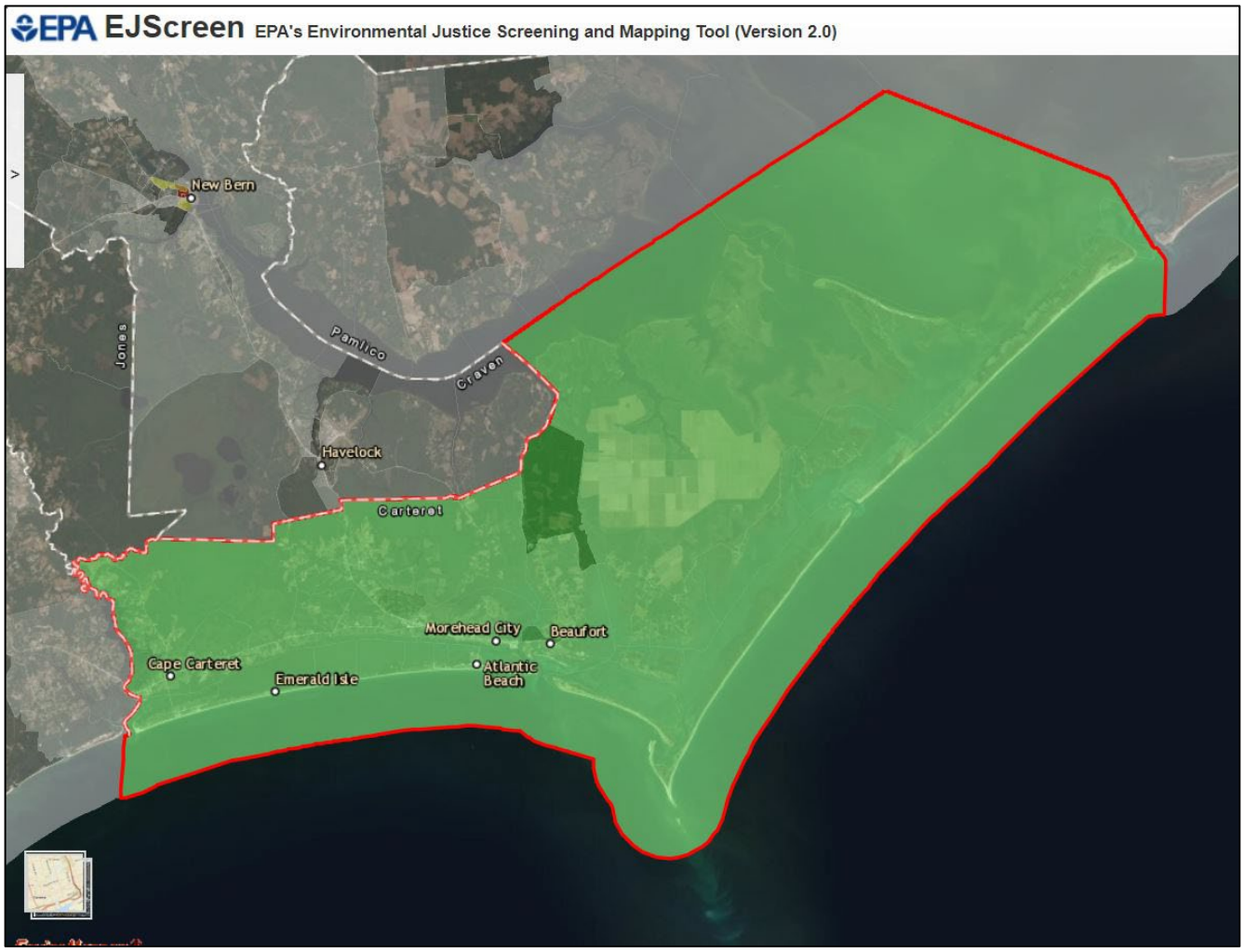


Figure 19: User-Defined Environmental Protection Agency EJScreen Tool Analysis Boundary for Carteret County (EPA 2020)

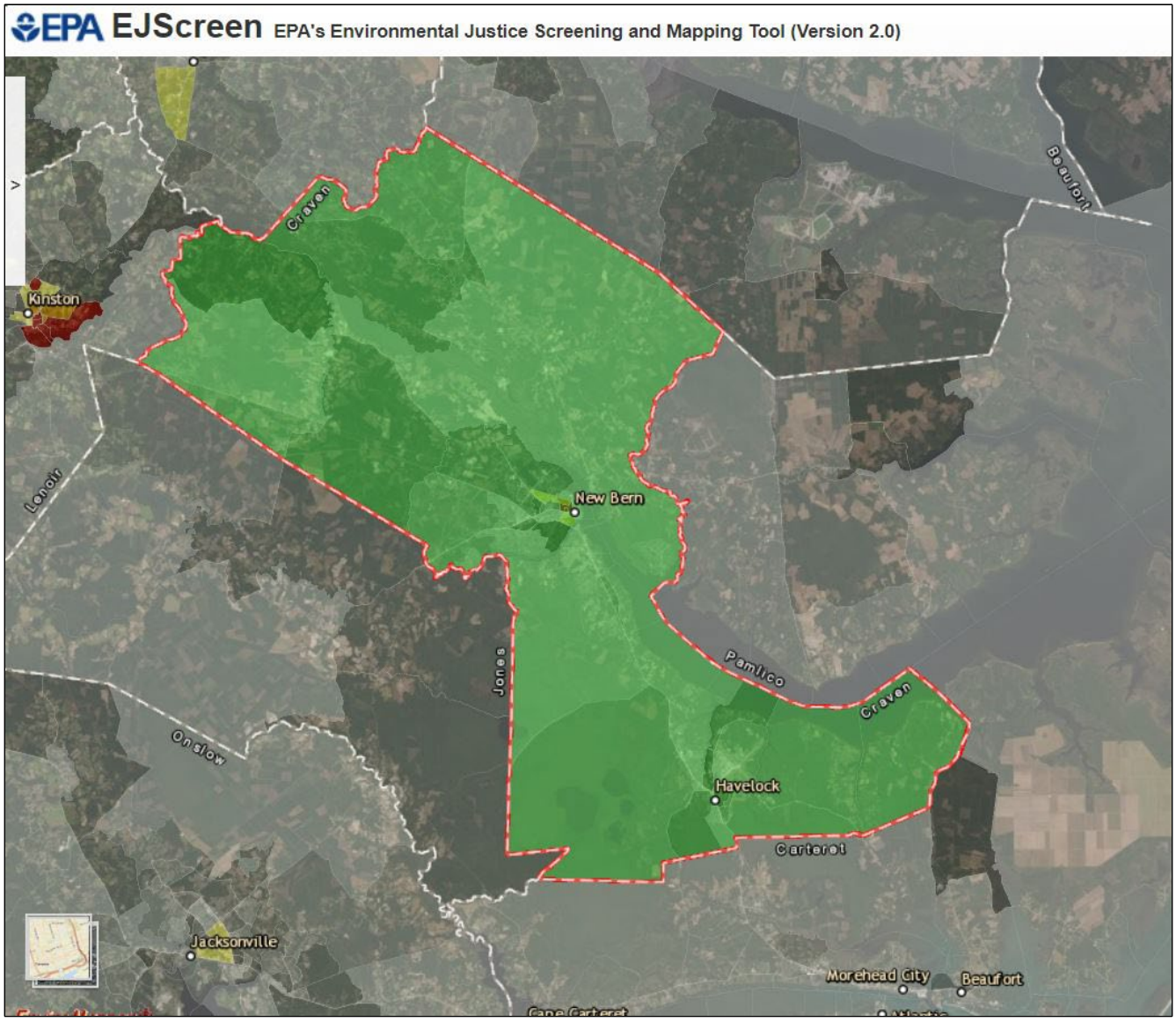


Figure 20: User-Defined Environmental Protection Agency EJScreen Tool Analysis Boundary for Craven County (EPA 2020)

Table 13: Environmental Protection Agency EJScreen Tool Environmental Justice Criteria Percentages (EPA 2020)

Population Type	User-Defined Project Area % Carteret/Craven	North Carolina Average %	U.S. Average %
Minority Population	14/34	47	39
Low Income Population	28/34	36	33

4.4.2 Environmental Vulnerability

An environmental resources vulnerability analysis was conducted for the Carteret and Craven Counties Focus Area to determine the degree to which natural areas are susceptible to loss or degradation when exposed to coastal storm hazards and sea level rise. A table was created from this analysis to assess the numerical level of vulnerability of natural habitats, which are assigned by the NOAA Coastal Change Analysis Program (C-CAP), against the hazards of sea level rise, storm surge inundation, saltwater intrusion, erosion, and wind damage. Based on the results of this assessment, a weighted formula was developed to assign a vulnerability rating of each C-CAP class (low, medium, or high) for each state and territory in the SACS study area (**Table 15**). **Figure 21** presents the results of the vulnerability scoring for each C-CAP habitat found within the focus area.

Table 14: Coastal Change Analysis Program Classes Vulnerability Rating

Coastal Change Analysis Program (C-CAP) Habitat	Vulnerability Rating
Evergreen Forest	Medium
Grassland	Medium
Deciduous Forest	Medium
Mixed Forest	High
Unconsolidated Shore	Medium
Estuarine Forested Wetland	Low
Estuarine Emergent Wetland	Low
Palustrine Emergent Wetland (Persistent)	Medium
Palustrine Scrub/Shrub Wetland	Medium
Palustrine Forested Wetland	Medium
Palustrine Aquatic Bed	Medium
Scrub/Shrub	Medium
Estuarine Scrub/Shrub Wetland	Low
Open Water	Medium
Estuarine Aquatic Bed	Low

In addition to rating the vulnerability of the natural habitats to the hazards identified above, the ability for the natural habitat to adapt to these conditions was also assessed. Low tolerances of certain habitats to water and soil chemistry changes caused by saltwater inundation, intrusion, and impediments to migration were identified as important vulnerability considerations. Anthropogenic activities, such as increased residential and commercial development in the coastal plain and the construction of structural coastal storm risk management infrastructure (e.g., sea walls), can produce barriers that impede inland migration of natural resources.

Please see Appendix B of the Environmental Technical Report for a more detailed summary of the resource vulnerability table and scoring criteria.

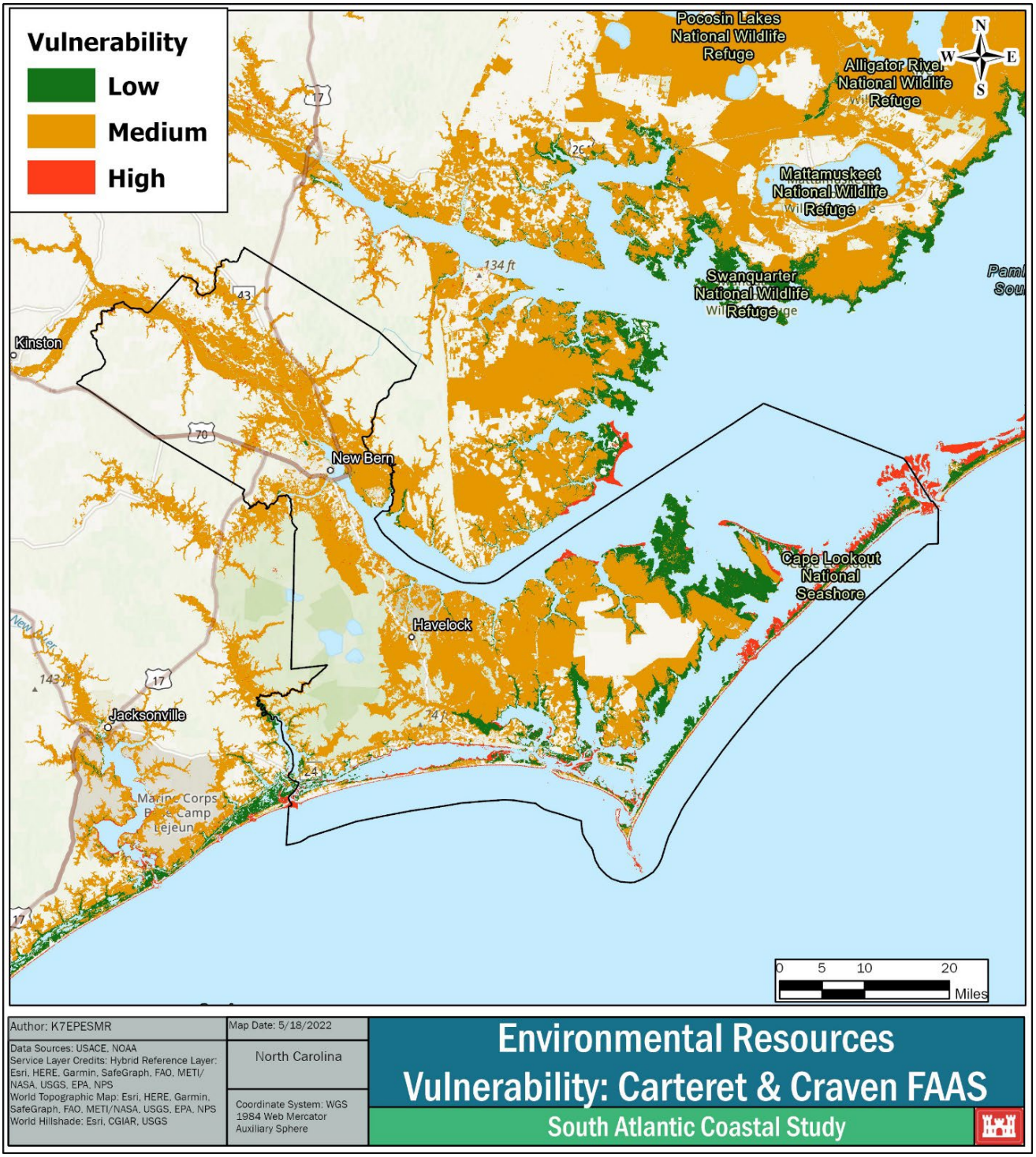


Figure 21: Carteret County and Craven County Vulnerability Rating for Coastal Change Analysis Program Habitats

4.5 Consequences

This focus area has been repeatedly impacted by coastal storms over the years. Hurricane Florence in 2018 provides an example of the catastrophic consequences that can occur in this area. Storm surge and exceptionally high rainfall totals produced catastrophic flooding across much of southeastern and eastern North Carolina, with the hardest hit areas including New Bern, Newport, and portions of Carteret County. Florence also produced extensive wind damage along the North Carolina coast, from Cape Lookout southwestward across Carteret, Onslow, Pender, and New Hanover Counties. Thousands of downed trees caused widespread power outages to nearly all of eastern North Carolina. Economic damages in the City of New Bern alone were over $100 million. According to the National Hurricane Center, rainfall across Carteret County led to flooding of the Newport River for the first time in recent history, as the river overflowed its banks and inundated many homes and businesses, resulting in hundreds of water rescues. U.S. Highway 70 was closed in numerous spots between Havelock and Morehead City due to floodwaters.

Consequences are measured in terms of metrics such as economic damage, acreage of habitat lost, value of crop damage, and potential loss of life. The Tier 1 and Tier 2 analyses incorporated both vulnerability and consequence in the overall risk assessment. The FEMA Hazus Flood Model uses damage functions to represent the vulnerability of different types of infrastructure to flood hazards. The consequences of infrastructure impacts are represented in dollar-damages through the Tier 2 Economic Risk Assessment. Social vulnerability was assessed during the Tier 1 Risk Assessment with consequences including life loss and relocation of vulnerable populations.

4.6 Risk Assessment

Population, infrastructure, environmental, and cultural resources are at risk within the Carteret and Craven Counties Focus Area. The risk is driven by a combination of factors, including wave attack, erosion, and inundation from coastal storms. This risk will increase as sea level rises.

4.6.1 Priority Environmental Areas

Four PEAs were identified within, or partially within, the Carteret and Craven Counties Focus Area. These areas were identified through collaboration with multiple state and federal stakeholders.

Cape Lookout National Seashore

Located near the Beaufort, Harkers Island, Marshallberg, Davis, and Portsmouth census places and the Lenoxville, Stacy, Sealevel, and Lola non-census places in Carteret County, the Cape Lookout National Seashore contains approximately 28,200 acres of ocean beach, sand dunes, shrub thicket, deciduous/evergreen/mixed forest, brackish and freshwater marshes, tidal flats, and tidal wetlands.

Managed by the National Park Service, the seashore preserves a 56-mile section of the southern Outer Banks, from Ocracoke Inlet to Beaufort Inlet, and contains habitat for a variety of animals, including reptiles, over 250 species of birds, and mammals. Additionally, the seashore provides critical habitat for a variety of different types of beach-nesting birds, especially in the summer months, and provides sea turtle nesting habitat for multiple species. Four protection zones for nesting birds and sea turtles are within the seashore's boundaries. Shackleford Banks, situated toward the western extent of the seashore, is home to a unique population of wild horses.

Cedar Island National Wildlife Refuge

Located near the Cedar Island, Godwin Hills, Roe, and Lola non-census places in Carteret County, Cedar Island National Wildlife Refuge contains approximately 14,400 acres of maritime shrub, marsh (e.g., brackish and freshwater), cypress-gum swamp, bay forest, low pocosin, pond pine woodlands, and longleaf pine-coastal fringe sandhill habitat.

Managed by the U.S. Fish and Wildlife Service, the refuge contains habitat for a variety of animals, including numerous reptiles, over 250 species of birds, and various mammals. Refuge marshes are some of the most important locations for breeding black rails, a species of special management concern in the southeast and newly listed as federally threatened as of November 9, 2020.

Croatan National Forest

Located in or near the New Bern, Brices Creek, Neuse Forest, and Havelock census places and the Riverdale, Pine Grove, Slocum Village, Havelock Station, Hancock Village, Cherry Point, Blades, Harlowe, and North Harlow non-census places in Craven County, as well as the Peletier, Cedar Point, Cape Carteret, Bogue, Broad Creek, and Newport census places and the Stella, Ocean, Wildwood, Holly Springs, and Union Point non-census places in Carteret County, the Croatan National Forest contains 159,000 acres of estuary, hardwood forest, longleaf pine, and pocosin.

Managed by the U.S. Forest Service, the forest is home to a variety of marine and terrestrial animals. Examples of wildlife include black bear, raccoon, squirrel, bobcat, river otter, muskrat, mink, a variety of reptiles and amphibians, as well as osprey, peregrine falcon, various owls, quail, bald eagle, wild turkey, and American alligator. The forest is abundant with pine trees, including old growth longleaf pine stands, which provide habitat to the endangered red-cockaded woodpecker. There are many hardwood areas, including communities of cypress trees in swamps. Carnivorous plants such as Venus flytraps, sundew, and pitcher plants are also found within the forest. There are a few sandy areas that provide pristine habitat for eastern diamondback rattlesnakes. The tannic-stained blackwater present throughout the forest serves as habitat to several species of fish that thrive in the forest's unique riverine conditions. Furthermore, the forest contains four officially designated wilderness areas that are part of the National Wilderness Preservation System.

Upper Broad Creek Natural Area

Located partially within the Fairfield Harbour census place in Craven County, The Upper Broad Creek Natural Area contains approximately 5,300 acres of tidal and forested wetlands in close proximity to developed areas. Managed by the North Carolina Wildlife Resources Commission, the area is home to species typically found in brackish waters because of its proximity to the mouth of the Neuse River. Protected species such as manatees periodically visit the area’s waters.

Potential strategies and measures to protect particularly vulnerable parts of identified PEAs include building a comprehensive actionable plan for stormwater management in unincorporated areas overlapping with managed lands, constructing living shorelines to protect habitats and marshes from wave action and erosion, using dredged material beneficially to support marsh or beach resiliency, implementing sediment management strategies to support beach nourishment and island breach repairs, and studying and monitoring benchmark surface elevation in wetlands to better understand the effects of sea level rise in terms of habitat inundation.

4.6.2 Population and Infrastructure Risk

As shown in the SACS Tier 2 Economic Risk Assessment, North Carolina ranks third in terms of economic risk among the states and territories within the SACS area, behind South Carolina and Florida. North Carolina ranks lower in risk than these two other states likely due to existing strategies to limit high-density development in vulnerable coastal areas, including preserving large amounts of natural shoreline along areas such as Cape Lookout and Hammock Beach State Park. However, analysis also shows that North Carolina has the highest increase in future economic risk among all states when accounting for sea level rise. This is due to the large extent of North Carolina's low-lying areas—many of which are in back bay areas such as the Pamlico and Core Sounds. Additionally, North Carolina is a top five destination state for people to relocate to (News and Observer 2020), and many people will continue to move into coastal areas while coastal storm risk increases.

Figure 22 illustrates future projected development overlaid with future flood hazard when accounting for sea level rise (note that Integrated Climate and Land-Use Scenarios data do not consider any local land use ordinances or protections). This illustrates the importance of existing strategies such as the North Carolina Climate Risk Assessment and Resilience Plan, which is further discussed in Section 5 of this report.

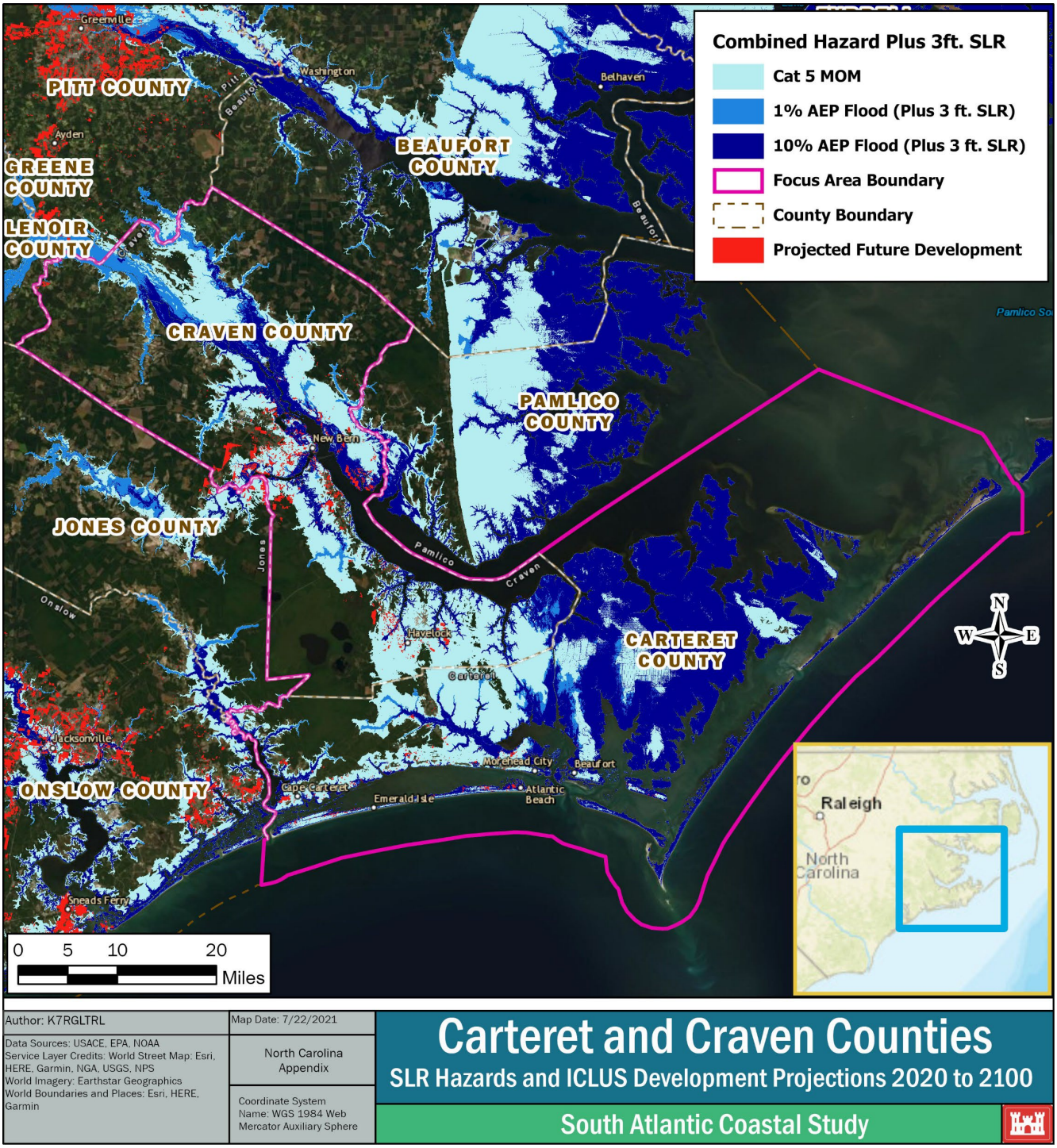


Figure 22: U.S. Environmental Protection Agency Integrated Climate and Land-Use Scenarios Data Overlaid with Sea Level Rise

Figure 23 provides a snapshot of the Tier 2 Economic Risk Assessment for the focus area. Each circle on the map denotes separate census places and displays the distribution of economic risk from low to high. Bar charts on the figure highlight the census places with the greatest economic risk, with quantifications of the existing (green shading) and future risks, including sea level rise (black shading). Economic risks displayed are not cumulative. The analysis includes National Economic Development risk and consequences of events. The total expected annual damages (EAD) for the Carteret and Craven Counties Focus Area are $60.4 million in the existing condition and $173.2 million in the future conditions, with 3 feet of sea level rise. Under existing conditions, a 2-percent AEP (50-year) flood event will cause $0.67 billion of damages and under future conditions, it would cause $1.9 billion of damages. The consequences are almost tripled for the future conditions with 3 feet of sea level rise. The census places with the greatest risk include Morehead City, New Bern, Atlantic Beach, Fairfield Harbor, and Beaufort.

Data derived from the Tier 2 Economic Risk Assessment realize the opportunity of gathering additional data on coastal hazards and vulnerability to refine current and future CSRM efforts. High-risk locations identified above are directly correlated with problems within the focus area identified in Section 2.1. This information, in conjunction with the suite of SACS products and tools, was used to develop draft action strategies.

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Focus Area

Carteret / Craven Counties

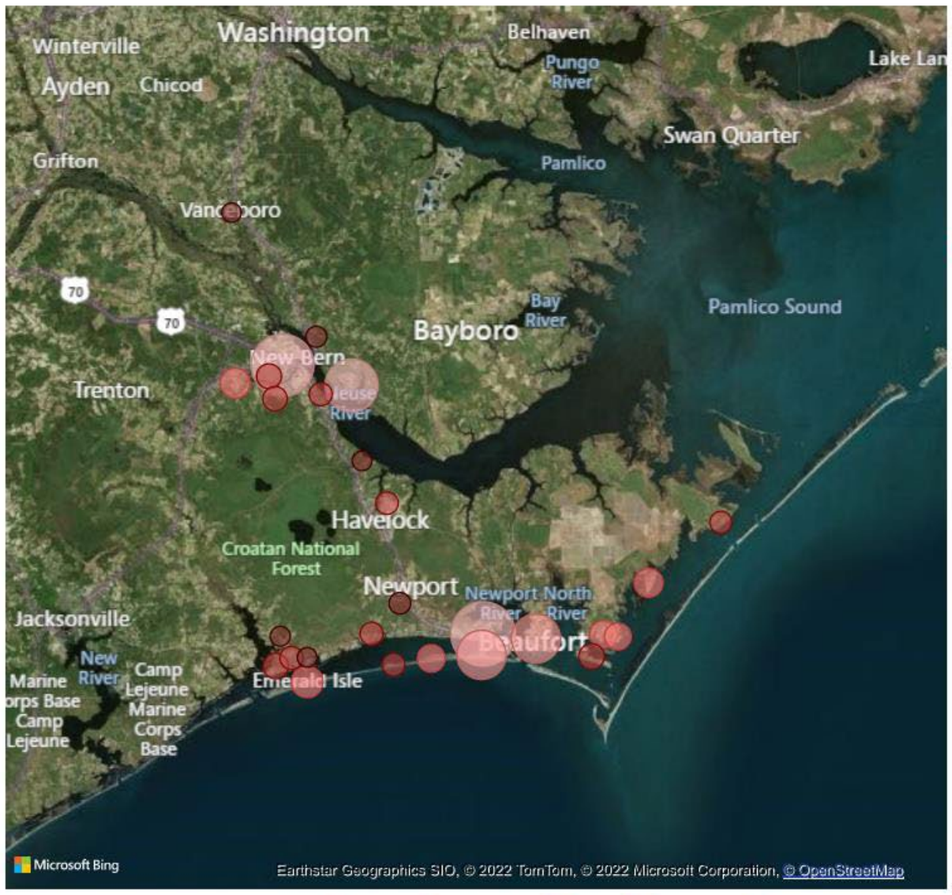
Carteret / Craven Counties

$60,358,470
Existing Risk ($EAD)

$173,242,162
Future Risk ($EAD)

Focus Area Risk by County

County	Existing Risk ($)	Future Risk ($)
Carteret	$46,047,326	$129,871,503
Craven	$14,311,144	$43,370,659
Total	**$60,358,470**	**$173,242,162**



Existing Consequences by Return Interval Event

Future Consequences by Return Interval Event

Existing Risk ($EAD) & Future Risk ($EAD) by Census Places in Focus Area

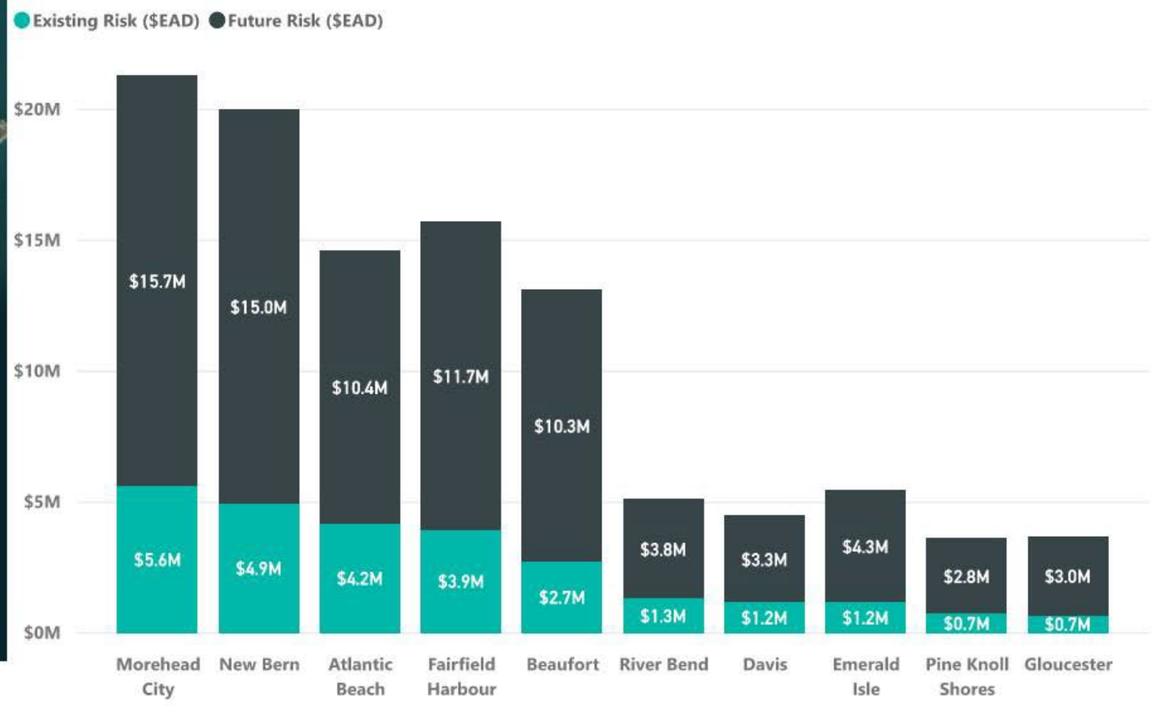


Figure 23: Existing and Future Economic Risk in Carteret and Craven Counties due to Storm Surge

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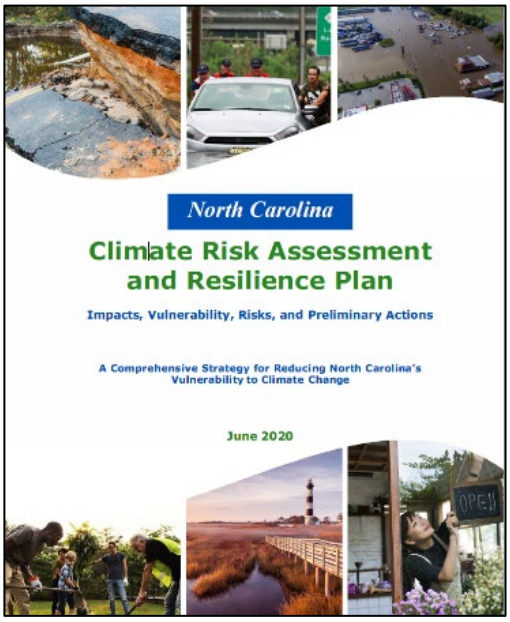
5. Action Strategy Development

North Carolina continues to be proactive with resiliency efforts along the coastline, and initiatives have been implemented or are planned throughout all levels of government, as well as by non-governmental entities. This FAAS for the Carteret and Craven Counties Focus Area within the scope of the SACS was developed in support of the significant ongoing efforts already at work within the region. One major existing strategy in North Carolina falls under the Governor's Executive Order 80 (North Carolina Office of the Governor 2018), which is a commitment to address climate change and transition to a clean energy economy. Within Executive Order 80 is the North Carolina Climate Risk Assessment and Resiliency Plan (NCDEQ 2020). This existing plan builds upon North Carolina's ongoing work in this area and establishes the North Carolina Resilience Strategy, which includes four elements:

1. North Carolina Climate Science Report
2. State Agency Resilience Strategy
3. Statewide Vulnerability Assessment and Resiliency Strategies
4. North Carolina Enhanced Hazard Mitigation Plan



Accordingly, the Carteret and Craven Counties FAAS report does not seek to create a strategy separate from significant and ongoing efforts, but to support those of the region and develop additional considerations for future federal and non-federal efforts. The scope of the SACS ties into several critical sectors of study within the North Carolina Climate Risk Assessment and Resiliency Plan, including coastal resources, ecosystems, housing, building and support services, public safety, and transportation. Where possible, the Carteret and Craven Counties FAAS seeks to contribute to the overall North Carolina Climate Risk Assessment and Resiliency Plan while supporting the SACS Shared Vision statement as created by the stakeholders of Carteret and Craven Counties.

