

North Carolina

Walter Clark
Jennifer Kassakian
James G. Titus

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NORTH CAROLINA

Prepared by:

Walter Clarkⁱ

Jennifer Kassakianⁱⁱ

and

James G. Titusⁱⁱⁱ

ⁱNorth Carolina Sea Grant, Raleigh, North Carolina

ⁱⁱIndustrial Economics, Incorporated, Cambridge, Massachusetts

ⁱⁱⁱU.S. Environmental Protection Agency, Office of Air and Radiation, Washington, DC

CONTENTS

SUMMARY 894

INTRODUCTION 905

Purpose of This Study 906

Caveats 907

How to Read This Report 908

METHODS 910

Overall Approach 910

Phase 1: Stakeholder Review Draft Based on State Input 915

Phase 2: More Detailed Maps Based on County Input 916

Map Scale 916

NORTH CAROLINA’S STATE POLICIES..... 918

State Ownership of Coastal Lands 918

North Carolina’s Coastal Management Program 918

 The Regulatory Program 918

 The Planning Program 920

COUNTY-SPECIFIC RESPONSES TO SEA LEVEL RISE..... 921

Currituck County 923

Camden County 928

Pasquotank County 932

Perquimans County 937

Chowan County 941

Hertford County 944

Bertie County 944

Martin County 947

Washington County 949

Tyrrell County 952

Dare County 957

Hyde County 966

Beaufort County 969

Pamlico County972

Craven County976

Carteret County978

Onslow County982

Pender County985

New Hanover County988

Brunswick County.....991

Appendix A: Length of Shorelines by Likelihood of Shore Protection995

Appendix B: Area of Land by Likelihood of Shore Protection1007

Appendix C: Elevation Uncertainty1020

Appendix D: Summary of Data Sources1027

CREDITS AND ACKNOWLEDGMENTS1030

MAPS

Map 9-1. Study Results for North Carolina900

Map 9-2. Currituck County: Likelihood of Shore Protection926

Map 9-3. Camden County: Likelihood of Shore Protection.....931

Map 9-4. Pasquotank County: Likelihood of Shore Protection936

Map 9-5. Perquimans County: Likelihood of Shore Protection939

Map 9-6. Chowan County: Likelihood of Shore Protection941

Map 9-7. Hertford County: Likelihood of Shore Protection943

Map 9-8. Bertie County: Likelihood of Shore Protection966

Map 9-9. Martin County: Likelihood of Shore Protection948

Map 9-10. Washington County: Likelihood of Shore Protection951

Map 9-11. Tyrrell County: Likelihood of Shore Protection956

Map 9-12. Dare County (Mainland and Roanoke Island): Likelihood of Shore Protection.964

Map 9-13. Dare County (Northern Spit): Likelihood of Shore Protection965

Map 9-14. Dare County (Hatteras): Likelihood of Shore Protection965

Map 9-15. Hyde County: Likelihood of Shore Protection.....968

Map 9-16. Beaufort County: Likelihood of Shore Protection.....971

Map 9-17. Pamlico County: Likelihood of Shore Protection975

Map 9-18. Craven County: Likelihood of Shore Protection.....977

Map 9-19. Carteret County: Likelihood of Shore Protection981

Map 9-20. Onslow County: Likelihood of Shore Protection984

Map 9-21. Pender County: Likelihood of Shore Protection.....987

Map 9-22. New Hanover County: Likelihood of Shore Protection990

Map 9-23. Brunswick County: Likelihood of Shore Protection 994

FIGURES

Figure 1. Lands in North Carolina Vulnerable to Sea Level Rise 912
Figure 2. Location of Counties in North Carolina Study Region 922

TABLES

Table 1. Government Participants and Reviewers 901
Table 2. Area of Land Vulnerable to Sea Level Rise in North Carolina 903

PHOTOS

Photos by James G. Titus

Photos 1 and 2. Camden County, North Carolina. 929

Photos 3–6. Elizabeth City, North Carolina. 936

Photos 7–10. Batchelor Bay and the Roanoke River, Bertie County..... 945

Photos 11 and 12. Plymouth 950

Photos 13–15. Tyrrell County..... 955

Photo 16. Roanoke Island Wetlands 960

Photos 17–20. Shore Erosion at Kitty Hawk..... 961

Photos 21 and 22. Geotextile containers protecting homes along the shore
at Nags Head 962

Photos 23 and 24. Hatteras Island 962

Photos 25–28. Swan Quarter and Vicinity..... 967

Photo 29. Belhaven City Hall..... 970

Photos 30–31: Pamlico County 973

Photos 32–35. Sea Level, North Carolina and Vicinity 979

SUMMARY

Sea level is rising about one inch about every eight years along the coast of North Carolina. Ocean shores are eroding along the Atlantic coast, threatening homes along the Outer Banks. Wetlands are converting to open water, and wind-generated tides flood several communities in the low-lying lands between Albemarle and Pamlico sounds. These effects would become more commonplace if rising global temperatures cause the rate of sea level rise to accelerate. The Intergovernmental Panel on Climate Change, for example, estimates that by the end of the next century, sea level is likely to be rising 0 to 3 inches per decade more rapidly than today (excluding the possible impacts of increased ice discharges from the Greenland and Antarctic ice sheets).

Rising sea level erodes beaches, drowns wetlands, submerges low-lying lands, exacerbates coastal flooding, and increases the salinity of estuaries and aquifers. Coastal communities must ultimately choose between one of three general responses:

- *Aarmor the shore* with seawalls, dikes, revetments, bulkheads, and other structures. This approach preserves existing land uses, but wetlands and beaches are squeezed between the development and the rising sea.
- *Elevate the land* and perhaps the wetlands and beaches as well. This approach can preserve both the natural shores and existing land uses.
- *Retreat* by allowing the wetlands and beaches to take over land that is dry today. This approach can preserve natural shores, but existing land uses are lost.

Each of these approaches are being pursued somewhere in North Carolina. Dikes protect some low-lying farms in Tyrill County, and another dike is planned for Swan Quarter. Many estuarine shores have been armored with wooden bulkheads or stone revetments. The Corps of Engineers has placed sand onto ocean beaches. In the aftermath of Hurricane Floyd, many homes in Carteret County were elevated. Homes have been lost to retreating ocean shores in Kitty Hawk and Nags Head, and after Hurricane Floyd destroyed homes in eastern Pamlico County, local officials discouraged rebuilding in the most vulnerable locations.

Nevertheless, there is no explicit plan for the fate of most low-lying coastal lands as sea level rises. Environmental planners do not know whether to assume that the coastal wetlands will be lost or simply migrate inland. Those who plan coastal infrastructure do not know whether to assume that a given area will be submerged by rising waters or protected from the sea. And even in developed areas that will presumably be protected, public works departments do not know whether to assume that the land surfaces will gradually be elevated or that the area will be protected with a dike.

This report develops maps that distinguish shores that are likely to be protected from the sea from those areas that are likely to be submerged, assuming current coastal policies, development trends, and shore protection practices. Our purpose is primarily to promote the dialogue necessary to decide where people will yield the right of way to the inland migration of wetlands and beaches, and where we will hold back the sea. The authors consulted with the state regional coastal divisions and planners from 17 coastal county governments on existing and future development (4 counties provided digital planning data and 2 provided hard copies that we digitized). All of the counties provided advice on how to best interpret expectations and existing statutes, regulations, and policies. The result is a statewide series of county maps that uses available understanding and planner expectations.

By “shore protection” we mean activities that prevent dry land from converting to either wetland or water. Activities that protect coastal wetlands from eroding or being submerged were outside the scope of this study. This study does not analyze the timing of possible shore protection; it simply examines whether land would be protected once it became threatened. Nor do we analyze whether shore protection is likely to be a transitional response or sustained indefinitely.

The maps divide the dry land close to sea level into four categories of shore protection:

- Shore protection almost certain (brown);
- Shore protection likely (red);
- Shore protection unlikely (blue); and
- No shore protection, i.e. protection is prohibited by existing policies (light green).

For reasons related to data quality, our study area includes lands within about 17 to 18 feet (5 meters) above the tides. (We did not project the fates of secured federal installations but depicted them in red so that they stand out.)

One can also view these maps as representing three shore protection scenarios. For example, in an “enhanced wetland migration” scenario, only the areas depicted in brown would be protected; but in an “enhanced shore protection” scenario, only the areas depicted in light green would be submerged. Thus the prospects for shore protection are best understood in the areas shown in brown and light green, while those shown in red and blue are most amenable to coastal planning.

Results

Map 1 shows our assessment of the likelihood of shore protection for the coastal zone of North Carolina, and adjacent areas in Virginia. Table A quantifies the area of land within approximately three feet (one meter) above the tides for each of the shore protection categories by county. Table B quantifies the length of shoreline along the Atlantic

Ocean, the Pamlico and Albemarle sounds, and the back barrier sounds by likelihood of shore protection.

Ocean Coast

North Carolina's ocean coast, like most states, includes moderate and densely developed communities that will almost certainly be protected, and undeveloped roadless barrier islands that will almost certainly retreat. Unlike the other mid-Atlantic states, however, North Carolina's coast also includes a roadless coastal barrier that is nevertheless being developed, densely populated areas that nevertheless have been yielding homes to the sea, and a major lighthouse that has been relocated landward. Of the 303 miles of ocean shore, shore protection is almost certain along 118 miles and precluded by environmental management policies along 106 miles. Approximately 48 miles (77 kilometers) of shoreline are along National Park Service lands where shores will be allowed to retreat, but the existence of a major coastal highway are likely to lead officials to fill inlet breaches and otherwise prevent the island from disintegrating. Shore protection is uncertain for another 89 miles of shoreline: likely along 53 miles and unlikely along the other 26.

The northern 14 miles of the state's coastline is a designated undeveloped coastal barrier and hence ineligible for most federal programs. This stretch of barrier island includes two sections of Currituck National Wildlife Refuge, each about 1 mile long, which are both off-limits to development and make it infeasible for the County to even consider a road along the barrier island. Nevertheless, the privately owned areas are gradually being developed, even though they are accessible only by boat or four-wheel drive vehicles traveling along the beach. Given the lack of eligibility for beach nourishment and flood insurance, county planners view shore protection as unlikely in the roadless area. The rest of the Currituck County ocean shore will almost certainly be protected.

Dare County officials view most of the coast from Kitty Hawk to Nags Head as almost certain to be protected, given both the development density and recent authorizations for beach nourishment. Homes have been condemned as shores erode and septic fail; but now that the through streets parallel to the shore are at risk, officials have decided to hold the line. Nevertheless, the beaches in some of the communities north of Kitty Hawk are not yet open to the public, and hence currently ineligible for beach nourishment. Although officials expect that property owners along the shore will eventually provide easements for public access, until that happens shore protection is likely but not certain. Roanoke Island is also certain to be protected, aside from conservation lands owned by The Nature Conservancy.

From Nags Head to Hatteras Island, most of the coast is part of Cape Hatteras National Seashore, with a coastal highway the entire length from which one can catch a ferry to Ocracoke Island. The National Park Service generally allows shores to retreat, and the road has been relocated inland in places. Congress appropriated \$9.8 million to move the Cape Hatteras Lighthouse 1,600 feet inland. Nevertheless, county and state officials view the coastal highway as essential infrastructure. While the gradual landward migration of the barrier islands may be tolerated, the barrier island itself will not be allowed to disintegrate. The various isolated communities within the barrier island system are likely to be protected, but protection is not certain because beach nourishment may not be cost-effective for the relatively short stretches of developed beach. Similarly, the town of Ocracoke is certain to be protected, but most of the island is part of Cape Hatteras National Seashore and hence shore protection would not occur under current policies.

South of Ocracoke lie the undeveloped Portsmouth Island and Core Bank, which constitute Cape Lookout National Seashore. Given the lack of a bridge to the mainland, shores would not be protected under current policies. To the southwest, the rest of the coast consists mostly of developed barrier islands where shore protection is certain, conservation lands will not be protected, and designated “undeveloped coastal barriers” are nevertheless being developed and likely to be protected even without federal subsidies.¹

Pamlico and Albemarle Sounds.

The lands along these two sounds account for 70 percent of the nontidal wetlands, 40 percent of the dry land, and 55 percent of all land within 1 meter above spring high water in the entire mid-Atlantic. This area has about 50 percent of the dry land within about three feet (one meter) above the tides where protection is precluded or unlikely. If nontidal wetlands are included, this area has 63 percent of the land that would be submerged (and potentially converted to tidal wetland) if sea level rises three feet.

Given the large areas of land available for potential wetland creation, this area represents an environmental planning opportunity that is national in scope. Nevertheless, development continues, particularly along the shores of the sounds. Significant urbanization has been slow to come to this area for many reasons. Most of it is farther from population centers than the Delaware and Chesapeake estuaries. Development along coastal bays often intensifies only when inexpensive land along the barrier islands becomes exhausted. The Outer Banks were slower to develop than the barrier islands of

¹NORTH CAROLINA, sections on Carteret, Onslow, Pender, and Brunswick Counties

New Jersey, Delaware, and Maryland. And most important, the land is mostly low and wet.

Unlike the Delaware Estuary, this region does not have a long history of diking tidal wetlands to reclaim land from the sea for agricultural purposes. But it is starting to gain experience with dikes to protect agricultural lands from flooding. In Tyrell County, the Gum Neck has been protected with a dike for two decades. A dike is now planned for the town and farms around Swan Quarter, the county seat of Hyde County. Especially in Tyrell County, officials expect substantial amounts of agricultural lands to be protected with dikes as sea level rises. With most the county below the 5-meter contour, shore protection is a matter of self-preservation to this county. Hurricane Floyd led Pamlico County, by contrast, to encourage people to gradually abandon the eastern portion of the county, by working with FEMA to relocate people rather than rebuild damaged homes. In parts of Carteret County, by contrast, people learned the opposite lesson and elevated homes.

Caveat

This report relies less on digital land use and planning data than the companion studies of the other mid-Atlantic States. When the study was initiated, county land use data was generally unavailable—and the land use/land cover data then available was dated. With the exception of 6 counties, these maps rely on hand-drawn renderings of existing and expected development based on interviews with state and local officials. As a result, the precision of the maps is less than for the other mid-Atlantic studies.

This report may overstate the amount of land where shore protection is unlikely compared to the other mid-Atlantic states in this volume, for two reasons. First, the more densely developed counties that dominate the other states generally expect development everywhere that a policy is not in place to prevent it; the rural counties that dominate North Carolina tend to expect development in priority growth areas, but not in privately owned farms and forests where no one is yet planning to develop. Second, the interviews for this report took place between 2001-2003. Since that time, people have decided to develop areas where development was not expected a few years ago.

These caveats do not change the fundamental finding that North Carolina has more undeveloped lands potentially available for wetland migration than the other mid-Atlantic States. They may suggest, however, that this environmental planning opportunity is diminishing as the lands around North Carolina's sounds are developed.

Conclusions

1. *The prospects for shore protection appear to be largely established along 74 percent of the 303 miles of open ocean coast.*

- High property values and dense development make shore protection almost certain along 39 percent of the Atlantic Coast. [118 miles]
- Policies would preclude shore protection along approximately 35 percent (106 miles) of the ocean coast.