5.1 Identify Possible Solutions

A series of workshops was held with focus area stakeholders to identify ongoing, planned, and needed actions to address problems and realize opportunities identified earlier in this report. Proposed actions were evaluated based on their ability to address those problems, realize opportunities, and contribute to the objectives. Actions were grouped into categories of Infrastructure and Mitigation, Sediment Management, and Education and Outreach.

There are several SACS key products that can be used to help identify measures and possible solutions. The SACS Measures and Cost Library (MCL) can be used to identify suitable measures based on wave energy (USACE 2022b). Planning-level rough-order-of-magnitude (ROM) cost estimates and the Tier 2 Economic Risk Assessment can be used to identify potential economic benefits. The 2020

RSM Optimization Update and SAND Report can be used to identify opportunities for RSM strategies and suitable sand sources. In general, measures are organized into structural, nonstructural, and NNBF.

- **Structural measure**: Structural measures consist of human-made structures designed to reduce the occurrence and/or severity of an event that leads to harm.
- **Nonstructural measure**: Nonstructural measures reduce risk by either removing the item of concern from the exposure or reducing the item's degree of vulnerability to the harm.
- **NNBF**: The use of natural features or the human design of features that mimic or work in concert with natural processes to meet a planning objective. NNBF can include policy, and may be considered a structural or nonstructural measure, depending on the feature.

The broad measures identified herein (structural, nonstructural, and NNBF) could be further developed to target specific areas for CSRM. The goal of alternatives development is to achieve the objectives by combining one or more measures while avoiding constraints. Measures identified will be further evaluated, screened, and used in combination (as appropriate) to determine area-specific project viability to meet the planning objectives. Components, or actions, of a strategy are characterized in **Table 15** of this report as one of several types of risk management measures. A risk management measure is defined for the purposes of this study as any feature or activity implemented at a specific location to meet one or more planning objectives.

Table 15: General Focus Area Issues and Potential Measures

Issues Identified in Carteret and Craven Counties Focus Area	Potential Measures		
	Structural	Nonstructural	NNBF
Damage to infrastructure from storm surge and erosion	• Build seawall/revetment • Build detached breakwaters • Build floodwalls and bulkheads • Perform beach nourishment	• Relocate utilities and critical infrastructure • Implement building codes and zoning • Elevate structures • Retreat the shoreline	• Build dunes • Create living shorelines (oyster sills, vegetation) • Restore wetland/ marsh
Loss of environmental resources due to storm surge and erosion	• Perform beach nourishment (habitat protection and expansion)	• Conduct stormwater management • Preservation • Conduct local permitting	• Create living shorelines • Restoration – wetland/ marsh • Conduct RSM (thin-layer placement – marsh resilience)
Road closures that impact life safety	• Seawall/revetments • Road elevations	• Relocate infrastructure	• Create living shoreline sill
Risk communication	• N/A	• Implement early warning systems • Educate and engage the public • Prepare emergency plans/hazard mitigation plans	• N/A
Cultural resource protection	• Build breakwater structures • Conduct RSM (erosional areas)	• Elevate or relocate structures • Conduct study/excavation of sites	• Create living shorelines

Each of the following identified actions have been organized as existing, planned, or needed actions. They are also identified as either actions led by USACE or if they are actions led by others.

5.1.1 Existing or Ongoing Actions

The following are actions that have already been implemented or are currently being implemented:

USACE Actions

- Conduct RSM at Morehead City Harbor, which includes Fort Macon State Park and Atlantic Beach.

Actions by Others

- Establish hurricane evacuation zones for Carteret and Craven Counties.
- Conduct coastal storm risk management and beachfill placement for Bogue Banks.
- Conduct the New Bern Flood Resiliency Study for the City of New Bern.
- North Carolina Resilient Coastal Communities Program, which is applicable to all 20 coastal counties, including Carteret and Craven Counties.
- Restore living shorelines and marshes, which includes approximately 22 projects.
- Participate in the ReBUILD NC Program, which is applicable to Carteret and Craven Counties.
- Participate in the FEMA Hazard Mitigation Grant Program, which is applicable to Carteret and Craven Counties.
- Form working groups, coalitions, and councils:
  - *North Carolina Sentinel Site Cooperative*
  - *Carteret, Craven, and Onslow Counties*
  - *The Collaboratory for Coastal Adaptation Over Space and time (C-CoAST)*
- North Carolina Coastal Community Resilience Guide, which is applicable to Carteret and Craven Counties.
- National Estuarine Research Reserve Program, including the Rachel Carson Reserve Living Shoreline.
- North Carolina Coastal Federation, CCC, and North Carolina Department of Transportation partner to protect education infrastructure, critical state roadways, and estuarine habitats with living shorelines.
- Conduct saltwater inundation and intrusion research.
- Working Lands Guidebooks, which are applicable to coastal farmlands in North Carolina, including Carteret and Craven Counties.

5.1.2 Planned Actions

The following actions are planned to be implemented:

USACE Actions

- Develop a statewide non-federal dredged material management plan through Section 22 Planning Assistance to States program.

Actions by Others

- Perform the Bogue Banks Master Beach Renourishment Plan (a CSRM Project).
- Conduct refuge management planning.
- Perform broadband infrastructure asset mapping for Down East communities (Carteret).

5.1.3 Needed Actions

The following actions were identified as potentially needed:

- Protection of Lola Road in Carteret County.
- Discuss an offshore resources sediment management strategy.
- Identify new Dredged Material Management Areas (DMMAs), upland placement, and/or marsh restoration.
- Implement an RSM Optimization Update strategy.
- Hold a community interest night, which is a risk and vulnerability workshop that provides guidance for Down East communities.
- Incorporate CHS and other risk and vulnerability data into the broadband infrastructure asset mapping for the Down East communities in Carteret County.
- Conduct an Albemarle-Pamlico Estuary back bay erosion/marsh restoration study.
- Conduct an enhanced building-level risk assessment.
- Implement recommendations from the New Bern Flood Resiliency Study.
- Develop a coupled model (freshwater rainfall and coastal storm surge) for North Carolina.
- Stakeholder Training Workshops of SACS Coastal Hazards System Data

5.2 Evaluation of Actions

The potential actions listed in Section 5.1 were compared with the identified problems and opportunities, and ultimately the overall study objectives that were developed through the stakeholder engagement process, keeping in focus the overarching goals of the shared vision statement.

Potential actions that contribute to at least one study objective were included in the FAAS. Any measures not directly contributing to an objective were screened out for the purposes of the SACS FAAS. However, it is recognized that these screened actions may be worthwhile efforts of value through a separate application. The following evaluation also reveals how specific actions are contributing to the problems, opportunities, and objectives of the strategy (**Table 16**).

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Table 16: Evaluation of Potential Actions - Connecting Actions to Identified Problems, Opportunities, and Objectives in the Carteret and Craven Counties Focus Area

Action Type	Recommended Action	P1	P2	P3	P4	P5	P6	P7	IOB 1	IOB 2	IOB 3	IOB 4	IOB 5	IOB 6	IOB 7	IOB 8	IOB 9	IOB 10	O1	O2	O3	O4	O5	O6	OBJ 1	OBJ2	G1	G2
Infrastructure and Mitigation	Neuse River Basin Flood Risk Management Study (USACE)					X																				X	
Infrastructure and Mitigation	New Bern Flood Resilience Study (City of New Bern)	X	X			X							X								X				X		
Infrastructure and Mitigation	Resilient Coastal Communities Program (NCDCM)	X	X		X	X		X		X						X	X								X		X
Infrastructure and Mitigation	Completed Living Shorelines (24 total)			X																	X					X		
Infrastructure and Mitigation	Refuge Management Planning			X															X			X				X		
Infrastructure and Mitigation	Home Elevations/Buyouts (FEMA Hazard Mitigation Grant Program)	X	X																						X			
Infrastructure and Mitigation	ReBUILD NC Strategic Buyout Program (North Carolina Office of Recovery and Resiliency)	X	X																						X			
Sediment Management	Statewide Non-Federal Dredged Material Management Plan (USACE/ NCDEQ)			X																	X					X		
Sediment Management	RSM Optimization Update Opportunities	X																								X		
Sediment Management	Bogue Banks CSRM (USACE Study/Local Project)	X		X																					X	X		
Education and Outreach	Establishment of Hurricane Evacuation Zones		X		X																				X			
Education and Outreach	North Carolina Coastal Community Resilience Guide (NCDCM)	X						X																	X	X		
Education and Outreach	Identification, Mitigation, and Adaptation to Salinization on Working Lands in the U.S. Southeast – Guidebooks (USDA)																											
Other Needed Actions	Silver Jackets: Down East Communities – Community Interest Night (USACE)	X	X				X									X									X			
Other Needed Actions	Protection of Lola Rd. in Carteret County		X	X	X	X										X					X		X		X		X	
Other Needed Actions	Back bay Erosion/Marsh Restoration Study – Albemarle-Pamlico Estuary System (USACE)			X														X	X		X	X			X	X	X	
Other Needed Actions	Silver Jackets Nonstructural Flood Risk Management Program – CHS Training Workshop	X	X					X															X		X			
Other Needed Actions	Headquarters-level Discussion for Potential Barrier Removal – FEMA Floodplain Maps (FEMA, USACE)													X														X
Other Needed Actions	Enhanced Building-level Risk Assessments (North Carolina Emergency Management, University of North Carolina Wilmington, USACE)	X	X																						X			

Action Type	Recommended Action	P1	P2	P3	P4	P5	P6	P7	IOB 1	IOB 2	IOB 3	IOB 4	IOB 5	IOB 6	IOB 7	IOB 8	IOB 9	IOB 10	O1	O2	O3	O4	O5	O6	OBJ 1	OBJ2	G1	G2
Other Needed Actions	RSM Optimization Update Opportunities Strategy			X																						X		
Other Needed Actions	Planning Assistance to States – Down East Community – Risk Asset Mapping (in support of BAND effort)	X																							X			
Other Needed Actions	Compound Flooding Modeling Effort (National Hurricane Center and National Water Center)					X						X													X		X	
Other Needed Actions	Offshore Sand Management Strategy Discussions (Bureau of Ocean Energy Management [BOEM], USACE, NCDCM)																							X				X
Other Needed Actions	Apply CHS to North Carolina Office of Recovery and Resiliency Strategic Buyout Program	X						X															X					X

Note: Orange shaded row denotes an action that was screened from the FAAS.

5.2.1 Evaluation of Needed Actions

This section discusses future needed actions in more detail, split between USACE actions and action led by other agencies.

5.2.1.1 Needed USACE Actions

Protection of Lola Road in Carteret County

Purpose and need: Lola Road in the far eastern end of Carteret County serves as the only transportation route for the citizens who live along this isolated region of the County. Much of the shoreline in this area has been previously fortified with rock to reduce erosion and protect homes. However, a stretch of natural area includes an eroding shoreline, which now comes within 20 feet of the road. Undermining of the road from erosion would present a life-safety issue for vehicles, and it would cut off residents from the rest of the county.

Potential benefits and impacts of action: Action taken to project this stretch of road could prevent future road closure due to erosion or overwash. There is the potential to incorporate ecological improvements through a solution with NNBF. **Figure 24** shows the threatened location along Lola Road.

Figure 24: Site of Potential Measure along Lola Road to Mitigate Erosion

The SACS MCL tool as well as data from the SAS CHS were utilized to evaluate potential measures that could be implemented for this problem.

After identifying the problem and assessing potential risk using SACS tools and stakeholder input, potential structural, nonstructural, and NNBF measures were identified (**Table 17**).

Table 17: Initial Measures for Lola Road in Carteret County

Lola Road in Carteret County
1.No Action (without project condition)
2. Structural Solution
a. Revetment
3. NNBF
b. Living Shoreline – Sills

The MCL tool provides a ROM cost estimate range for the selected measures including high and low values, equivalent annual costs (EAC), and the total first construction cost (**Table 18**). EAC is the annual cost range based over a 50-year analysis period. The MCL tool is useful in the preliminary stages of planning to efficiently identify a variety of possible solutions and obtain ROM costs for early comparison of measures.

Table 18: Measures and Cost Library - Derived Costs for Lola Road in Carteret County

Measure	Unit(s)		ROM Cost Range (EAC)	ROM Total First Construction Cost
Living Shoreline – Sills	Linear Feet	1,000	$76,000–$360,000	$2,055,000–$9,730,000
Revetment	Linear Feet	1,000	$249,000–$706,000	$6,721,000–$19,065,000

There are multiple measures that could be applied at Lola Road. Based on the MCL tool, a living shoreline sill appears to be an adequate measure for erosion control given the typical waves energy of the location, and it may be more economical than a revetment. The living shoreline sill would also have added habitat and aesthetic value.

Offshore Resources Sediment Management Strategy Discussion

Purpose and need: Section 3.1 of the SACS-funded SAND Report identifies areas of sand deficiencies in North Carolina, specifically in the southern portion of the state. The SAND Report indicates future discussions may be needed to update the SACS Geoportal database with offshore sand resources, coordinate stakeholder/USACE workshops to address sediment budget needs and optimization opportunities and establish a framework for statewide sediment resource management. Although the issue of availability of offshore sand resources may be more critical for areas south of Carteret County, there is likely a valuable long-term outcome for this focus area.

Potential benefits and impacts of action: Discussing an offshore resources management strategy could lead to developing a strategy for managing offshore sand resources and implementing actions specific to that strategy. This could help identify new sand sources and avoid multiple-user conflicts in North Carolina.

Albemarle-Pamlico Estuary Back Bay Erosion/Marsh Restoration Study

Purpose and need: The SACS indicates significant economic and environmental damage occurring in northeast North Carolina in the Albemarle-Pamlico and Currituck Sounds that will increase with sea level rise. The Albemarle-Pamlico Estuary System has been designated as an estuary of national significance by the U.S. Environmental Protection Agency. Authorization for a back bay study is needed to address coastal storm and sea level rise impacts to reduce economic and environmental damage.

Although there has been much focus on the changes along the oceanfront shoreline, shoreline dynamics along more sheltered estuaries, like those along the Albemarle-Pamlico Estuary System are an increasing concern. These boundary resources serve as critical habitat for a variety of ecosystem goods and services. It is vital to understand continued changes that coastal North Carolina will soon face so natural resources can be appropriately managed. Likewise, saltmarsh form critical habitats along these same estuarine shorelines. Research conducted by agencies such as NOAA and other stakeholders indicates marsh loss as an emerging problem and supports the need for subsequent analysis to identify areas of concern and potential management factors that could be implemented at these locations. Given the size of the peninsula system, it could require a multi-agency strategy, and effort should be made to maximize potential partnerships.

Potential benefits and impacts of action: This action would address a significant data gap in the back bay of an area of national significance, which would help to understand erosion rates, identify critical areas of habitat loss, and identify site-specific locations where ecosystem restoration measures could be implemented. This action would also identify risk areas for population and infrastructure in the back bay.

Incorporating Coastal Hazards System and other Vulnerability and Risk Data with Broadband Asset Mapping for the Down East Communities in Carteret County

Purpose and need: Reliable internet and broadband are necessities that affect all aspects of life and communication in the Down East communities in Carteret County. There are currently plans through the Building a New Digital (BAND) effort to expand broadband infrastructure. This effort should consider sea level rise and storm vulnerabilities. Data and/or tools from the SACS could potentially be used for this effort.

Potential benefits and impacts of action: Incorporating CHS data into the asset mapping effort will help make risk-informed decisions for broadband infrastructure investment. Carteret County's overall initiative goal is to improve quality of life for the citizens of the Down East communities.

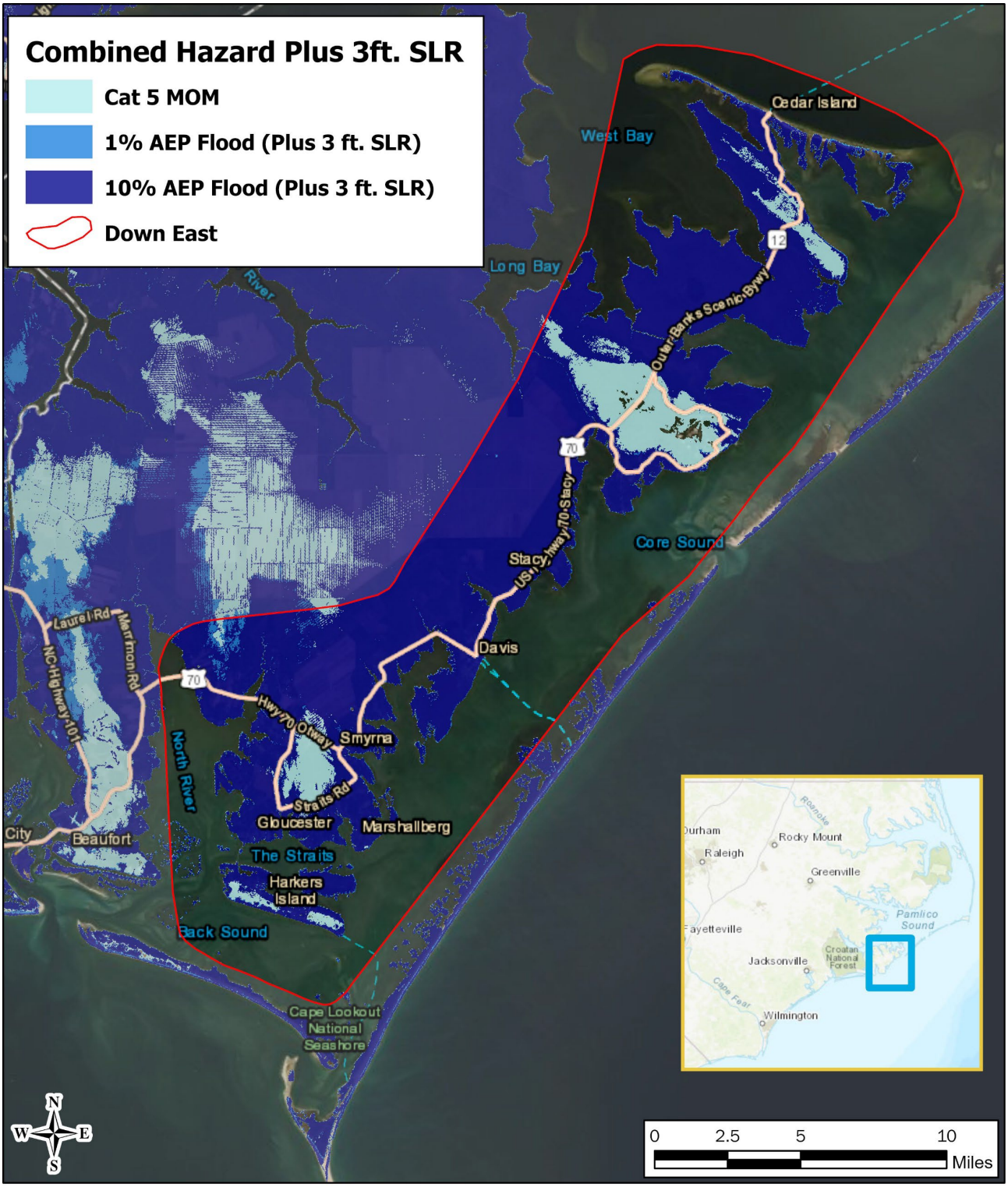

Figure 25: Inundation Hazard with Sea Level Rise in the Down East Communities of Carteret County

Community Interest Night – Down East Communities Risk and Vulnerability Education and Outreach

Purpose and need: If supported by the Down East Council, USACE would work with the council to host one or more community interest nights to educate the communities on SACS data and tools to provide practical guidance. A key goal would be to communicate the science and data and what local communities can understand and use. There would potentially be multiple sessions held—one in each community.

Potential benefits and impacts of action: The Down East communities in Carteret County are steeped in history and tradition, but citizens live within areas of higher risk of flooding from coastal storms. This risk will increase with sea level rise. Providing practical and useful guidance that local communities can use is a valuable education and outreach initiative. This effort should improve local citizens' ability to make risk-informed decisions on several issues that affect daily life. The goal is to increase community resilience.

Figure 26: Public Coordination in Coastal North Carolina (Photo Source: USACE)

Identify New Dredged Material Management Areas, Upland Placement, and/or Marsh Restoration

Purpose and need: Suggestions from both the RSM Optimization Update and the DMMA Offloading and Sediment Exchange Study were further discussed between the team, leadership, and the 2020 RSM Optimization Update team. Approximately 1.6 MCY of upland placement material could be diverted from the Morehead City Harbor project for RSM uses, including but not limited to beneficial use or marsh restoration. Recommendations for USACE include:

1. Work with the RSM Optimization Update team to ensure maximum efficiency of placement and overall health of the environment for each project.

2. Work with local and state stakeholder groups on placement opportunities.

Potential benefits and impacts of action: Improved sediment management, reduced lifecycle costs, enhanced partnerships with stakeholders, and more resilient projects and coastal communities are all benefits of RSM. Maximizing natural and economic efficiencies is critical to maintaining sustainable water resource projects as the total volume of USACE dredging has remained relatively stable over the past several decades while the cost of dredging has increased substantially (USACE 2020d). identifying new uses for upland material will maximize upland site capacity and potentially extend the life cycle of the site.

Stakeholder Training Workshops of SACS Coastal Hazards System Data

Purpose and need: This action would provide training as a workshop or series of workshops where potential users of the CHS wave and water level modeling data could learn about and be trained on the application of the data and related tools.

Potential benefits and impacts of action: This initiative would help ensure that stakeholders who may benefit from using CHS data are aware of its availability and application methods. The goal of the workshops would be to maximize use of the data where it would provide value for risk assessment, planning decisions, or coastal project designs.

5.2.1.2 Needed Actions by Others

Enhanced Building-Level Risk Assessment

Purpose and need: This action would include using CHS data and North Carolina Emergency Management building footprints to perform an enhanced building-level risk assessment for more targeted nonstructural measure evaluation. Stakeholder coordination has indicated that Carteret County and Craven County may be good candidates for initial use of this approach. With several significant hurricanes impacting North Carolina in recent times, there have been significant efforts toward structural mitigation, such as elevations and buyouts. An enhanced building-level risk assessment could be important to assessing future structural mitigation needs.

Potential benefits and impacts of action: A potential benefit of conducting building-level risk assessments instead of census block assessments is obtaining refined costs, which could ultimately improve benefit-cost ratios with the use of targeted buyouts. Improved benefit-cost ratios could help justify these nonstructural projects, such as building buyouts. North Carolina was the first to complete the United States Geological Survey 3D Elevation Program, providing building-level footprints that can be used for a variety of coastal research topics. Combined with the SACS-developed wave and water

levels from the CHS, this could provide a more targeted and strategic approach to coastal storm management, including improved benefit-cost ratios to assist with economic justification or elevations, buyouts, and relocations and could potentially identify suitable locations for infrastructure management actions like breakwaters or shoreline stabilization. University of North Carolina Wilmington staff have worked with the North Carolina LiDAR building footprints on other projects and expressed interest working with stakeholders to facilitate this process when CHS becomes available. USACE's Wilmington District has facilitated communication between those stakeholder groups interested in pursuing this action and will continue to do so as CHS data becomes available.

Develop Coupled Model for North Carolina

Purpose and Need: A coupled model (freshwater riverine and ocean storm surge) is needed for North Carolina to explain risk from coastal storms due to compound flooding. Significant damage has occurred in the state due to the combination of storm surge and inland freshwater rainfall from coastal storm events—Hurricanes Floyd in 1999, Matthew in 2016, and Florence in 2018. This is a complex modeling effort and the technological capabilities now exist to complete this project.

Potential benefits and impacts of action: A coupled model for North Carolina could provide greater projections of flood risk from coastal storms by accounting for both the coastal storm surge and the inland rainfall and how those 2 forces may combine to further increase flooding in specific areas. This information could assist decision-making by planners and emergency management officials. **Table 16** explains how each action relates to the problems, opportunities, barriers, and objectives identified by the stakeholders for the focus area.

5.2.2 Impacts of Sea Level Rise and Climate Change

As discussed in Section 4.1.3, sea level rise and climate change will increase exposure to hazards for low-lying coastal areas, including this focus area. The SACS uses a 3-foot sea level rise scenario, which is consistent with the USACE Intermediate Scenario for a 100-year projection and the USACE High Scenario for a 50-year projection. Sea level rise and climate change are fundamentally incorporated into the FAAS and were considered carefully by stakeholders when identifying specific problems and needs. Sea level rise scenarios were modeled throughout SACS using Hazus, the CHS, and the NOAA Sea Level Rise Viewer to estimate the severity of hazard due to sea level rise throughout the study area. Site-specific considerations for each project area beyond those already addressed in the SACS would likely be addressed during Tier 3 analysis follow-on activities with stakeholders.

5.2.3 Potential Benefits and Impacts

The FAAS includes a focused array of problems and needs, potential lead stakeholders, potential solutions, a summary of needed actions, a time frame for implementation, and potential funding sources. These elements are essential to make actionable recommendations and were coordinated closely with stakeholders. Potential benefits of the FAAS can be evaluated either individually as specific solutions to identified problems, or collectively as a system of solutions that address the shared vision. This report does not prioritize individual actions that make up the FAAS, although these actions could be prioritized to maximize finite resources. Prioritization could be based on several factors, including benefit-cost, time frame of incurring negative effects, or availability of authorities and funding. The FAAS provides a consistent platform to evaluate stakeholder-identified problems and needs in the focus area.

5.3 Focus Area Action Strategy

The Carteret and Craven Counties FAAS captures existing efforts and identifies needs and opportunities for future actions in Carteret and Craven Counties. This focus area includes several areas, such as the city of New Bern, which has sustained significant damage from coastal storm surge and riverine flooding; the Bogue Banks barrier island; high-value natural areas such as Cape Lookout and the Rachel Carson Reserve; and the socially vulnerable and low-lying communities of the Down East region.

The data from the SACS and many other studies provide consensus that this area is highly vulnerable and will increase in risk and vulnerability with continued hazards such as coastal storms, erosion, and sea level rise. The shared vision statement developed by the stakeholder group reflects the economic and environmental value of the area, as well as the social resilience of the communities that have lived there for generations. The vision strives toward a balance of those values with a goal to continue that balance to benefit future generations.

The actions identified within the FAAS work to address the identified problems and realize opportunities. Specific components of the strategy that translate into future needed actions are also documented as Recommendations in Section 6 Actions have been organized into three themes: sediment management, infrastructure and mitigation, and education and outreach. These components are outlined in Section 5.1 and are discussed in **Table 19**, which includes details for each action and paths to implement future needed actions.

Table 19: Actions Developed for Carteret and Craven Counties Focus Area

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority: (high, medium, low)	Potential Funding Source
Completed	NNBF	Completed Living Shorelines	Projects	There are approximately 21 completed living shorelines in the area.	Various locations in Carteret County	Various federal/non-federal entities and NGOs	–	–	–	–
Completed	Nonstructural	North Carolina Coastal Community Resiliency Guide	Outreach/Education	This online interactive North Carolina Coastal Communities Resilience Guide is designed to walk users through some of the key steps and questions required for effective community- level resiliency planning while pointing to relevant tools, resources, and examples. The guide outlines a process for building resilience and climate change considerations into existing efforts such as comprehensive land use, hazard mitigation, or capital improvement planning while also focusing on other co-beneficial strategies for reducing risk in your community. The primary audience for this guide is local government staff and officials in the coastal region of North Carolina. NCDCM's goal is to update and adapt this online tool over time.	Applicable in the focus area	North Carolina Division of Coastal Management (NCDEM)	–	–	–	State
Ongoing	Nonstructural	Neuse River Basin Flood Risk Management Study	Study	This is a congressionally authorized study to investigate and formulate measures to address flood risk in the Neuse River Basin. The study area includes Craven County. Potential flood risk management measures could include structural, nonstructural and/or NNBF that contribute to the reduction of flood damage and life safety risk.	Entire Neuse River Basin, including Craven County	USACE, NCDEQ	–	Mid	Medium	USACE (through Public Law 116-20)
Ongoing	NNBF	Bogue Banks CSRM Project	Beachfill	The Bogue CSRM project is currently moving towards construction by the local sponsor. USACE has coordinated on the offshore geotechnical investigation and established borrow sources for the 50-year life of the project.	Bogue Island	Local	–	–	–	–
Ongoing	Nonstructural	Establishment of Hurricane Evacuation Zones	Policy	In coordination with a recent initiative implemented in 2019, 20 coastal counties, including Carteret and Craven, have established predetermined evacuation zones to simplify the coastal evacuation process in the event of an emergency. The initiative is titled "Know Your Zone." North Carolina Know Your Zone is a tiered evacuation system that highlights areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards. The Know Your Zone lookup tool is a color-coded interactive map residents and visitors can use to determine the evacuation zone where they live, work, or are visiting based upon a street address. Evacuation zones highlight areas most at risk to storm surge and flooding. Know Your Zone is intended to streamline the evacuation process by supporting personal readiness in preparation for hazardous weather events. When a storm is approaching, local officials in Carteret and Craven Counties will determine the zones that are most threatened to assess which residents should evacuate.	Carteret County and Craven County	North Carolina Emergency Management (NCEM), Carteret County, Craven County	Implemented. Public outreach is ongoing	–	–	–
Ongoing	Nonstructural	Down East Community – BAND Economy in North Carolina	Study	Reliable internet and broadband are a necessity that affects all aspects of life and communication in the Down East communities in Carteret County. There are currently plans through the BAND effort to expand broadband infrastructure. This effort should consider sea level rise and storm vulnerabilities. Data and/or tools from the SACS could potentially be used for this effort.	Carteret County – Down East Communities	Carteret County Economic Development Foundation	–	Short	Medium	Carteret County Economic Development Foundation; EIS grant
Ongoing	Nonstructural	New Bern Flood Resiliency Study	Study	The City of New Bern is engaged in a process to develop a resiliency and hazard mitigation plan to enhance overall community resilience, better understand flood risk within the community, and identify potential flood mitigation solutions. The purpose of this effort is to create a more resilient New Bern.	City of New Bern (Craven County)	City of New Bern	–	Short	High	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority: (high, medium, low)	Potential Funding Source
ongoing	Nonstructural	Home Elevations/Buyouts	Unknown	This FEMA program helps homeowners through the Hazard Mitigation Grant Program.	Statewide, but applicable in coastal counties	FEMA/State of North Carolina	FEMA Hazard Mitigation Grant Program	Mid	–	FEMA
Ongoing	Nonstructural	ReBUILD NC Homeowner Recovery Program	Program	The Homeowner Recovery Program helps repair, reconstruct, replace, or elevate homes or reimburse residents for completed repairs for homes that were damaged by Hurricane Florence or Matthew.	Statewide, but applicable in coastal counties	North Carolina Office of Recovery and Resiliency (NCORR)	Housing and Affordable Rental Program	Short	High	–
Ongoing	Nonstructural	ReBUILD NC Strategic Buyout Program	Program	This program enables eligible property owners, located in areas that are prone to repeated flooding, to relocate to safer land. NCORR provides financial incentives to homeowners to remain in communities. The affordable housing program focuses on constructing affordable and safe housing.	Statewide, but applicable in coastal counties	NCORR	Strategic Buyout Program	Short	High	–
Ongoing	Nonstructural	Working Lands Climate & Salinization Study – Guidebooks	Outreach/Education	Guidebooks are being produced as part of research on sustainability of working/agricultural lands in the face of saltwater intrusion and inundation. These are intended to be used as a tool to help farmers adapt to changes occurring due to sea level rise and coastal storms.	Applicable statewide, including working lands in Carteret and Craven Counties	Mike Govazzi (USDA) - Program Coordinator for Southeast Hub	USDA	Short	–	USDA
Planned	Nonstructural	Statewide Non-Federal Coastal Dredged Material Management Plan Study	Study	The North Carolina Division of Water Resources and USACE are partnering to develop a statewide non-federal dredged material management plan. Coastal dredged material placement facilities will be evaluated to identify current non-federal conditions, capacities, and placement needs of each site. This information will be essential for the State of North Carolina to determine future dredge material capacity needs, capacity restoration efforts at current sites, and to determine what new placement sites must be developed or acquired, including for beneficial use. This Planning Assistance to States (PAS) study will only assess the non-federal components of a dredged material management plan. The study will focus on dredged material placement facilities owned, operated, or managed by the State of North Carolina, local municipalities, private marinas, conservation groups, and other non-federal stakeholders that are located along or adjacent to the AIWW.	AIWW (statewide)	USACE, North Carolina Division of Water Resources	Study initiation January 2021	Short	High	USACE Planning Assistance to States (PAS) program; NCDEQ
Planned	All	Resilient Coastal Communities Program	Study/Projects	The North Carolina Resilient Coastal Communities Program aims to facilitate a community-driven process for setting coastal resilience goals, assess existing and needed local capacity, and identify and prioritize projects to enhance community resilience to coastal hazards. Participating communities will walk through a framework leading to the development of "shovel-ready" projects. Local governments throughout the 20 coastal counties will be eligible to apply for direct technical assistance to complete a community engagement process, risk and vulnerability assessment, and develop a resilience project portfolio. The four phases of the program include: Phase 1: Community Engagement and Risk and Vulnerability Assessment Phase 2: Planning, Project Selection and Prioritization Phase 3: Engineering and Design Phase 4: Implementation	To be determined. All 20 coastal counties are eligible to apply.	NCDCM	–	Mid	High	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority: (high, medium, low)	Potential Funding Source
Planned	NNBF	Refuge Management Planning	Study	Conduct refuge management planning for all refuges within the Cape Fear and the Albemarle-Pamlico Estuary System (APES) region. This includes shoreline and estuarine habitat management goals for listed species and other trust resources.	APES, including Alligator River National Wildlife Refuge	USFWS	–	Mid	Medium	USFWS
Planned	Nonstructural	Compound Flooding Modeling Effort	Study	Parts of southeastern North Carolina have been impacted by a combination of inland rainfall from coastal storms, plus storm surge. Determine if there is interest, support, and capability to pursue a modeling effort that captures both storm surge and inland rainfall from coastal storms.	Eastern NC	NOAA	–	Mid	High	NOAA
Needed	NNBF	Protection of Lola Rd in Carteret County	Study	Lola Road in the far eastern end of Carteret County serves as the only transportation route for the citizens who live along this isolated region of the County. A stretch of natural area includes an eroding shoreline, which now comes within 20 feet of the road. Undermining of the road from erosion would present a life-safety issue for vehicles, and it would cut off residents from the rest of the county. Action taken to project this stretch of road could prevent future road closure due to erosion or overwash.	Lola Road in eastern Carteret County	USACE, Carteret County	1. identify eligible non-Federal partner on need/solutions; 2. Submit study initiation request for CAP 14.	Short	High	USACE CAP Section 14
Needed	NNBF	RSM Optimization Update Opportunities	Beneficial Use	The RSM Optimization Update indicates opportunities for additional beneficial use of dredged material from Morehead City Harbor. Wilmington District is currently placing approximately 1.2 million CY of beach-quality material in a nearshore placement site 2 out of every 3 years. If material were placed in the active littoral system, an estimated $6 million in annual shoreline protection benefits to state and local government could be realized at no additional expense. Opportunities could also be explored to create or enhance coastal and wetland habitats.	Bogue Banks area	USACE	–	Mid	Low	USACE RSM
Needed	NNBF	Wetland/Fisheries Analysis	Study	Use cross-agency partnerships to identify the areas most appropriate for marsh restoration projects. Stakeholders from NOAA and BOEM have indicated the potential benefits of marsh restoration on the oceanfront and that more coordination with the U.S. Fish and Wildlife Service would be required to address fisheries habitat. To increase beneficial use of dredged material, appropriate locations would need to be identified for dredge material placement.	–	NOAA, USFWS, BOEM, USACE, National Fish and Wildlife Foundation	–	Mid	Low	–
Needed	Nonstructural	Statewide Offshore Sand Management Strategy Discussions	Coordination	Section 3.1 of the SACS-funded SAND Report identifies areas of sand deficiencies in North Carolina. The SAND Report indicates future discussions may be needed to move forward. Information from the SAND Report should be used to work with federal and state partners to identify management strategies to support multiple berm and dune project needs. Discussion topics may include strategies for finding new sand sources and strategies to manage finite resources.	Applicable statewide	USACE, BOEM, State of North Carolina	1. Establish agency POCs. 2. Coordinate kickoff discussion	Short	Medium	Collaborate Funding (e.g., for USACE - RSM or PAS)
Needed	Nonstructural	Down East Community Interest Night – Risk and Vulnerability Workshop/Guidance	Outreach/Education	If supported by the Down East Council, USACE would work with the council to host one or more Community Interest Nights for to provide practical guidance to the community on SACS data and tools. The intent of the outreach and education events would be to communicate the information and tools the SACS effort has produced and explain how the communities can use these to live more safely in this low-lying coastal area. There would potentially multiple sessions—one in each community.	Carteret County – Down East Communities	USACE, Down East Council	1. Work with partner to determine appropriate scope of outreach/content. 2. Request FPMS funds	Short	Medium	USACE FPMS

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority: (high, medium, low)	Potential Funding Source
Needed	Nonstructural	Back Bay Erosion Study Authorization for Albemarle-Pamlico Sound	Study	The SACS indicates significant economic and environmental damage occurring in northeast North Carolina in the Albemarle-Pamlico and Currituck Sounds that will increase with sea level rise. The Albemarle-Pamlico Estuary System is designated as an estuary of national significance. A back bay study is needed to identify erosion and wetland loss trends, and to help prioritize areas for future mitigation.	Albemarle and Pamlico Sounds	USACE	1. Draft scope of work for PAS study. 2. Identify non-federal partner. 3. Finalize scope and sign cost-sharing agreement. 4. Obtain Federal and non-Federal funds to begin work.	Short	High	USACE Planning Assistance to States
Needed	Nonstructural	Enhanced Building-Level Risk Assessment – Proof of Concept Exercise	Study	Use CHS data and NCEM building footprints to perform an enhanced building-level risk assessment for more targeted nonstructural measure evaluation. Long-term goals of conducting building-level risk assessments vs. by census block risk assessments would be to obtain enhanced/updated costs and ultimately improve benefit-cost with use of targeted buyouts. Improved benefit-cost ratios help justify projects. Building-level risk assessments helps target areas and refine costs. It significantly improves cost benefit analyses and a provides a more targeted strategy and improves building buyouts.	Various	NCEM, University of North Carolina Wilmington, NCORR, USACE	–	Mid	Medium	UNCW; NCORR
Needed	Nonstructural	Saltwater Inundation and Intrusion Research	Study	Scientific research should be conducted to further document and understand the sea level rise-related phenomena of saltwater intrusion and inundation, and its impacts in coastal North Carolina. Research may help identify adaptive measures.	Various	USDA, NC State University, East Carolina University, Duke University, others	Ongoing	Long	Low	–

[1]Timeframe: short = <2 years; mid = 2–10 years; long = >10 years

6. Recommendations

The focus area action strategy was developed to advance the shared vision and manage increased coastal storm risk as a result of sea level rise in the Carteret and Craven Counties Focus Area as shown in **Figure 27**. The shared vision is the overarching goal of the FAAS, broadly representing problems and opportunities stakeholders wish to address in the focus area. Resultingly, FAAS goals and objectives support the shared vision. SACS key products and other stakeholders' shared tools and data were used to support FAAS goals and objectives by assessing risk and identifying ongoing, planned, and needed actions to communicate and address the risk.

Figure 27: Focus Area Action Strategy Supports the Focus Area's Shared Vision

Recommendations are made for either multi-agency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and coordination with stakeholders throughout the focus area. Recommendations are organized into six categories, as shown in **Figure 28,** and three implementation timeframes (near-, mid-, and long-term). Importantly, follow-on study efforts should incorporate an integrated approach to the maximum extent practicable, including consideration of structural, nonstructural, and NNBF measures, as well as the shared responsibility of all stakeholders to contribute to coastal storm risk management. Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation timeframes include:

Figure 28: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.
- **Mid-Term Implementation (5-10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance emerging efforts to address coastal storm risk.
- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination before implementation and may be the most challenging to implement on regional scales from technical, political, or social perspectives. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term timeframe is reflective of the time to implementation based on immediate action to advance these recommendations which include complex issues such as land-use, zoning, and building codes. Given the uncertainty surrounding impacts from sea level rise and other factors (e.g., development trends), long-term recommendations may require reconsideration prior to implementation.

Table 20 provides the recommendations for the Carteret and Craven Counties Focus Area.

Table 20: Recommendations for the Carteret Craven Focus Area

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Activities and Areas Warranting Further Analysis	Mid-Term (5-10 years)	USACE	Community Interest Night - Down East Community (FPMS Special Study)	The USACE should coordinate with the Down East Council in Carteret County to develop and facilitate a community-based education event (or events) for the Down East communities built around SACS data and tools for practical risk assessments. The intent of the outreach and education events would be to bridge the gap between what information and tools the SACS effort has produced, and what the local community can use to help inform ways in which to live more safely in the years and decades ahead in this low-lying coastal area. This would be conducted by development of an interagency proposal and funding request through the Silver Jackets Non-structural Flood Risk Management (FPMS) program.	Stakeholder Collaboration
Study Efforts (follow-on USACE Planning Assistance to States (PAS) study)	Near-Term (<5 years)	Multi-Agency Action	Back Bay Erosion/Marsh Restoration Study – Albemarle-Pamlico Estuary System (APES) (USACE)	A study evaluating erosion trends, habitat loss and potential mitigation measures in the Albemarle-Pamlico Estuary System (APES) is needed to gain a better understanding of changes that coastal North Carolina is facing so that natural resources can be managed appropriately. The APES has been designated as an estuary of National Significance and is at continued risk of damage as a result of coastal storms and sea level rise as indicated by analysis within the SACS and other studies. This would be pursued under the USACE Planning Assistance to States (PAS) program.	Identify Non-Federal Sponsor (USACE Study)
Study Efforts (Activities under CAP)	Near-Term (<5 years)	USACE	Lola Road - Emergency Streambank and Shoreline Erosion Protection	An analysis to evaluate suitable shoreline stabilization adjacent to Lola Road in Carteret County is needed to prevent undermining of the only transportation route for residents in a portion of eastern Carteret County. Section 14 of the USACE Continuing Authorities Program could be pursued to meet this need through a partnership between USACE and an eligible non-federal entity.	Identify Non-Federal Sponsor (USACE Study)

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SOUTH ATLANTIC COASTAL STUDY (SACS)

Brunswick and New Hanover Counties Focus Area

FINAL REPORT

AUGUST 2022

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1. Introduction

This Focus Area Action Strategy (FAAS) identifies action strategies to reduce risk to coastal storms and increase resilience in the Brunswick and New Hanover Counties in North Carolina. The South Atlantic Coastal Study (SACS) key products and analyses were leveraged to assess existing and future conditions and quantify existing and potential risks. Stakeholders were engaged throughout the development of the Brunswick and New Hanover Counties FAAS to elicit feedback on problems and opportunities, identify and prioritize specific institutional and other barriers, and identify potential action strategies to improve resilience. Agencies invited to participate included the U.S. Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), the Bureau of Ocean Energy Management (BOEM), the U.S. Coast Guard, the Town of Leland, Carolina Beach, Kure Beach, Oak Island, Ocean Isle Beach, Holden Beach, Brunswick County, New Hanover County, and other local county and city officials. State agencies include the State of North Carolina, the North Carolina Department of Environmental Quality and Division of Coastal Management (NCDEQ DCM), the North Carolina National Estuarine Research Reserve System (NC NERRS), the North Carolina Wildlife Resources Commission (NC WRC), the North Carolina Department of Transportation's (NCDOT) Ferry Division, and the North Carolina Department of Public Safety. Private consultants and research and academic institutions include the architectural and engineering firm Moffatt & Nichol, and the University of North Carolina Wilmington (UNCW).

The FAAS was developed according to the Coastal Storm Risk Management (CSRM) Framework, an iterative process that gains resolution each time it is implemented. Under the Tier 1 analysis, national datasets were utilized to assess potential risk across the entire SACS study area, as documented in the SACS Main Report. For the Tier 2 analysis, more refined data, and analyses unique to each individual state or territory were incorporated. The Tier 2 analysis for the Brunswick and New Hanover Counties Focus Area is documented within the North Carolina Appendix. The FAAS is a third iteration of the SACS study framework, incorporating data and knowledge unique to the local area to identify risks to coastal storm events and develop potential strategies to address the identified risks.

This FAAS is carried out as part of SACS, which was authorized by Section 1204 of the Water Resources Development Act of 2016 as described in the Main Report. The FAAS refers to ongoing, planned, and needed actions to manage coastal storm risk based on stakeholder coordination conducted during Focus Area Vision Meetings, a series of interactive webinars held between July and December 2020. The status and description of actions provided in this report represents a snapshot in time, and specific actions may have been modified or the status may have been changed from the description provided. However, final recommendations resulting from stakeholder coordination on specific actions were updated to represent the most recent information as of June 2022.

Figure 1 shows the three focus areas selected within North Carolina for the SACS focus area action strategy development. Section 1.1 of this report discusses the study area for the Brunswick and New Hanover Counties Focus Area.

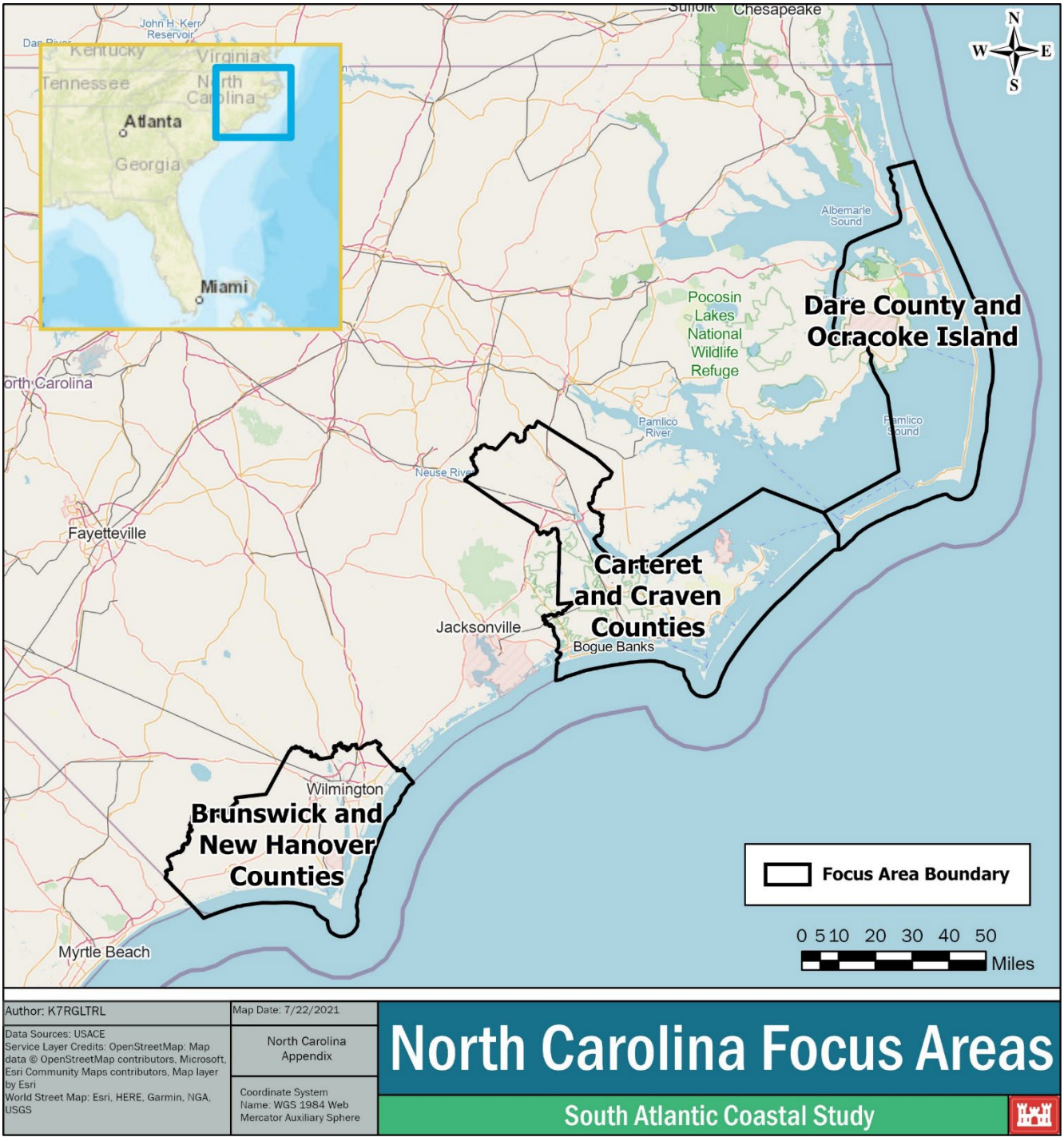


Figure 1: South Atlantic Coastal Study Focus Areas in North Carolina

1.1 Study Area

The Brunswick and New Hanover Counties Focus Area is in the southeastern tip of North Carolina, encompassing approximately 85 linear miles of ocean shoreline (**Figure 2**). The principal drainage for the focus area is the Cape Fear River, a 191-mile-long river flowing into the ocean near Cape Fear. The Atlantic Intracoastal Waterway (AIWW)—an inland navigation channel of artificial canals, barrier islands, natural inlets, saltwater rivers, bays, and sounds—is a defining feature of the focus area. The Wilmington Harbor Federal Navigation Channel is an approximately 38-mile Federal navigation channel that begins at the outer ocean bar at the mouth of the Cape Fear River in Brunswick County, North Carolina, and extends upriver to the City of Wilmington in New Hanover County, North Carolina, where it services the Port of Wilmington.

The coastline within the focus area varies from densely developed communities to natural reserves. The largest community is the City of Wilmington with a population of approximately 120,000. Smaller beach communities dominate the Atlantic Ocean coastline and are seasonal tourism destinations that drive the local economy. They include Carolina Beach, Kure Beach, Holden Beach, Oak Island, Sunset Beach, and Wrightsville Beach. Other significant municipalities include Calabash, Leland, Shallotte, and Southport. In total, the population of Brunswick and New Hanover Counties together is approximately 375,000 persons. Other significant features in the area include Military Ocean Terminal Sunny Point (MOTSU), the U.S.S. North Carolina Battleship memorial, Wilmington Harbor deep draft port, Brunswick Town, and the Brunswick Nuclear Plant. Additionally, the U.S. Coast Guard has stations located at Wrightsville Beach and Oak Island, and the NCDOT Ferry Division has terminals located at Fort Fischer and Southport.

Since 1960, 43 hurricane and tropical storm centers have passed within 50 miles of the focus area. On average, a storm event occurs every 1.4 years (NOAA n.d.). The Brunswick and New Hanover Focus Area currently totals almost 124 million in economic risk to structures alone—a figure that doubles when projecting future conditions with sea level rise. This area also contains five priority environmental areas (PEAs), making this region both highly valuable and highly vulnerable to coastal storm hazards.

Figure 2: Brunswick and New Hanover Counties Focus Area Boundary

1.2 Prior Reports and Efforts by Stakeholders within the Focus Area

Prior and ongoing stakeholder efforts within the Brunswick and New Hanover Counties Focus Area related to coastal storm risks and impacts from sea level rise are listed in **Table 1**.

Table 1: Stakeholder Reports and Efforts in the Focus Area

Agency/Stakeholder	Report/Tool/Project	Year Completed
North Carolina Department of Environmental Quality (NCDEQ)	North Carolina Climate Risk Assessment and Resilience Plan	2020
Pender County, North Carolina	Southeastern NC Regional Multi-jurisdictional Hazard Mitigation Plan	2016
U.S. Army Corps of Engineers (USACE), Wilmington District	Wilmington Harbor, Northeast Cape Fear River, General Design Memorandum	1990
USACE, Wilmington District	Wilmington Harbor Ocean Bar – General Design Memorandum, Supplement and Environmental Assessment	1993
USACE, Wilmington District	Final Feasibility Report and Environmental Impact Statement on Improvement of Navigation, Cape Fear – Northeast Cape Fear River Comprehensive Study	1996
USACE, Wilmington District	Integrated Feasibility Report and Environmental Assessment, Wilmington Harbor Navigation Improvements, Wilmington, North Carolina	2018
USACE, Wilmington District	Environmental Assessment, Preconstruction Modifications of Authorized Improvements, Wilmington Harbor, North Carolina	2000

Existing Sand Needs Projects

There are existing federal CSRM projects at Wrightsville Beach, Carolina Beach, Kure Beach, and Ocean Isle Beach. Figure Eight Island provides beach nourishment locally through the Homeowner's Association (HOA) and New Hanover County. The South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND) (USACE 2020c) reported a 30 percent deficit for Brunswick County and a 22 percent deficit to the 50-year sand budget for New Hanover County with a 55-percent contingency. Estimated 50-year Sand Requirements in Brunswick and New Hanover Counties are summarized in **Table 2**. Of the proven offshore resources (90-percent confidence) reported in SAND, two were in Brunswick County and four were in New Hanover County. Several potential offshore resources (70-percent confidence) were reported, but they require additional sediment characterization before utilization. Existing studies at Wrightsville Beach, Carolina Beach, Kure Beach, Oak Island, and Holden Beach will provide additional geotechnical information for offshore borrow sources that could further inform these sand budgets in the future.

Table 2: Estimated 50-Year Sand Need in Brunswick and New Hanover Counties (USACE 2020c)

Feature Name	County	Federally Sponsored?	Project Sponsor	Federal Authorization Year	Nourishment Interval (Years)	Estimated 50-Year Sand (2020-2070) Requirement (cubic yards)
Bald Head Island	Brunswick	Yes	USACE, FEMA, Village of Bald Head Island	1991	2	25,704,000
Holden Beach	Brunswick	Yes	USACE, FEMA, Town of Holden Beach	1971	1	12,903,000
Caswell Beach	Brunswick	Yes	USACE	2001	9	4,160,000
Oak Island	Brunswick	Yes	USACE, FEMA, Town of Oak Island	1986	6	9,639,000
Ocean Isle Beach	Brunswick	Yes	USACE, Town of Ocean Isle Beach	1966	3	10,353,000
Carolina Beach	New Hanover	Yes	USACE, Town of Carolina Beach	1955	3	16,677,000
Kure Beach	New Hanover	Yes	USACE	1998	3	18,513,000
Wrightsville Beach	New Hanover	Yes	USACE	1939	4	9,204,000
Figure Eight Island	New Hanover	No	New Hanover County, Figure “8” Beach HOA	n/a	2	15,276,000
Masonboro Island	New Hanover	Yes	USACE	1986	4	6,420,000

Existing Regional Sediment Management Projects

The 2020 South Atlantic Division Regional Sediment Management (RSM) Optimization Update provided a detailed review of the existing actions in place (**Table 3**) as well as recommendations for actionable strategies (USACE 2020b). RSM projects for this focus area located at Masonboro Inlet and Wrightsville Beach, Carolina Beach and Kure Beach, Ocean Isle Beach, and within the AIWW were reported to beneficially use 100-percent of the material at these locations, providing an annual RSM value of more than $4 million. Maintenance of Wilmington Harbor produces 3.8 million cubic yards (MCY) of material every dredging cycle. Approximately 1.0 MCY of beach-suitable material is designated for beneficial use placement on nearby Bald Head and Oak Islands according to the Wilmington District, resulting in $3.8 million in benefits realized through shoreline protection and coastal flood risk management. The remaining 2.8 MCY is unsuitable for beach nourishment and is placed in upland or sediment management sites. The RSM Optimization Update recommends maximizing beneficial use opportunities. This could include partnership coordination with other agencies, bird island maintenance, thin-layer placement, living shorelines, island or habitat creation, and other opportunities that may be available for non-beach-suitable material. Thin-layer placement in shallow, low-energy estuary and marsh could provide environmental benefits such as promotion of submerged aquatic vegetation and habitat restoration. Beneficial use and re-use of material also helps extend the life of dredged material management areas (DMMAs).

Table 3: Regional Sediment Management Actions in Brunswick and New Hanover Counties (USACE 2020b)

RSM Source	County	Federally Sponsored?	Placement Area	Total Dredge Volume (cubic yards)	Average Dredge Interval (years)	Average Volume per Project (cubic yards)	Average Annualized Dredge Volume (cubic yards)	50 Year Source Volume (cubic yards)
Tubbs Inlet - Jinks Creek, Mary's Creek, Turtle Creek	Brunswick County	No	–	–	–	–	–	0
Wilmington Harbor	Brunswick County	Yes	Bald Head Island, Oak Island	1,000,000	2	1,000,000	500,000	25,000,000
Lockwoods Folly AIWW Crossing	Brunswick County	Yes	Holden Beach, Oak Island	100,000	3	100,000	33,333	1,666,667
Shallotte Inlet AIWW Crossing	Brunswick County	Yes	Ocean Isle Beach	100,000	3	100,000	33,333	1,666,667
Shallotte Inlet	Brunswick County	Yes	Ocean Isle Beach	500,000	4	500,000	125,000	6,250,000
AIWW_DA_286 (DA 286) DMMA	Brunswick County	Yes	Brunswick County	–	–	–	–	–
Mason Inlet	New Hanover County	No	Figure Eight Island	1,971,453	2.2	328,600	149,364	7,468,182
Masonboro Inlet	New Hanover County	Yes	Masonboro Island, Wrightsville Beach	800,000	4	800,000	200,000	10,000,000
Carolina Beach Inlet AIWW Crossing (Snows Cut)	New Hanover County	Yes	Carolina Beach	100,000	3	100,000	33,333	1,666,667
Carolina Beach Inlet	New Hanover County	Yes	Carolina Beach	900,000	3	900,000	300,000	15,000,000
Masonboro Ebb Shoal	New Hanover County	No	Wrightsville Beach	–	–	–	34,400	4,220,000

RSM Source	County	Federally Sponsored?	Placement Area	Total Dredge Volume (cubic yards)	Average Dredge Interval (years)	Average Volume per Project (cubic yards)	Average Annualized Dredge Volume (cubic yards)	50 Year Source Volume (cubic yards)
AIWW_DA_275 (DA 275) DMMA	New Hanover County	Yes	New Hanover County	–	–	–	–	–
AIWW_DA_272 (DA 272) DMMA	New Hanover County	Yes	New Hanover County	–	–	–	–	–
AIWW_DA_241 (DA 241) DMMA	New Hanover County	Yes	New Hanover County	–	–	–	–	–
AIWW_DA_274 (DA 274) DMMA	New Hanover County	Yes	New Hanover County	–	–	–	–	–
WH_U0004 (WH 4) DMMA	New Hanover County	Yes	New Hanover County	–	–	–	–	–

Other Existing Risk Management Strategies

The Brunswick and New Hanover County Focus Area also includes other risk management strategies such as living shorelines, rock revetments, and marsh restoration projects. NOAA's community-based restoration funding program, the North Carolina Coastal Federation, Restore America's Estuaries, USACE, and other state and local partners have worked together to install the following living shorelines in the Brunswick and New Hanover Focus Area:

- Living Shorelines at the Lower Cape Fear River and the Waterfront Park, Town of Sunset Beach
- Salt Marsh and Oyster Restoration at Airlie Gardens
- Beach Shoreline Restoration at Wrightsville Beach
- Bradley Oaks Living Shoreline Demonstration at Oak Island

1.3 Shared Vision

The shared vision provides an overall goal for the focus area. Actions identified in this report incrementally contribute to the shared vision by achieving objectives to address problems and realize opportunities identified in the focus area. The Brunswick and New Hanover Counties Focus Area shared vision was developed with stakeholder input provided in the Focus Area Visioning Meetings described in the Main Report. The shared vision is:

Our vision is to develop a stakeholder-led, science-based cohesive actionable strategy to address coastal storm risk and sea level rise while strengthening the economic, environmental, and social resilience of the Brunswick and New Hanover Counties Focus Area for current and future generations.

2. Problems and Opportunities

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

2.1 Problems

The following problems were identified as the most significant throughout the focus area and may not be exhaustive of all problems. These problems will increase in both intensity and extent as sea levels rise depending on the vulnerability and resiliency of the exposed population, infrastructure, and environmental resources. Problems 1, 2, and 3 were the most often cited during stakeholder coordination. Each problem is given an abbreviated label (e.g., P3 for problem 3) for cross reference in **Table 15** located in Section 5.2 of this report.

Problem (P)1: Coastal storms create erosion and storm surge that negatively impact environmental resources.

- Erosion reduces important nesting habitat for threatened and endangered species, such as sea turtles, within all of the beaches along Brunswick and New Hanover Counties. Furthermore, storm surge damages dune habitat. These impacts will increase with sea level rise.

P2: Quantities of known beach-suitable offshore sand sources do not meet the current projected need over the next 50 years for coastal storm mitigation projects within the focus area.

- The SAND Report indicates a deficit in available sand of 53,000,000 cubic yards versus the projected need for Brunswick and New Hanover Counties together over the next 50 years, indicating the need to search for additional suitable materials for future CSRM projects.

P3: Erosion along the oceanfront and back bay shorelines threatens infrastructure.