2. *Shore protection is still uncertain along about 26 percent of the Atlantic Coast.*

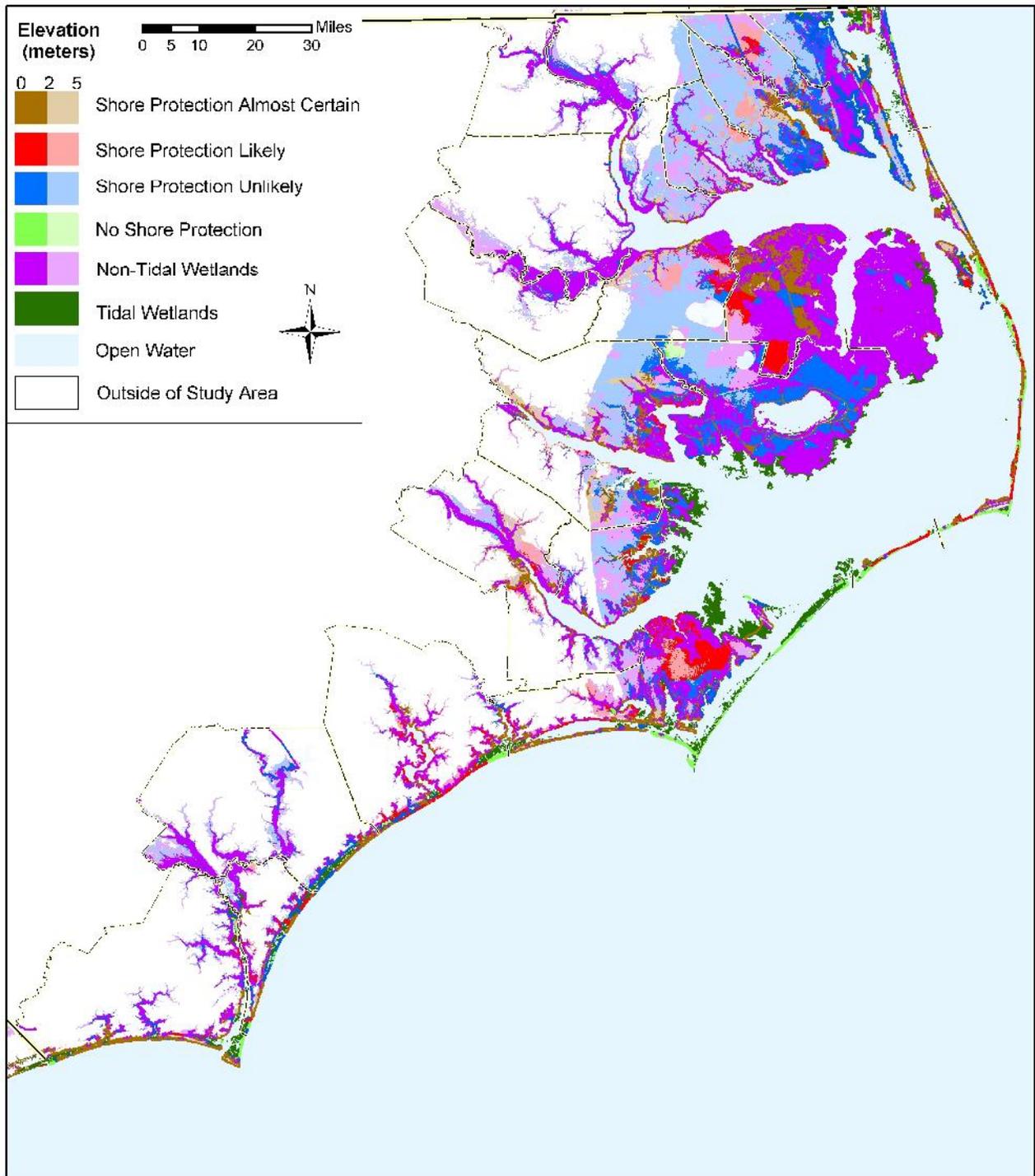
- Approximately 48 miles of shoreline are along National Park Service lands where shores will be allowed to retreat, but the existence of a major coastal highway are likely to lead officials to fill inlet breaches and otherwise prevent the island from disintegrating
- About 17 percent (53 miles) of the shore is likely—but not certain—to be protected. Most of these areas are developed, but planners are not certain whether those areas would qualify for federal beach nourishment due to high shore protection costs, insufficient development density, or lack of public access to the beach.
- About 9 percent of the ocean shore (26 miles) is unlikely to be protected. Most of these lands are designated undeveloped barrier islands under the Coastal Barrier Resources Act.

3. *Along the 1,192 miles of estuarine shorelines, the prospects for shore protection are much less certain than along the ocean. These lands include approximately 526 square kilometers of dry land within one meter above the tides.*

- Only 29 percent of the estuarine shore is developed enough for planners to view shore protection as almost certain to be protected
- Less than 9 percent of the estuarine shores are within conservation areas.

4. *Despite the momentum toward coastal development, all of our options still appear to be open for more than half of the dry land in the mid-Atlantic.*

- Development and shore protection are likely on about 74 square miles; but it is not too late to design land use plans that could accommodate both development and wetland migration.
- In the other 286 square miles, development and shore protection seem unlikely today; but people may want to move into these areas in the future.



Map 9-1. North Carolina: Likelihood of Shore Protection. For each shore protection category, the darker shades represent lands that are either less than 7 feet (2 meters) above spring high water, or within 1000 feet of the shore. The lighter shades show the rest of the study area. This map is based on data published between 1999 and 2003, and site-specific changes suggested by planners in 2002 and 2003.

Table 9-1 ____.
Area of Land within 3.3 ft (1 m) above Spring High Water
by Likelihood of Shore Protection
(square miles)

County	Likelihood of Shore Protection				Nontidal Wetlands	Total ¹	Elevation Error ² (inches)	Tidal Wetlands
	Almost Certain	Likely	Unlikely	No Protection				
Beaufort	16.5	6.5	16.5	3.3	42.0	85.0	8	13.6
Bertie	0.1	0.0	1.7	0.0	49.1	51.0	4	0.1
Brunswick	3.6	0.5	3.5	0.4	18.2	26.7	5	42.0
Camden	2.6	1.1	7.2	0.0	57.9	68.8	6	2.8
Carteret	8.5	16.4	16.4	3.8	33.7	80.4	4	128.1
Chowan	0.4	0.1	2.0	0.0	13.1	15.6	4	0.0
Craven	3.6	0.8	2.8	0.2	31.4	38.9	6	4.7
Currituck	2.5	0.1	14.4	0.6	58.0	75.8	5	47.7
Dare	8.8	7.0	6.2	4.1	217.9	244.1	6	63.8
Gates	0.0	0.0	4.4	0.2	34.7	39.4	13	0.0
Hertford	0.0	0.0	2.1	0.0	21.2	24.2	13	0.0
Hyde	15.1	1.3	150.4	1.8	192.6	361.3	6	76.7
Martin	0.0	0.0	1.0	0.0	28.6	29.7	6	0.0
New Hanover	1.4	1.2	2.1	0.3	14.1	19.4	7	21.4
Onslow	2.9	6.2	3.3	0.3	12.4	25.8	6	26.4
Pamlico	4.8	3.2	14.9	0.0	28.4	51.4	6	43.1
Pasquotank	2.8	0.3	12.2	0.0	24.2	39.4	5	0.1
Pender	1.0	0.2	2.8	0.0	44.5	48.8	7	14.7
Perquimans	0.9	1.0	2.5	0.0	18.0	22.6	5	0.0
Tyrrell	67.0	23.2	18.6	0.6	204.3	313.7	6	1.5
Washington	1.9	5.2	1.5	0.0	33.0	41.7	5	0.1
North Carolina	144.6	74.2	286.4	15.7	1177.5	1703.5		486.5

1. Total Land includes the five categories listed plus land for which no data was available.
2. This table is based on the area of map polygons within 3.3 feet (1 meter) above the tides. Although the area of the polygons can be tabulated very precisely, the 3.3 feet (1 meter) elevation estimate is subject to the accuracy limits of the underlying elevation data. The elevation error column displays the accuracy limits (root mean square error) of the data used to identify the 1-meter elevation contour.

See Table B-2 in Appendix B for details.

Table 9-2. Shoreline Length by Major Water Body and Likelihood of Shore Protection (miles)¹

County	Likelihood of Shore Protection				Nontidal Wetlands	Outside Study Area	Totals
	Almost Certain	Likely	Unlikely	No Protection			
Atlantic Ocean	118	53	26	106	0	0	303
Brunswick	34	0	1	5	0	0	40
Carteret	25	0	0.3	43	0	0	68.3
Currituck	9	1	10	2	0	0	22
Dare	24	25	0.2	37	0	0	86.2
Hyde	0	4	0	11	0	0	15
New Hanover	11	4	9	4	0	0	28
Onslow	5	18	0.6	4	0	0	27.6
Pender	10	0	4	0	0	0	14
Albemarle Sound	30	2	18	0	41	0	91
Bertie	0.2	0	3	0	2	0	5.2
Camden	1	0	5	0	0	0	6
Chowan	7	1	2	0	8	0	18
Currituck	2	0	2	0	0	0	4
Dare	3	0	0	0	0.3	0	3.3
Pasquotank	0.9	0.1	5	0	0.1	0	6.1
Perquimans	5	0.8	0.7	0	2	0	8.5
Tyrell	4	0	0.3	0	16	0	20.3
Washington	8	0	0	0	13	0	21
Alligator River	0.4	0	0	0	65	0	65.4
Dare	<0.1	0	<0.1	0	27	0	27
Hyde	0	0	0	0	9	0	9
Tyrell	0.4	0	<0.1	0	29	0	29.4
Cape Fear River	8	10	13	<0.1	15	0	46
Brunswick	5	3	7	<0.1	8	0	23
New Hanover	4	8	6	<0.1	7	0	25
Chowan River	11	0.7	9	0	23	0	43.7
Bertie	4	0.7	7	0	4	0	15.7
Chowan	8	0	0.6	0	15	0	23.6
Gates	0	0	0.2	0	0.4	0	0.6
Hertford	0	0	0.7	0	4	0	4.7
Little River	4	2	1	9	0	0	16
Pasquotank	3	0.6	0.9	4	0	0	8.5
Perquimans	1	1	0.1	5	0	0	7.1
Neuse River	35	11	10	2	22	0	80
Carteret	0	5	1	0	0.8	0	6.8
Craven	21	3	5	2	12	0	43
Pamlico	14	2	4	0	10	0	30
North River	2	0.4	32	0	0	0	34.4
Camden	0	0	12	0	0	0	12
Currituck	2	0.4	20	0	0	0	22.4
Pamlico River	32	16	5	4	13	0	70
Beaufort	32	16	3	4	8	0	63
Pamlico	0	0	2	0	5	0	7
Pamlico Sound							
Dare	0.1	2	2	0	0	0	4.1
Pasquotank River	19	3	10	0	0	0	32
Camden	9	2	6	0	0	0	17

County	Likelihood of Shore Protection				Nontidal Wetlands	Outside Study Area	Totals
	Almost Certain	Likely	Unlikely	No Protection			
Pasquotank	10	1	4	0	0	0	15
Perquimans River							
Perquimans	9	7	0.2	19	0	0	35.2
Back Barrier Bays	199	99	117	98	159	0	672
Brunswick	60	5	8	8	5	0	86
Carteret	49	13	15	51	7	0	135
Currituck	13	3	43	1	20	0	80
Dare	42	27	0.6	24	50	0	143.6
Hyde	1	12	8	5	57	0	83
New Hanover	12	11	17	4	0.9	0	44.9
Onslow	8	24	7	4	8	0	51
Pamlico	0	0	1	0	8	0	9
Pender	12	2	17	0	1	0	32
State Total ¹	1,458	772	1,655	445	2,921	15	7,267

Note:
¹ Includes tributaries to major water bodies.

INTRODUCTION

North Carolina has more than 300 miles of ocean beaches and, depending upon the method used to measure, between 4,000 and 7,000 miles of estuarine shoreline.² These beaches and shorelines form the eastern edges of narrow barrier islands and a low-lying coastal plain. Much of this area is less than 20 feet above mean sea level (msl) with large percentages less than 5 feet above msl.³ A rising sea level will have a significant environmental, social, and economic impact on the state.

These impacts were examined in a 1990 paper titled *The Effects of Global Warming and Sea-Level Rise on Coastal North Carolina*.⁴ The paper looked at 22 counties in eastern North Carolina and compared population patterns, topography, and various studies predicting rates of sea level rise. The paper noted the dramatic population increases that occurred between 1970 and 1986. For example, during that time period the populations of the United States and North Carolina increased 18.6 percent and 24.5 percent, respectively, compared to 30.2 percent for the 22

coastal counties.⁵ More recently, population increases have slowed for the state's coastal area as a whole, but growth continues to be dramatic in several counties with ocean beaches. For example, between 1990 and 2000, Pender County grew by 42 percent, Brunswick County by 43 percent, Currituck County by 32 percent, New Hanover County by 33 percent, and Dare County by 32 percent. For the same time period, the overall growth rate for the state was 37 percent.⁶ Based on 2000 census data, over 10 percent of the states eight million residents live within the coastal counties.⁷

The 1990 study continued by examining the impact of a 5-foot rise in sea level. Citing the "drowned-valley concept" developed by Kana et al.,⁸ the study estimated that this change would inundate more than 1.23 million acres of lowlands and swamps. This would result in water covering 87 percent of Dare County, 75 percent of Tyrrell County, more than 66 percent of Hyde County, and more than 50 percent of Currituck County. Regarding ocean beach erosion, the paper cited studies that indicate that a 5-foot rise in sea level would result in shoreward erosion of 500 to 5,000 feet and "would dramatically alter shoreline configuration."⁹ Different studies have presented

² The NC Division of Coastal Management reports an ocean shoreline of 320 miles and an estuarine shoreline of nearly 4,000 miles, with shoreline defined as the boundary between land and open water. (NC Division of Coastal Management, Coastal Facts, accessed at <http://dcm2.enr.state.nc.us/News/facts.htm> on December 11, 2007). This study estimates an ocean shoreline of 303 miles and a remaining shoreline of 6,964 miles, with shoreline defined as the upper boundary of the tides (i.e., boundary between dry land or nontidal wetlands and tidal wetlands or open water)

³ See box on "Reference Elevations and Sea Level Rise" for an explanation of spring high water and sea level rise.

⁴ Wilms, P.R., 1990, "The Effects of Global Warming and Sea-Level Rise on Coastal North Carolina," *Carolina Planning* 16(2): 44–49 at 45.

⁵ Ibid. at p. 45.

⁶ North Carolina State Data Center, 2000 Census Lookup, September 10, 2002, available from <http://sdc.state.nc.us/>.

⁷ U.S. Census Bureau, population estimates by county, accessed at <http://www.census.gov/popest/counties/CO-EST2006-01.html> on December 11, 2007.

⁸ Kana, T.W., J. Michel, M.O. Hayes, and J.R. Jensen, 1984. "The physical impact of sea level rise in the area of Charleston, South Carolina," pp. 105–150 in *Greenhouse Effect and Sea Level Rise*, M.C. Barth and J.G. Titus, eds., Van Nostrand Reinhold, New York.