P4: Coastal storms threaten life safety and damage public and private infrastructure.

- Forty-three percent of residents in the focus area live in areas vulnerable to coastal storm surge. Estimated annual damages are significant for the area, and the estimates are projected to more than double in future conditions with sea level rise. The greatest damages are expected to occur in the lower-lying areas of Oak Island, Wilmington, Carolina Beach, and Wrightsville Beach.

P5: Cultural and historical sites are impacted from erosion and storm surge from coastal storms, such as the U.S.S. North Carolina Battleship memorial, Brunswick Town, and downtown Wilmington.

P6: Storm surge and precipitation from coastal storms and elevated groundwater levels cause compound flooding- when multiple flood sources combine to increase overall flooding which damages public and private infrastructure.

P7: There is a need for increased access to and utilization of existing SACS data and tools, including Coastal Hazards System (CHS) data.

2.1.1 Institutional and Other Barriers

As described in the SACS Institutional and Other Barriers Report, “Institutional and other barriers” impede the attainment of SACS goals and limit the ability to provide comprehensive CSRM (USACE 2022a). Several institutional and other barriers (IOBs) were identified within the Brunswick and New Hanover Counties Focus Area by stakeholders:

- **IOB 1:** Current hazards modeling does not capture all risks, such as compound flooding.
- **IOB 2:** Federal funding for CSRM projects is inconsistent from one budget cycle to the next.
- **IOB 3:** Recovery actions by all levels of government have tended to focus more on recovery and less on resiliency.
- **IOB 4:** National Flood Insurance Program (NFIP) reforms are needed.

- **IOB 5:** Government processes are slowing recovery aid allotment.
- **IOB 6:** Updated FEMA flood maps show less properties at risk than in previous maps. There is concern about the logic of this reclassification and the risk-message it sends to new residents moving into the area.
- **IOB 7:** There is insufficient collaboration and cooperation among federal/state/local stakeholders to permit and manage use of offshore sand sources (i.e., Frying Pan Shoals).

2.2 Opportunities

Stakeholders identified several opportunities that include conditions, resources, and factors that could contribute favorably to the Brunswick and New Hanover Counties Focus Area:

- **Opportunity (O)1**: Integrate CHS data and other modeling efforts focused on probabilistic coastal hazard assessment to analyze future beach erosion, barrier island lowering or breaching, and/or marsh loss.
- **O2**: Optimize RSM.
- **O3**: Apply future-conditions projections to flood maps and infrastructure investments.
- **O4**: Increase knowledge of offshore sand resources.
- **O5**: Increase understanding of coastal wetland trends and restoration strategies.
- **O6**: Further advance outcomes of CSRM projects to reduce risk of damage to back bay areas, cultural resources, and historic sites.

3. Objectives and Constraints

Planning objectives are statements that describe the desired results of the planning process by solving the problems and taking advantage of the opportunities identified within the planning process. Constraints are conditions that limit the planning process. The final strategy formulated during this study is intended to meet the planning process objectives while working within the constraints.

3.1 Objectives

Overall objectives were developed for the focus area, generally focused on reducing coastal storm risks. Objectives and goals of the focus area include:

- **Objective (OBJ) 1:** Reduce coastal storm inundation risk to population and infrastructure within both the oceanfront and back bay vulnerable areas of Brunswick and New Hanover Counties.
- **OBJ 2:** Reduce the risk to environmental and cultural resources due to inundation, wave attack, and erosion as a result of coastal storms.

Goals:

- **G1:** Identify potential federal involvement in specific resiliency actions that can begin implementation within 2 to 10 years.
- **G2:** Improve interagency communication to address institutional barriers to coastal resiliency.

3.2 Constraints

A constraint may limit the planning process. To the maximum extent practicable, the SACS analysis will minimize information, observations, and recommendations that may be inconsistent with coastal storm risk management plans developed by other federal and applicable state and local agencies and tribes within the study area.

4. Existing and Future Conditions

4.1 Hazards

In a general sense, a hazard is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014). For a full list of hazards information relevant to the focus area, see Sections 4.1.1, 4.1.4, 4.3.1.1 and 4.3.2.1 of the North Carolina Appendix. For the FAAS, hazards were divided into two categories: primary hazards and secondary hazards. Primary hazards are those directly addressed within the scope of the SACS and secondary hazards are those not directly addressed but still relevant and important to the focus area.

4.1.1 Primary Hazards

For the Brunswick and New Hanover Counties Focus Area, primary hazards include inundation, wave attack, and erosion. Coastal erosion can be hazardous to natural shorelines such as marshes and sandy beaches and can lead to increased vulnerability of cultural and environmental resources and infrastructure. Coastal erosion poses a major hazard within this focus area.

4.1.1.1 Inundation

Inundation hazard within Brunswick and New Hanover Counties is most prevalent along the beach and back bay areas, and along the lower rivers and creeks that are tidally influenced. **Table 4** provides stillwater elevations for the 10-percent, 2-percent, 1-percent, and 0.2-percent annual exceedance probability (AEP) events from FEMA Flood Insurance Studies (FISs) (FEMA 2019a, 2019b). The areas that are subject to more frequent occurrences of the inundation hazard are:

- **The Barrier Islands and Back Bay:** All the islands from Figure Eight Island in the north to Sunset Beach farthest south have low elevations and are subject to flooding from coastal storm surge. There are many low-lying areas along the back bay areas that also show increased probabilities of storm surge inundation as compared with areas of higher elevation.

- **Lower Cape Fear River and Tributaries**: Cape Fear is the largest river basin in North Carolina. The lower basin is within the focus area and contains many areas that can be affected by storm surge inundation and riverine flooding due to significant inland rainfall from coastal storms. The Northeast Cape Fear River and Black River feed into Cape Fear and can experience significant surge events. Within the City of Wilmington are smaller tributaries such as Smith Creek and Burnt Mill Creek, which can backflow from coastal storm surge into urbanized areas.

Table 4: Brunswick and New Hanover Counties Storm Tide Elevations from the Federal Emergency Management Agency Flood Insurance Study (FEMA 2019a; 2019b)

Shorelines	10% Annual Exceedance Probability (AEP) (feet-NAVD88)	2% AEP (feet-NAVD88)	1% AEP (feet-NAVD88)	0.2% AEP (feet-NAVD88)
Brunswick	6.6	9.1	10.3	12.7
New Hanover	7.1	9.8	11.1	13.7

Figure 3 provides a map of the focus area showing the likelihood of flooding based on three probability events. Specifically, areas that may flood during a 10-percent Annual Exceedance Probability (AEP) event are shaded in dark blue. One-percent AEP events are shaded in medium blue. Category 5 hurricane Maximum of Maximum (MOM) represents flooding in a worst-case Category 5 Hurricane scenario and is shaded in light blue (Zachry et al. 2015).

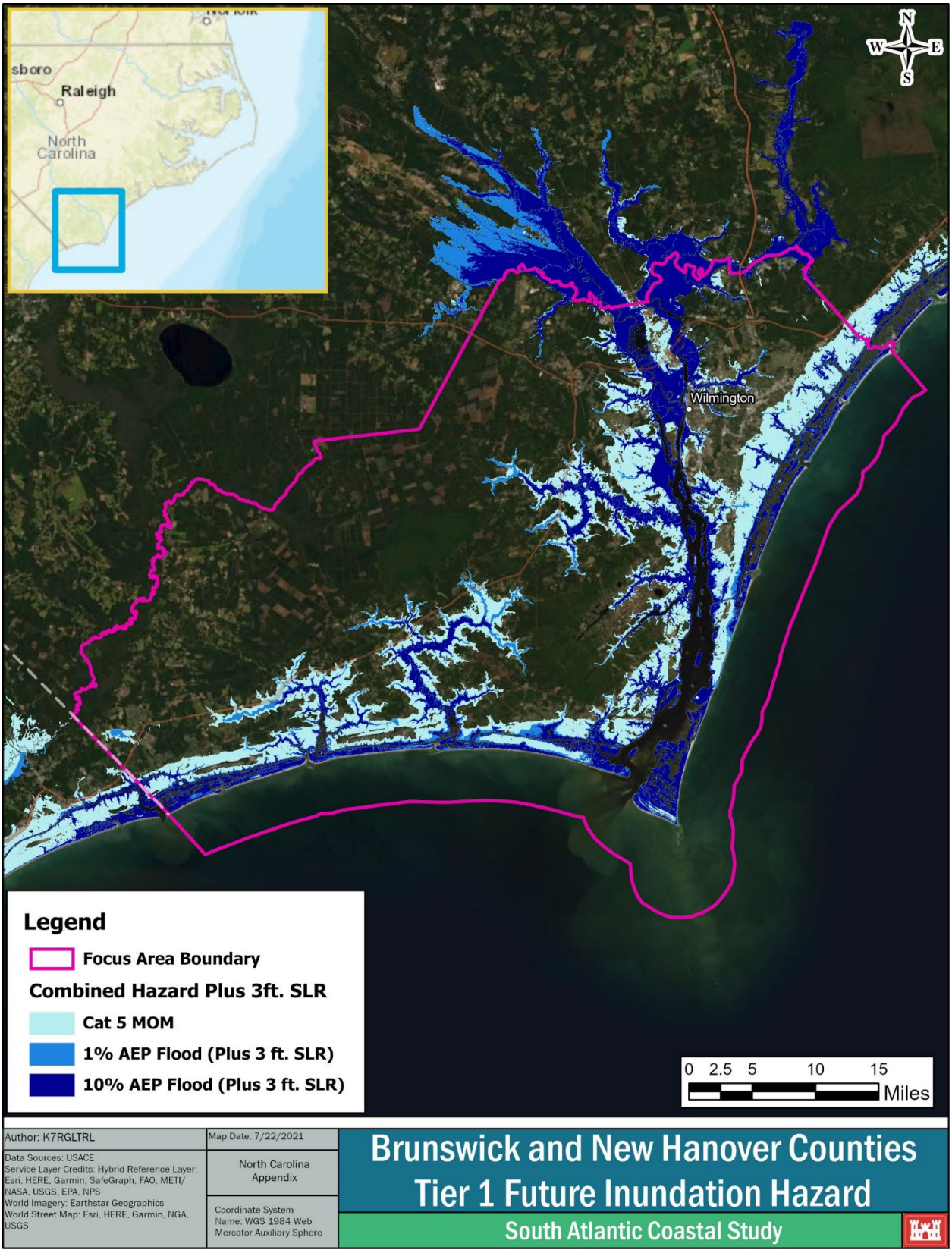


Figure 3: Combined Hazards Plus 3 Feet of Relative Sea Level Rise for the 10-Percent Annual Exceedance Probability (Darkest Blue), 1-Percent Annual Exceedance Probability Storm (Medium Blue), and Category 5 Hurricane Maximum of Maximum (Light Blue)

CHS develops AEP water levels throughout the South Atlantic, including Brunswick and New Hanover Counties, under existing and future sea levels (USACE 2020a). **Table 5** shows stillwater levels under the existing sea level for various AEP. The highest stillwater levels are seen in back bay areas: AIWW and the Carolina Beach Yacht Basin. **Table 6** shows stillwater levels under the high sea level rise scenario (7.35 feet of sea level rise). Under this scenario, stillwater levels range from 15.62 to 18.60 feet NAVD88 for the 1-percent AEP throughout the focus area. Nonlinear effects, which are changes to stillwater levels due to sea level rise that are not a simple addition of the sea level rise value (in this case, 7.35 feet), are evident in this focus area. Unlike the other focus areas, nonlinear effects seem to primarily reduce the water levels in this focus area, with an average reduction of 0.41 feet for 1-percent AEP among the points displayed in **Table 6**. The largest nonlinear effect took place at the Carolina Beach Yacht Basin, with a reduction in 0.90 foot.

Table 5: Brunswick and New Hanover County Stillwater Elevations from the USACE Coastal Hazards System – Existing Sea Level

Location	10% Annual Exceedance Probability (AEP) (feet-NAVD88)	5% AEP (feet-AVD88)	2% AEP (feet-AVD88)	1% AEP (feet-AVD88)	0.2% AEP (feet-AVD88)
Wrightsville Beach	6.70	7.21	8.37	9.37	11.56
AIWW - Wrightsville Beach	7.49	8.91	10.85	12.02	14.55
Carolina Beach	6.73	7.27	8.36	9.29	11.24
Cape Fear River - MOTSU	5.96	6.51	7.59	8.39	9.83
Cape Fear River - Wilmington	5.66	6.36	7.51	8.24	9.61
Carolina Beach Yacht Basin	7.53	8.85	10.48	11.68	13.97
Oak Island	7.79	8.17	8.79	9.38	10.71
AIWW - Holden Beach	8.38	9.09	10.54	11.60	13.72
Ocean Isle Beach	8.43	8.83	9.60	10.40	12.35

Table 6: Brunswick and New Hanover County Stillwater Elevations from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet-NAVD88)	5% AEP (feet-AVD88)	2% AEP (feet-AVD88)	1% AEP (feet-AVD88)	0.2% AEP (feet-NAVD88)
Wrightsville Beach	13.93	14.35	15.24	16.03	18.03
AIWW - Wrightsville Beach	14.78	15.95	17.55	18.60	20.83
Carolina Beach	13.95	14.41	15.26	16.05	17.84
Cape Fear River - MOTSU	13.78	14.69	15.82	16.54	17.95
Cape Fear River - Wilmington	13.30	14.06	15.01	15.62	16.83
Carolina Beach Yacht Basin	14.62	15.72	17.16	18.13	20.19
Oak Island	15.09	15.43	15.92	16.43	17.46
AIWW - Holden Beach	15.68	16.24	17.39	18.24	20.01
Ocean Isle Beach	15.68	16.07	16.55	17.17	18.61

4.1.1.2 Wave Attack

Waves cause damage through the force that they impart directly on structures, habitats, and shorelines. Waves also generate alongshore and cross-shore currents at shorelines that can mobilize and erode sediments. In the context of the SACS, wave attack refers to the process of destructive waves impacting a shoreline and leading to increase erosion along that shoreline. Erosion is addressed in Section 4.1.1.3.

The offshore wave climate for New Hanover County can be described using data from USACE Wave Information Studies (WIS) station 63298, which is located approximately 13 miles from Masonboro Island at a depth of 52 feet. WIS stations are output locations for a series of coastal wave hindcast model estimates for a 35-year period from 1980 to 2014. The average significant wave height at this station is 3.7 feet, with a period of 8.8 seconds. The estimated 1-percent AEP significant wave height based on the hindcast data at this location is 15.6 feet.

Similarly, the offshore wave climate for Brunswick County can be represented using WIS station 63310, located approximately 20 miles from Holden Beach. The wave climate at this location is slightly different from station 63298 because it is located south of Cape Fear. The average significant wave height at this station is 3.7 feet, with a period of 8.7 seconds, and an estimated significant wave height of 24.6 feet for 1-percent AEP.

The CHS analysis developed by USACE models wave heights for a range of storm events. While WIS data can describe offshore wave heights using hindcast model estimates, the CHS describes wave heights at a range of AEP throughout the region for current and future conditions.

Table 7 shows modeled wave heights at various AEP throughout the focus area for the existing sea level, while **Table 8** shows modeled wave heights for the future, USACE high sea level rise scenario from CHS (7.35 feet). Points representing ocean waves were chosen at locations roughly 5 miles offshore and are much larger than waves in back bay regions. For example, the 1-percent AEP wave height on the ocean side of Wrightsville Beach is 30.14 feet, while the 1-percent AEP wave height in the AIWW near the same beach is 3.87 feet.

Wave heights correlate to fetch (length over which wind stress is applied), duration of the wind stress, and water depth. Therefore, waves in deep ocean water can become much larger than waves in back bay regions. This also applies to sea level rise; as the sea level increases, the depth at which the wave develops increases, allowing for larger waves.

Table 7: Brunswick and New Hanover Wave Heights from the USACE Coastal Hazards System – Existing Sea Level

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Wrightsville Beach	22.20	25.52	28.52	30.14	33.10
AIWW - Wrightsville Beach	2.05	2.68	3.46	3.87	5.07
Carolina Beach	23.18	26.39	28.84	29.91	32.68
Cape Fear River - MOTSU	2.91	3.49	4.31	4.64	5.43
Cape Fear River - Wilmington	2.15	2.61	3.21	3.55	4.40
Carolina Beach Yacht Basin	2.13	2.78	3.54	4.04	5.00
Oak Island	17.45	19.06	21.23	22.60	24.43
AIWW - Holden Beach	0.90	1.17	1.65	2.02	2.79
Ocean Isle Beach	19.62	21.93	24.17	25.33	27.39

Table 8: Brunswick and New Hanover County Wave Heights from the USACE Coastal Hazards System – High Sea Level Rise Scenario (7.35 feet)

Location	10% AEP (feet)	5% AEP (feet)	2% AEP (feet)	1% AEP (feet)	0.2% AEP (feet)
Wrightsville Beach	23.46	26.99	30.21	32.01	33.46
AIWW - Wrightsville Beach	4.57	5.60	6.78	7.42	8.05
Carolina Beach	24.58	28.11	30.91	32.20	33.45
Cape Fear River - MOTSU	3.60	4.32	5.19	5.62	6.00
Cape Fear River - Wilmington	2.55	3.01	3.57	3.86	4.11
Carolina Beach Yacht Basin	5.03	6.08	7.19	7.89	8.47
Oak Island	19.25	21.29	23.72	25.10	26.11
AIWW - Holden Beach	2.28	2.99	3.81	4.31	4.74
Ocean Isle Beach	21.17	23.83	26.27	27.52	28.54

4.1.1.3 Erosion

The North Carolina Division of Coastal Management's (NCDCM) 2019 shoreline change rates discussed in the Tier 2 Risk Assessment reported a mix of erosion and shoreline accretion across Brunswick and New Hanover Counties. The average shoreline change rate for eroding shorelines varied between -0.09 feet/year at Kure Beach and -6.36 feet/year at Masonboro Island. For accreting shorelines, values ranged from 0.42 feet/year at Oak Island and 5.5 feet/year at Sunset Beach.

The NCDCM's 2020 Web Map Viewer update of shoreline change and erosion rates showed areas of significant shoreline erosion at the east end of Holden Beach, with up to 6 feet per year; portions of Bald Head Island; Fort Fisher State Park; and Masonboro Island, with up to 14 feet per year. Various oceanfront shorelines receive routine sand placement, which influences the shoreline change data toward accretion rather than erosion (e.g., Wrightsville Beach, Carolina Beach). Although data sets were not found for the back bay areas of this focus area, erosion is a hazard in the back bay shorelines and shorelines. Future efforts to investigate erosion and shoreline change could assist in refining future predictions.

The NCDCM's 2019 shoreline change rates discussed in the Tier 2 analysis (**Table 9**) reported that all coastal shorelines of Brunswick and New Hanover Counties were experiencing erosion, except for Wrightsville Beach, Oak Island, and Ocean Isle Beach, with Masonboro Island seeing the highest shoreline change rate of 6.36 feet per year. Over 2,000,000 cubic yards of sand have been placed onto Wrightsville Beach in the past 10 years and this proactive placement strategy has resulted in reduced shoreline loss with only the northern and southern tips of the island experiencing erosion (NCDCM 2019). Farther south, and despite nearly 40 nourishment events, Carolina Beach experiences an average shoreline retreat of 2.5 feet per year. Kure Beach experienced an erosion trend moving from accretion on the north end to erosion on the south end, peaking at 6.4 feet per year (NCDCM 2019). In Brunswick County, Holden Beach and the south side of Bald Head Island were experiencing erosion while all other beaches experienced accretion. Construction of a terminal groin and implementing responsible sediment management practices on Bald Head Island have reduced the southside erosion rate to 4 feet per year. Additionally, Holden Beach was identified as a critical erosion area by the Tier 2 Economic Risk Assessment and has been funded for study.

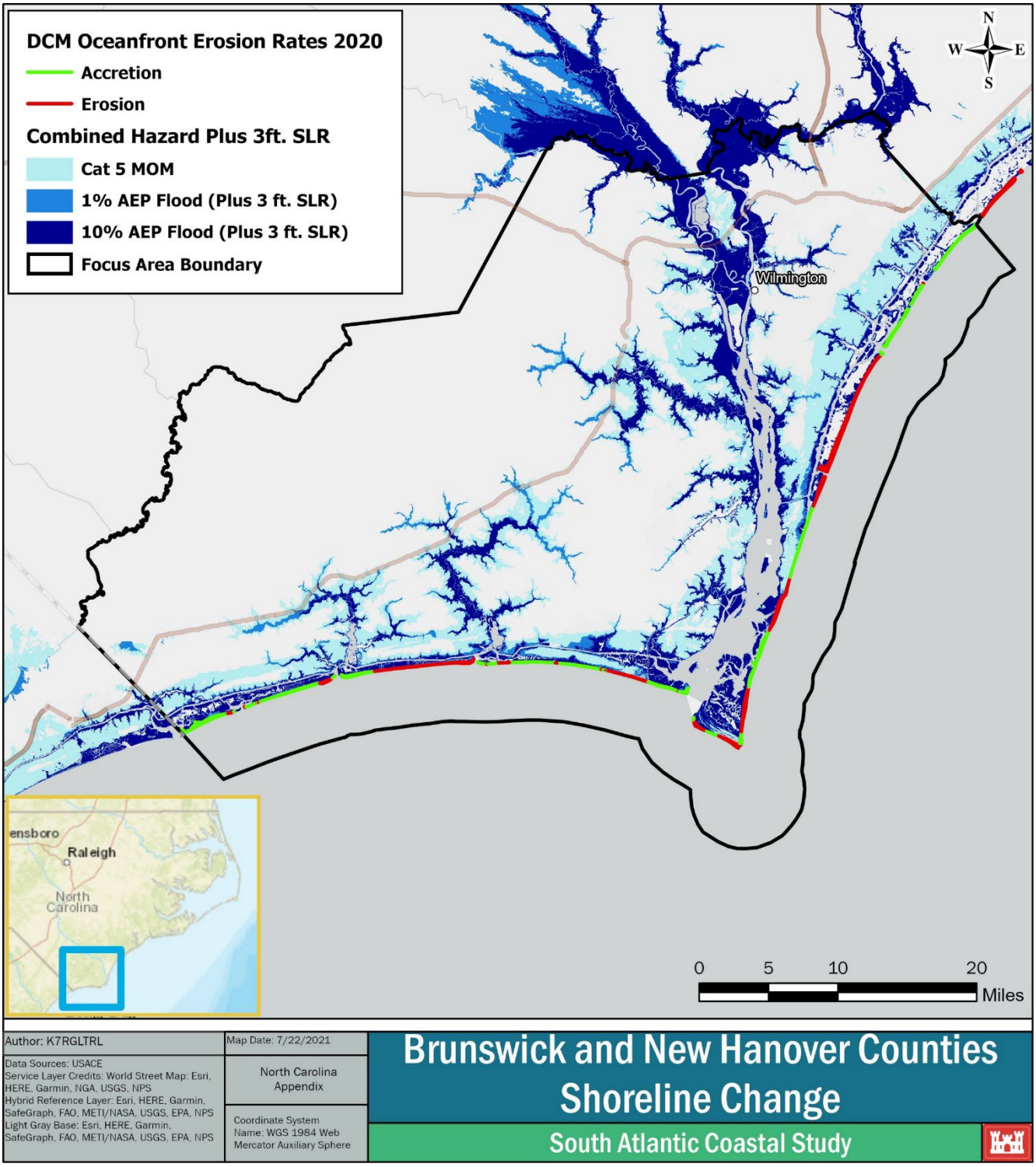


Figure 4: Shoreline Change Rates in the Change Rate Data for New Hanover and Brunswick Counties Focus Area

Table 9: Oceanfront Shoreline Change Rates

Location	2020 Rate	Average (feet/year)
Bald Head Island	Erosion	-2.04
Carolina Beach	Erosion	-0.95
Caswell Beach	Accretion	0.77
Figure Eight Island	Accretion	3.24
Fort Caswell	Accretion	5.05
Fort Fisher	Erosion	-1.85
Holden Beach	Erosion	-0.47
Kure Beach	Erosion	-0.09
Masonboro Island	Erosion	-6.36
Oak Island	Accretion	0.42
Ocean Isle	Accretion	1.19
Sunset Beach	Accretion	5.5
Wrightsville Beach	Accretion	3.2
Zeke's Island	Erosion	-0.27

4.1.2 Secondary Hazards

For the Brunswick and New Hanover Counties Focus Area, secondary hazards include wind, compound flooding, and saltwater inundation and intrusion. While SACS does not specifically address these hazards, they are important because they can impact the focus area.

4.1.2.1 Wind

In Brunswick and New Hanover Counties, high wind speeds can damage roofs, mobile homes, and, if strong enough, can destroy entire buildings. Flying debris can also cause additional damage to resources. High winds can destroy environmental resources by downing and defoliating large patches of trees and other vegetation. Wind directions are generally from the north during colder months and from the south during warmer months (Cedar Lake Ventures, Inc. n.d.). This difference in wind direction creates changes in approach patterns of wind-blown waves, thus creating a different angle of wave attack that drives sediment transport and causes property damage. Similarly, extratropical cyclones (e.g., nor'easters) typically approach this focus area from the north during colder months and tropical cyclones (e.g., hurricanes and tropical storms) typically approach this focus area from the south during warmer months, creating different angles of approach for wind-induced damages. See Section 4.1.4.4 of the North Carolina Appendix for additional details on wind hazard.

4.1.2.2 Compound Flooding

Compound flooding is a combination of hazards that magnify the overall hazard when they occur simultaneously. When storm surge is combined with other factors such as rainfall runoff, high tides and/or high groundwater elevations, the resulting flood hazard can be exacerbated. Areas in the lower Cape Fear River basin have experienced the effects of compound flooding during multiple coastal storm events, including Hurricanes Floyd (1999) and Hermine (2016). Research within this specific river basin indicates that multiple factors likely come into play, which could result in the compounding of flood factors, including the relative timing and magnitude among storm tide, coastal rainfall, and river flows. High-intensity rain bands in advance of the landfall of an approaching coastal

storm, or high-intensity precipitation occurring at the time of landfall, can result in compound flooding (Gori et al. 2020). There are other compound flooding events along the lower Cape Fear River in connection with high tides that cause inundation at various locations, including downtown Wilmington, the U.S.S. North Carolina Battleship Memorial, and the Town of Carolina Beach. While SACS did not evaluate these other sources of inundation, Gori et al. (2020) modeled compound flooding along the Cape Fear River using a storm suite of historical tropical cyclones. Conclusions found that the combined impacts of localized rainfall runoff and riverine contributions added up to 1.18 feet of additional water due to compound flooding. Compound flooding can contribute significantly to increased runoff volumes, ocean elevation, water table elevation, riverbank overtopping, and overwhelming of containment structures and drainage and outflow systems.

4.1.2.3 Saltwater Intrusion and Inundation

Saltwater inundation and intrusion (North Carolina Appendix Sections 4.1.4.6, and 4.3.2.1) has significant consequences to both the environment and the economy in eastern North Carolina, including upland forest retreat, crop yield decline, marsh migration, eutrophication, degradation of habitat by invasive species, coastal forest loss, and decreased ecosystem service benefits (Weston et al. 2011; Tully et al., 2019; Ury et al. 2019).

Lerner et al. (2013), in conjunction with the Conservation Fund in Arlington, Virginia, and the Audubon Maryland-DC in Baltimore, Maryland, determined that at the current rate of transition—either from marsh to open water or from forest to marsh, and with predictions for sea level rise—bolstering existing marshes in the Blackwater National Wildlife Refuge of the Chesapeake Bay would not be enough to maintain the existing marsh habitat. They suggested that mapping marsh movement corridors could potentially identify the most supportive route for continued marsh development along the Atlantic Coast. In 2019, North Carolina State University, in conjunction with the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's 2019 Soil Science Collaborative Research Projects, began a 2-year study into the spatial distribution of North Carolina areas impacted by salinization with the goal to inform predictions about future changes within the transition zone and identify risks to water and septic infrastructure through the next 100 years (Howard 2019). Other adaptive strategies include planting salt-tolerant crops, implementing greater conservation efforts, and installing saltwater management controls (Myers 2019). Current research efforts imply that saltwater intrusion constitutes a serious risk to many coastal communities of North Carolina and is expected to increase in both area and potential negative impacts with rising sea level.

4.1.3 Sea Level Rise Effects on Hazards

At NOAA National Ocean Service (NOS) gauge no. 8658120 in Wilmington, North Carolina, the mean sea level trend is 0.008 feet per year, with a 95-percent confidence interval of 0.001 feet per year, based on monthly mean sea level data from 1935 to 2020 (**Figure 5**), which is equivalent to a change of 0.84 feet over 100 years. Relative sea level rise between 2020 and 2120 is shown graphically in **Figure 6** and numerically in **Table 10** (USACE 2021). Tidal data and extreme water levels for NOS gauge no. 8658120 are shown in **Figure 7**.

At NOS gauge no. 8659084 in Southport, North Carolina, the mean sea level trend is 0.0066 feet per year, with a 95-percent confidence interval of 0.0013 feet per year based on monthly mean sea level data from 1933 to 2008, which is equivalent to a change of 0.66 feet over 100 years (**Figure 8**). This gauge is non-compliant with USACE guidance due to gaps in data that cause the source to fall short of its minimum record of 40 years. This gauge is no longer active.

As sea levels rise in this focus area the hazards of inundation (flooding), wave attack, and erosion will have increased negative impacts. The NOAA Sea Level Rise Viewer was used to simulate an inundation footprint due to a given water level rise (NOAA 2020). **Figure 9** shows a portion of the Brunswick and New Hanover Counties Focus Area using 3 feet of relative sea level rise, a probable value for the study area for the next 50 to 100 years roughly corresponding to the USACE Intermediate Scenario for 2120 and USACE High Scenario for 2070 in North Carolina. References to these tools can be found in North Carolina Appendix Section 3.6.3.2.

3 feet of relative sea level rise would result in loss of miles of wetlands, in particular, the salt marsh of the back bay at Masonboro Island Reserve and Bald Head Island, and the freshwater marsh along the Cape Fear River. Overflowing tidal creeks would cause further loss of wetlands on the mainland and increase the risk of inundation and high-tide flooding in residential areas. Widening of Rich's Inlet, Mason Inlet, Carolina Beach Inlet, and Shallotte Inlet would further increase marsh loss, erosion, and susceptibility to saltwater intrusion. In addition, barrier islands provide a buffer for the mainland by absorbing storm energy. Loss of back bay marsh increases the risks of overtopping and reduces the efficiency of these buffers, leading to more inland damage during coastal storms.