⁹ Hoffman, J.S., J.B. Wells, and J.G. Titus, 1983, "Projecting future sea level rise; methodology, estimates to the year

similar estimates of shoreline erosion that depend upon a number of factors including proximity to inlets, effects of littoral drift, shoreline stabilization, whether it is ocean or estuarine shoreline, and especially the forecast change in relative sea level.^{10, 11} When these figures are coupled with population statistics, it is apparent that North Carolina should be planning for long-range impacts of sea level rise.¹²

In addition to having large percentages of low-lying coastal areas subject to long-term sea level rise, North Carolina is experiencing an increase in tropical storms with short-term flooding ramifications. In 1999 the state experienced unprecedented flooding of the coastal plain from Hurricane Floyd. Four years earlier, the state experienced severe flooding with Hurricane Fran. It can be hypothesized that flooding associated with these types of storms is exacerbated by rising sea level along the eastern edges of the state's coastal plain.

The 1990 study includes these very relevant observations and remarks:

Given the potential economic impact and social disruption attendant to a five-foot sea level rise, one can anticipate that man's response to the phenomenon will be aimed at protecting what has already been built. Consequently, the environmental impacts of man's response to sea-level rise could be greater than the impacts of sea level rise itself.¹³

2100, and research needs," U.S. Environmental Protection Agency, Washington, D.C.

¹⁰ Riggs, Stanley (accessed October 2007). Chapter 5: Four Basic Concepts Concerning Estuarine Shoreline Erosion, in: *The Soundfront Series: Shoreline Erosion in North Carolina Estuaries*. http://www.ncseagrant.org/index.cfm?fuseaction=page&file_name=sfs_shoreline_erosion.html

¹¹ Leatherman, S., K. Zhang and B. Douglas. 2000a. Sea level rise shown to drive coastal erosion. *EOS Transactions* 81 (6) (February 8, 2000): 55-57.

¹² The term "sea level rise" is used as a shorthand for "relative sea level rise."

¹³ Wilms 1990 at 47

As of the stakeholder review of this study in 2003, North Carolina has not altered its coastal management policies to directly deal with the economic and environmental ramifications of sea level rise. Nevertheless, a number of policies implicitly deal with the consequences. For example, the state has policies that require oceanfront setbacks for new development based on historical erosion rates. And coupled with the setback requirement is a prohibition on hardened/permanent erosion control structures on ocean beaches. Beachfill projects have occurred in places like Wrightsville Beach and Carolina Beach, but North Carolina has also allowed shores in Kitty Hawk and elsewhere to retreat, forcing the relocation of shorefront homes.

Along the estuarine shoreline, policies regulating development are even fewer. In 1999, the state did establish a buffer zone along much of the state's coastal rivers and estuarine shoreline. Although this buffer may delay some of the impacts of rising sea level, the primary motivation for action was water quality protection—not protection from sea level rise or storm events. North Carolina's Coastal Area Management Act (CAMA) does require land use planning in the state's 20 coastal counties, and the state's planning guidelines require local governments to address the issue of sea level rise. Most of the current plans, however, only lightly touch on the issue and defer action to the state's coastal management program. For example, some thought has been directed at the environmental consequences of armoring small parcels of land along the shore, but no one has decided—and relatively few people even have opinions—whether the large peninsula that separates Albemarle and Pamlico sounds should be protected with a dike or allowed to gradually submerge.

Purpose of this Study

This study develops maps that distinguish the areas likely to be protected¹⁴ as the sea rises from the areas where shores are expected to retreat naturally, either because the cost of holding back

¹⁴For purposes of this study, "protect" generally means some form of human intervention that prevents dry land from being inundated or eroded. The most common measures include beach nourishment and elevating land with fill, rock revetments, bulkheads, and dikes.

the sea is greater than the value of the land or because there is a current policy of allowing the shoreline to retreat. This report is part of a national effort by the U.S. Environmental Protection Agency (EPA) to encourage the long-term thinking required to deal with the impacts of sea level rise issues.

Maps that illustrate the areas that might ultimately be submerged convey a sense of what is at stake, but they also leave people with the impression that submergence is beyond their control. Maps that illustrate alternative visions of the future may promote a more constructive dialogue.

For each state, EPA is evaluating potential state and local responses to sea level rise, with a focus on maps showing the likelihood that lands will be protected from erosion and inundation as the sea rises. These maps are intended for two very different audiences:

State and local planners and others concerned about long-term consequences. Whether one is trying to ensure that a town survives, that wetlands and beaches are able to migrate inland¹⁵, or some mix of both, the most cost-effective means of preparing for sea level rise often requires implementation several decades before developed areas are threatened.¹⁶ For the last 25 years, EPA has attempted to accelerate the process by which coastal governments and private organizations plan for sea level rise, and evaluated whether the nation's wetland protection program will achieve its goals as sea level rises.¹⁷ Preparing for sea level rise requires society to decide which areas will be

¹⁵ In some areas, wetlands may accrete sufficient sediment to vertically increase elevation and thus avoid inundation. For further information on the potential for wetland accretion, see Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, A.S. Kolker, L.L. Leonard, R.A. Orson, and J.C. Stevenson. 2007. Site-Specific Scenarios for Wetlands Accretion as Sea Level Rises in the Mid-Atlantic Region. Supporting Document for CCSP 4.1.

¹⁶ Titus, J.G., 1998, "Rising seas, coastal erosion and the takings clause: How to save wetlands and beaches without hurting property owners," *Maryland Law Review* 57:1279–1399.

¹⁷ EPA began helping coastal communities prepare for an acceleration of sea level rise in 1982, long before the agency developed a policy for reducing greenhouse gases. See, e.g., EPA, 1983, *Projecting Future Sea Level Rise*. See also the report of EPA's 1983 Sea Level Rise Conference: *Greenhouse Effect and Sea Level Rise: A Challenge for this Generation*, M.C. Barth and J.G. Titus, editors, Van Nostrand Reinhold, New York.

elevated or protected with dikes and which areas will be abandoned to the sea. A key step toward such a decision is the baseline analysis of what will happen given current policies and trends. This report provides that baseline analysis.

National and international policy makers.

National and international policies regarding the possible need to reduce greenhouse gas emissions require assessments of the possible impacts of sea level rise. Such assessments depend to a large degree on the extent to which local coastal area governments will permit or undertake shore protection efforts.¹⁸ Moreover, the United Nations Framework Convention on Climate Change, signed by President Bush in 1992, commits the United States to taking appropriate measures to adapt to the consequences of global warming.

Caveats

This report has two fundamental limitations. First, it is literally a "first approximation" of the likelihood of shore protection. Like most first-of-a-kind studies, our effort includes methodological judgments that may later prove ill-advised. We examine the implications of current trends in coastal development and coastal management policies. We have attempted to account for uncertainty by dividing our study area into lands where shore protection is almost certain, likely, unlikely, and precluded by current policies. But many important factors can not be foreseen—and in many cases the only available data are several years old. Therefore, we often relied on planners to fill in the gaps by telling us about recent and expected development. But what is expected now may be different from what was expected when we visited the planners. As new information emerges, assessments of the likelihood of shore protection will change.

Second, this study is not even intended to address all of the issues that some people think about when they hear the term "shore protection." Our intention is to distinguish those lands where a

¹⁸ Titus, J.G., et al., 1991, "Greenhouse effect and sea level rise: The cost of holding back the sea," *Coastal Management*, 19:171-204; and Yohe, G., "The cost of not holding back the sea: Toward a national sample of economic vulnerability," *Coastal Management* 18:403–431.

natural retreat would occur from those areas where people will at least attempt to hold back the sea. Our maps are *not* intended to identify:

- the vulnerability of particular lands (we simply evaluate whether lands would be protected *if and when* they are threatened);
- options for protecting existing wetlands (we analyze protection only of dry land);
- which areas will receive government funded shore protection;
- whether people will hold back the sea forever, which would depend on cost factors and scientific uncertainties outside the scope of this analysis; and¹⁹
- whether hard structures, soft engineering, or some hybrid of the two approaches is likely in areas that will be protected, or the environmental impacts of shoreline armoring.

How to Read this Report

This chapter is one of eight state-specific chapters in Volume 1. Each of the eight chapters was written and reviewed as a stand-alone document, because the authors assumed that many readers are only interested in the analysis of a single state. To assist readers interested more than one state, each chapter (except the short chapter on the District of Columbia) is organized in a similar fashion, including a summary of likely responses, introduction, methods, relevant state policies, county-specific policies and responses, result appendices, and other appendices as needed.

Some subsections appear verbatim in each of the eight chapters, including the subsections on purpose, caveats, and the text box on tides and reference elevations. Subsections on map scale and use of experts have text that is nearly verbatim, except for changes that reflect state-to-state differences. The methods sections reflect

differences in available data for each state, but the study area subsection is nearly the same from state to state.

This chapter has separate sections in which we describe:

- *methods* by which we assess the likely sea level rise responses;
- *state policies* that affect the management of the coastal lands;
- county-specific policies and the likely extent of future shore protection.

At the end of this chapter, we provide detailed quantitative results in three appendices:

- (A) best estimates of the length of shoreline by likelihood of shore protection;
- (B) best estimates of the area of land at various elevations by likelihood of shore protection; and
- (C) uncertainty ranges of the amount of land at various elevations by likelihood of shore protection.

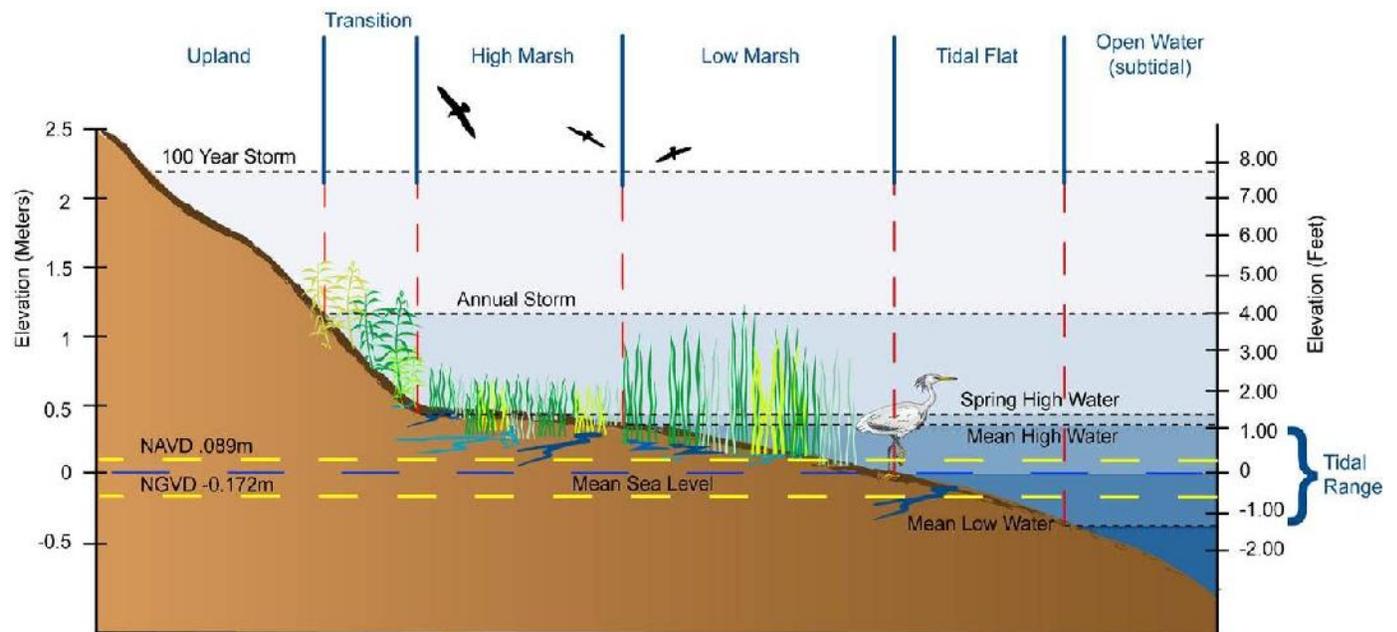
Because the quantitative results were developed after this study was complete, those results are not integrated into the text of this report, other than the summary. The final appendix (D) provides a complete list of data sources.

¹⁹For example, the sea could rise 10–20 feet over several centuries if one of the world’s ice sheets were to melt. See, e.g., IPCC, 2001, *Climate Change Science 2001*, Cambridge University Press, New York and London.

BOX 9-1: TIDES, SEA LEVEL, AND REFERENCE ELEVATIONS

Tides are caused by the gravitational attraction of the moon and sun on the ocean water. Most places have two high and low tides every day, corresponding to the rotation of the earth. The daily tide range varies over the course of the lunar month. *Mean high water* and *mean low water* are the average elevations of the daily high and low tides. During full and new moons, the gravitational pull of the moon and the sun are in alignment, which causes the tide range to be 15–25 percent more than average. The averages of the full and new moon high and low tides are known as *spring high water* and *spring low water*. In addition to the astronomic tides, water levels fluctuate owing to winds, atmospheric pressure, ocean current, and—in inland areas—river flow, rainfall, and evaporation. Daily tide ranges in the mid-Atlantic are as great as 8 feet in parts of the Delaware River and less than an inch in some of the sounds of North Carolina.

In coastal areas with tidal marshes, the high marsh is generally found between mean high water and spring high water; low marsh is found from slightly below mean sea level up to spring high water. In bays with small (e.g. 6 inch) tide ranges, however, winds and seasonal runoff can cause water level fluctuations more important than the tides. These areas are known as “*irregularly flooded*”. In some locations, including much of Currituck and Albemarle sounds and their tributaries, the astronomic tide range is essentially zero, and all wetlands are irregularly flooded. Freshwater wetlands in such areas are often classified as “nontidal wetlands” because there is no tide; but unlike most nontidal areas, the flooding—and risk of wetland loss—is still controlled by sea level. Wetlands whose hydrology is essentially that of nontidal wetlands, but lie at sea level along an estuary with a very small tide range, are called *nanotidal wetlands*.



The term *sea level* refers to the average level of tidal waters, generally measured over a 19-year period. The 19-year cycle is necessary to smooth out variations in water levels caused by seasonal weather fluctuations and the 18.6-year cycle in the moon’s orbit. The sea level measured at a particular tide gauge is often referred to as local mean sea level (LMSL).

Tide gauges measure the water level relative to the land, and thus include changes in the elevation of the ocean surface and movements of the land. For clarity, scientists often use two different terms:

- *Global sea level rise* is the worldwide increase in the volume of the world’s oceans that occurs as a result of thermal expansion and melting ice caps and glaciers.
- *Relative sea level rise* refers to the change in sea level relative to the elevation of the land, which includes both global sea level rise and land subsidence.

In this report, the term “sea level rise” means “relative sea level rise.”

Land elevations are measured relative to either water levels or a fixed benchmark. Most topographic maps use one of two fixed reference elevations. USGS topographic maps measure elevations relative to the National Geodetic Vertical Datum of 1929 (NGVD29), which was approximate sea level in 1929 at the major coastal cities. New maps and high-resolution data measure elevations relative to the North American Vertical Datum of 1988 (NAVD88). This report measures elevations relative to spring high water (for 2000), which indicates how much the sea must rise before the land is inundated by the tides. Along most of Albemarle and Pamlico Sounds, spring high water is close to mean sea level, but because other chapters use spring high water we retain that measure in this chapter as well.

METHODS

This section provides detailed information on the approaches employed over the course of this study, which was conducted between 1999 and 2003.²⁰ The study consisted of two phases: The first phase was based on state input and produced an initial draft report. The second stakeholder review phase produced a final draft.