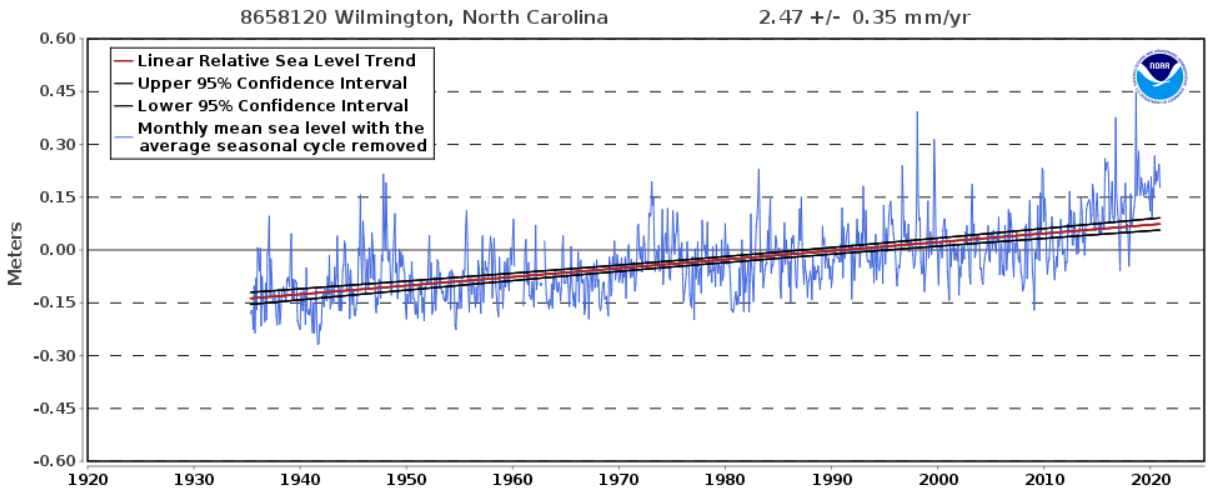


Figure 5: Relative Sea Level Trend, National Ocean Service Gauge 8658120 – Wilmington, North Carolina

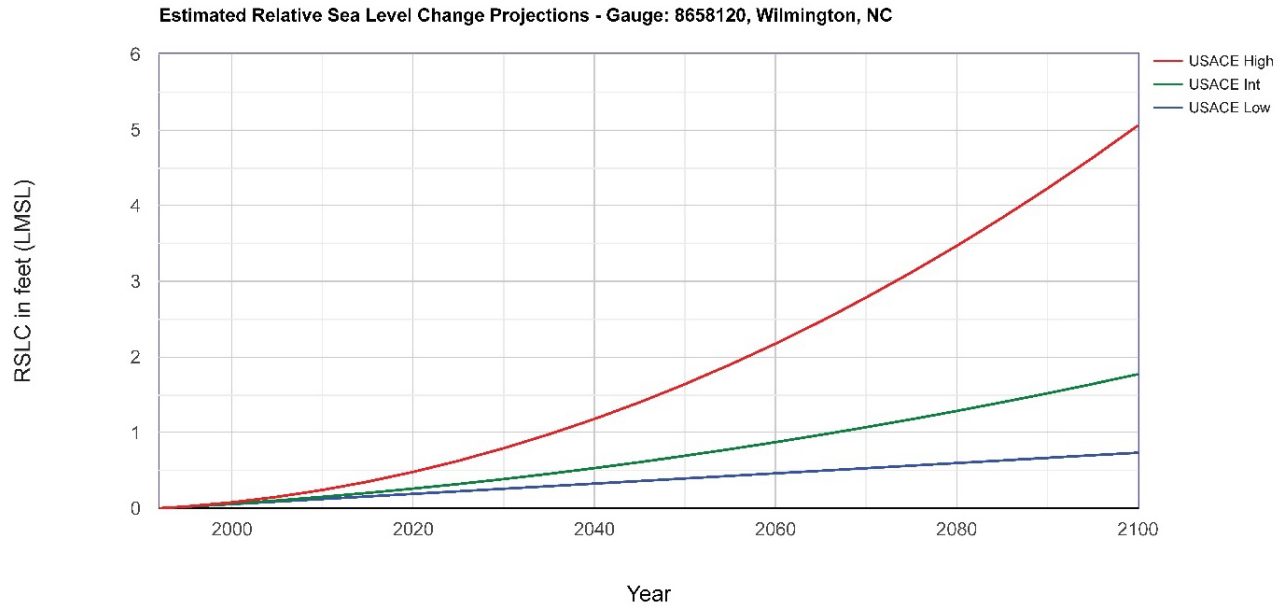
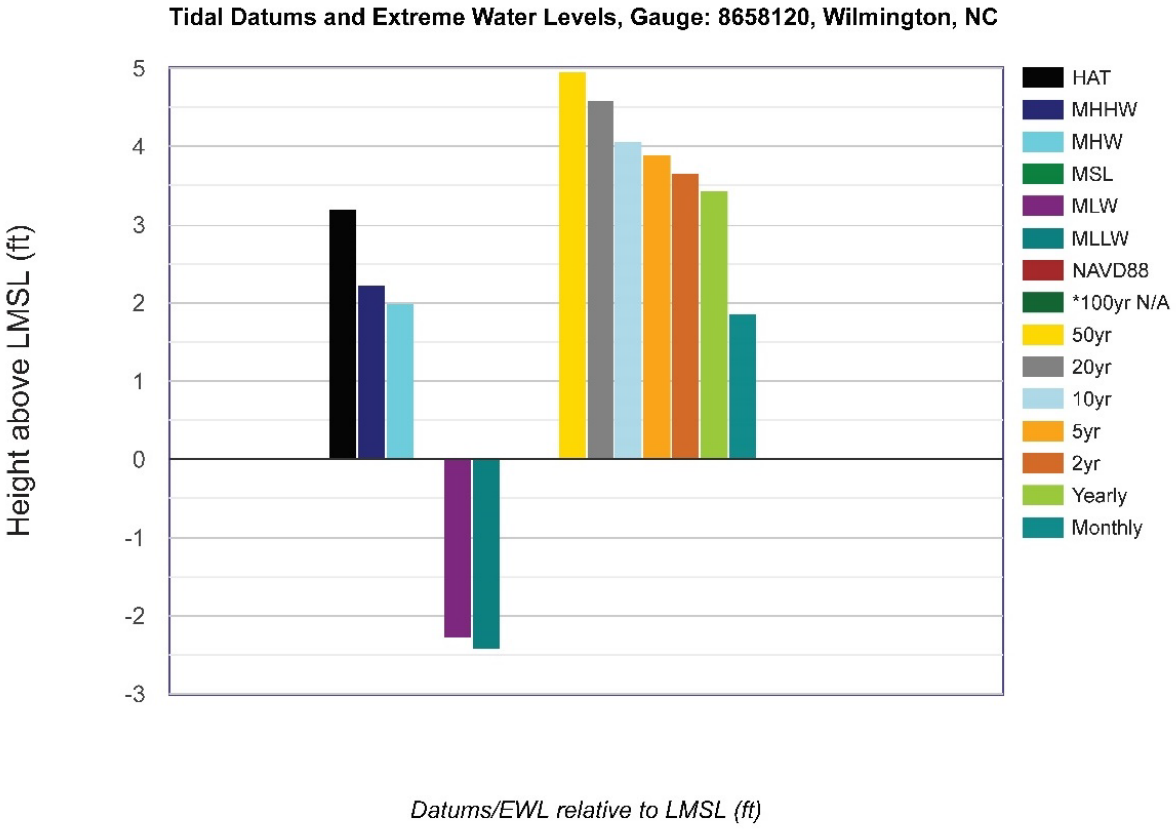


Figure 6: Estimated Relative Sea Level Change Projections Relative to 1992 from 2020 to 2120 – Wilmington, North Carolina

Table 10: Estimated Relative Sea Level Rise from 2020 to 2120 for Various USACE Projections – Wilmington, North Carolina

Location	USACE Low Scenario (feet)	USACE Intermediate Scenario (feet)	USACE High Scenario (feet)
Wilmington, NC	0.68	2.07	6.46



EWL – Extreme Water Level
HAT – Highest Astronomical Tide
LMSL – Local Mean Sea Level
MHHW – Mean Higher High Water
MHW – Mean High Water
MSL – Mean Sea Level
MLW – Mean Low Water
MLLW – Mean Lower Low Water

Figure 7: Tidal Data and Extreme Water Levels – Wilmington, North Carolina

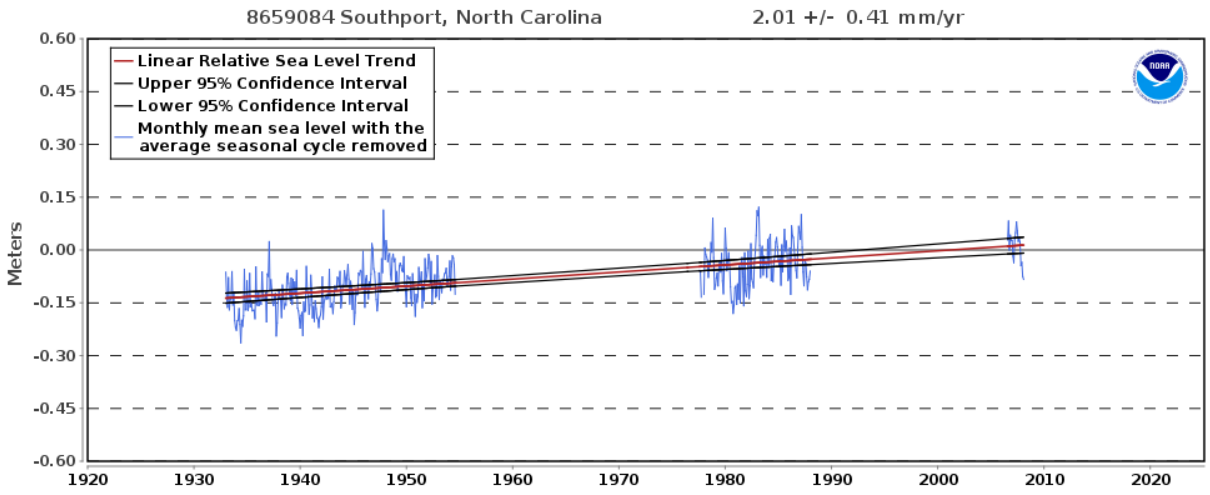


Figure 8: Relative Sea Level Trend, National Ocean Service Gauge 8659084 (Non-Compliant) – Southport, North Carolina

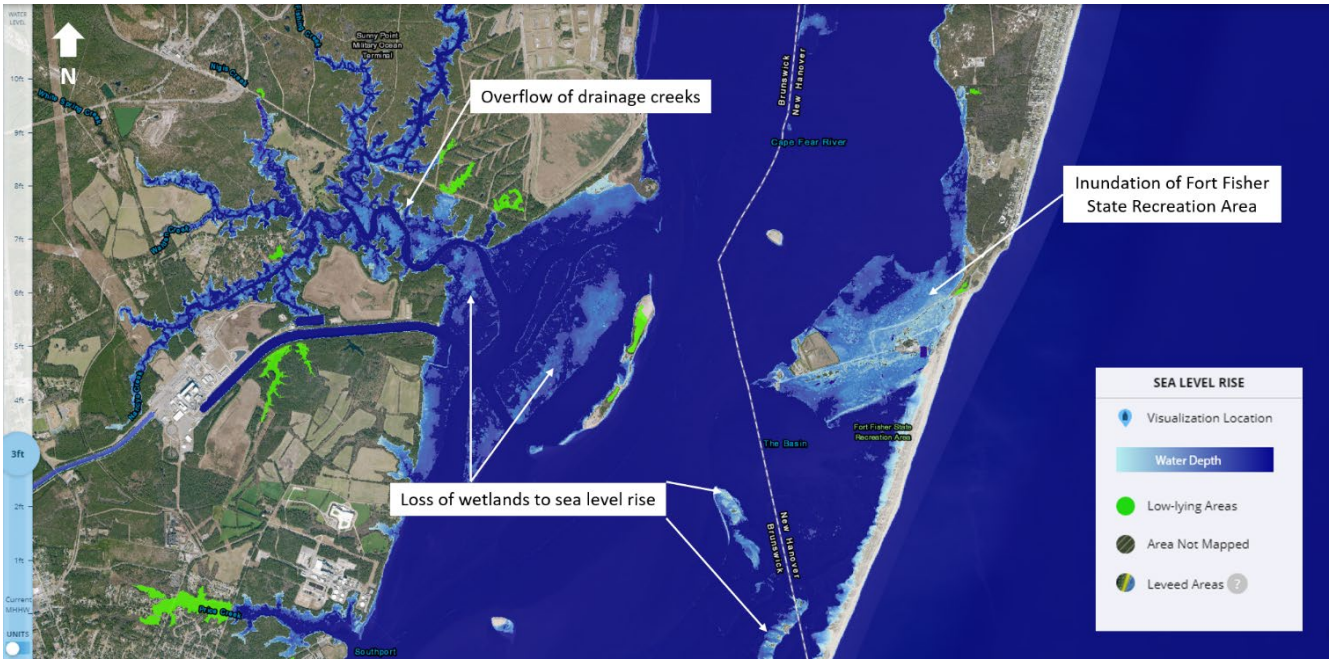


Figure 9: Projected 3 Feet of Relative Sea Level Rise Using the National Oceanic and Atmospheric Administration Sea Level Rise Viewer

4.2 System Performance

The focus area contains a range of risk management measures. These include a combination of natural features, constructed components, policy initiatives and other factors that influence how the overall system within the focus area performs in response to coastal hazards. Generally, constructed measures have been developed and implemented individually rather than holistically. As sea level rises, the coastal storm risk footprint is expanding to encompass multiple areas that have previously been managed separately. For example, beach nourishment projects have significantly reduced risk to infrastructure on the oceanfront sides of barrier islands. However, as sea level rises, infrastructure is at increasing risk of inundation from the back bay side of islands.

Beach nourishment projects reduce damages to oceanfront infrastructure, anchor the coastal system, and serve as a first line of defense to storm damages on the back bay side. Natural resources, such as salt marsh and offshore barrier islands, serve as a first line of defense, and their preservation is important for environmental and risk management purposes.

System components in the focus area include:

- Coastal land use plans in accordance with the North Carolina Coastal Area Management Act (The land use plans for both Brunswick and New Hanover Counties outline policies and regulations that guide development.)
- Oceanfront construction setback regulations
- Structure elevation, relocation, and buyout measures

- Beach nourishment projects on the densely populated barrier islands
- Oceanfront sand placement as beneficial use from navigation projects
- Terminal groin structure at Bald Head Island
- Numerous hardened structures (e.g., bulkheads, revetments) along points of the back bay and Cape Fear River shorelines to reduce erosion and inundation
- Several living shoreline projects along points of the back bay shoreline to reduce erosion and inundation
- Preservation of undeveloped barrier islands (Masonboro Island and Zeke's Island)
- Natural dune systems on barrier islands providing storm risk management
- Extensive salt marsh habitat in back bay areas

Within the focus area, holistic management of the coastal system is increasingly necessary. This includes continued efforts for collaboration and coordination between federal, state, local and all stakeholders to better understand each other's role in risk management and work effectively to combine authorities and activities to holistically assess and address coastal storm risk.

The South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report) reported a 30-percent deficit for Brunswick County and a 22-percent deficit to the 50-year sand budget for New Hanover County with a 55-percent contingency. Brunswick County has a 50-year sand need of 97,300,000 cubic yards, which includes Bald Head Island, Caswell Beach, Holden Beach, Oak Island, and Ocean Isle Beach. New Hanover County has a 50-year sand need of 102,400,000 cubic yards, which includes beach nourishment activities at Figure Eight Island, Wrightsville Beach, Masonboro Island, Carolina Beach, and Kure Beach. Of the proven offshore resources (90-percent confidence) reported in SAND, two were in Brunswick County and four were in New Hanover County. Several potential offshore resources (70-percent confidence) were reported, but they require additional sediment characterization before utilization. Existing studies at Wrightsville Beach, Carolina Beach, Kure Beach, Oak Island, and Holden Beach will provide additional geotechnical information for offshore borrow sources that could further inform these sand budgets in the future.

The RSM Optimization Update provided a detailed review of the existing actions in place as well as recommendations for actionable strategies. RSM projects for this focus area located at Masonboro Inlet and Wrightsville Beach, Carolina Beach, Kure Beach, Ocean Isle Beach, and within the AIWW were reported to beneficially use 100 percent of the material at these locations and provide an annual RSM value of over $4 million. Maintenance of Wilmington Harbor produces 3.8 million cubic yards of material every dredging cycle. Approximately 1.0 million cubic yards of beach-suitable material is designated for beneficial use placement on nearby Bald Head and Oak Islands, resulting in $3.8 million in benefits realized through shoreline protection and coastal flood risk management. The remaining 2.8 million cubic yards is unsuitable for beach nourishment and is placed in upland or sediment management sites. The RSM Optimization Update recommends maximizing beneficial use opportunities. This could include partnership coordination with other agencies, bird island maintenance, thin-layer placement, living shorelines, island or habitat creation, and other opportunities that may be available for non-beach-suitable material. Thin-layer placement in shallow,

low-energy estuary and marsh could provide environmental benefits such as promotion of submerged aquatic vegetation and habitat restoration. Beneficial use and reuse of material also helps extend the life of dredged material management areas and may provide short-term supply benefits to local projects.

4.3 Exposure

Exposure describes who and what may be harmed by the hazard. Details on exposure related to this focus area can be found in the North Carolina Appendix Sections 4.1.2, 4.1.5, 4.3.1.2 and 4.3.2.2. The following sections outline elements potential exposed to the identified hazards.

4.3.1 Exposed Population

Brunswick and New Hanover Counties make up the most populated area of the North Carolina coast with over 300,000 people in the two counties. Almost half of the people are exposed to storm surge inundation. **Figure 10** shows the percentage of people in Brunswick and New Hanover Counties that are exposed to coastal storm surge by hurricane category.

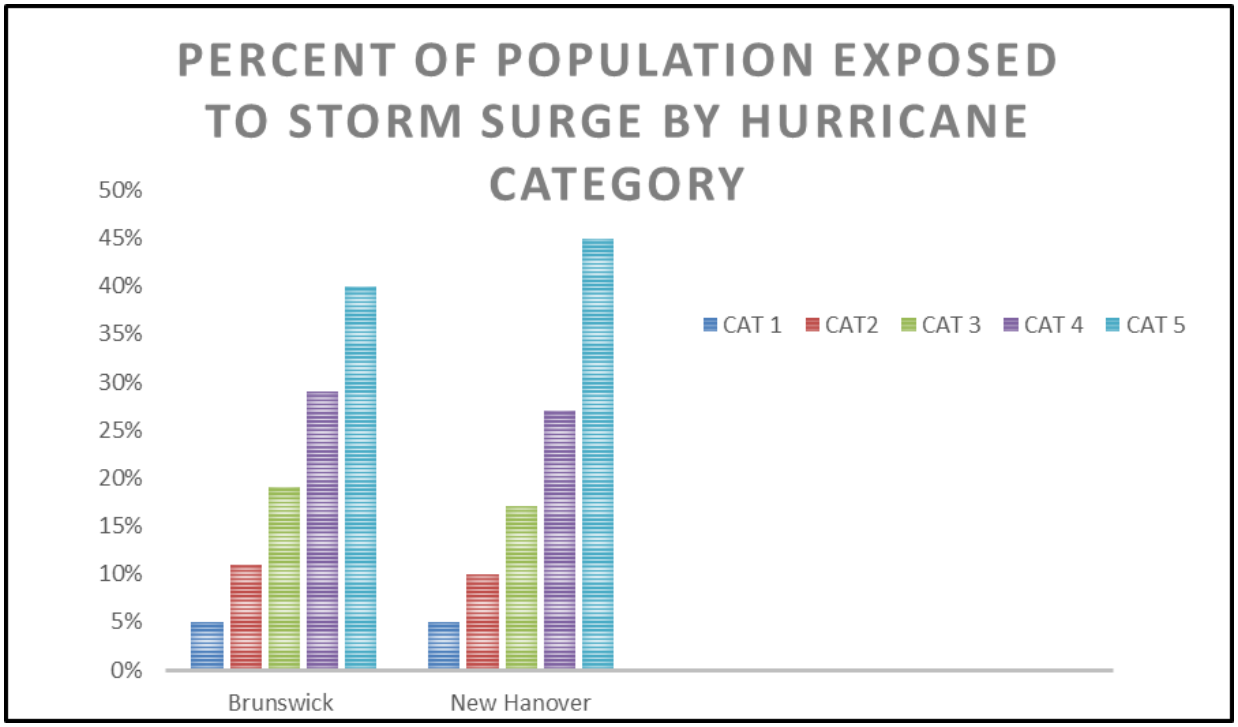


Figure 10: Percentage of Population Exposed to Storm Surge by Hurricane Category (FEMA 2016)

Although census data portray the number of people living in an area year-round, in many beachfront towns the seasonal population increases during the high-risk months of May through September, which coincides with hurricane season. Thus, the exposure of people to hazards is significantly greater than originally assessed in the Tier 1 analysis, which was based on permanent population figures. These additional people include second-home owners and vacationers who may be staying in rental homes or hotels. Projected seasonal populations were gathered from communications with

two beach communities within the focus area–Wrightsville Beach and Oak Island. Consistent with data collected from beach communities throughout the North Carolina coastline, there is a significant increase in population of about seven times greater than the permanent population. **Figure 11** shows the permanent versus seasonal populations for Wrightsville Beach and Oak Island, as well as one neighboring beach community just north of the focus area.

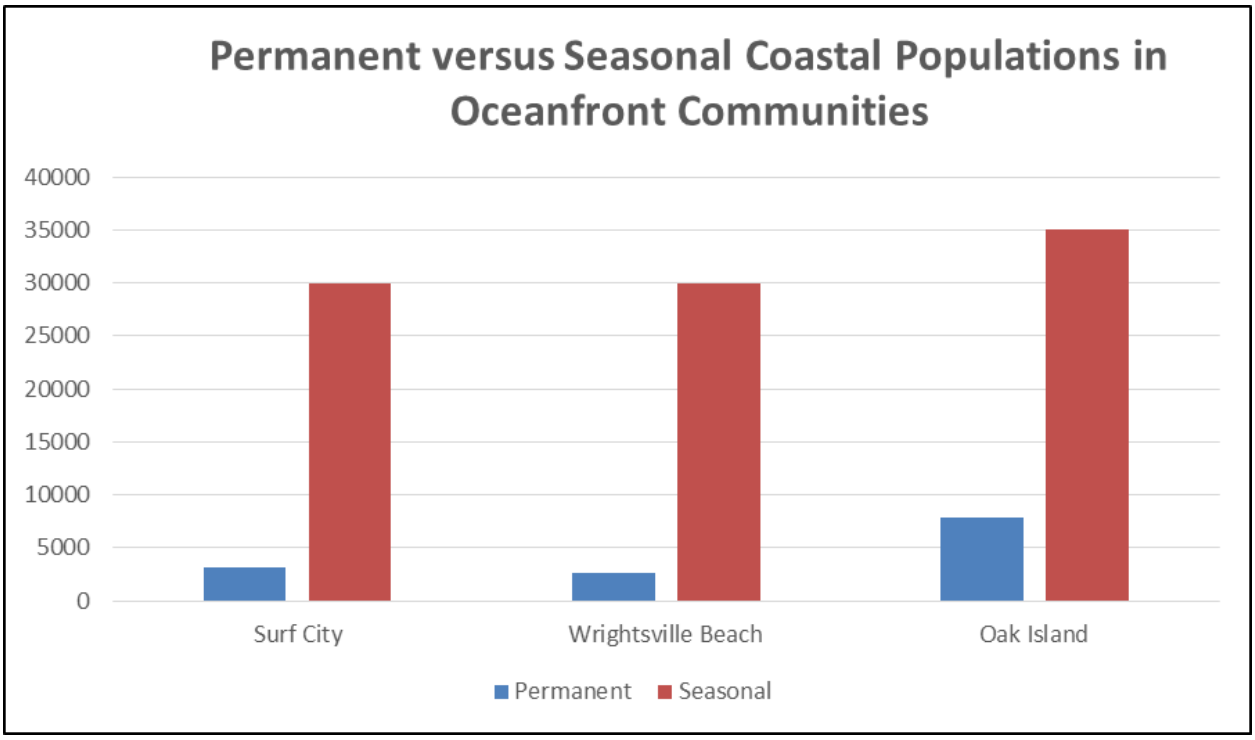


Figure 11: Permanent versus Seasonal Population in Beachfront Communities

4.3.2 Exposed Infrastructure

Assets exposed to risk include residential, commercial, industrial, public, and transportation infrastructure. Information from the 2016 North Carolina Hurricane Evacuation Study (HES) identifies the number of critical facility types and whether they are exposed to specific categories of storm surge within Brunswick and New Hanover Counties. **Table 11** represents Brunswick County, while **Table 12** represents New Hanover County.

Table 11: Brunswick County Critical Facility Exposure to Coastal Storm Surge Inundation

Facility Type	CAT 1 MOM	CAT 2 MOM	CAT 3 MOM	CAT 4 MOM	CAT 5 MOM	Outside of Surge Risk Area	In 1% AEP Event	Total
Emergency Operations Centers	0	0	0	0	0	1	0	1
EMS Locations	0	1	2	5	9	9	2	18
Fire Stations	2	4	9	14	22	19	3	41
Police Stations	0	4	5	7	8	6	2	14
Airport	0	0	0	1	1	5	1	6
Total	2	9	16	26	38	39	8	80

Table 12: New Hanover County Critical Facility Exposure to Coastal Storm Surge Inundation

Facility Type	CAT 1 MOM	CAT 2 MOM	CAT 3 MOM	CAT 4 MOM	CAT 5 MOM	Outside of Surge Risk Area	In 1% AEP Event	Total
Emergency Operations Centers	0	0	0	0	0	1	0	1
EMS Locations	0	0	0	0	1	2	0	3
Fire Stations	1	1	3	4	7	14	0	21
Prisons	0	0	0	0	1	0	0	1
Police Stations	2	2	4	5	8	10	1	18
Shelters	0	0	0	0	1	4	0	5
Airport	0	0	0	0	0	2	0	2
Total	3	3	7	9	18	33	1	51

4.3.3 Exposed Environmental and Cultural Resources

The Brunswick and New Hanover Counties Focus Area is rich with significant and unique environmental and cultural resources. Because of factors including plentiful food sources, multiple habitat types, tidal influence, and ocean access, man and nature have inhabited coastal North Carolina for ages. Coastal storms and sea level rise continue to expose vulnerable environmental and cultural resources to risk of alteration or loss. To offer additional protection to at-risk environmental and cultural resources, where actionable and practicable, several potential structural and nonstructural measures have been identified. These measures are summarized in Sections 4.3.3.1 and 4.3.3.2 in addition to environmental and cultural resources priority areas/sites within the focus area. For additional information concerning exposed environmental and cultural resources in this focus area and in other North Carolina areas included in the SACS, please refer to the North Carolina Appendix.

4.3.3.1 Environmental Resources

The majority of exposed environmental resources were identified in the Tier 1 Risk Assessment, although the Tier 2 analysis refined our Tier 1 understanding of environmental exposure by incorporating state-level data. As seen in **Figure 12**, which depicts the SACS Tier I Risk Assessment Viewer's Environment, Culture, and Habitat Exposure Index, North Carolina's areas of highest exposure are concentrated in low-lying areas on barrier islands, back bay areas, and tidally influenced riverine areas. The reasoning for this is proximity to the hazards of sea level rise and coastal storm damage. Areas directly adjacent to water bodies are relatively more exposed than landward areas. Similarly, species that require these most exposed habitats are particularly exposed. As an example, shorebirds and sea turtles that use beaches as nesting habitat may experience a higher degree of exposure to hazards as compared with species that nest inland or at higher elevations.

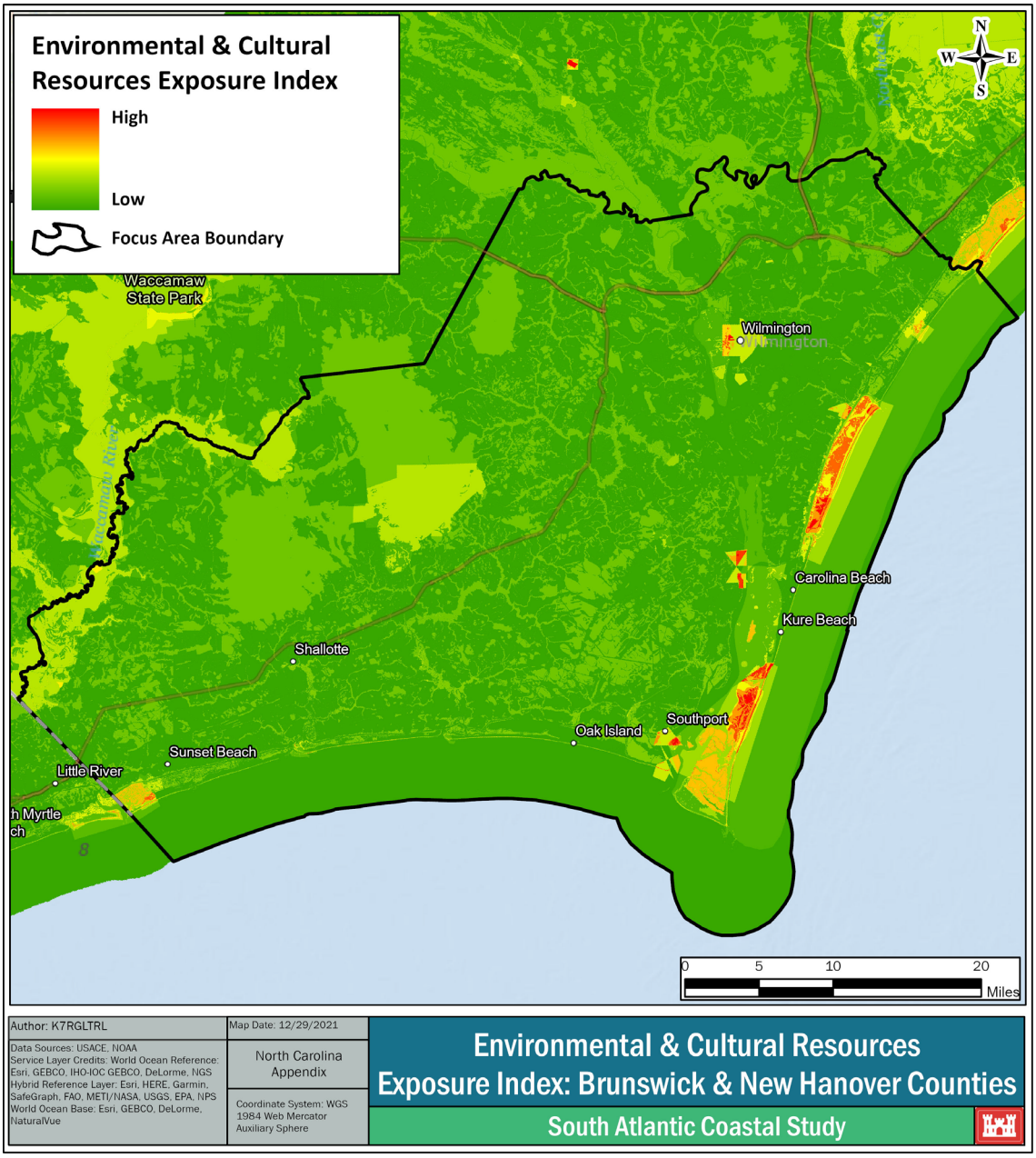


Figure 12: South Atlantic Coastal Study Tier 1 Risk Assessment Viewer (Environmental and Cultural Resources Exposure Index)

The primary data source used in Tier 2 analysis was the Data Explorer online tool curated by the North Carolina Natural Heritage Program (2020). This tool identifies natural areas with high ecological value, existing managed areas, and other areas of environmental significance within the state's boundaries. Natural areas in this focus area exposed to storm surge inundation include upland forests, coastal plain early successional habitats, scrub/shrub habitats, beaches and dunes, forested wetlands, shrub and herbaceous wetlands, wet pine savanna, pocosins, and submerged aquatic vegetation. Beaches, dunes, and other areas abutting water bodies are particularly exposed to erosion. For additional information regarding Tier 2 Environmental Resources Vulnerability and Risk Analysis, please refer to the Environmental Technical Report.

4.3.3.2 Cultural Resources

Ten at-risk resource sites and historic districts are identified within, or partially within, the focus area. These cultural resources were identified through collaborative discussions with the North Carolina Office of State Archaeology and the North Carolina State Historic Preservation Office.

- **USS North Carolina (NH0004):** Listed on the National Register of Historic Places (NRHP) in 1981, the U.S.S. NORTH CAROLINA is near the Wilmington census place in New Hanover County. The former World War II battleship was completed in April 1941, decommissioned in June 1947, and transferred to North Carolina in 1961. The ship is also a National Historic Landmark.
- **Cape Fear Memorial Bridge (NH2326):** Although not listed on the NRHP, the bridge is located within the Wilmington Historic District. Completed in 1969, the bridge carries U.S. Route 17, U.S. Route 76, and U.S. Route 421 across the Cape Fear River between Brunswick and New Hanover Counties.
- **Upper and Lower Cape Fear Shipwreck Districts:** Listed on the NRHP in 1985, and located offshore, the Upper and Lower Cape Fear Shipwreck Districts' boundaries reach from the Little River at the North Carolina/South Carolina state line in Brunswick County to New Topsail Inlet in Pender County. Shipwreck density is greatest in the vicinity of Cape Fear River inlets.
- **Fort Fisher (NH0562):** Listed on the NRHP in 1966, Fort Fisher is located partially within the Kure Beach census place in New Hanover County. Used between 1861 and 1865 as a Civil War fort, it is also a National Historic Landmark.
- **Battery Buchanan (NH1473):** Listed on the NRHP in 1966, Battery Buchanan is located near the Kure Beach census place in New Hanover County. The Civil War battery is part of Fort Fisher.
- **Wilmington Historic District (NH0003):** Listed on the NRHP in 1974, the Wilmington Historic District is in the Wilmington census place in New Hanover County. The district exists in a nineteenth- to twentieth-century port town, with notable Italianate and Greek Revival influence.
- **Masonboro Sound Historic District (NH0780):** Listed on the NRHP in 1992, the Masonboro Sound Historic District is in the Wilmington census place in New Hanover County. The district is comprised of 10 contributing dwellings, and 13 contributing outbuildings constructed in the nineteenth and early twentieth century.
- **James and Frances Sprunt Cottage (NH0683):** Listed on the NRHP in 2003, the James and Frances Sprunt Cottage is in the Wrightsville Beach census place in New Hanover County. Constructed in 1937, the structure is an intact example of a two-story beach cottage with local significance.
- **Trask Memorial Bridge (NH3471):** Although not listed on the NRHP, the Trask Memorial Bridge has been determined eligible under Section 106 of the National Historic Preservation Act and is in the Wrightsville Beach census place in New Hanover County. Completed in 1956, the bridge carries U.S. Route 74, U.S. Route 76, U.S. Route 421 across the Atlantic Intracoastal Waterway.

- **Joy Lee Apartment Building and Annex (NH0628):** Listed on the NRHP in 1997, the Joy Lee Apartment Building and Annex are in the Carolina Beach census place in Brunswick County. The site consists of multiple stucco beach apartments constructed in 1945.

Potential strategies and measures to protect vulnerable areas of identified cultural resources may include elevating or relocating structures, excavating, and studying sites in eroding areas, constructing living shorelines or other breakwater structures to protect resources from wave action and erosion, and using dredged material beneficially to buffer the effects of wave attack.

4.3.3.3 Environmental and Cultural Resource Uncertainty

At this time, no certain effects of climate change on tropical cyclone activity in terms of frequency, intensity, and rainfall across all global basins have been identified. Current science related to climate effects on tropical cyclone activity have not reached the point of standard consensus necessary to inform change in storm analysis baselines. Similarly, the rate of sea level rise in North Carolina is unknown, although some models suggest that sea level will continue to rise, threatening natural and human environments. If protective measures are not implemented, habitat types with limited tolerance to salinity may migrate inland, be displaced, or be lost because of inundation or erosion. Similarly, cultural resources may be subjected to increased erosive forces, increased saline conditions, and potential inundation due to coastal storm damage and sea level rise.

4.4 Vulnerability

Vulnerability is the susceptibility of harm to human beings, property, and the environment when exposed to a hazard (USACE 2017). Regarding environmental vulnerability to the effects of coastal storms and sea level rise, salinity changes may alter or eliminate habitat types, precluding use by various species, including threatened and endangered species. Coastal storms may alter existing habitat through erosion, storm surge, and high winds. Coastal storms may also redistribute sand such that beaches and dunes may be expanded or reduced. Sand redistribution and salinity changes may significantly alter available habitat types and associated acreage for threatened and endangered species.

The Brunswick and New Hanover Counties Focus Area is highly vulnerable to coastal storms and sea level rise in part due to the following:

- **Habitat Conversion**: **Figure 13** illustrates the significant increase in acreages vulnerable to inundated in the between existing conditions and future conditions with sea level rise. Storm surge and sea level rise hazards may inundate currently upland natural communities and/or introduce increased localized salinity which may force habitat conversion.

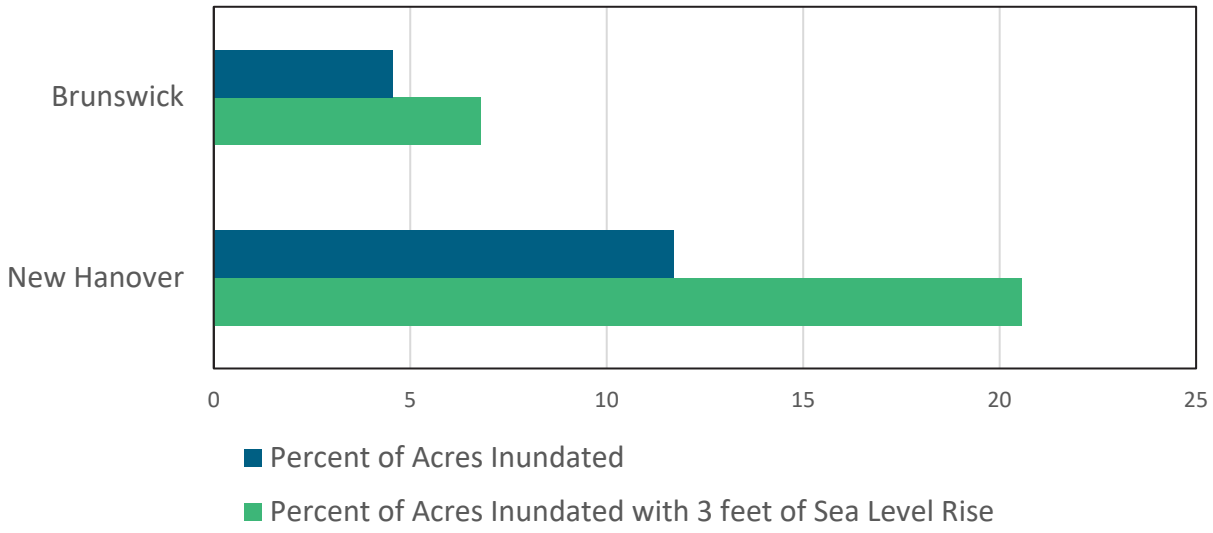


Figure 13: Comparison of Land Currently Vulnerable to Inundation and in Future Conditions with Sea Level Rise

- **Naturally dynamic barrier islands:** The barrier island portions of the Brunswick and New Hanover Counties Focus Area have historically migrated west via natural processes such as overwash as the islands slowly roll back up the continental shelf as sea levels rise. Static human development conflicts with this natural migratory process, creating vulnerability for people, property, and the islands.
- **High-density development and populations**: Brunswick and New Hanover Counties make up the most urbanized and populated area in all of coastal North Carolina.

The 2016 North Carolina HES used NOAA surge modeling, land surveying, and photography to visualize the vulnerability of landmark structure for potential surge height and depth of water for all categories of hurricane. **Figure 14** through **Figure 18** from the HES study illustrate the vulnerability of specific landmark locations within the focus area to storm surge inundation for a Hurricane Category 3 MOM. Although these images would not represent the inundation levels of all Category 3 hurricanes, they do represent what is possible in a worst-case scenario for a Category 3, based on the modeling.

Figure 14: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Shell Island Hotel in Wrightsville Beach, North Carolina (FEMA 2016)

Figure 15: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Courthouse on 3rd Street in Downtown Wilmington (FEMA 2016)

Figure 16: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the USS North Carolina Battleship Memorial on the Cape Fear River (FEMA 2016)

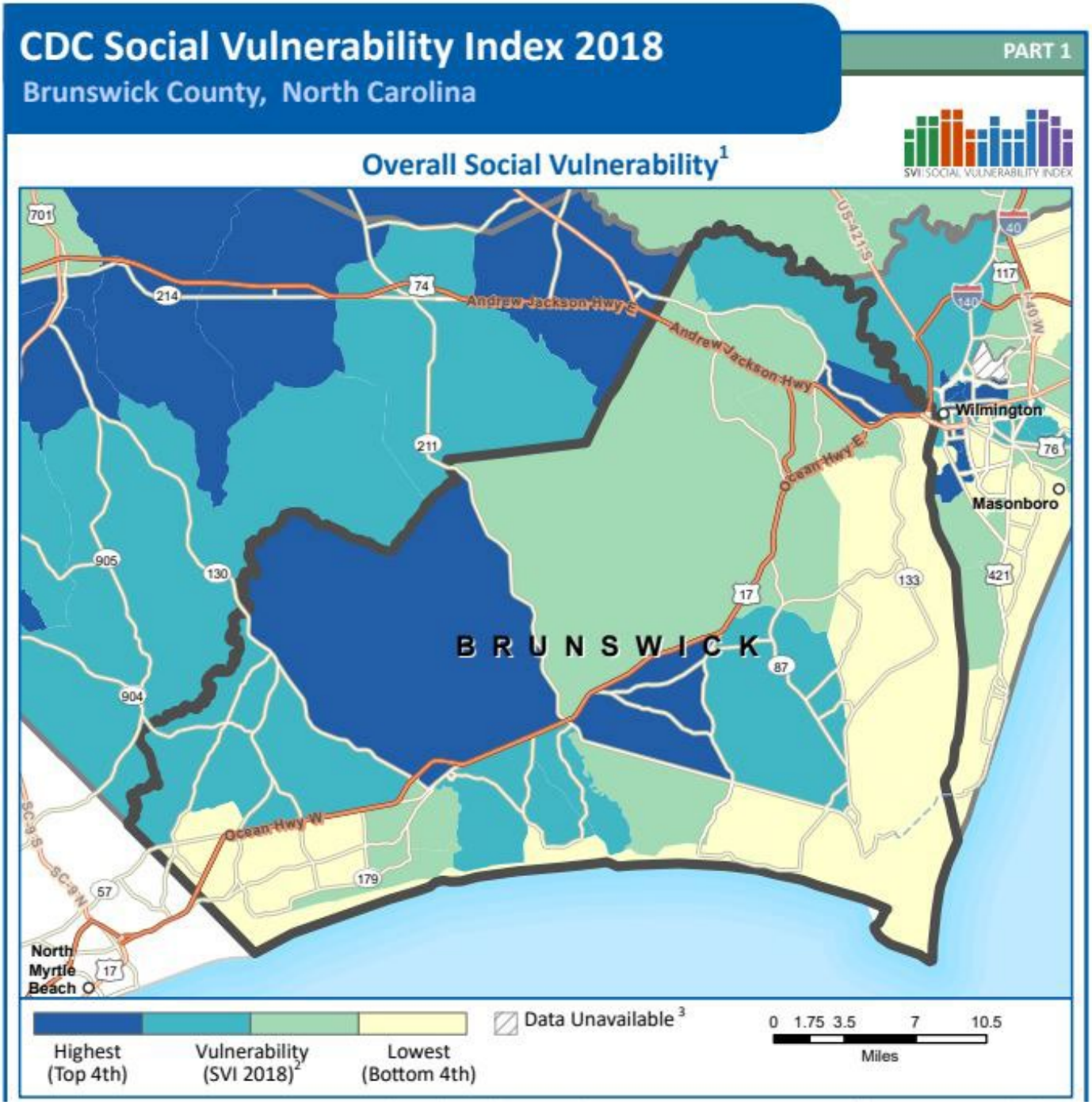
Figure 17: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Town Hall in Oak Island, Brunswick County (FEMA 2016)

Figure 18: Category 3 Maximum of Maximum Storm Surge Inundation (Water Height Represented by Pale Blue Line) at the Town Hall in Holden Beach, Brunswick County (FEMA 2016)

4.4.1 Social Vulnerability

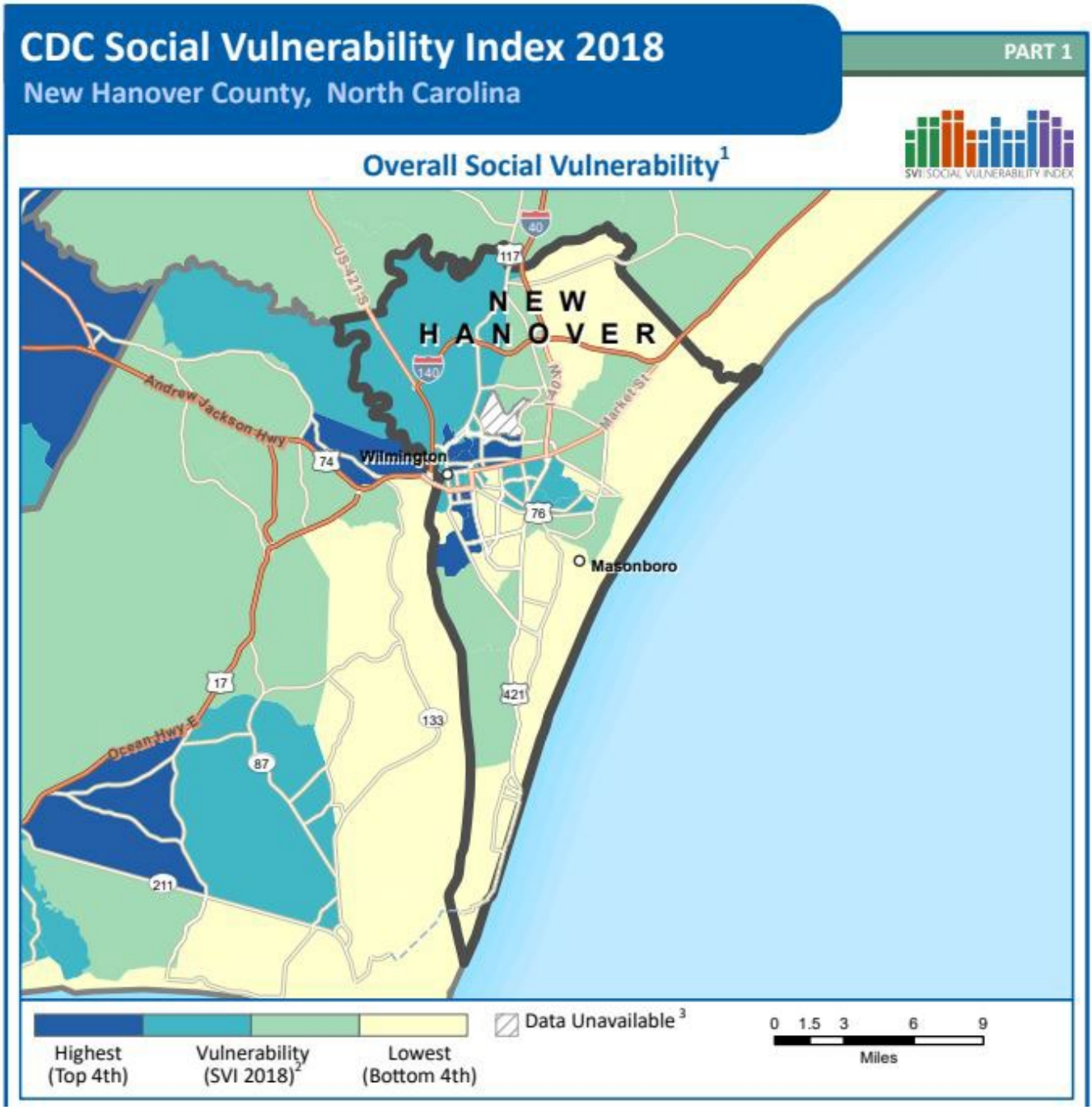
Social Vulnerability Index

The Centers for Disease Control and Prevention Social Vulnerability Index (CDC SVI) was used to further evaluate social vulnerability within the focus area by assessing overall SVI percentile rankings at the census tract scale. The CDC SVI depicts the social vulnerability of communities by assigning an SVI percentile ranking that ranges from 0 (lowest vulnerability) to 1 (highest vulnerability) based on national comparisons. The overall CDC SVI ranking for Brunswick County is in the 0.25 to 0.5 quartile, which indicates a moderate level of vulnerability within the focus area. At a more refined scale, census tracts in the areas of Shallotte, Mill Branch, Exum, Bolivia, and Leland have significantly higher CDC SVI rankings (>0.7501) than neighboring communities, indicating a high level of social vulnerability (**Figure 19**). New Hanover County also has an overall CDC SVI ranking in the 0.25 to 0.5 quartile, indicating a moderate level of vulnerability within the focus area. At the census track level, the highest areas of social vulnerability are located close to downtown Wilmington (**Figure 20**). The North Carolina Appendix provides additional detail about the CDC SVI.



[1]*Overall Social Vulnerability: All 15 variables.*
[2]*Data Sources: CDC/ATSDR/GRASP, U.S. Census Bureau, Esri StreetMap TM Premium.*
[3]*Census tracts with 0 population.*

Figure 19: Brunswick County Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)



[1]*Overall Social Vulnerability: All 15 variables.*
[2]*Data Sources: CDC/ATSDR/GRASP, U.S. Census Bureau, Esri StreetMap TM Premium.*
[3]*Census tracts with 0 population.*

Figure 20: New Hanover County Centers for Disease Control Social Vulnerability Index Ranking by Census Tract (CDC 2018)

Environmental Justice

USACE conducted an evaluation of environmental justice (EJ) by determining whether the study area contains a concentration of minority and/or low-income populations.

As defined in Executive Order 12898 and the Council on Environmental Quality (CEQ) guidance, a minority population is when one or both of the following conditions are met within a given geographic area:

- American Indian, Alaskan Native, Asian, Pacific Islander, Black, or Hispanic population of the affected area exceeds 50 percent.
- Minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis.

An affected geographic area consists of a low-income population when the percentage of low-income persons:

- is at least 50 percent of the total population, or
- is meaningfully greater than the low-income population percentage in the general population or other appropriate unit of geographic analysis.

The Environmental Protection Agency (EPA) EJScreen is an EJ mapping and screening tool that provides the EPA with a nationally consistent dataset and approach for combining environmental and demographic indicators (EPA 2020). EJScreen users choose a geographic area; the tool then provides demographic and environmental information for that area. For the purposes of this evaluation, only demographic information was applied for the area.

The low-income population is the percentage of a block group's population in households when the household income is less than or equal to twice the federal "poverty level."

The minority population is the percentage of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino (i.e., all people other than non-Hispanic, white-alone individuals). The word "alone" in this case indicates that the person is of a single race, not multiracial.

Using the EJScreen tool, the study area was user-defined (**Figure 21** and **Figure 22**) to calculate the average percentages for EJ criteria. The result is a population-weighted average, which equals the block group indicator values averaged over all residents estimated to be inside the study area. **Table 13** compares the average percentages for the study area, the State of North Carolina, and the United States.

Based on the information provided by the EJScreen tool, for Brunswick County, the average minority population is approximately 18 percent of the total population, and approximately 28 percent of the population is considered low-income. For New Hanover County, the average minority population is approximately 23 percent, and approximately 33 percent of the population is considered low-income. When assessed at a county-level geographic scale, Brunswick and New Hanover Counties do not meet

the EJ community minimum threshold because the minority population and low-income percentages are below 50 percent. While these are overall county estimates, 2019 Census Bureau estimates show figures vary from one census tract to another. In Brunswick County, areas near Shallotte, Longwood, and inland from Sunset and Holden Beaches have higher percentages of low-income populations. In New Hanover County, census areas near downtown Wilmington have a high percentage of minority and low-income populations. Areas in midtown, in the vicinity of The University of North Carolina at Wilmington, have a high percentage of low-income populations.

Figure 21: User-Defined Environmental Protection Agency EJScreen Tool Analysis Boundary (EPA 2020)

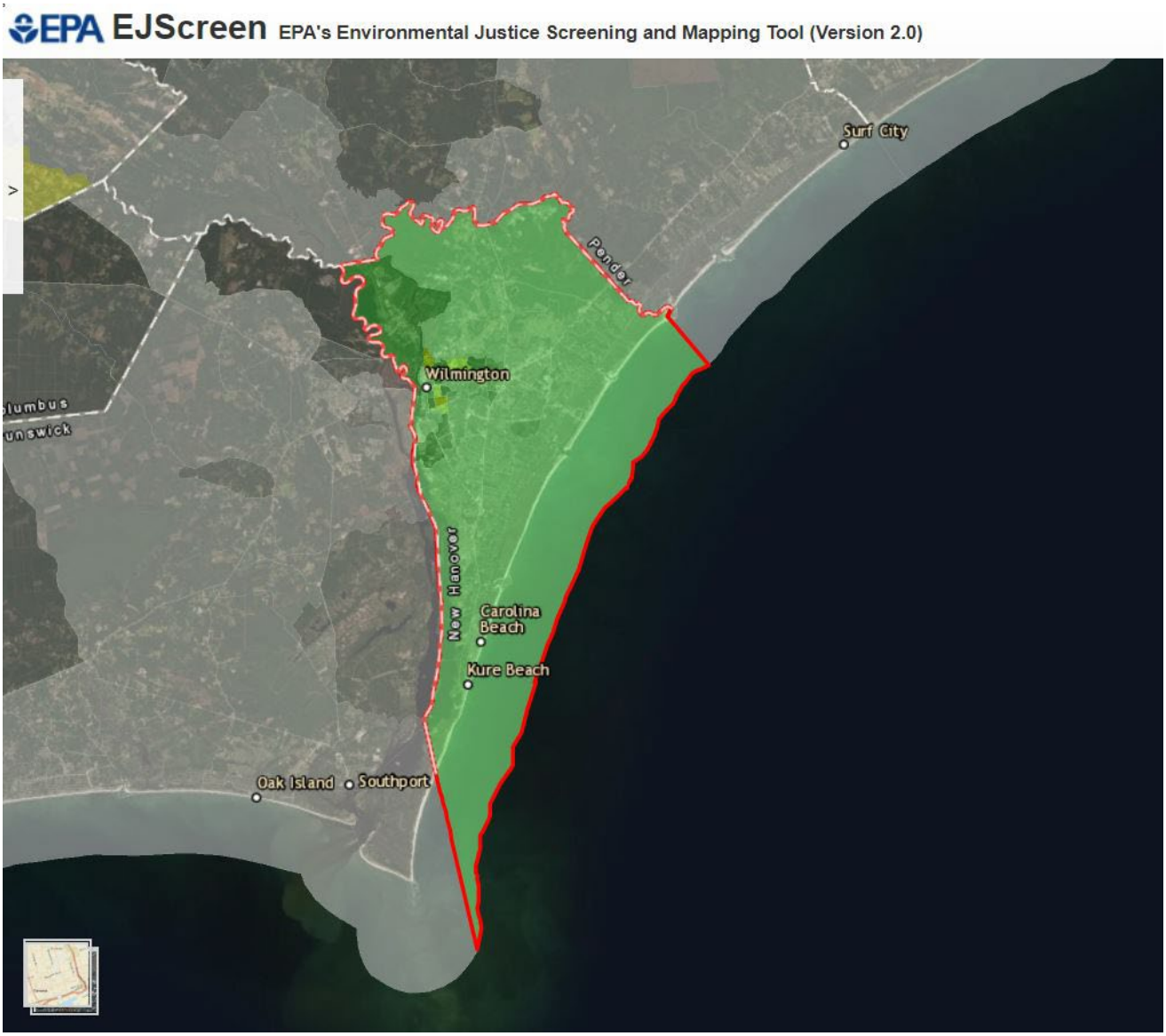


Figure 22: User-Defined Environmental Protection Agency EJScreen Tool Analysis Boundary (EPA 2020)

Table 13: Environmental Protection Agency EJScreen Tool Environmental Justice Criteria Percentages (EPA 2020)

Population Type	User-Defined Project Area % Brunswick/New Hanover County	North Carolina Average %	U.S. Average %
Minority Population	18/23	47	39
Low Income Population	28/33	36	33

4.4.2 Environmental Vulnerability

An environmental resources vulnerability analysis was conducted for the Brunswick and New Hanover Counties Focus Area to determine the degree to which natural areas are susceptible to loss or degradation when exposed to coastal storm hazards and sea level rise. A table was created from this analysis to assess the numerical level of vulnerability of natural habitats, which are assigned by the NOAA Coastal Change Analysis Program (C-CAP), against the hazards of sea level rise, storm surge inundation, saltwater intrusion, erosion, and wind damage. Based on the results of this assessment, a weighted formula was developed to assign a vulnerability rating of each C-CAP class (low, medium, or high) for each state and territory in the SACS study area (**Table 14**). **Figure 23** presents the results of the vulnerability scoring for each C-CAP habitat found within Planning Reach NC_02, which includes the focus area.

Table 14: Coastal Change Analysis Program Classes' Vulnerability Rating

NOAA Coastal Change Analysis Program (C-CAP) Habitat	Vulnerability Rating
Evergreen Forest	Medium
Grassland	Medium
Deciduous Forest	Medium
Mixed Forest	High
Unconsolidated Shore	Medium
Estuarine Forested Wetland	Low
Estuarine Emergent Wetland	Low
Palustrine Emergent Wetland (Persistent)	Medium
Palustrine Scrub/Shrub Wetland	Medium
Palustrine Forested Wetland	Medium
Palustrine Aquatic Bed	Medium
Scrub/Shrub	Medium
Estuarine Scrub/Shrub Wetland	Low
Open Water	Medium
Estuarine Aquatic Bed	Low

In addition to rating the vulnerability of the natural habitats to the hazards identified above, the ability for the natural habitat to adapt to these conditions was also assessed. Low tolerances of certain habitats to water and soil chemistry changes caused by saltwater inundation, intrusion, and impediments to migration were identified as important vulnerability considerations. Anthropogenic activities, such as increased residential and commercial development in the coastal plain and the construction of structural coastal storm risk management infrastructure (e.g., sea walls), can produce barriers that impede inland migration of natural resources.

Please see Appendix B of the Environmental Technical Report for a more detailed summary of the resource vulnerability table and scoring criteria.

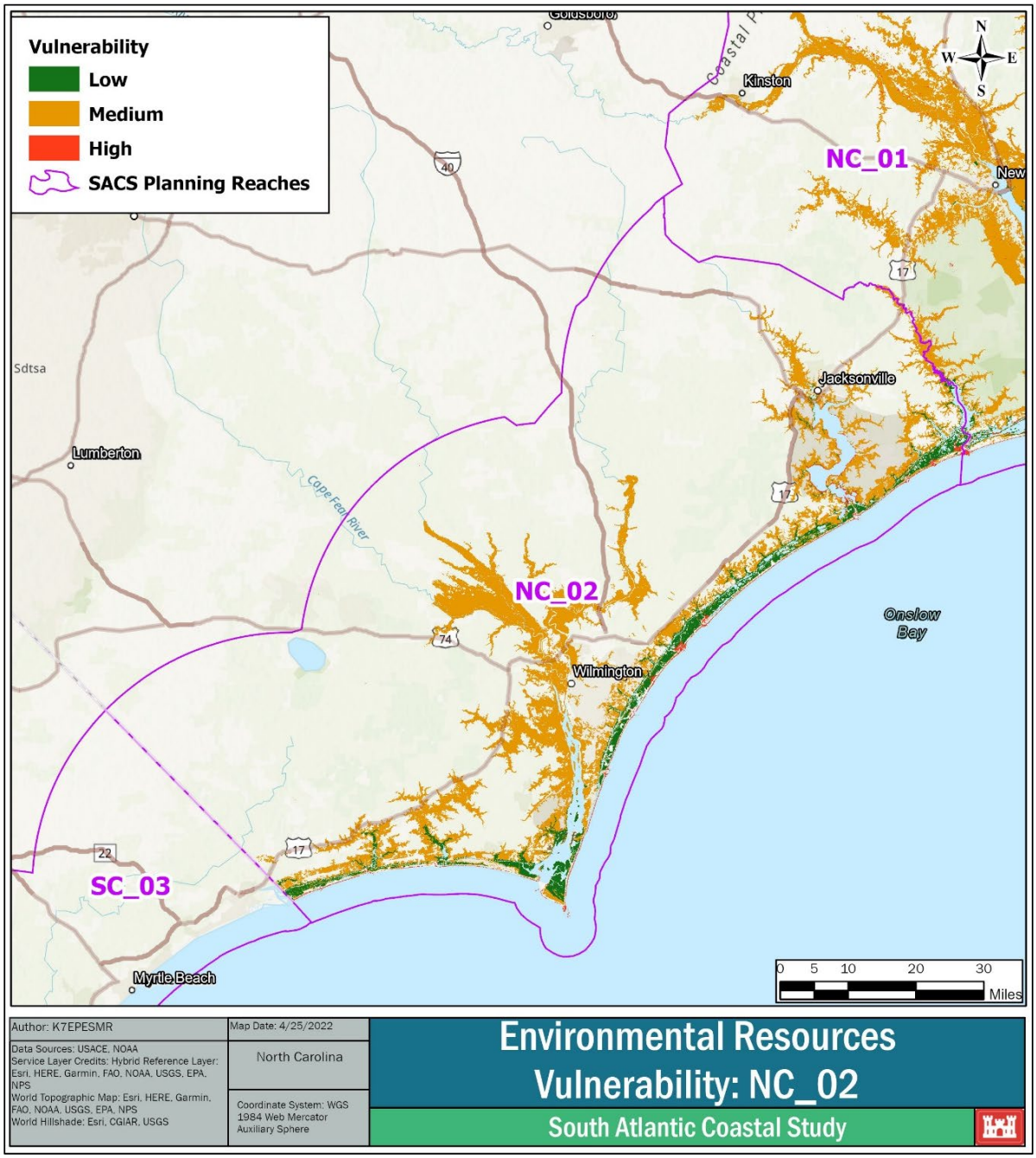


Figure 23: Brunswick County and New Hanover County Vulnerability Rating for Coastal Change Analysis Program Habitats

4.5 Consequences

The focus area has endured many coastal storms over the years averaging a storm within 50 nautical miles every 2.4 years, and each one has been unique in the exact set of impacts that it brought. Hurricane Florence was a recent and consequential storm that impacted the area. As reported by the National Hurricane Center, in New Hanover County, widespread flash flooding closed many roads and inundated neighborhoods. Up to 3 feet of water entered homes in the North Chase neighborhood

and 350 water rescues were performed in Wrightsboro and Ogden. The Cape Fear River flooded portions of downtown Wilmington with water over 2 feet deep. New Hanover County and Wilmington were isolated from the outside world for several days as every access route including Interstate 40 and U.S. Highways 17, 74, 76, and 421 were closed due to flooding. More than 22 million gallons of untreated sewage overflowed into area waterways. Strong winds blew down a large number of trees and power lines, cutting electricity to over 90 percent of the county. Many homes and businesses suffered wind damage to roofs, garage doors, and siding, and roads were blocked because of downed trees. There was damage to every school building in the county and the UNC–Wilmington campus alone suffered $140 million in damage.

In Carolina Beach and Kure Beach, significant beach erosion cut escarpments up to 10 feet high into the dune face. The southern end of Masonboro Island was overwashed, and 15 to 20 feet of dunes were lost on the north end of the island.

In Brunswick County, widespread flash flooding resulted in flooded neighborhoods and the closing of many roads, including portions of U.S. Highway 17 and NC Highway 87. Extremely high water in Town Creek flooded 30 homes in the Stoney Creek neighborhood. Sanford Dam at Boiling Spring Lakes, built in 1961, was breached, destroying Alton Lennon Drive, and flooding one structure. NC Highway 133 was closed because of flooding in several locations. High winds downed trees and power lines across the area. In Southport, falling trees damaged homes, businesses, and churches. Caswell Beach suffered downed trees and a loss of water and sewer service. On Bald Head Island substantial beach erosion occurred, followed by longer-term flooding due to high water levels on the Cape Fear River. Power to the island was out for two weeks and ferry service was unavailable. Over 80 percent of the county was without power (Berg et. al 2019).