The following subsections discuss:

- scope of the study area;
- summary of the overall study approach
- detailed description of the methods used to develop the initial maps;
- our approach for gathering updated information and to confirm the content of the maps and report; and
- the appropriate scale for viewing the resulting maps.

Table 1 lists state and local officials who provided input to the study.

Study Area

The study area for our analysis includes all land below the 5-meter (NGVD) contour. This landward boundary was picked largely because it was readily available, appearing on the USGS 100,000-scale maps that formed the basis of the initial round of discussions with state officials. Shaded portions of the map displayed in Figure 1 identify lands below the 6-meter contour. Table 2 lists area of land vulnerable to sea level rise by jurisdiction, sorted by area of dry land vulnerable. This large study area is not meant to suggest that

sea level rise would inundate all of these lands. In defining our study area, the most important consideration was to include all the land that might be vulnerable to sea level rise. As better elevation data become available, we can always exclude relatively high ground from a particular published map or assessment using the data developed by this study. The 5-meter contour includes virtually the entire coastal floodplain as well as some areas that are not currently in the floodplain.

Our study area also includes all dry land within 1,000 feet of tidal wetlands or open water to account for possible erosion²¹ and to ensure that the study area is large enough to be seen on maps depicting a county on a single sheet of paper. We found that maps without a 1,000 foot study area along bluffs were difficult to read and did not convey the anticipated response.

Overall Approach

Through conversations with staff of the North Carolina Department of Natural Resources, Division of Coastal Management and local officials, we developed decision guidelines that identify a land use or type category and its likelihood to be protected.²² Next we discussed

²¹ The 1,000-foot buffer is conservatively overinclusive. Rates of shoreline erosion vary. But given the format of most land use data, extending the study area 1,000 feet inland did not require us to obtain data or engage in discussions that we would not have undertaken otherwise.

²² This report makes projections about future events and is therefore subject to uncertainty. Changes in political climate and policies would change the responses of state and local planners as we have presented them. Improvements in technology could alter the cost or effectiveness of protection and affect individuals' decisions to abandon or protect their property. It is impossible to forecast changes in policies or other factors and we thus base our response maps on the

²⁰ Changes to policies and trends after the stakeholder review meetings are not captured in this report.

area-specific differences anticipated by the planners.²³ Through this approach we delineated the possible responses into three degrees of protection:

- lands almost certain to be protected by human intervention (e.g., structural measures or beach nourishment),²⁴
- lands that are reasonably likely to be protected though human intervention, but where some uncertainty remains, and
- lands where natural forces such as erosion will mostly likely be unchallenged.

Using a three-color scheme, we indicated directly on a set of United States Geological Survey (USGS) 1:100,000 scale maps which category each land area falls under.²⁵ These anticipated responses were then digitized and reconstructed using the Environmental Systems Research Institute's ARC/INFO application. Further detail was added to the maps using Coastal Barrier Resources Act (COBRA) barrier beach hard copy maps (hand-digitized at a 1:100,000 scale) referenced to the location of roads as identified in the U.S. Census Bureau's TIGER Road Files.

policies and trends identified during the study (i.e., 2001 through 2003).

²³The results of these original efforts are hereafter referred to as the stakeholder review draft.

²⁴For the purposes of this report and our mapping exercise we group beach nourishment and structural engineering together as "protection." This project does not attempt to answer the question of who will provide the funding for these activities. Although determinations may be made that protection is more likely in areas that money is currently being spent to protect, it is difficult to project the availability of funding in the future as political climate, the economy, and other factors that influence public and private spending are subject to change.

²⁵ A 1:100,000 scale map has a horizontal positional accuracy of plus or minus 166.67 feet.

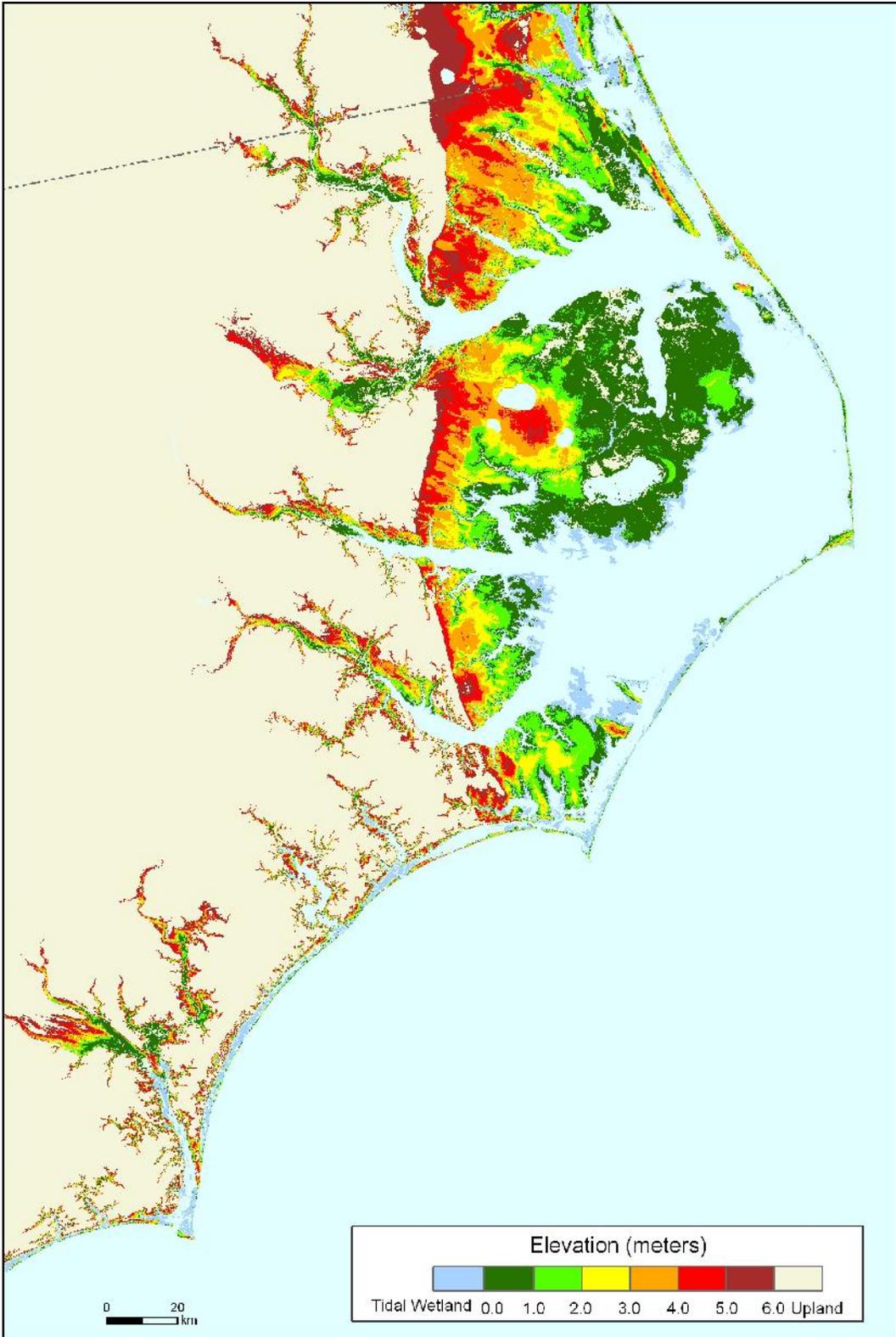


Figure 9-1. Lands Vulnerable to Sea Level Rise. Source: Titus and Wang (see Table ?-3) based upon on LIDAR obtained from the State of North Carolina. For details on the accuracy of this map, see Annex 3 and Appendix 9-C. Elevations are relative to spring high water. Because the map has a contour interval of 1 meter (3.28 feet), we did not convert the legend from metric to the English units used in the text of this report.

TABLE 1. GOVERNMENT PARTICIPANTS AND REVIEWERS

Name	Title and Affiliation	Role
John Thayer Jane Dautridge Kathy Vinson	District planning manager, NC Division of Coastal Management	State source of shore protection expectations
Alex Marks Scott Jones Ted Tyndall	Former district planning manager, NC Division of Coastal Management	State source of shore protection expectations
Lynn Mathis Dennis Hawthorne Terry Moore David Moye	Field representative, NC Division of Coastal Management	State source of shore protection expectations
Jack Simoneau	Former planning and inspections director, Currituck County	County source of shore protection expectations
Gary Ferguson	Planning and inspections director, Currituck County	County stakeholder reviewer
Allen Castelloe Carl Classen	EMS director, Bertie County County manager, Camden County	County stakeholder reviewer Suggested use of county GIS data
Julie Stamper	GIS coordinator, Pasquotank County	Provided GIS data and county stakeholder reviewer
Bobby Darden	Assistant county manager, Perquimans County	County stakeholder reviewer
Chad Sary	Director, Department of Planning and Inspections, Chowan County	County stakeholder reviewer
Bill Early	Planning and zoning administrator, Hertford County	County stakeholder reviewer
Donnie Pittman	County manager, Martin County	Agreed to review materials but could not be reached for comment
Ann Keyes Debbie Askew	Washington County GIS director, Washington County	County stakeholder reviewer Provided GIS data
J.D. Brickhouse Webb Fuller Ray Sturza	County manager, Tyrrell County Town manager, Nags Head Planning director, Dare County	County stakeholder reviewer Town stakeholder reviewer County stakeholder reviewer
Donna Creef Alice Keeney Jeremy Smith Gill Robbins Miriam Prescott Don_Baumgardner	Chief planner, Dare County County planner, Hyde County County planner, Beaufort County Planner, Beaufort County Map coordinator, Pamlico County Craven County	County stakeholder reviewer County stakeholder reviewer County stakeholder reviewer Provided hard copy data County stakeholder reviewer County stakeholder reviewer
Katrina Marshall	Director of planning and inspections, Carteret County	County stakeholder reviewer
Angie Manning	Staff planner, Onslow County	County stakeholder reviewer
Zoe Bruner	Director of planning and inspections, Town of Wrightsville Beach	County stakeholder reviewer
Leslie Bell Chris O'Keefe Dexter Hayes	Planning director, Brunswick County New Hanover County Planning Department Planning director, New Hanover County	County stakeholder reviewer County stakeholder reviewer County stakeholder reviewer

Note:

1. Titles and affiliations are based on the position held by participants at the time of the study meetings, which occurred between 1999 and 2003. Since the discussions with planners, individuals may have changed positions or left the corresponding agency.

TABLE 2. AREA OF LAND VULNERABLE TO SEA LEVEL RISE IN NORTH CAROLINA (SQUARE MILES)^a

Jurisdiction ^b	Vulnerable land ^c	Tidal wetlands	0-2 feet Elevation ^d		0-4 feet Elevation ^d		0-8 feet Elevation ^d	
			Dry land	Nontidal Wetland	Dry land	Nontidal Wetland	Dry land	Nontidal Wetland
Hyde	402.5	76.7	153.6	172.3	187.8	209.4	236.5	232.8
Tyrrell	274.9	1.5	83.8	189.7	125.4	214.8	143.9	226.1
Carteret	186.3	128.1	34.2	24.0	73.8	47.8	159.1	85.8
Beaufort	80.3	13.6	32.5	34.2	62.2	51.5	140.0	87.2
Dare	284.8	63.8	23.9	197.1	33.8	234.9	48.3	256.7
Pamlico	85.5	43.1	17.2	25.2	39.2	31.9	83.1	52.2
Currituck	116.6	47.7	13.7	55.3	29.1	62.0	81.8	73.2
Onslow	49.5	26.4	12.0	11.1	17.0	13.7	28.8	18.2
Pasquotank	31.2	0.1	8.9	22.1	27.3	26.8	71.7	34.6
Brunswick	66.1	42.0	7.4	16.7	12.6	20.5	24.2	26.3
Camden	66.0	2.8	7.2	56.0	18.5	59.9	64.2	69.1
Craven	37.7	4.7	5.5	27.5	12.7	37.0	35.4	56.6
New Hanover	39.1	21.4	4.6	13.1	8.1	15.2	15.0	18.1
Washington	34.2	0.1	4.5	29.6	16.3	36.2	53.1	46.5
Gates	37.5	0.0	3.6	33.9	6.3	36.0	11.5	40.2
Pender	58.3	14.7	3.5	40.2	6.7	49.8	16.7	64.9
Perquimans	19.8	0.0	3.1	16.6	7.6	20.6	40.5	31.2
Hertford	22.3	0.0	2.3	20.0	4.4	22.3	9.1	25.9
Chowan	14.2	0.0	1.8	12.4	3.8	14.4	11.1	17.9
Bertie	48.5	0.1	1.2	47.2	2.8	51.6	6.9	62.7
Jones ^e	4.8	0.0	1.0	3.8	1.6	5.1	3.5	7.5
Pitt ^e	10.0	0.0	0.6	9.3	1.5	11.7	5.0	16.4
Martin	25.2	0.0	0.5	24.7	2.3	34.6	7.8	46.0
Northampton ^e	0.7	0.0	0.0	0.7	0.1	1.0	0.4	2.5
Columbus ^e	0.2	0.0	0.0	0.2	0.0	0.6	0.1	1.8
Duplin ^e	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bladen ^e	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.9
Edgecombe ^e	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Halifax ^e	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sampson ^e	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Statewide totals	1,996	486	427	1,083	701	1,309	1,298	1,602

^a J.G. Titus and J. Wang. 2007. Maps of Lands Close to Sea Level along the Middle Atlantic Coast of the United States: An Elevation Data Set to Use While Waiting for LIDAR. Background Document supporting Climate Change Science Program Synthesis and Assessment Product 4.1, Question 1.

^b Jurisdictions ranked by amount of dry land within 2 feet above the ebb and flow of the tides.

^c The area of tidal wetlands plus the area of land within 2 feet above spring high water.

^d Elevations relative to spring high water, that is, the average highest tide during full moons and new moons. Therefore, the land within 2 feet of spring high water is the area that would be tidally flooded if the sea rises 2 feet.

^e Not included in this study.

To obtain information on local-level expectations and to improve the accuracy of these maps, we reviewed the stakeholder review draft maps with county planners and managers and then revised the maps accordingly, in many cases using county geographic information system (GIS) data.²⁶ The response maps that result from these efforts are in each county section.²⁷ The appendix provides a detailed summary of data sources used in the production of the maps.

To account for the various uncertainties, the maps created under Phase 2 of this study divide dry land into four categories:

Brown—areas that will **almost certainly** be protected if and when the sea rises enough to threaten them, assuming a continuation of existing policies and trends.

Red—areas where shore protection is **likely**, but where it is still reasonably possible that shores might retreat naturally if development patterns change or scientists were to demonstrate an ecological imperative to allow wetlands and beaches to migrate inland.

Blue—areas where shore protection is **unlikely** generally because property values are unlikely to justify protection of private lands, but in some cases because managers of publicly owned lands are likely to choose not to hold back the sea.

Light Green—areas where there would be **no shore protection** under existing policies, which already appear to preclude holding back the sea. These areas include both publicly and privately owned lands held for conservation purposes.

Although our maps are based on a continuation of current policies, we were also mindful of the possible implications of changing priorities. If the costs or environmental consequences of shore protection led society to deliberately reduce shore protection compared with what one might expect given current policies, then (ignoring site-specific environmental and shore protection cost issues) the

²⁶In these cases, we define the GIS data in the individual county-specific sections.