Each storm can have differing impacts. The Tier 1 and Tier 2 analyses incorporated both vulnerability and consequence in the overall risk assessment. The FEMA Hazus Flood Model uses damage functions to represent the vulnerability of different types of infrastructure to flood hazards. The consequences of infrastructure impacts are represented in dollar-damages through the Tier 2 Economic Risk Assessment. The Tier 2 analysis assigned vulnerability scores to NOAA's Coastal Change Analysis Program (C-CAP) land cover classifications based on potential exposure to hazards. Vulnerability scores were assigned based on adaptive capacity of the natural resources to inundation. Environmental consequences include resources disturbed, lost, or permanently altered because of the hazard. Social vulnerability was assessed during the Tier 1 Risk Assessment with consequences including life loss and relocation of vulnerable populations.

4.6 Risk Assessment

Population, infrastructure, environmental, and cultural resources are at risk within the Brunswick and New Hanover Counties Focus Area. The risk is driven by a combination of factors, including wave attack, erosion, and inundation from coastal storms. This risk will increase as sea level rises.

4.6.1 Priority Environmental Areas

Five PEAs are identified within, or partially within, the Brunswick and New Hanover Counties Focus Area. These areas were identified through collaboration with multiple state and federal stakeholders.

Masonboro Island Reserve

Located near the Wrightsville Beach, Wilmington, Myrtle Grove, Seabreeze, and Carolina Beach census places in New Hanover County, Masonboro Island Reserve contains approximately 5,600 acres of beach/dune habitat, tidal marsh, tidal flats, and scrub/shrub habitat. The reserve is the largest undisturbed barrier island along the southern part of the North Carolina coast at over 8 miles long between Masonboro Inlet and Carolina Beach Inlet.

Designated in 1991 and managed by NCDCM, the North Carolina Division of Parks and Recreations, and private entities, the reserve is an essentially pristine barrier island and estuarine system. The various salinity patterns found in the extensive subtidal and intertidal areas along the sound side of the island support a myriad of estuarine species. Loggerhead and green sea turtles commonly nest on the beaches. Species of concern nesting within the reserve include the American oystercatcher, black skimmers, Wilson's plovers, and least terns.

Green Swamp Preserve

Located near the Bolivia census place and the New Hope, Piney Grove, and Prospect non-census places in Brunswick County, the Green Swamp Preserve contains nearly 13,000 acres of dense evergreen shrub bog pocosin. Some of the nation's finest examples of longleaf pine savannas provide habitat for the endangered red-cockaded woodpecker.

Managed by the North Carolina Wildlife Resources Commission, the Nature Conservancy, and private entities, the preserve contains at least 14 species of insectivorous plants such as Venus flytraps, sundews, and pitcher plants. The preserve is also home to many rare animals, including the American alligator, Henslow's sparrow, Bachman's sparrow, and Hessel's hairstreak butterfly.

Sunset Beach Bird Island Coastal Reserve

Located within the Sunset Beach census place in Brunswick County, the Sunset Beach Bird Island Coastal Reserve contains nearly 1,300 acres of sand dunes, salt marsh, beach, maritime grasslands, shrub thickets, and salt/mud flats.

Managed by NCDCM, the reserve is considered an Audubon Important Bird Area and provides important habitat and nesting opportunities for numerous species listed as endangered, threatened, or of special concern, including the Kemp's ridley and loggerhead sea turtles, and various colonial shorebirds.

Fort Fisher State Recreation Area

Located near the Kure Beach census place in Brunswick County, Fort Fisher State Recreation Area contains nearly 300 acres of beaches, dunes, tidal wetlands, and forested wetlands.

Managed by NCDCM, the North Carolina Division of Parks and Recreation, and the U.S. Department of Defense (i.e., Military Ocean Terminal Sunny Point), loggerhead sea turtles, piping plovers, and other rare species nest along the sandy shore.

Carolina Beach State Park

Abutting the Carolina Beach census place, Carolina Beach State Park contains approximately 750 acres of scrub/shrub, forested wetlands, evergreen forest, and tidal wetlands near developed areas.

Managed by the North Carolina Division of Parks and Recreation, private entities, and the U.S. Department of Defense (i.e., Military Ocean Terminal Sunny Point), the park is bordered by the Cape Fear River and Snow's Cut River, and it is home to multiple carnivorous plants, including Venus flytrap, sundews, and pitcher plants. The small ponds within the park, known as limesink ponds, are each home to unique plant communities. Additionally, the park is located along a bird migration corridor and attracts multiple species. Reptiles such as the American alligator, multiple species of amphibians, and mammals such as the eastern fox squirrel are resident species.

Potential strategies and measures to protect particularly vulnerable areas of identified PEAs may include building a comprehensive actionable plan for stormwater management in unincorporated areas overlapping with managed lands, constructing living shorelines to protect habitat and marshes from wave action and erosion, using dredged material beneficially to support marsh or beach resiliency, implementing sediment management strategies that support beach nourishment and island breach repairs, and continuing to study and monitor benchmark surface elevation in wetlands to better understand the effects of sea level rise in terms of habitat inundation.

4.6.2 Population and Infrastructure Risk

Figure 24 provides a snapshot of the Tier 2 Economic Risk Assessment for the focus area. Each circle on the map denotes separate census places and displays their economic risk from low to high. Bar charts on the figure highlight the census places with the greatest economic risk, with quantifications of the existing (green shading) and future risks, including sea level rise (black shading). Economic risks displayed are not cumulative. The distribution of existing and future economic risks is further broken down by counties with the greatest risk. The analysis includes National Economic Development risk and consequences of events. The total expected annual damages (EAD) for the Brunswick and New Hanover Counties Focus Area are $124.5 million under existing conditions and $260.4 million under future conditions, an increase of 110 percent with 3 feet of sea level rise. The total value accumulates all damages in the focus area. Oak Island, Wrightsville Beach, Wilmington, Carolina Beach, Holden Beach, Ocean Isle Beach, Myrtle Grove, Sunset Beach, Bald Head Island, Sea Breeze, Saint James, and Caswell Beach are all areas within the Brunswick and New Hanover Counties Focus Area.

A problem in this area is the damage to structures due to coastal storm driven inundation and erosion. Under existing conditions, a 2-percent AEP (50-year) flood event will cause $1.4 billion of damages and under future conditions, it would cause $2.9 billion of damages. The consequences are more than doubled for the future conditions with 3 feet of sea level rise. The census places with the greatest risk include Oak Island, Wrightsville Beach, Wilmington, Carolina Beach, Holden Beach, and Ocean Isle Beach.

Focus Area

New Hanover / Brunswick Counties

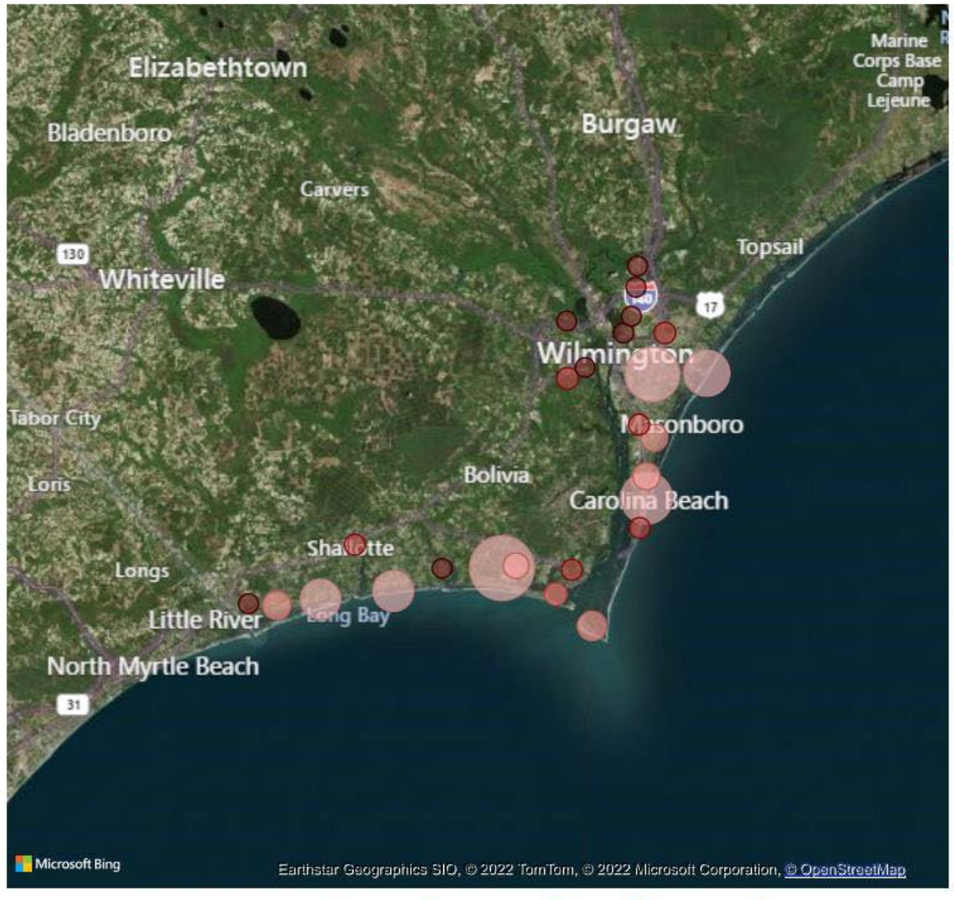
New Hanover / Brunswick Counties

$124,545,754
Existing Risk ($EAD)

$260,354,786
Future Risk ($EAD)

Focus Area Risk by County

County	Existing Risk ($)	Future Risk ($)
Brunswick	$61,208,656	$128,851,585
New Hanover	$63,337,098	$131,503,201
Total	**$124,545,754**	**$260,354,786**



Existing Consequences by Return Interval Event

Future Consequences by Return Interval Event

Existing Risk ($EAD) & Future Risk ($EAD) by Census Places in Focus Area

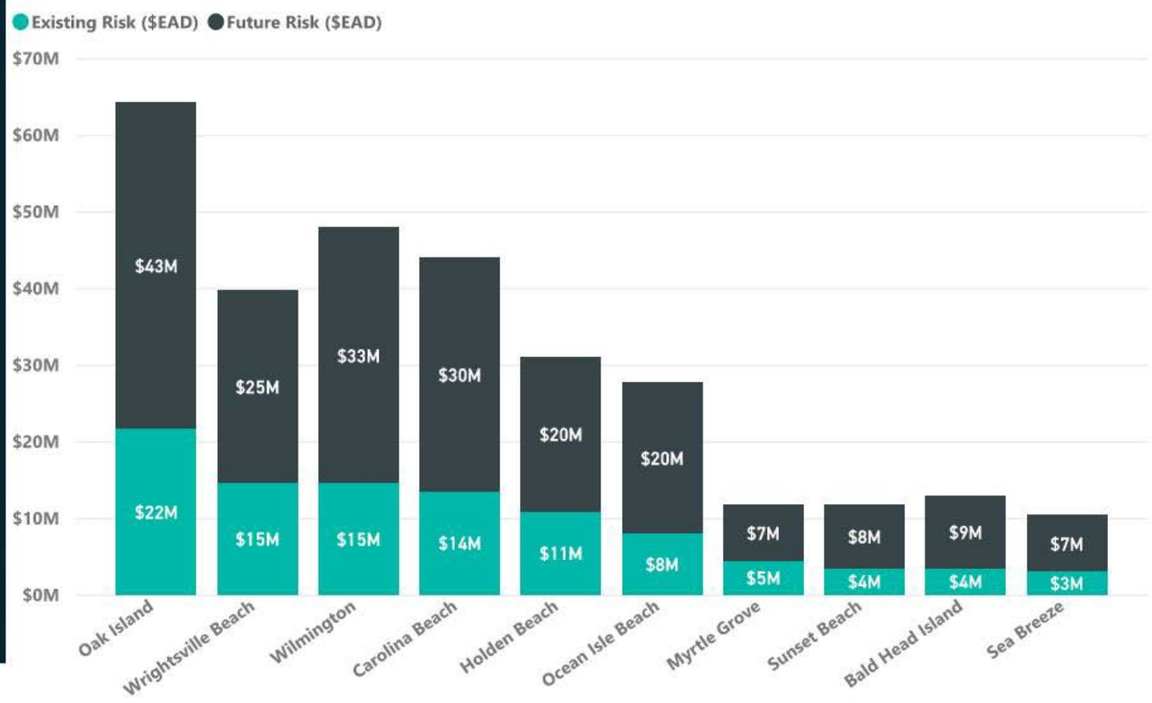


Figure 24: Existing and Future Economic Risk in Brunswick and New Hanover Counties due to Storm Surge

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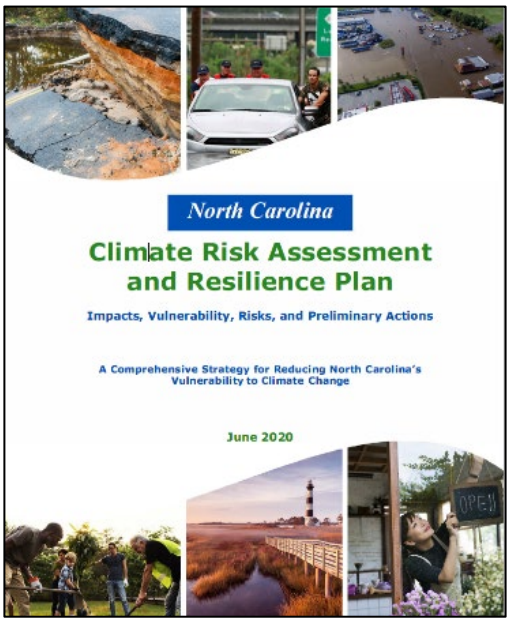
5. Action Strategy Development

North Carolina continues to be proactive with resiliency efforts along the coastline, and initiatives have been implemented or are planned throughout all levels of government, as well as by non-governmental entities. This FAAS for the Brunswick and New Hanover Counties Focus Area within the scope of the SACS was developed in support of the significant ongoing efforts within the region. One major existing strategy in North Carolina falls under the governor's Executive Order 80 (North Carolina Office of the Governor 2018), which is a commitment to address climate change and transition to a clean energy economy. Within Executive Order 80 is the North Carolina Climate Risk Assessment and Resiliency Plan (NCDEQ 2020). This existing plan builds upon North Carolina's ongoing work in this area and establishes the North Carolina Resilience Strategy, which includes four elements:

1. North Carolina Climate Science Report
2. State Agency Resilience Strategy
3. Statewide Vulnerability Assessment and Resiliency Strategies
4. North Carolina Enhanced Hazard Mitigation Plan



Accordingly, the Brunswick and New Hanover Counties FAAS does not seek to create a strategy separate from significant and ongoing efforts, but to support those of the region and develop additional considerations for future federal and non-federal efforts. The scope of the SACS ties into several critical sectors of study within the North Carolina Climate Risk Assessment and Resiliency Plan, including coastal resources, ecosystems, housing, building and support services, public safety, and transportation. Where possible, the Brunswick and New Hanover Counties FAAS seeks to contribute to the overall North Carolina Climate Risk Assessment and Resiliency Plan while supporting the SACS Shared Vision statement as created by the stakeholders of Brunswick and New Hanover Counties.

5.1 Identify Possible Solutions

A series of workshops were held with focus area stakeholders to identify ongoing, planned, and needed actions to address problems and realize opportunities identified earlier in this report. Proposed actions were evaluated based on their ability to address those problems, realize opportunities, and contribute to the objectives. Actions were grouped in categories of Infrastructure and Mitigation, Sediment Management, and Education and Outreach.

There are several SACS key products that can be used to help identify measures and possible solutions. The SACS Measures and Cost Library (MCL) can be used to identify suitable measures based on wave energy (USACE 2022b). Planning-level rough-order-of-magnitude (ROM) cost estimates and the Tier 2 Economic Risk Assessment can be used to identify potential economic benefits. The 2020

RSM Optimization Update and SAND Report can be used to identify opportunities for RSM strategies and suitable sand sources. In general, measures are organized into structural, nonstructural, and natural and nature-based features (NNBF).

Components, or actions, of a strategy are characterized in this report as one of several types of risk management measures. A risk management measure is defined for the purposes of this study as any feature or activity implemented at a specific location to meet one or more planning objective. There are three types of management measures identified for this study:

- **Structural measure**: Structural measures consist of human-made structures designed to reduce the occurrence and/or severity of an event that leads to harm.
- **Nonstructural measure**: Nonstructural measures reduce risk by either removing the item of concern from the exposure or reducing the item's degree of vulnerability to the harm.
- **NNBF**: the use of natural features or the human design of features that mimic or work in concert with natural processes to meet a planning objective. NNBF can include policy, and may be considered a structural or nonstructural measure, depending on the feature.

Each of the following identified actions have been organized as existing, planned, or needed actions, as well as if they are actions led by USACE or actions led by others.

5.1.1 Existing or Ongoing Actions

The following are actions that have already been implemented or are currently being implemented:

USACE Actions

- Conduct RSM for the Carolina Beach Inlet, Lockwoods Folly Inlet, Masonboro Inlet Navigation Project (jetties that maintain a navigable inlet), Masonboro Island placement (last action in 2010); and Wilmington Harbor, including Bald Head Island and Oak Island.
- Conduct coastal storm risk management with the existing Wrightsville Beach CSRM, Carolina Beach CSRM, and Ocean Isle CSRM projects through 2036.
- Conduct studies for Wrightsville Beach, Carolina Beach, and Holden Beach to evaluate future CSRM projects over the next 50 years.

Actions by Others

- Establish hurricane evacuation zones in Brunswick and New Hanover Counties.
- Develop a southeastern North Carolina hazard mitigation plan.
- Participate in the Resilient Coastal Communities Program, which is applicable to all 20 coastal counties, including Brunswick and New Hanover.
- Restore living shorelines and marshes with approximately four projects.

- Participate in the ReBUILD NC Program, which is applicable to Brunswick and New Hanover Counties.
- Participate in the FEMA Hazard Mitigation Grant Program, which is applicable to Brunswick and New Hanover Counties.
- Coastal Community Resilience Guide, which is applicable to Brunswick and New Hanover Counties.
- Participate in the National Estuarine Research Reserve Program for Masonboro Island, Zeke's Island, Bald Head Woods, and Bird Island.
- Conduct saltwater inundation and intrusion research.
- Working Lands Guidebooks, which are applicable to coastal farmlands in North Carolina.

5.1.2 Planned Actions

The following actions are planned to be implemented:

USACE Actions

- Develop a statewide non-federal dredged material management plan through Section 22 Planning Assistance to States program.

Actions by Others

- Conduct refuge management planning.
- Make improvements to evacuation route Highway 211 in Brunswick County.
- Implement the Southport Waterfront Master Plan.
- North Waterfront Park in Downtown Wilmington.
- Conduct the Living with Water Project at the Battleship North Carolina memorial.
- Restore the Brunswick Town Fort Anderson Shoreline.
- Conduct the Clear Run Branch Drainage Improvements and Stream Restoration project.

5.1.3 Needed Actions

The following actions were identified as potentially needed:

- Develop a New Oak Island CSRM project.
- Conduct a beach, dune, and back-barrier marsh restoration study for Masonboro Island.
- Conduct a Cape Fear River Basin flood risk management study.
- Develop a coupled model (freshwater plus coastal storm surge) for North Carolina.

- Discuss an offshore resources sediment management strategy.
- Identify new Dredged Material Management Areas (DMMAs), upland placement, and/or marsh restoration.
- Implement RSM Optimization Update strategies.
- Conduct an enhanced building-level risk assessment.
- Continue management actions for flood risk at Battleship North Carolina memorial.
- Silver Jackets Nonstructural Flood Risk Management Program – CHS Training Workshop

5.2 Evaluation of Actions

The potential actions listed in Section 5.1 were compared with the identified problems and opportunities, and, ultimately, the overall study objectives that were developed through the stakeholder engagement process, keeping in focus the overarching goals of the shared vision statement.

Potential actions that contribute to at least one study objective were included in the FAAS. Any measures not directly contributing to an objective were screened out for the purposes of the SACS FAAS. However, it is recognized that these screened actions may be worthwhile efforts of value through a separate application and could be implemented by others, if feasible. The following evaluation also reveals how specific actions are contributing to addressing the problems, opportunities, and objectives of the strategy (**Table 15**).

Table 15 : Evaluation of Potential Actions—Connecting Actions to Identified Problems, Opportunities, and Objectives in the Brunswick and New Hanover Counties Focus Area

Action Type	Potential Action	P1	P2	P3	P4	P5	P6	P7	IOB 1	IOB 1	IOB 3	IOB 4	IOB 5	IOB 6	IOB 7	O1	O2	O3	O4	O5	O6	OBJ 1	OBJ 2	G1	G2
Infrastructure and Mitigation	Infrastructure Retrofits Considering Sea Level Rise (New Hanover County)				X													X				X			
Infrastructure and Mitigation	Transportation Improvements to Evacuation Route Highway 211				X																	X			
Infrastructure and Mitigation	Resilient Coastal Communities Program (NCDCM)			X	X						X											X			X
Infrastructure and Mitigation	Home Elevations/Buyouts (FEMA Hazard Mitigation Grant Program)		X																			X			
Infrastructure and Mitigation	Removal of hazardous legacy infrastructure from the beach																								
Infrastructure and Mitigation	ReBUILD NC Strategic Buyout Program (North Carolina Office of Recovery and Resiliency [NCORR])		X																			X			X
Sediment Management	New CSRM Study – Wrightsville Beach (USACE)	X		X	X																	X	X	X	
Sediment Management	New CSRM Study – Carolina Beach (USACE)	X		X	X																	X	X	X	
Sediment Management	New CSRM Study – Holden Beach (USACE)	X		X	X																	X	X	X	
Sediment Management	Statewide Non-Federal Dredged Material Management Plan (USACE/NCDEQ)	X		X													X						X		
Sediment Management	PPE recommendations	X		X	X																	X	X	X	
Education and Outreach	Establishment of Hurricane Evacuation Zones				X																				X
Education and Outreach	North Carolina Coastal Community Resilience Guide (NCDCM)			X	X													X				X			X
Education and Outreach	Working Lands Climate & Salinization Study – Guidebooks (USDA)																								
Other Needed Actions	Beach, Dune, and Back-barrier Marsh Restoration Study – Masonboro Island (USACE)	X		X																X	X		X	X	
Other Needed Actions	Cape Fear River Basin – Flood Risk Management Study (USACE)				X	X																X	X	X	X
Other Needed Actions	New CSRM Study – Oak Island (USACE)	X		X	X																	X	X	X	
Other Needed Actions	Silver Jackets Nonstructural Flood Risk Management Program – CHS Training Workshop			X	X	X		X	X							X						X	X		X
Other Needed Actions	Offshore Sand Management Strategy Discussions (Bureau of Ocean Energy Management [BOEM], USACE, NCDCM)		X												X				X		X			X	X
Other Needed Actions	Headquarters-level Discussion for Potential Barrier Removal – FEMA Floodplain Maps (FEMA, USACE)				X							X		X										X	X
Other Needed Actions	Incorporate Federal CSRM Project Performance Recommendations	X		X	X																	X	X	X	
Other Needed Actions	RSM Optimization Update Opportunities Strategy	X		X											X		X						X		
Other Needed Actions	Apply CHS directly to NCORR Strategic Buyout Program				X			X								X									X
Other Needed Actions	Development of Coupled Model for North Carolina						X																		

Note: Orange shaded row denotes an action that was screened from the FAAS.

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5.2.1 Evaluation of Needed Actions

This section discusses future needed actions in more detail, split between USACE actions and action led by other agencies.

5.2.1.1 Needed USACE Actions

Offshore Resources Sediment Management Strategy Discussion

Purpose and need: Section 3.1 of the SACS-funded SAND Report identifies areas of sand deficiencies in North Carolina, specifically in the southern portions of the state (USACE 2020c). The SAND Report indicates discussions may be needed to move forward. This action would include updating the SACS Geoportal database of offshore sand resources, coordinating stakeholder/USACE workshops to address sediment budget needs and optimization opportunities, and potentially establishing a framework for statewide sediment resource management. This action may be most critical for the Brunswick and New Hanover Counties Focus Area, as the SAND Report identified deficiencies specific to this area. **Table 16** and **Table 17** show the potential deficit of available sand compared with projected needs for each county, while **Figure 25** and **Figure 26** show the locations of sand needs and potential sources.

Potential benefits and impacts of action: This action could result in the development of a strategy to manage offshore sand resources, and the implementation of actions specific to that strategy. This could identify new sand sources and avoid multiple-user conflicts in North Carolina.

Table 16: Deficit of Identified Available Sand Compared with the Projected Need for New Hanover County (USACE 2020c)

New Hanover County	50 year Sand Need		Offshore Borrow Areas		Estimated 50-year Regional Sediment Management Volume (CY)	Balance (CY)
	Estimated Volume (cubic yard [CY])	Volume (CY) with +55% Contingency	Estimated Volume (CY)	Estimated Volume (CY) Confidence Factor		
Figure Eight Island	15,300,000	23,700,000	–	–	–	–
Kure Beach	18,500,000	28,700,000	–	–	–	–
Masonboro Beach	6,400,000	10,000,000	–	–	–	–
Wrightsville Beach	9,200,000	14,300,000	–	–	–	–
Carolina Beach	16,700,000	25,800,000	–	–	–	–
Proven BA 90% Confidence)	–	–	30,100,000	27,100,000	–	–
Potential BA (70% Confidence)	–	–	20,000,000	14,000,000	–	–
Unverified Plus BA (non-volume contributing	–	–	0	0	–	–
Mason Inlet	–	–	–	–	7,500,000	–
Masonboro Inlet	–	–	–	–	10,000,000	–
Carolina Beach Inlet AIWW Crossing (Snows Cut)	–	–	–	–	1,700,000	–
Carolina Beach Inlet	–	–	–	–	4,200,000	–
AIWW_DA_241 (DA 241) DMMA	–	–	–	–	15,000,000	–
AIWW_DA_272 (DA 272) DMMA	–	–	–	–	0	–
AIWW_DA_275 (DA 275) DMMA	–	–	–	–	0	–
AIWW_DA_274 (DA 274) DMMA	–	–	–	–	0	–
WH_U0004 (WH 4) DMMA	–	–	–	–	0	–
Total:	**66,100,000**	**102,400,000**	**50,100,000**	**41,100,000**	**38,400,000**	**-23,000,000**

Table 17: Deficit of Identified Available Sand Compared with the Projected Need for Brunswick County (USACE 2020c)

Brunswick County	50-year Sand Need		Offshore Borrow Areas		Estimated 50-year Regional Sediment Management Volume (CY)	Balance (CY)
	Estimated Volume (cubic yard [CY])	Volume (CY) with +55% Contingency	Estimated Volume (CY)	Estimated Volume (CY) Confidence Factor		
Bald Head Island	25,700,000	39,800,000	–	–	–	–
Caswell Beach	4,200,000	6,400,000	–	–	–	–
Holden Beach	12,900,000	20,000,000	–	–	–	–
Oak Island	9,600,000	14,900,000	–	–	–	–
Ocean Isle Beach	10,400,000	16,000,000	–	–	–	–
Proven BA (90% Confidence)	–	–	8,500,000	7,600,000	–	–
Potential BA (70% Confidence)	–	–	36,400,000	25,500,000	–	–
Unverified Plus BA (non-volume contributing)	–	–	9,600,000	0	–	–
Tubbs Inlet – Jinks Creek, Mary's Creek, Turtle Creek	–	–	–	–	0	–
Wilmington Harbor	–	–	–	–	25,000,000	–
Lockwoods Folly AIWW Crossing	–	–	–	–	1,700,000	–
Shallotte Inlet AIWW Crossing	–	–	–	–	1,700,000	–
Shallotte Inlet	–	–	–	–	6,500,000	–
AIWW_DA_286 (DA 285) DMMA	–	–	–	–	0	–
Total:	**62,800,000**	**97,300,000**	**44,900,000**	**33,100,000**	**34,600,000**	**-29,600,000**

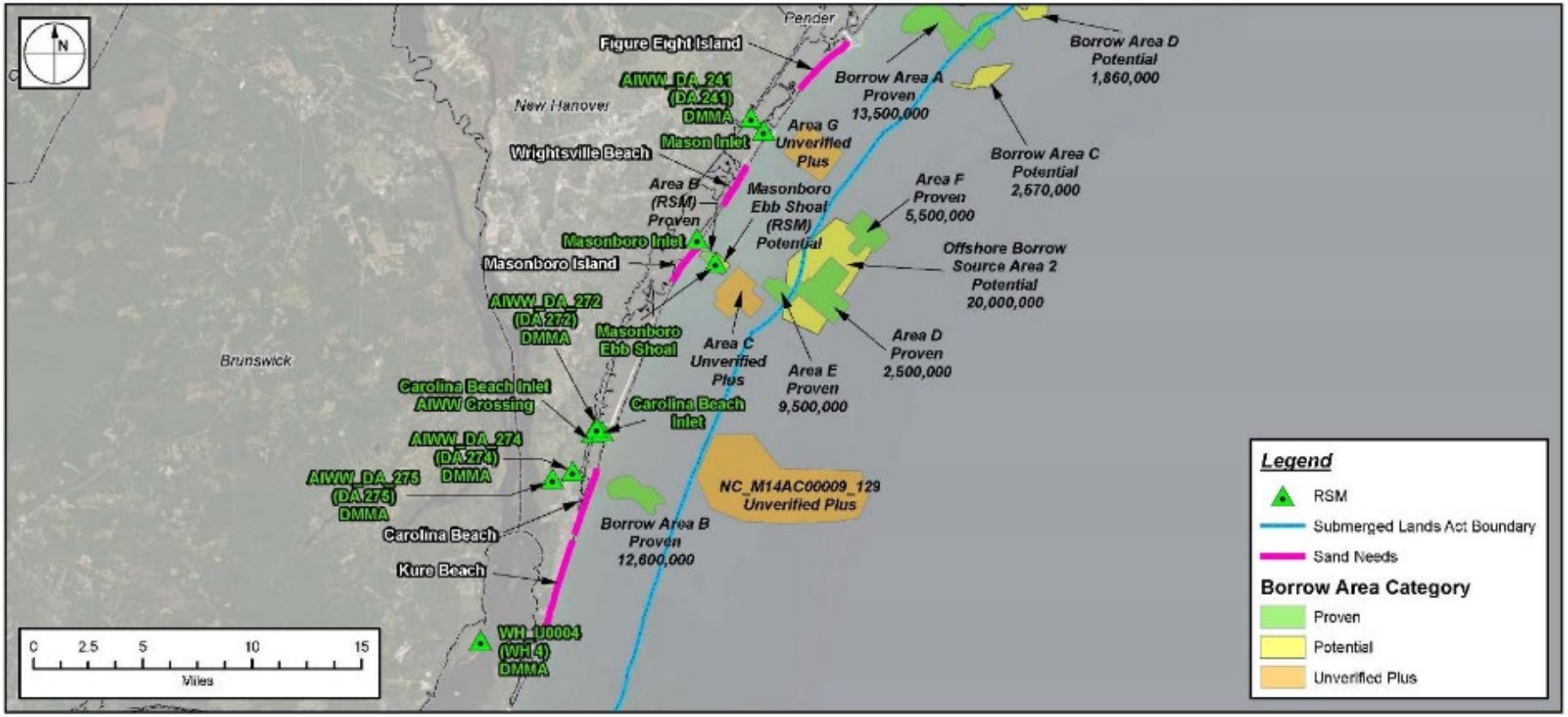

Figure 25: New Hanover County Sand Needs and Sources (USACE 2020c)

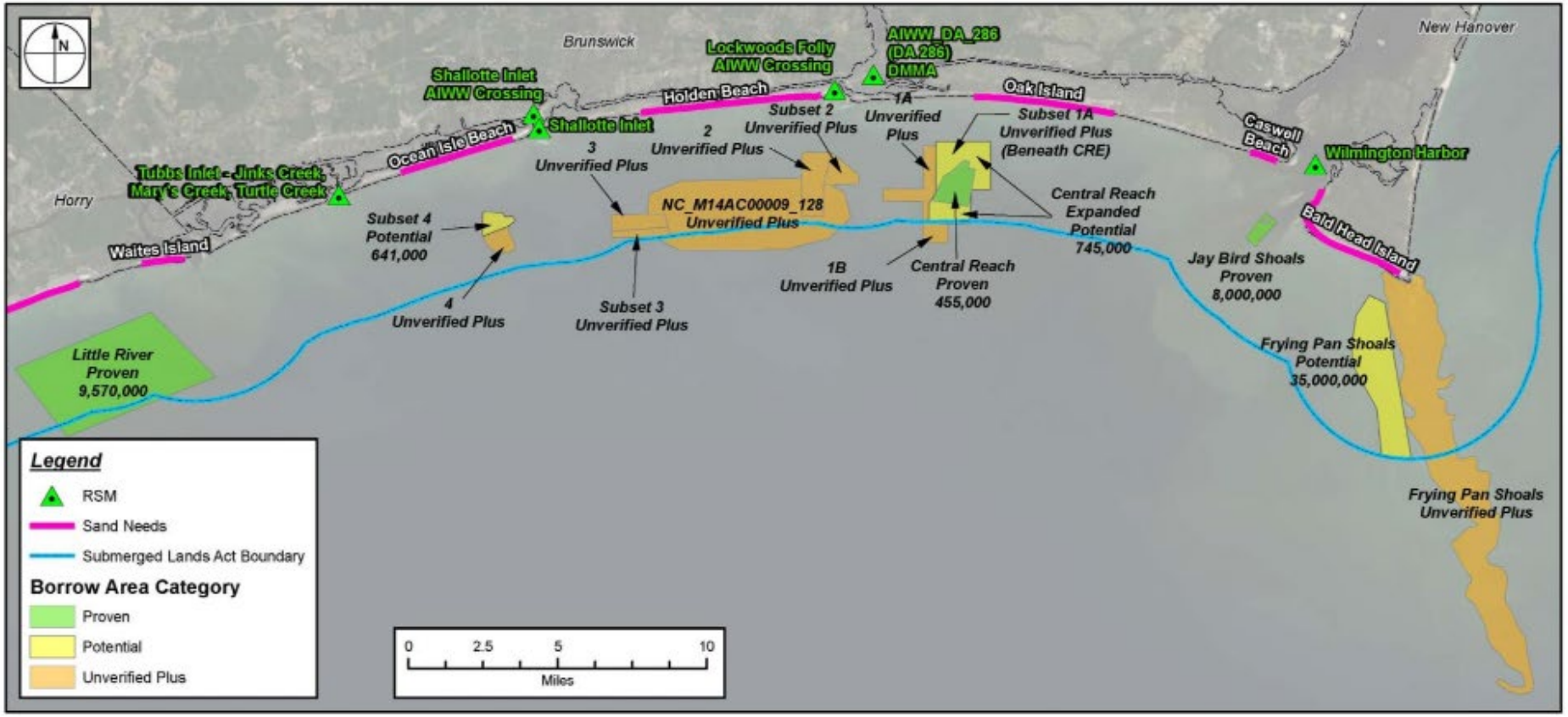

Figure 26: Brunswick County Sand Needs and Sources (USACE 2020c)

Coastal Storm Risk Management Project – Oak Island

Purpose and need: Located in Brunswick County, North Carolina, the Town of Oak Island has suffered extensive damage from coastal storms over, most recently in 2020. A CSRM project could reduce future risk to the community.