²⁷The scope of this project does not allow for the type of analysis that would ensure complete and accurate information at a high level of detail. Consequently, the maps should not be displayed at greater than 1:100,000 scale, roughly a single county on an 11 × 17" sheet of paper.

light green, blue, and red identify those areas where retreat would be feasible as a matter of land-use planning. If development and/or land values increase beyond what is currently expected, the brown, red, and blue areas might all be protected.

Outside the study area, we generally show nontidal wetlands as purple and tidal wetlands as dark green. We differentiate tidal and nontidal wetlands because the effects of sea level rise are potentially very different. We differentiate nontidal wetlands from dry land because this report only evaluated whether dry land would be protected.²⁸

Phase 1: Stakeholder Review Draft Based on State Input

Walter Clark created the initial set of maps, using hard-copy maps and the expert opinions of various regional staff of the North Carolina Department of Natural Resources, Division of Coastal Management. His general approach was to visit the regional offices with a USGS 1:100,000 scale map, discuss the project, and have these experts draw on the map the boundaries of existing development and future development. The initial maps showed developed areas as certain to be protected, and areas where development is expected in the future as likely to be protected. Clark provided these 1:100,000 scale maps, as well as the initial draft of this report, to EPA, whose GIS contractor hand-digitized the resulting maps. Daniel Hudgens revised this digital data set to distinguish coastal wetlands, dry lands within conservation areas (light green), and other areas that Clark did not show as likely to be protected. Jim Titus drew the boundaries of the Coastal Barrier Resources Act lands onto copies of those digitized maps, which were digitized by IEc. Leslie Katz of IEc reformatted Clark's report and maps so that each county had a separate map and report section. EPA and the North Carolina Association of County

²⁸Shore protection designed to protect dry land does not necessarily have the same impact on nontidal wetlands. Erosion control structures designed to prevent homes from eroding into the sea may also protect adjacent nontidal wetlands. Efforts to elevate land with fill to keep it dry would not necessarily be applied to nontidal wetlands. Some nontidal wetlands in developed areas may be filled for development.

Commissioners then sent this stakeholder review draft to each of the coastal counties.

Phase 2: More Detailed Maps Based on County Input

The North Carolina report was one of the initial pilot efforts. EPA's experience with ongoing efforts elsewhere suggested that the original set of maps for North Carolina required improvements for two reasons. First, hand-drawn maps mislocate boundaries and omit important areas even when they rely on people who know an area well. Such errors may be acceptable in a map showing the entire state on a single sheet of paper, but this project seeks to create maps that are useful at a scale of 1:100,000 or better. The gradual availability of digital maps seemed more likely to produce a useful final product.

Second, the original maps relied almost entirely on the judgment of state officials with a regional (i.e., multicounty) perspective rather than on the counties, who have land use authority and more detailed expertise. Because the counties have the more detailed land cover and land use planning data, obtaining county data appeared to be the most efficient way to improve the precision and reliability of the maps.

With the assistance of The Nature Conservancy (TNC)²⁹ and the Partnership for the Sounds, the EPA project manager briefed officials of all the counties along Albemarle Sound, plus Hyde and Pamlico counties, and obtained their cooperation, including the provision of some form of digital data and insights on the areas that would be protected. IEC had telephone conversations with the remaining counties, as well as follow-up conversations with several counties that EPA had briefed. Approximately half the counties provided digital land cover or land use planning maps, along with suggested "decision rules" on how to classify particular land categories. Most counties also provided site-specific information on shore protection, which would not necessarily have been reflected in the land use data. In a few cases, counties indicated that the original Clark maps

were correct, or correct aside from a small number of revisions. The particular revisions are explained in the county-specific sections.

Map Scale

The "protection almost certain" and "protection likely" polygons are based on the annotations that state and local planners drew onto hard-copy maps, for all but four counties.³⁰ The original data source was hand-digitized data created from 1:100,000 topographic maps marked by state regional planners. The stakeholder review generally involved hand annotations to county maps on 11 × 17 inch paper, i.e., a scale of roughly 1:150,000. In some cases, those reviews included hard-copy land use maps that, in effect, replaced all the polygons provided by the original state assessment. Nevertheless, these hard copy maps generally were at approximately the 1:100,000 scale and thus did not change the appropriate map scale. Because the annotations are not necessarily as precisely drawn as national map accuracy standards might assume, we recommend that the reader view our data as 1:300,000 scale.

We obtained higher resolution land use, planning, or zoning data from Camden, Dare, Pasquotank, and Perquimans counties. Given the scale of that input data, those maps can reasonably be viewed as 1:24,000 or better.

The quality of our input data is not the primary uncertainty associated with our map boundaries. Future development and shore protection are very uncertain. Thus, the scales we suggest are simply our advice regarding the maximum scale at which one ought to display the maps for a given location rather than our assessment of the accuracy of what will actually transpire in the decades ahead.

Instead, we adopted a simpler model: First, we identify those areas where conservation lands preclude shore protection, areas that governments have decided to revert to nature for flood mitigation or environmental reasons, and those areas that are so densely developed that no one seriously doubts the likelihood of shore protection

²⁹TNC set up meetings with Bertie and Currituck counties, concerning work it was doing under an EPA grant. The EPA project manager took the opportunity to explain other EPA activities, including this study.

³⁰The light green was based on state conservation layers.

(given current policies). Second, along estuaries we assume that residential, commercial, and other developed lands will be protected and that undeveloped lands will not be protected.³¹ We rely on local planners to help us identify current and project future development. Third, along ocean coasts, our premise is that current shore-protection policies generally have defined the areas where beach nourishment is almost certain, and that shore protection is likely in other areas that reach high densities. All of these aspects of the study are essentially data-driven, using a very simple model of the areas where shores are protected.

Unlike other state assessments, at the time of the study, we had land use data for only a limited number of counties. For these counties (Camden, Dare, Pasquotank, and Perquimans) we relied on local planners to provide facts or opinions in those cases in which the necessary data were unavailable, out of date, or provided an ambiguous result requiring a human tie-breaker. In these counties, most of the map changes provided by local planners involved cases where our data showed no development, but planners were aware of recent or imminent development. But in a small number of cases, planners reviewed our initial results, made a policy-based conjecture, and requested a map change.

In counties for which we were unable to acquire land use data, we relied more heavily on the land use planners to identify the location of current development as well as areas where future development is expected. We hope that the way we document our results does not leave researchers with the impression that our estimates of the likelihood of shore protection are simply the opinions of planners on a subject over which they lack expertise. We rely on planners to help us identify current and future land use and identify policies related to development and shore protection—matters that fall within their responsibility. Given expected development, the favorable or unfavorable economics of shore

protection—not planner opinions—generally determine our results.

For most readers, these distinctions may be of little interest. For brevity, the report often says “planners expect shore protection” at a specific location, when a more precise exposition of our analysis might say “planners provided us with data on existing land use data and/or master plans. These data, along with site-specific planner knowledge, imply a level of development that would more than justify shore protection if current policies and economic trends continue. Therefore, planners expect shore protection.”

³¹The cost of shore protection along estuaries is small compared to property values in developed areas—and homes are rarely given up to retreating estuarine shores except for where policies prohibit shore protection.

NORTH CAROLINA'S STATE POLICIES

State Ownership of Coastal Lands

In North Carolina, the state retains title to lands subject to the flow of the Atlantic Ocean up to the mean high tide line.³² According to the North Carolina Supreme Court, the mean high tide line constitutes the boundary between private land and state-owned public trust lands along ocean or inlet shorelines. This boundary is ambulatory and moves with erosion and accretion.

On the estuarine shoreline (sounds and coastal rivers), the state owns submerged lands below navigable waters.³³ The “navigability test” is a significant departure from the long-held view that the state owns all lands subject to the ebb and flow of the tides. From a practical standpoint, however, the mean high water line may still represent the boundary between public and private land in that the state has not addressed the “full breadth test” for determining navigability. This test embodies the notion that if a portion of a waterbody is navigable, then the full breadth of the waterbody is navigable as a matter of law.³⁴

North Carolina's Coastal Management Program

North Carolina established a coastal management program in 1974 with the passage of the Coastal Area Management Act (CAMA). CAMA recognized that the state's coastal area was being subjected to pressures that “are the result of the often conflicting need of a society expanding in industrial development, in

population and in the recreational aspirations of its citizens....”³⁵ CAMA's jurisdictional area, referred to as the coastal area, includes 20 of North Carolina's coastal counties, estuarine waters within these counties, and the Atlantic Ocean seaward to the end of state jurisdiction. Within this area, a regulatory and planning program seeks to create a unique state and local partnership to manage coastal lands.

The Regulatory Program

CAMA directed the Coastal Resources Commission (CRC, created by CAMA) to designate areas of environmental concern (AECs).³⁶ These are specific areas (within the broader coastal area) that need special protection because of ecological resources dependent upon the habitat, recreational value, or overall environmental sensitivity. Several of these areas would be directly impacted by sea level rise—most importantly the ocean hazard AEC (those areas immediately adjacent to the Atlantic Ocean) and the coastal shorelines AEC (those areas adjacent to the coastal rivers, estuaries, and sounds).

The CRC developed management guidelines for the AECs, and any development activity within these areas must be consistent with the guidelines. The North Carolina Division of Coastal Management in the Department of Environment and Natural Resources administers a permit program to ensure that development activity meets AEC standards.³⁷ Sea level rise is one of the supporting foundations for the ocean hazard AEC standards. It is addressed only indirectly in the coastal shoreline standards.

³²See *Carolina Beach Fishing Pier, Inc. v. Town of Carolina Beach*, 277 N.C. 297, 177 S.E. 2d 513 (1970) (holding that the boundary between private property and state-owned public trust lands along an ocean or inlet shoreline is the mean or ordinary high water mark).

³³*State v. Gwathmey*, 324 N.C. 287, 464 S.E.2d 674 (1995).

³⁴Kalo, J.J., 1996, “Redefining Ownership of Estuarine Marshlands”; *Gwathmey v. State of North Carolina*, Legal Tides, UNC Sea Grant.

³⁵North Carolina General Statute 113A-102(a).

³⁶North Carolina General Statute 113A-113.

³⁷Development is defined very broadly in North Carolina General Statute 113A-103(5).

The Ocean Hazard AEC

The CRC recognizes that North Carolina's ocean shoreline is subject annually to threats from severe storms and long-term erosion associated with sea level rise. Consequently, the commission has established development standards that require setbacks for new construction and prohibit hardening of the ocean shorelines. Regarding setbacks, the commission's rules require that a setback line be established a minimum distance from the first line of stable, natural vegetation. For single family residences and other structures that have 5,000 square feet of total floor area or less, the setback is determined by multiplying the annual erosion rate by 30.³⁸ At a minimum, this line must be 60 feet from the first line of stable, natural vegetation. The setback is doubled to 120 feet for structures larger than 5,000 square feet. The first line of stable natural vegetation and the mean high tide are likely to move landward as sea level rises. This will result in a landward migration of property lines and setbacks.

North Carolina does not allow hard erosion control structures on the ocean shoreline.³⁹ The state does allow beach nourishment as an option for protecting oceanfront properties.⁴⁰

The Coastal Shorelines AEC

Since the passage of CAMA in 1974, much of the management focus in the coastal area has been directed toward the ocean shoreline. Until recently, it was the ocean shoreline that generated most of the "high profile" conflicts, i.e., long-term and storm-related erosion threatening oceanfront properties, beach ownership and access questions, beach nourishment issues, storm mitigation, etc. Conflicts along the non-ocean shoreline, however, are becoming more numerous. Fears about future wetland loss have caused an examination of the methods used to stabilize non-ocean shorelines. And the recent

devastation wrought by Hurricane Floyd has focused attention on the vulnerability of riverine development to storms. Because of these concerns, the CRC identified the coastal shorelines AEC and adopted new standards to manage development in this vulnerable area. The new rules took effect on August 1, 2000.

The most significant new rule is the requirement of a 30-foot buffer along the entire coastal shorelines AEC.⁴¹ The rule will prohibit most new development within 30 feet of the mean high water line except for development classified as water dependent. Water-dependent development includes docks, wharves, mooring pilings, boat ramps, bridges and bridge approaches, bulkheads, and revetments.⁴² Although controversial, bulkheads and other hard erosion control structures will continue to be allowed along these non-ocean shorelines.

The new rules will minimize further development of land immediately along non-ocean coastal waters and therefore limit (beyond current limitations) the potential for damage and loss due to sea level rise and coastal storms.

³⁸North Carolina Administrative Code, Title 15A, 07H.0306(a)(2)(4).

³⁹North Carolina Administrative Code, Title 15A, 07H.0308(a)(1)(B).

⁴⁰North Carolina Administrative Code, Title 15A, 07H.0308(a)(3).

⁴¹North Carolina Administrative Code, 07H.0209(d)(3)(as published in 13:23 N.C.R. 1938-1940). As noted by a peer reviewer, John Thayer of the CAMA Local Planning & Access Program within the NC Division of Coastal Management, the 30 foot buffer is superceded by a 50' buffer rule along several of the rivers due to the Environmental Management Commission's rules.

⁴²North Carolina Administrative Code, 07H.0208(a)(1).

The Planning Program ⁴³

In addition to the regulatory component of North Carolina's coastal management program, there is a directive within CAMA for coastal area planning.⁴⁴ The act requires local governments within the 20-county coastal area to develop land use plans under general guidelines developed by the CRC. The plans are intended to provide a mechanism for local governments to establish their own development priorities within the framework of state guidelines. If properly structured, the coastal planning process could be used to mitigate long-term effects of sea level rise.

The CRC's guidelines ask local governments to identify constraints to development and formulate policies to respond to these conditions. The plans are to list areas likely to have conditions making development costly or that would cause undesirable consequences if developed. The guidelines require that local governments address sea level rise in their plans. The local plan is required to develop policies regarding the restriction of development within areas that might be susceptible to sea level rise. After examining the 20 county plans and several municipal plans, it is clear that most

local governments have all but ignored this charge. The plans that do address the issue generally defer to the state to take action after further study. The county-specific response descriptions briefly summarize each county's sea level rise policy.

CAMA requires local ordinances to be consistent with plans only when the ordinance affects an AEC.⁴⁵ Because AECs constitute only about 1 percent of the total land area of the coastal counties, this requirement has significant limitations. As long as this provision remains, CAMA's planning program will be largely advisory and will not contain the types of enforceable policies necessary to influence major land use decisions in a way to mitigate future hazards—including sea level rise.

⁴³ One peer reviewer, John Thayer of the CAMA Local Planning & Access Program within the NC Division of Coastal Management, indicates that the states land use planning policies have changed since this study was prepared, although the new rule also does not specifically identify guidance or tools related to sea level rise considerations. "Effective August 2002 the State's Land Use Plan Guidelines were repealed and replaced with new rules. Since the discussions, as of July 2007, one-third (1/3) of the city and county Land Use Plans have been certified per the 2002 Guidelines including the following counties: Gates, Pamlico, New Hanover, Camden, and Currituck. Most of the remaining counties are expected to have their updated LUP certified by the Commission this year. Therefore local LUP characterizations in this report are based on documents prepared per the state's Administrative Code T15A: 07B Land Use Plan Guidelines in effect prior to 2002. Some documents are based on even earlier state rules in effect prior to 1996." From "Comments for Peer Review Draft Document Titled 'Likelihood of Shore Protection in North Carolina'" submitted by John Thayer to Stephen Keach on July 12, 2007.