Potential benefits and impacts of action: The authorized project would reduce flood damages due to coastal storms along this coastline area.

Identify new Dredged Material Management Areas, Upland Placement, and/or Marsh Restoration

Purpose and need: Suggestions from both the RSM Optimization Update and the DMMA study were further discussed between the team, leadership, and the RSM Optimization Update team. Recommendations for USACE include:

1. Working with the RSM Optimization Update to ensure maximum efficiency of placement and overall health of the environment for each project.

2. Work with local and state stakeholder groups on placement opportunities in the focus area.

Beach, Dune, and Back-barrier Marsh Restoration – Masonboro Island

Purpose and need: The Tier 2 Environmental Resources Vulnerability Analysis recognized that natural barrier islands such as Masonboro are valuable and at-risk natural resources (**Figure 27**). Masonboro Island is suffering degradation from coastal storms, sea level rise, and anthropogenic effects. Ecosystem restoration measures could be implemented to preserve or restore habitat.

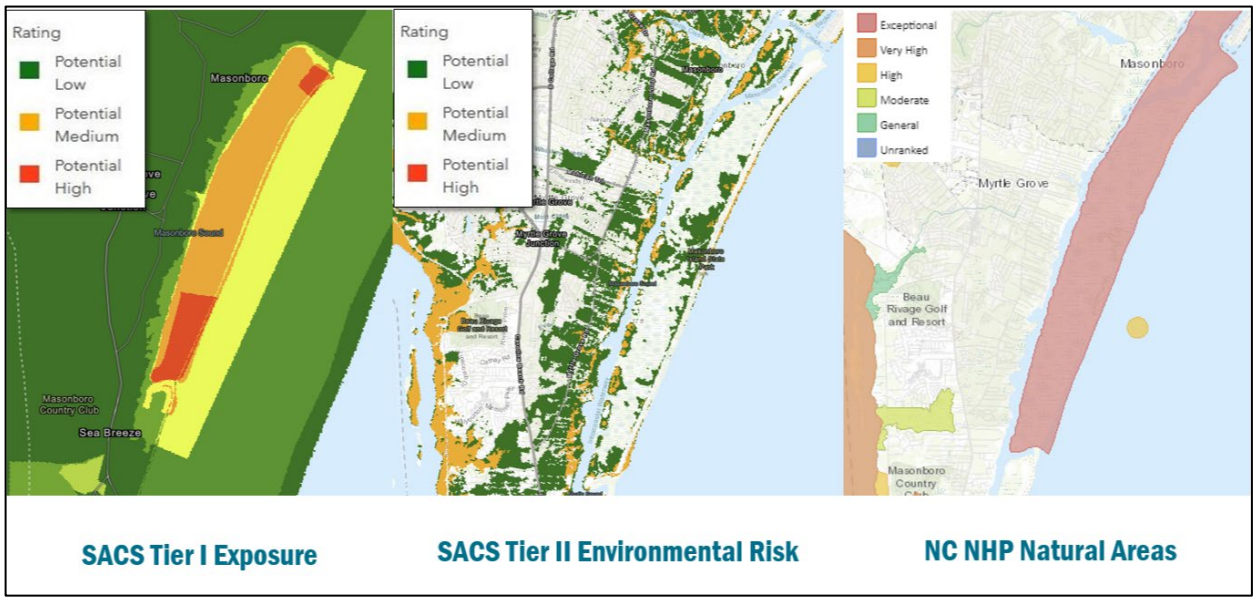

Figure 27: General Area of Convergence of High Risk and High Value at Masonboro Island, as Indicated by the Tier 1 Risk Assessment, Tier 2 Environmental Resources Inundation Risk Analysis, and North Carolina Natural Heritage Program Natural Areas Map

Potential benefits and impacts of action: A study and potential recommended measures primarily have ecosystem restoration benefits. Ancillary benefits include maintaining the protective services the island provides to back bay infrastructure along the mainland shoreline behind the island (**Figure 28**).

Cape Fear River Basin Flood Risk Management Study

Purpose and need: The Cape Fear River Basin has sustained loss of life and significant economic damage from coastal storms, compounded by inland precipitation, a significant portion of which is in the focus area. Significant risk to infrastructure, populations, and environmental resources is projected to increase with projected population growth and sea level rise. A study investigating improvements to coastal storm risk, flood risk management, and ecosystem restoration is needed in the Cape Fear River Basin.

Potential benefits and impacts of action: This action would identify measures that could be implemented to reduce the risk of future damage to important population and infrastructure and environmental and cultural resources.

Stakeholder Training Workshops of Coastal Hazards System Data

Purpose and need: This action would provide training as a workshop or series of workshops where potential users of the Coastal Hazards System wave and water level modeling data could learn about and be trained on the application of the data and related tools.

Potential benefits and impacts of action: This initiative would help ensure that stakeholders who may benefit from using CHS data are aware of its availability and application methods. The goal of the workshops would be to maximize use of the data where it would provide value for risk assessment, planning decisions, or coastal project designs.

5.2.1.2 Needed Actions by Others

Develop Coupled Model for North Carolina

Purpose and need: A coupled model (freshwater riverine and ocean storm surge) is needed for North Carolina to explain risk from coastal storms due to compound flooding. Significant damage has occurred in the focus area and other locations in coastal North Carolina due to the combination of storm surge and inland freshwater rainfall from coastal storm events—Hurricanes Floyd in 1999, Matthew in 2016, and Florence in 2018. This is a complex modeling effort, and the technological capabilities now exist to complete this project.

Potential benefits and impacts of action: A coupled model for North Carolina could provide greater projections of flood risk from coastal storms by accounting for both the coastal storm surge and the inland rainfall and how those two forces may combine to further increase flooding in specific areas. This information could assist decision-making by planners and emergency management officials.

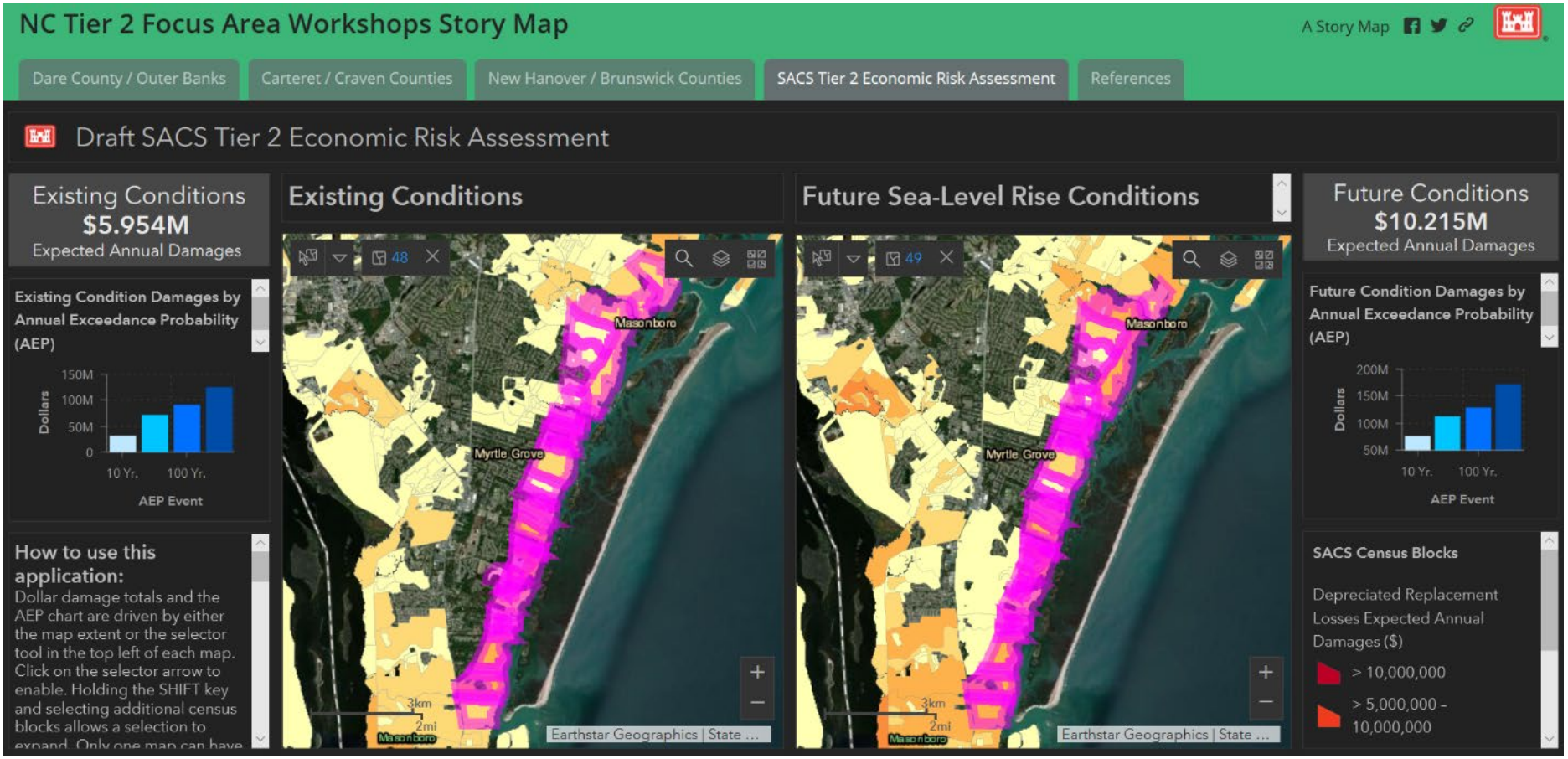

Figure 28: South Atlantic Coastal Study Tier 2 Economic Risk Assessment Tool Illustrating Exposed Structure Values Directly Behind Masonboro Island

5.2.2 Impacts of Sea Level Rise and Climate Change

As discussed in Section 4.1.3, sea level rise and climate change will increase exposure to hazards for low-lying coastal areas, including this focus area. The SACS has consistently used a 3-foot sea level rise scenario, which is consistent with the USACE Intermediate Scenario for a 100-year projection and the USACE High Scenario for a 50-year projection. Sea level rise and climate change are fundamentally incorporated into the FAAS and were considered carefully by stakeholders when identifying specific problems and needs. Sea level rise scenarios were modeled throughout SACS using Hazus, the CHS, and the NOAA Sea Level Rise Viewer to estimate the severity of hazard due to sea level rise throughout the study area. Site-specific considerations for each project area beyond those already addressed in SACS would likely be addressed during Tier 3 analysis follow-on activities with stakeholders.

5.2.3 Potential Benefits and Impacts

The FAAS includes a focused array of problems and needs, potential lead stakeholders, potential solutions, a summary of needed actions, a time frame for implementation, and potential funding sources. These elements are essential to make actionable recommendations and were coordinated closely with stakeholders. Potential benefits of the FAAS can be evaluated either individually as specific solutions to identified problems, or collectively as a system of solutions that address the shared vision. This report does not prioritize individual actions that make up the FAAS, although these actions could be prioritized to maximize finite resources. Prioritization could be based on several factors, including benefit-cost, time frame of incurring negative effects, or availability of authorities and funding. The FAAS provides a consistent platform to evaluate stakeholder-identified problems and needs in the focus area.

5.3 Focus Area Action Strategy

The Brunswick and New Hanover Counties Focus Area represents the most populated area in coastal North Carolina, and Brunswick County is one of the most rapidly growing counties in the nation. The strategy captured existing efforts as well as identified needs and opportunities for future actions in Brunswick and New Hanover Counties.

The actions identified within the FAAS have been organized into three themes: sediment management, infrastructure and mitigation, and education and outreach. These components are outlined in Section 5.1 and discussed in **Table 18**. **Table 18** includes additional details for each action and paths to implement future needed actions.

Table 18: Actions Developed for Brunswick and New Hanover Counties Focus Area – NC_01 Focus Area

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Implemented	NNBF	Completed Living Shorelines	Projects	There are two completed living shorelines in the area.	Bradley Oaks (NHC) and Airlie Gardens (NHC)	–	–	–	–	–
Implemented	Nonstructural	North Carolina Coastal Community Resiliency Guide	North Carolina Coastal Community Resilience Guide (NCDCM)	This online interactive North Carolina Coastal Communities Resilience Guide is designed to walk users through some of the key steps and questions required for effective community- level resiliency planning while pointing to relevant tools, resources, and examples. The guide outlines a process for building resilience and climate change considerations into existing efforts such as comprehensive land use, hazard mitigation, or capital improvement planning while also focusing on other co-beneficial strategies to reduce risk in the community. The primary audience for this guide is local government staff and officials in the coastal region of North Carolina. NCDCM's goal is to update and adapt this online tool over time.	Applicable for all coastal counties	NCDCM	–	–	–	State
Implemented	Nonstructural	Working Lands Climate & Salinization Study – Guidebooks	Outreach	Guidebooks are being produced as part of research on sustainability of working/agricultural lands in the face of saltwater intrusion and inundation. These are intended to be used as a tool to help farmers adapt to changes occurring due to sea level rise and coastal storms.	Applicable statewide to include working lands in southeastern North Carolina	USDA	–	Short	–	USDA
Ongoing	NNBF	Wrightsville Beach Coastal Storm Risk Management Study (additional 50 years)	Study	This 3-year study is underway to evaluate and recommend future 50-year federal participation in CSRM for the Town of Wrightsville Beach.	Town of Wrightsville Beach	USACE, Town of Wrightsville Beach, NHC	–	Mid	High	USACE
Ongoing	NNBF	Carolina Beach Coastal Storm Risk Management Study (additional 50years)	Study	This 3-year study is underway to evaluate and recommend future 50-year federal participation in CSRM for the Town of Carolina Beach.	Town of Carolina Beach	USACE, Town of Carolina Beach, NHC	–	Mid	High	USACE
Ongoing	NNBF	Holden Beach CSRM Study	Study	USACE is studying the feasibility and justification of Federal partnership for coastal storm risk management measures at the Town of Holden Beach for a 50-year period.	Town of Holden Beach	USACE, Town of Holden Beach	1. complete current study	Mid	High	USACE/Holden Beach

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Ongoing	Nonstructural	Establishment of Hurricane Evacuation Zones	Policy	In coordination with a recent initiative implemented in 2019, 20 coastal counties, including New Hanover and Brunswick, have established predetermined evacuation zones to simplify the coastal evacuation process in the event of an emergency. The initiative is titled "Know Your Zone." North Carolina Know Your Zone is a tiered evacuation system that highlights areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards. The Know Your Zone lookup tool is a color-coded interactive map residents and visitors can use to determine the evacuation zone where they live, work, or are visiting based upon a street address. Evacuation zones highlight areas most at risk to storm surge and flooding. Know Your Zone is intended to streamline the evacuation process by supporting personal readiness in preparation for hazardous weather events. When a storm is approaching, local officials in Brunswick and New Hanover Counties will determine the zones that are most threatened to assess which residents should evacuate.	Brunswick County and New Hanover County	North Carolina Emergency Management (NCEM), Brunswick County, New Hanover County	Implemented. Public outreach is ongoing.	–	–	–
Ongoing	Nonstructural	Home Elevations/Buyouts	Unknown	This FEMA program helps homeowners through the Hazard Mitigation Grant Program.	Statewide	FEMA/State of North Carolina	FEMA Hazard Mitigation Grant Program	Mid	High	FEMA
Ongoing	Nonstructural	ReBUILD NC Homeowner Recovery Program	North Carolina Office of Recovery and Resiliency (NCORR)	The Homeowner Recovery Program helps repair, reconstruct, replace, or elevate homes or reimburse residents for completed repairs to homes that were damaged by Hurricane Florence or Matthew.	Areas damaged by Hurricanes Florence/Matthew	NCORR	Housing and Affordable Rental Program	Short	High	–
Ongoing	Nonstructural	ReBUILD NC Strategic Buyout Program	NCORR	This program enables eligible property owners, located in areas that are prone to repeated flooding, to relocate to safer land. NCORR provides financial incentives to homeowners to remain in communities. The affordable housing program focuses on constructing affordable and safe housing.	Statewide	NCORR	Strategic Buyout Program	Short	High	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Ongoing	Nonstructural	Saltwater Inundation and Intrusion Research	Study	Scientific research should be conducted to further document and understand the sea level rise-related phenomena of saltwater intrusion and inundation, and its impacts in coastal North Carolina. Research may help identify adaptive measures.	Various	USDA, NCSU, ECU, Duke University, others	–	Long	Low	–
Ongoing	Structural	Transportation/Evacuation Route Improvements	Project	Highway 211 is a major transportation/evacuation route in Brunswick County, which has been inundated by past coastal storm events. Impacts include life safety and prevention of ingress/egress. The North Carolina Department of Transportation (NCDOT), in collaboration with Brunswick County, the local Metropolitan Planning Organization, and the Grand Strand Area Transportation have included Highway 211 in NCDOT's State Transportation Improvement Program. The State Transportation Improvement Program identified improvements to Highways 211 and 906 as a multi-phase project to start in 2022 with final completion more than 10 years out. Improvements would include road widening extending to Highway 17, as well as elevation in sections.	Brunswick County	NCDOT, Brunswick County, Metropolitan Planning Organization, Grand Strand Area Transportation	–	Long	Medium	NCDOT

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Planned	Nonstructural	Statewide Non-Federal Coastal Dredged Material Management Plan Study	Study	The North Carolina Division of Water Resources and USACE are partnering to develop a statewide non-federal dredged material management plan. Coastal dredged material placement facilities will be evaluated to identify current non-federal conditions, capacities, and placement needs of each site. This information will be essential for the State of North Carolina to determine future dredge material capacity needs, capacity restoration efforts at current sites, and to determine what new placement sites must be developed or acquired, including for beneficial use. This Planning Assistance to State (PAS) study will only assess the non-federal components of a dredged material management plan. The study will focus on dredged material placement facilities owned, operated, or managed by the State of North Carolina, local municipalities, private marinas, conservation groups, and other non-federal stakeholders that are located along or adjacent to the Atlantic Intracoastal Waterway.	Atlantic Intracoastal Waterway (statewide)	USACE, North Carolina Division of Water Resources	Study initiation January 2021	Short	High	USACE Planning Assistance to States (PAS) program; NCDEQ

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Planned	All	Resilient Coastal Communities Program	Study/Projects	The North Carolina Resilient Coastal Communities Program aims to facilitate a community-driven process for setting coastal resilience goals, assessing existing and needed local capacity, and identifying and prioritizing projects to enhance community resilience to coastal hazards. Participating communities will walk through a framework leading to the development of "shovel-ready" projects. Local governments throughout the 20 coastal counties will be eligible to apply for direct technical assistance to complete a community engagement process, risk and vulnerability assessment, and develop a resilience project portfolio. The four phases of the program include: Phase 1: Community Engagement and Risk and Vulnerability Assessment Phase 2: Planning, Project Selection, and Prioritization Phase 3: Engineering and Design Phase 4: Implementation	To be determined. All 20 coastal counties are eligible to apply.	NCDCM	–	Mid	High	–
Planned	Structural	Infrastructure (wastewater pumping stations) retrofits considering sea level rise		The purpose is to secure funding to retrofit/elevate wastewater pumping stations located in the 100-year floodplain. These infrastructure components routinely flood during flooding and storm surge events. New Hanover County's Cape Fear Public Utility Authority has mapped all systems, plants, and infrastructure in GIS that are in floodplains and could be subject to future sea level rise. A pump station lifecycle is significantly shorter than the sea level rise projection timelines in the 2013 Pilot Study (50, 100 years). As such, current pump station upgrades and future pump stations are designed with flooding and sea level rise in mind. Cape Fear Public Utility Authority has completed other pump station projects since 2013 that similarly addressed flood elevations as part of an overall upgrade.	New Hanover County	Cape Fear Public Utilities	–	Mid	Medium	–

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Needed	NNBF	RSM Optimization Update Opportunities – Atlantic Intracoastal Waterway	Beneficial Use	Approximately 100,000 CY of material is dredged annually from the Atlantic Intercoastal Waterway that is placed in upland placement sites. Potential opportunities to conserve upland placement capacity and keep sediment in the system could include more beach placement, thin-layer placement, or island creation in the back barrier estuarine system adjacent to project channels.	Various	USACE	–	Mid	Low	USACE RSM
Needed	NNBF	RSM Optimization Update Opportunities – Wilmington Harbor	Beneficial Use	A significant amount of material is dredged from the Wilmington Harbor project that is not suitable for beach placement. This material, predominantly located in the inner channel, which may be used for environmental benefits, is currently placed in a DMMA at a cost of $3 to 8 per cubic yard. Thin-layer placement of dredged material in shallow, lower energy areas of rivers, estuaries, and marshes is a beneficial use gaining interest within the coastal management community that may provide beneficial opportunities at Wilmington Harbor. Other potential uses of dredged material in the project area could include filling relict dredge holes and island habitat creation.	Lower Cape Fear	USACE	–	Mid	Low	USACE RSM
Needed	NNBF	Beneficial Use of Dredged Material (DA 251) for Masonboro Island	Beneficial Use	This is an RSM opportunity. Sediment quality needs to be tested.	(DA 251) for Masonboro Island	USACE	–	Mid	Low	USACE RSM
Needed	NNBF	Oak Island CSRM Study	Study	There is an opportunity for federal participation in a CSRM project at the Town of Oak Island. The Town has submitted a letter of interest for Wilmington District to start a feasibility study. The congressional authority to initiate the study exists, but funding is needed. This potential study has been included in the Wilmington District's request for fiscal year (FY)21 work plan funding.	Town of Oak Island	USACE, Town of Oak Island	1. Authorization exists; continue to request congressional appropriations	Mid	High	USACE/Oak Island

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Needed	NNBF	Beach, Dune, and Back-Barrier Marsh Restoration	Study	New congressional authorization is needed for a comprehensive study of ecosystem restoration for Masonboro Island in New Hanover County. As part of the National Estuary Research Reserve and one of the few undeveloped barriers islands in North Carolina, Masonboro provides critical habitat to a variety of species as well as ancillary natural protective services to mainland infrastructure directly behind the island. This recommendation aligns with strategies outlined in the North Carolina Resilience Strategy sectors of coastal resources and infrastructure, and ecosystems. This recommendation would address degradation of the island from natural and anthropological hazards threatening ecologically and economically beneficial habitats.	Masonboro Island	USACE / Non-Federal partner	1. Finalize a draft scope; 2. Confirm a non-Federal partner; 3. Should a non-Federal entity choose to proceed in partnership with USACE, then that entity would request congressional authorization for new study through 7001 process.	Mid	High	–
Needed	NNBF	Wetland/Fisheries Analysis	Study	Use cross-agency partnerships to identify the most appropriate areas for marsh restoration projects. Stakeholders from NOAA and BOEM have indicated the potential benefits of marsh restoration on the oceanfront and that more coordination with the U.S. Fish and Wildlife Service would be required to address fisheries habitat. To increase beneficial use of dredged material, appropriate locations would need to be identified for dredge material placement.	–	NOAA, U.S. Fish and Wildlife Service, BOEM, USACE, National Fish and Wildlife Foundation	–	Mid	Low	–
Needed	Nonstructural	Statewide Offshore Sand Management Strategy Discussions	Coordination	Section 3.1 of the SACS-funded SAND Report identifies areas of sand deficiencies in North Carolina. The SAND Report indicates future discussions may be needed to move forward. Information from the SAND Report should be used to work with federal and state partners to identify management strategies to support multiple berm and dune project needs. Discussion topics may include strategies for finding new sand sources and strategies to manage finite resources.	Applicable statewide	USACE, BOEM, State of North Carolina	1. Establish agency POCs. 2. Coordinate kickoff discussion	Short	Medium	Collaborate Funding (e.g., for USACE - RSM or PAS)

Status (ongoing, planned, needed)	Category	Measure/Action Type	Sub-type	Description/Purpose	Location	Lead Stakeholder(s)	Summary of Specific Actions Needed to Implement	Time Frame[1]	Priority (high, medium, low)	Potential Funding Source
Needed	Nonstructural	Enhanced Building-Level Risk Assessment – Proof of Concept Exercise	Study	Use CHS data and NCEM building footprints to perform an enhanced building-level risk assessment for more targeted nonstructural measure evaluation. Long-term goals of conducting building-level risk assessments vs. by census block risk assessments would be to obtain enhanced/updated costs and ultimately improve benefit-cost with use of targeted buyouts. Improved benefit-cost ratios help justify projects. Building-level risk assessments helps target areas and refine costs. It significantly improves cost benefit analyses and provides a more targeted strategy and improves building buyouts.	Potentially applicable in any coastal county	NCEM, University of North Carolina Wilmington, NCORR, USACE	–	Short	Medium	UNCW, NCORR

[1]Timeframe: short = <2 years; mid = 2–10 years; long = >10 year

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6. Recommendations

The focus area action strategy was developed to advance the shared vision and manage increased coastal storm risk as a result of sea level rise in the Brunswick and New Hanover Counites Focus Area as shown in **Figure 29**. The shared vision is the overarching goal of the FAAS, broadly representing problems and opportunities stakeholders wish to address in the focus area. Resultingly, FAAS goals and objectives support the shared vision. SACS key products and other stakeholders' shared tools and data were used to support FAAS goals and objectives by assessing risk and identifying ongoing, planned, and needed actions to communicate and address the risk.

Figure 29: Focus Area Action Strategy Supports the Focus Area's Shared Vision

Recommendations are made for either multi-agency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and coordination with stakeholders throughout the focus area. Recommendations are organized into six categories, as shown **Figure 30**, and three implementation timeframes (near-, mid-, and long-term). Importantly, follow-on study efforts should incorporate an integrated approach to the maximum extent practicable, including consideration of structural, nonstructural, and NNBF measures, as well as the shared responsibility of all stakeholders to contribute to coastal storm risk management. Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation timeframes include:

Figure 30: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.
- **Mid-Term Implementation (5-10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance emerging efforts to address coastal storm risk.
- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination before implementation and may be the most challenging to implement on regional scales from technical, political, or social perspectives. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term timeframe is reflective of the time to implementation based on immediate action to advance these recommendations which include complex issues such as land-use, zoning, and building codes. Given the uncertainty surrounding impacts from sea level rise and other factors (e.g., development trends), long-term recommendations may require reconsideration prior to implementation.

Table 19 provides the recommendations for the Brunswick and New Hanover Counties focus area.

Table 19: Recommendations for the Brunswick and New Hanover Counties Focus Area

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	USACE	Masonboro Inlet Jetty project	Fund prior commitment for mitigation of Masonboro Inlet Jetty project (periodic sand by-pass) based on previous Continuing Authorities Program (CAP) 111 report.	Funding
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Cape Fear River Basin – FRM study (USACE)	This area sustained significant damage from Hurricane Florence. A flood risk management study was previously identified as a need but was not funded. SACS presents an opportunity to add support for future funding. A new congressional authorization would be needed.	New Study Authority
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Masonboro Island - Beach, Dune and Back-barrier Ecosystem Restoration (USACE)	A new congressional authorization is needed for a comprehensive study for the purpose of ecosystem restoration for Masonboro Island in New Hanover County. As part of the National Estuary Research Reserve and one of the few undeveloped barriers islands in North Carolina, Masonboro provides critical habitat to a variety of species as well as ancillary natural protective services to mainland infrastructure directly behind the island. This recommendation aligns with strategies outlined in the North Carolina Resilience Strategy sectors of Coastal Resources & Infrastructure, and Ecosystems.	New Study Authority

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description	Next Step to Implementation
Study Efforts (follow-on USACE feasibility study)	Near-Term (<5 years)	Congress	Oak Island CSRM feasibility study	A coastal storm risk management study for the Town of Oak Island is needed to reduce future risk of damages associated with hurricanes and other coastal storms. Current significant risks are expected to increase with sea level rise. Congressional authority for the project exists under Section 203 of the Flood Control Act of 1966 (PL 89 - 789).	Funding
Study Efforts (Activities under CAP)	Mid-Term (5-10 years)	USACE	NC Battleship Memorial - CAP 205	The USS Battleship North Carolina Memorial Park is impacted by flooding which significantly impacts safety, park operations, and the economics of the Park. These impacts will increase with sea level rise. The USS Battleship North Carolina Memorial is located on the west bank of the Cape Fear River across from the downtown Wilmington waterfront. It is owned by the State of North Carolina and operated by State employees. The park serves as a memorial to North Carolinians who gave their lives during World War II, as well as an education center and top tourist destination in the State of North Carolina.	Stakeholder Collaboration

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