⁴⁴North Carolina General Statute, 113A-106.

⁴⁵North Carolina General Statute, 113A-111.

COUNTY-SPECIFIC RESPONSES TO SEA LEVEL RISE

In this section, we provide background information on each county's relative risk to the impacts of sea level rise and any current county-level policies regarding land use planning and sea level rise, and then describe the anticipated future shoreline protection responses. The county-specific sections are organized from north to south, wrapping around Albemarle and Pamlico sounds.

Although we originally set out to evaluate all low land within the state, our final results omit consideration of several inland counties with relatively little vulnerable land.⁴⁶ During the initial meetings with Walter Clark, the state officials designated all land below the 5-meter USGS 1:100,000 contour that seemed likely to require shore protection. In so doing, they did not identify any areas likely to be developed and require shore protection in Bladen, Duplin, Gates, Halifax, Jones, Northampton, Pitt, or Sampson counties. We decided to exclude from further consideration those counties with minimal land in the study area, which left us with Gates and Pitt counties.

At the end of the stakeholder review, we still had not contacted officials from Gates or Pitt counties. We decided to retain Gates but omit Pitt from our final results. We kept Gates in the study because Gates has as much low land as several other counties in the study, and is across the Chowan River from Hertford County, with whom we did meet. We excluded Pitt because it has less low dry land than any county in the study area, and is upstream from the counties that we do consider. We provide no county-specific maps or writeup for Gates, however.

Figure 2 shows the location of the counties for which we provide final results.

⁴⁶ We estimate that only 0.4 percent of North Carolina's land under one meter in elevation is located within the inland counties. For additional information on the area of land below 5 meters within these counties, see Table B-3 of Appendix B.



Figure 9-2. Location of Coastal Counties examined by this study

CURRITUCK COUNTY

Land Use Policy Related to Sea Level Rise

Currituck County issued a draft land use plan in 1997.⁴⁷ Although never formally adopted, the plan recognizes that sea level rise is a significant issue facing coastal communities and that if sea level rises 5 feet, more than 50 percent of the county would be inundated. The plan states that the County is not opposed to construction in areas below 5 feet, but it will enforce current flood regulations as a means of minimizing the impact of sea level rise.

The outer banks of Currituck County have developed rapidly within the last 20 years after the opening of the beach road to Corolla. The area north of Corolla to the Virginia border has no paved roads, is designated as "undeveloped coastal barrier" under the Coastal Barrier Resources Act, and hence is ineligible for federal subsidies and other federal assistance such as flood insurance or federally backed mortgages. Nevertheless, this area has several communities with dirt roads, with the land in between owned by U.S. Fish and Wildlife Service. Although there are no roads through these wildlife refuges, automobile access to Corolla is available via the beach, and the county services (e.g., fire, trash) use special vehicles with 4-wheel drive.

Basis for Maps

The following discussion and the map of Currituck County are based on discussions with:

Jack Simoneau, former planning and inspections director, Currituck County; John Thayer, district planning manager, Lynn Mathis, field

representative, Dennis Hawthorne, field representative, North Carolina Division of Coastal Management; and Gary Ferguson, planning and inspections director, Currituck County.

The map is based on the original stakeholder review draft, except for a few site-specific changes suggested by county staff.⁴⁸

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These areas are privately owned and are either already developed or will be developed in the very near future.

Most of the nonwetland shoreline along Knotts Island Channel is developed and much of the shoreline is fortified. Two areas—one on the north end of Currituck Sound (Knotts Landing) and another on Knotts Island Bay—are developed, and much of the shoreline is fortified.

Existing development along Currituck and Albermarle sounds will also certainly be protected. These areas include developed portions of Millis Landing, Bell Island, Church Island (including the community of Waterlilly), Aydlett, Walnut Island, Point Harbor, and Newbern Landing.

Although the ocean beaches in North Carolina cannot be hardened, the state does allow beach nourishment. The state plans to continue encouraging nourishment in oceanfront communities. For this reason, the developed beach communities from Corolla south are

⁴⁷ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁴⁸ The original and stakeholder drafts were based in part on the perspectives of Jack Simoneau when he was planning and inspections director for the county.

almost certainly going to be protected in the long run.⁴⁹

The highway and connections to developed shoreline areas are certain to be protected. Highway 615 is an important transportation corridor in this area and will be protected. Because of the proximity to Virginia Beach/Norfolk via U.S. 158, much of the developable shoreline in this area has been built on and fortified. It is assumed that the areas along the 158 corridor will continue to develop. Highway 158 will be protected as will the connecting roads to developed shoreline areas. The Wright Memorial Bridge will also be maintained.

Protection Likely

Areas where protection is likely are depicted in red. These lands include undeveloped areas that are likely to be developed in the foreseeable future.

The mainland areas depicted in red are currently agricultural or forested, but development is likely soon. Most of these areas generally have road access and developable shoreline and are within proximity of Virginia Beach and Norfolk. The planners identified four areas where development is likely—along Coinjock Bay just south of Mills Landing, along Williams Slough, along Dowdy Bay south of Walnut Island, and along the North River west of Jarvisburg.

Along the Atlantic Coast, currently undeveloped portions of the beach area south of Corolla are likely to be protected. Although not a target for protection, these areas will most likely receive beach nourishment because they are close to developed areas.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are neither extensively developed nor currently expected to develop.

The barrier beach north of the town of Corolla is a designated “undeveloped barrier” under the Coastal Barrier Resources Act, and is therefore ineligible to receive federal funding for protection activities or flood insurance. The area is not serviced by any roads dedicated for maintenance. Moreover, there are no water lines or central wastewater treatment systems. Even though privately funded beach nourishment has been cost-effective in some areas, the County believes that retreat is more plausible for these areas.^{50,51}

Much of the shoreline along the North River is wetland, as is a long stretch of shoreline along

⁵⁰These areas were identified by hand-digitizing hard-copy COBRA barrier maps at a 1:100,000 scale. Based on county review.

⁵¹The original draft developed by Clark showed the COBRA areas as certain to be protected. The EPA project manager provided IEC with rough boundaries for the COBRA areas, and directed that they be shown as only likely to be protected, and added the following language to the stakeholder review draft:

Development along the Outer Banks north of Corolla may be slowed somewhat by the lack of road access, but the primary effect of the lack of road access seems to be that land values are lower and hence, more affordable to many people. Many people prefer this type of community over the more typical shore town. Although community infrastructure will probably always be less prevalent than on other parts of the Outer Banks, the density of homes may eventually be comparable. Hence, the cost-benefit ratio for beach nourishment may be almost as great here as in the areas that lie to the south. Nevertheless, as COBRA designated undeveloped coastal barriers, these communities are ineligible for federal beach nourishment funding, which makes protection here less likely than in equally developed areas that are eligible for federal subsidies. Although private funding of beach nourishment may eventually be justified, longshore currents would transport much of the sand to adjacent wildlife refuges, increasing the cost. Moreover, if a serious hurricane destroys shorefront homes, the unavailability of federal flood insurance implies that landowners would have to spend their own money rebuilding their homes, and hence may be unenthusiastic about taxing themselves to pay for a beach nourishment project at the same time.

The County requested that we remove this reasoning for depicting the COBRA areas as likely to be protected, and that the COBRA areas be depicted in blue based on the reasoning that now appears in the body of the report. Gary Ferguson. Email to Jennifer Kassakian, sent September 11, 2002, referencing marked up maps. Those marked up maps were received by Kassakian on September 13, 2002.

⁴⁹Based on both stakeholder review draft and county comments.

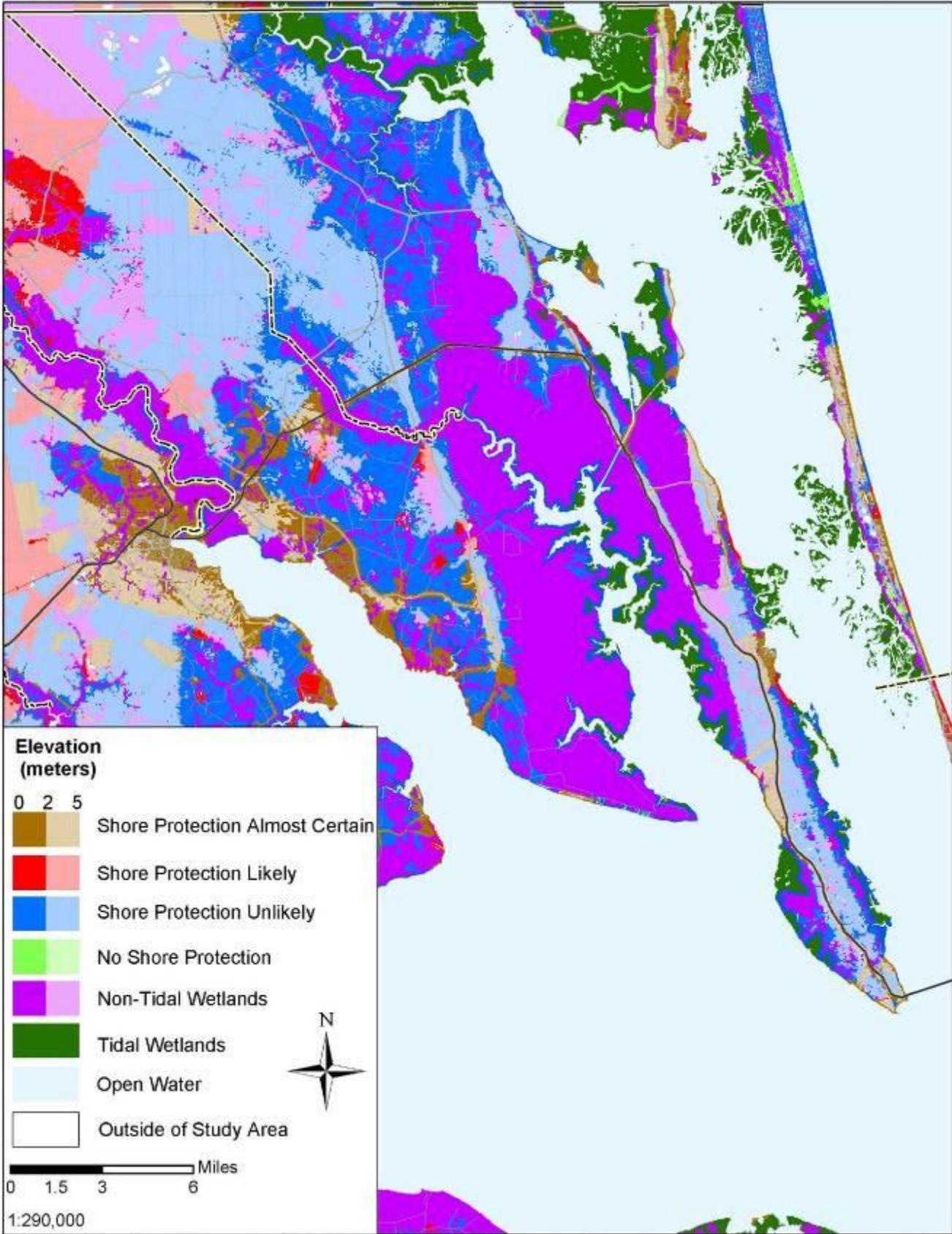
Currituck Sound from Dews Island to Harbinger. Any private land in these areas would become public as it falls below the mean high tide line. It is unlikely that this area will be protected.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green.

Much of Knotts Island is within the Mackay Island National Wildlife Refuge. The Currituck National Wildlife Refuge is located along the northern portion of Currituck County's outer banks. Wetlands are depicted in dark green.

Map 2 shows the results for anticipated responses for Currituck County.



Map 9-2. Currituck County: Likelihood of Shore Protection. The caption and detailed legend for this and the other county-specific maps is located on the following page.

Map 9-2. Currituck County: Likelihood of Shore Protection. For each shore protection category, the darker shades represent lands that are either less than 6.6 feet (2 meters) above spring high water, or within 1000 feet of the shore. The lighter shades show the rest of the study area. This map is based on information obtained from planners between 2001 and 2003. The intended use of this map is to convey county-wide prospects for shore protection, not to predict the fate of specific neighborhoods. Changes in the policies and trends we considered--or factors that we did not consider--may lead actual shore protection to deviate from the likelihoods depicted in this map

The following legend defines the meaning for the transportation network and political boundary symbols used in the county-specific maps throughout this chapter.

Map Legend	
Transportation Network	
	Toll and Other Limited Access Roads
	Highway
	Major Road
	Local Road
	Railroad
Political Boundaries	
	State Boundary
	County Boundary

CAMDEN COUNTY

Land Use Policy Related to Sea Level Rise

Camden County updated its CAMA-mandated land use plan in 1993.⁵² The plan contains a policy that supports restricting development within areas up to 5 feet above mean high water. The County considers its existing regulations adequate but states that it will rely on the North Carolina Division of Coastal Management “to monitor and regulate development in these areas.”

Basis for Map

The following discussion and map of Camden County are based on discussions with:

John Thayer, district planning manager, Lynn Mathis, field representative, Denis Hawthorn, field representative, North Carolina Division of Coastal Management; Carl Classen, county manager, Camden County

At the beginning of the stakeholder review process in 2002, the EPA project manager gave a 20-minute briefing on the project to the county manager.⁵³ The county manager asked us to revise the maps using the county’s GIS data, but provided no other comments. Later, the County provided its zoning data, which we have used to refine the boundaries of developed areas shown as protected

⁵² A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁵³ June 28, 2002, meeting on sea level rise held at the municipal offices of the Town of Nags Head. Attendees: Sam Pearsall of The Nature Conservancy; Audra Lusher of North Carolina Department of Environment and Natural Resources; Carl Classen, county manager of Camden County; Webb Fuller, town manager of Nags Head; Gary Ferguson, county manager of Currituck County; and Jim Titus, EPA.

or likely to be protected in the original maps.⁵⁴ In general, areas that state officials identified as developed and hence certain to be protected in the stakeholder review draft retain that designation. In addition, areas zoned as community cores, industrial, and commercial lands are also colored brown. For the areas that the state officials did not identify as developed, the maps assume that land zoned residential or planned development will probably be protected, and that areas zoned as general use are not likely to be protected.

The discussion that follows is based on the original stakeholder review draft, unless otherwise stated.⁵⁵

Anticipated Response Scenario

Protection Almost Certain

Even today, property owners are armoring shores wherever property is threatened (see Photo 1). Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Much of the shoreline following the north shore of the Pasquotank River to Elizabeth City has been

⁵⁴ Our approach for using county data to refine the original rough maps required a procedure for dealing with conflicting implications from the two alternative visions implied by the state officials and county zoning data. In general, we assume that buildout will eventually occur in areas zoned for some sort of development. Therefore, wherever the stakeholder review draft was blue and the county data suggested red or brown, we used the county data. The few areas that are zoned for general use but that the state expected to be protected are assumed to be protected. Those locations are near the sound and hence the designation that they will be protected is consistent with the assumption that waterfront areas currently zoned for general use will eventually be developed and protected.

⁵⁵ Because this discussion is based on the stakeholder review draft, it includes both those areas that represent departures from the general decision rule that were identified by state officials, and areas that were identified by both the state officials and the county data.

armored. Specifically, developed areas of Whithall Shores and Taylors Beach as well as the area around Tommys Point are almost certain to be protected.

Route 158, which leads to Elizabeth City, will certainly be maintained. The direct transportation corridors leading to the developed areas along the Pasquotank River will also certainly be protected, including portions of Highway 343 and spurs that lead to developed areas.

Protection Likely

Areas in red include currently agricultural or forested lands that are likely to be developed and therefore protected in the foreseeable future. They have road access, are relatively close to an urban area (Elizabeth City), and are being purchased with “the intent” to develop. Additional transportation corridors are likely to be protected should these areas develop. Any development, other than that related to agriculture, will probably follow transportation corridors, especially in the general vicinity of Elizabeth City. Residential areas that were not specifically called out for certain protection in the original stakeholder review draft are also depicted in red.⁵⁶

Protection Unlikely

The county includes numerous areas that are unlikely to be extensively developed (see Photo 2). Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. For inland areas north of the Pasquotank shoreline and south of Highway 158, the land is in active agricultural production and not likely to be protected—except for transportation corridors noted above.

Between the river and Highway 343 is low riverine wetland that is an extension of the Dismal Swamp. It is unlikely that this lowland wetland area will be protected.



Photos 1 and 2. Camden County, North Carolina. Photo 1 shows shoreline armoring near Camden Point. Photo 2 shows dead trees in the midst of wetlands, a possible effect of sea level rise (June 2002).

Most of the land east of Highway 343 to the Currituck County line is in active agricultural production. This area is unlikely to be protected.

One large farm in northern Camden County crosses the Currituck County line. It is generally below the 10-foot contour and could be affected by rising sea level. Because neither County suggested that this land is likely to be protected, however, we show these lands as unlikely to be protected.⁵⁷

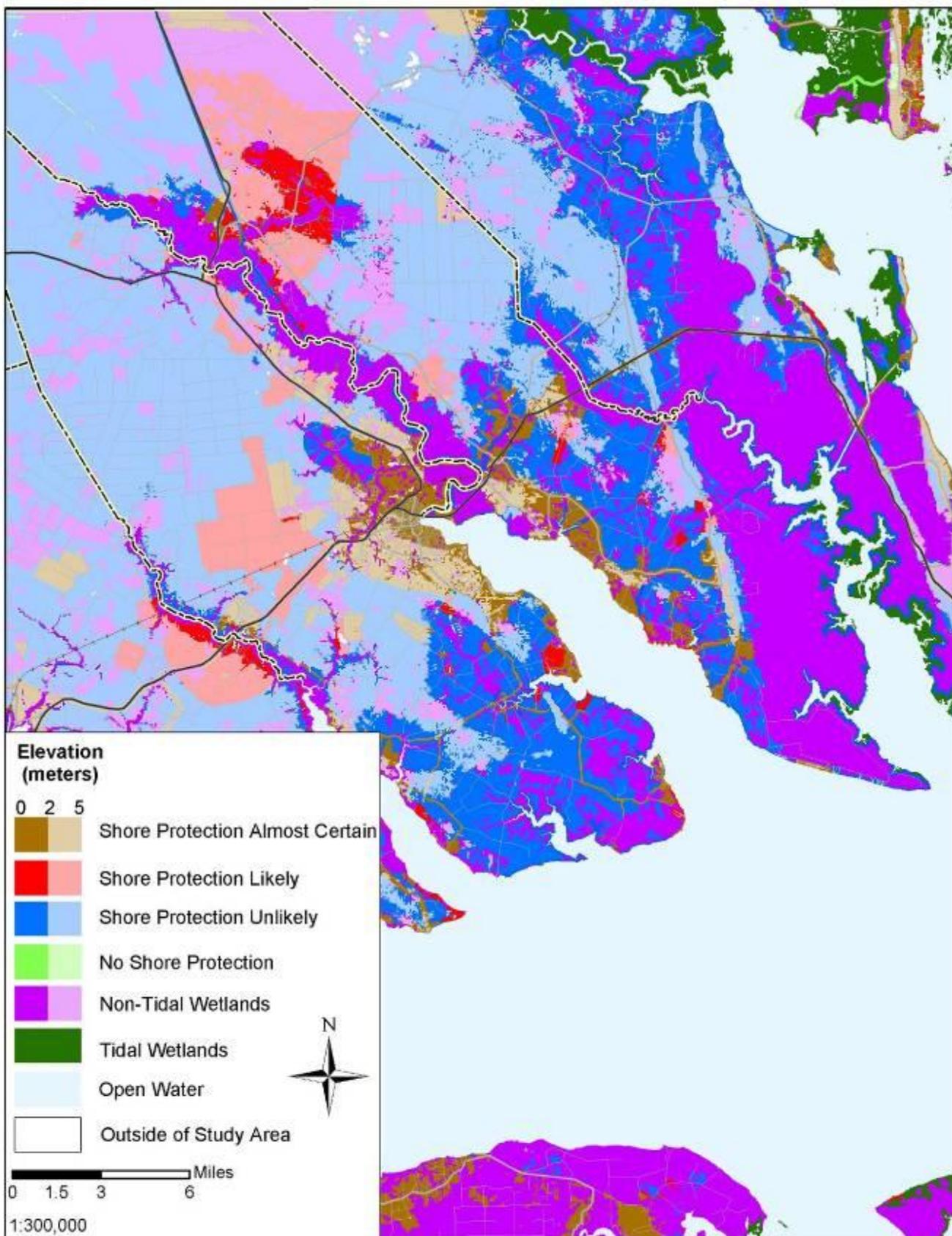
⁵⁶Based on decision rules using county data.

⁵⁷We welcome comments from those with any insights on this question.

No Protection

Conservation lands, which would not be protected as sea level rises, are depicted in light green. This area includes the part of the Great Dismal Swamp that is within Camden County. Wetlands are depicted in dark green.

Map 3 shows the results for Camden County.



Map 9-3. Camden County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

PASQUOTANK COUNTY

Land Use Policies Related to Sea Level Rise

Pasquotank County updated its CAMA-mandated land use plan in 1996.⁵⁸ There does not appear to be any reference to sea level rise in the original plan or in its update.

Elizabeth City updated its CAMA-mandated land use plan in 1992. The plan addresses sea level rise indirectly in its policies to “discourage development in the most hazardous areas.”

Basis for Map

The following discussion and the map of Pasquotank County are based on discussions with:

John Thayer, district planning manager, Lynn Mathis, field representative, and Denis Hawthorn, field representative, North Carolina Division of Coastal Management; Julie Stamper, GIS coordinator, Rodney Bunch, planning director, and Marsha Davis, planner, Pasquotank County

A few months after sending Pasquotank County the stakeholder review draft, EPA held a conference call with the planning staff.⁵⁹ The planning director suggested that EPA refine the map using the new land use plan that would be available within the next four months. Four months later, however, that plan was not available and the county GIS coordinator indicated that it was still three months away. Sympathizing with our need to complete this

⁵⁸ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁵⁹ April 8, 2003, conference call with Rodney Bunch, Marsha Davis, and Julie Stamper of Pasquotank County and Jim Titus and Jeff Whitlow of EPA.

study, she indicated that there were two alternatives: the land use zoning data or the old land use plan. She recommended that the land use zoning data would be more appropriate, and sent it to EPA.⁶⁰

We used the county data to refine the boundaries of developed areas shown as protected or likely to be protected in the original maps. For consistency, the revised maps assume that areas with similar land use classifications not identified by the stakeholder review draft will be protected as well. In general, areas that state officials identified as developed and hence certain to be protected in the stakeholder review draft⁶¹ retain that designation. Based on county data, the maps also assume that Elizabeth City, the Coast Guard Station, and residential areas zoned with lot sizes less than 25,000 square feet will certainly be protected. Outside of those areas that the stakeholder review draft designated as certain to be protected, the maps treat parcels zoned for lower density residential, mobile home residential, commercial, and industrial usage as likely to be protected,⁶² and

⁶⁰ Because the county planning director indicated that the forthcoming land use plan would be the most appropriate source of data for the sea level rise planning maps, we would hope to revise these maps if the data become available.

⁶¹ The original effort, which had relied on hand-drawn boundaries based on expert judgment on a 1:100,000 scale USGS map.

⁶² It would be unreasonable to assume that residential lands with lots less than 25,000 square feet (“moderate density”) are more likely to be protected than commercial/industrial areas, and we do not intend for the map to reflect such an assumption. Because we also were using the original maps, this decision rule is only meant to apply to areas that have not yet been developed. The county has large tracts of undeveloped commercial and industrial lands that are some distance from the communities certain to be protected; the moderate-density residential areas, by contrast are mostly developed and contiguous to communities that will be protected.

agricultural areas as unlikely to be protected. Site-specific departures from these general rules are based on the original stakeholder review draft. In most cases, if that draft treated an area as certain to be protected, we retained that designation.⁶³

The discussion that follows is based on the county data, unless otherwise noted.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Elizabeth City (see Photos 3–6) is certain to be protected. Beyond its corporate limits, Elizabeth

(Admittedly, this reasoning does not apply to the few cases where land was changed from brown to red; see explanation two notes hence.)

⁶³Our approach for using county data to refine the original rough maps required a procedure for dealing with conflicting implications from the two alternative visions implied by the state officials (stakeholder review) and county zoning data. In general, we assume that buildout will eventually occur in areas zoned for some sort of development. Therefore, wherever the stakeholder review draft was blue and the county data suggested red or brown, we used the county data.

The opposite conflict also occurred in a few locations, for different reasons. If the stakeholder review draft treated an entire area as developed and certain to be protected, whereas the county’s data showed it to be zoned for commercial, industrial, or low-density development, we assumed that there was no real conflict and the area is certain to be protected. If such an area was zoned for agriculture, we assumed that the state officials were providing an insight as to likely changes in zoning, and accepted the implication that the area will be protected. The assumption of certain protection did not always take precedence. If a brown area in the stakeholder review draft is mostly zoned for development but also includes some polygons with agricultural zoning, we assumed that the county data were providing a more precise boundary for the protected area; in such cases, the agricultural areas are treated as unlikely to be protected. (We also applied this approach to areas zoned for low density housing, commercial, and industrial development; we probably should have kept those areas as brown because there is no conflict between state officials’ assertions that the area is developed and the county zoning. Fortunately, the area covered by this assumption is minimal.)

⁶³

City is growing along the south shore of the Pasquotank River, with much of this shoreline already armored and developed to Pool Point. This area includes the Elizabeth City Municipal Airport and the U.S. Coast Guard Station.⁶⁴ Growth will continue in this area and will most likely move south along Highway 34 toward Weeksville and southwest along U.S. 17. These areas and the major roadways are also certain to be protected.⁶⁵

Between the Pasquotank and Little rivers, development is occurring in Glen Cove, Wade Point, and Frog Island and along the northeastern shore of the Little River. These areas have good access and it is anticipated that they will continue to grow. These lands and their transportation corridors are certain to be protected.⁶⁶

Protection Likely

Areas in red are those that are likely to be developed and therefore protected in the foreseeable future. They also include less dense and mobile home residential developments as well as commercial and industrially zoned lands.

It should be anticipated that greater “in-fill” development will occur within the corporate limits of Elizabeth City and south along the Pasquotank River. This includes areas between Glen Cove and Wade Point on the Pasquotank River and an area south of Symonds Creek on the northeastern shore of the Little River.⁶⁷

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop and agricultural lands. The area south of Weeksville on the Pasquotank River is low and wet. Also, access is limited in

⁶⁴Based on original stakeholder review draft and county comments.

⁶⁵Based on original stakeholder review draft.

⁶⁶Based on original stakeholder review draft.

⁶⁷Based on original stakeholder review draft.

the areas of Bluff Point and along Big Flatty Creek.⁶⁸

No Protection

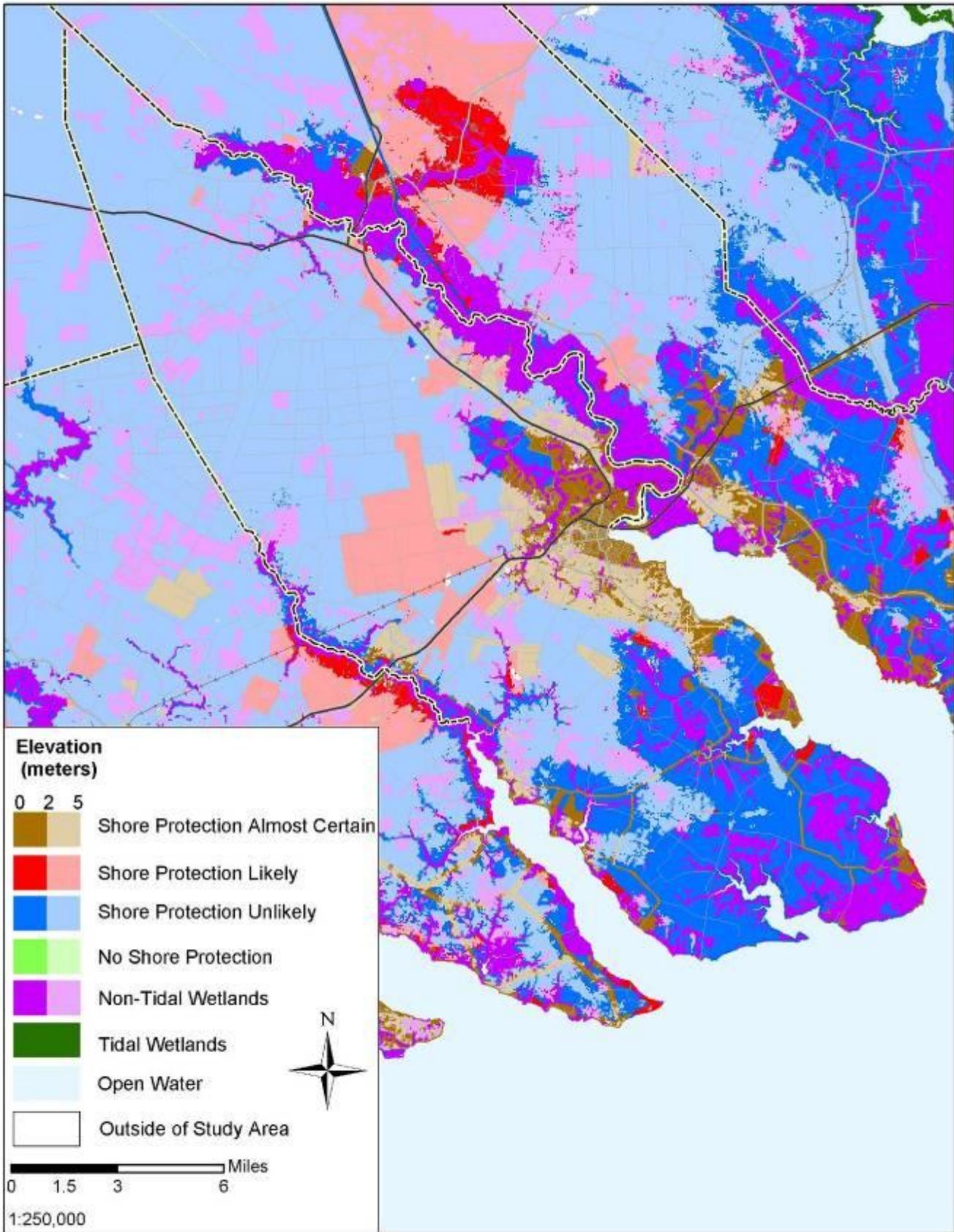
Planners did not identify any specific conservation lands within Pasquotank County. Wetlands are depicted in dark green.

Map 4 shows the results for Pasquotank County.

⁶⁸Based on original stakeholder review draft and county comment.



Photos 3–6. Elizabeth City, North Carolina. Photo 3 shows low-lying parkland in the center of town. Photos 4 to 6 show homes near and over the water, respectively, southwest of the downtown area (October 2002).



Map 9-4. Pasquotank County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

PERQUIMANS COUNTY

Land Use Policies on Sea Level Rise

Perquimans County's land use plan does not specifically address sea level rise. There is a statement relevant to sea level rise, however, in the Town of Hertford's plan. Hertford is the largest town in Perquimans County and is located on the upper reaches of the Perquimans River. The entire town is below 5-meter elevation.

Hertford updated its land use plan in 1991.⁶⁹ The plan states that the town's policy will be to not restrict development in areas up to 5 feet above mean high water (the potential area of impact from rising sea level) other than as currently regulated by CAMA, zoning, or the flood insurance program.

Basis for Map⁷⁰

The following discussion and the map of Perquimans County are based on discussions with:

John Thayer, district planning manager, Lynn Mathis, field representative, Dennis Hawthorn, field representative, North Carolina Division of Coastal Management; and Bobby Darden, assistant county manager, Perquimans County

The maps are based on the original stakeholder review draft, except for a few minor changes suggested by county staff. In addition, county subdivision data and roads data were used to more accurately depict the boundaries of existing development, which the stakeholder review draft had used to define areas certain to be protected

⁶⁹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁷⁰ Unless otherwise noted, edits to the original maps are hand-digitized at a 1:100,000 scale.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

About one-third of the shoreline in Durant's Neck following the southern shoreline of the Little River around Reed Point and up the northern shoreline of the Perquimans River has been armored or will be armored in the very near future. These lands, which include the areas of Deep Creek Point, Reed Point, and Carolina Shores, will almost certainly be protected. It is almost certain that the most direct transportation corridors along Durant's Neck will also be protected.

A large percentage of the shoreline in the Harvey Neck area is armored—particularly in the communities of Hertford, Winfall, Southern Shores, Holiday Island, and Snug Harbor.⁷¹ Hertford is the largest community in Perquimans County and will be protected (see land use plan above). A military area at Harvey Point is armored and will be protected. The most direct transportation corridors leading to these areas will also be protected.

The area around Yeopim Creek is being developed and will be protected.⁷²

Other developed areas that are included within the county's subdivisions will certainly be protected.⁷³

⁷¹ Winfall added based on county review.

⁷² Based on county review.

⁷³ Based on county review. These areas are identified using Perquimans County GIS subdivision data.

Protection Likely

Areas where protection is likely are depicted in red. Although currently agricultural or forested, these areas are likely to be developed in the near future.

The shorelines of the Perquimans and Little rivers that are currently undeveloped are likely to be developed in the future. The planners therefore conclude protection to be likely.⁷⁴

There are several areas that are likely to be developed (and therefore likely protected) on Durants Neck—particularly at end of the point on Albemarle Sound.

Development and subsequent protection are likely around the end of the Route 17 bypass near the Pasquotank County border.⁷⁵

A large area of the Harvey Neck shoreline—particularly along the Perquimans River—falls into this category. Most of the development will be residential. An industrial park is planned for the south shore of the Perquimans River just south of Crow Point.

The crossroads running from the main roads down Harvey Neck to the communities along the Perquimans River are likely to be protected, as are the homes along those corridors.⁷⁶

The "Campground" trailer park area near Holiday Island may be protected. It is also possible, however, that it will be relocated.⁷⁷

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

No Protection

Neither county planners and state planners nor available conservation data sets identified conservation lands within the study area in Perquimans County. Wetlands are depicted in dark green.

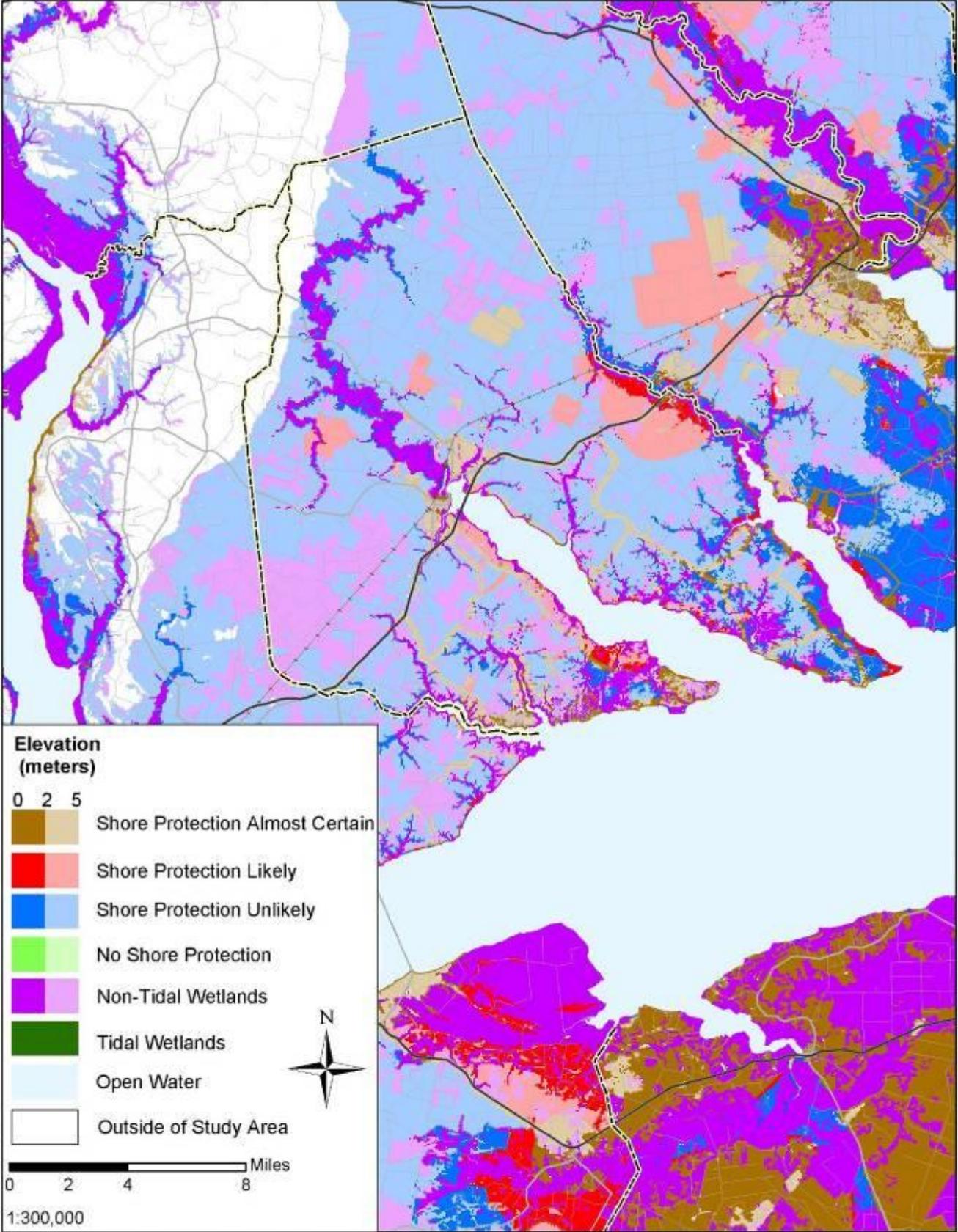
Map 5 shows the results for Perquimans County.

⁷⁴Based on county review.

⁷⁵Based on county review.

⁷⁶ These roads are added based on county review. These roads are identified using Perquimans County GIS roads data.

⁷⁷The County has not reviewed this designation. The stakeholder review draft showed this area as blue, unlikely to be protected. At the suggestion of county staff, immediately after meeting with them, the EPA project manager directly observed this area. Although the residences are very modest, they have a very high density and are not subject to wave attack, both of which make shore protection cost-effective. Compare this with the companion report on Maryland, Dorchester County (concluding that Taylor's Island family campground along Chesapeake Bay is likely to be protected from both erosion and inundation). On the other hand, because these homes can easily be moved, the area could be a candidate for retreat if wetland migration were a priority.



Map 9-5. Perquimans County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

CHOWAN COUNTY

Land Use Policies on Sea Level Rise

Chowan County updated its land use plan in 1991.⁷⁸ Regarding sea level rise, the plan states, “Chowan County believes that this issue is not ‘solid’ enough to propose realistic policy statements at this time, since it is one still being debated in scientific circles. However, the County is supportive of on-going research on this issue and supports related provisions of the Federal Flood Insurance.”

Edenton is the largest town in Chowan County and its land use plan does have language relevant to sea level rise. Edenton’s policy is to not restrict development in areas up to 5 feet mean high water if such development meets all zoning ordinance, flood zone restrictions, CAMA requirements, and building code requirements.

Basis for Map

The following discussion and Chowan County map is based on discussions with: Jane Dautridge, district planning manager, Terry Moore, field representative, and David Moye, field representative, North Carolina Division of Coastal Management; and Chad Sary, director, Department of Planning and Inspections, Chowan County

These maps are based on the original stakeholder review draft. The county reviewer agreed with both the maps and the supporting text.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are

privately owned and are either already developed or will be developed in the very near future. The Town of Edenton, which is the largest town in the county and is becoming a tourist destination in part because of its significant historic district, will be protected.

Most of the developable (nonwetland) shoreline from the northern shore of the Yeopim River along the shoreline of the Albemarle Sound up along the eastern shoreline of the Chowan River to the Gates County line is built with significant armoring and will be protected. Most of the development is residential permanent and vacation homes.

Major transportation corridors—U.S. 17 and Highway 32—will be protected as will offshoots that lead to developed areas.

Protection Likely

Areas in red are currently agricultural or forested lands that are likely to be developed and therefore protected in the foreseeable future. Two significant areas on the map meet this criterion—the shoreline area between Drummond Point at the mouth of the Yeopim River and Sandy Point north of the Highway 32 bridge. Much of this area—which faces the Albemarle Sound—is highly erodible and is likely to be armored as it is developed.

Protection Unlikely

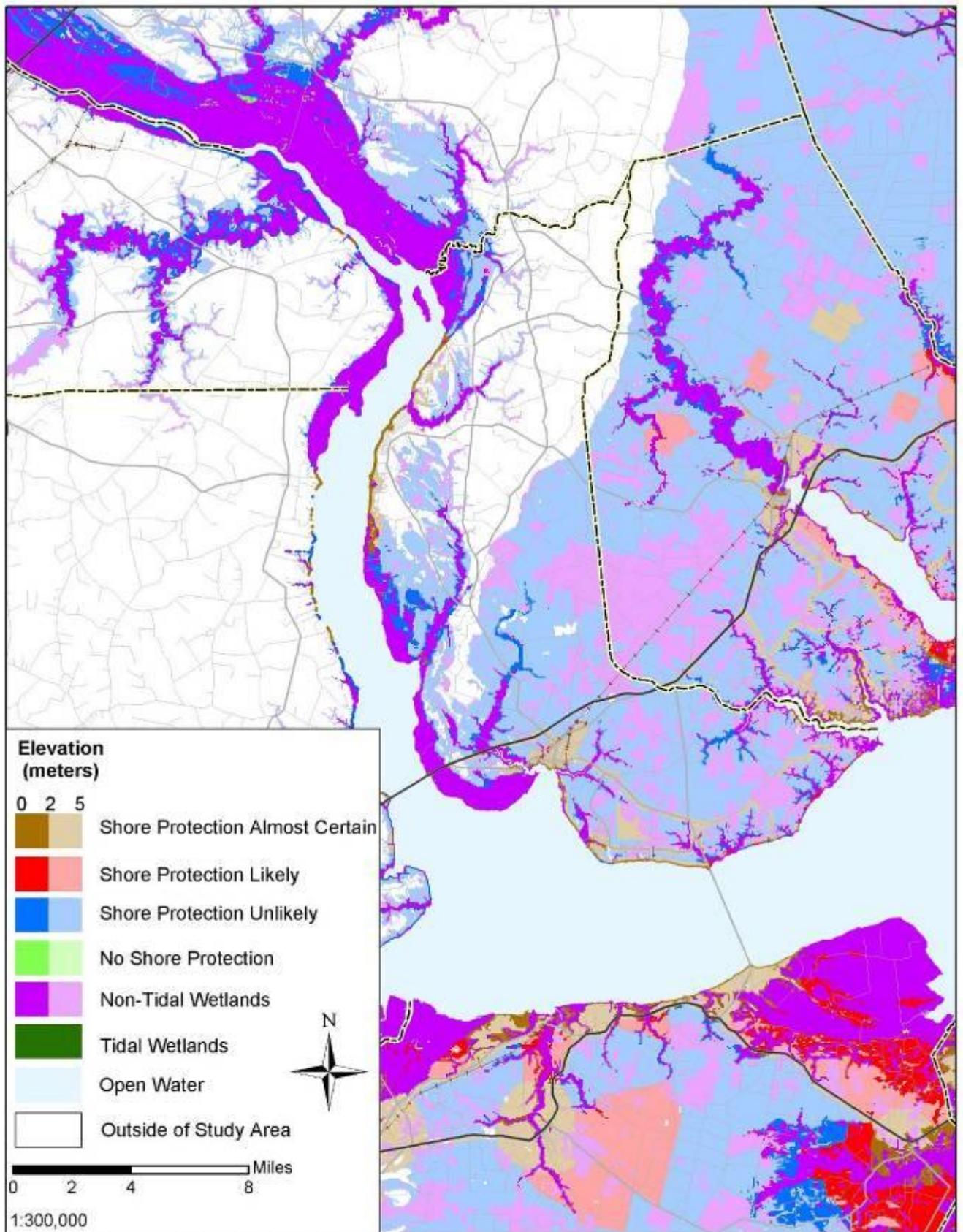
Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. One small area west of Edenton is identified on the map. Wetlands are depicted in dark green.

Map 6 shows the results for Chowan County.

⁷⁸ A more recent version of the plan may now be available. actual shore protection may deviate from the likelihoods depicted in this map.



Map 9-6. Chowan County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

HERTFORD COUNTY

Land Use Policy on Sea Level Rise

Hertford County updated its CAMA-mandated land use plan in 1997.⁷⁹ The policy states that a 5-foot rise in sea level would displace no people and only about 5 percent of the land area in the county; consequently the policy defers any local decision to state CAMA regulations.

Basis for these Maps⁸⁰

The following discussion and the map of Hertford County are based on discussions with:

Jane Dautridge, district planning manager, Terry Moore, field representative, and David Moye, field representative, North Carolina Division of Coastal Management; and Bill Early, planning and zoning administrator, Hertford County

The maps are based on the original stakeholder review draft, except for a few site-specific changes suggested by county staff.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. Most of the development in the county is located outside the study area. The developed area along the Chowan River east of Harrellsville, however, has been armored and will almost certainly continue to be protected in the future.⁸¹

Protection Likely

As part of the stakeholder review, the County indicated that no additional development will occur within the study area. Consequently, the County is reasonably certain about which areas will be protected, and hence no lands are included in the protection likely category.⁸²

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed and where development is not expected.

No Protection

Planners did not identify any conservation lands in Hertford County that lie within our study area. Wetlands are depicted in dark green.

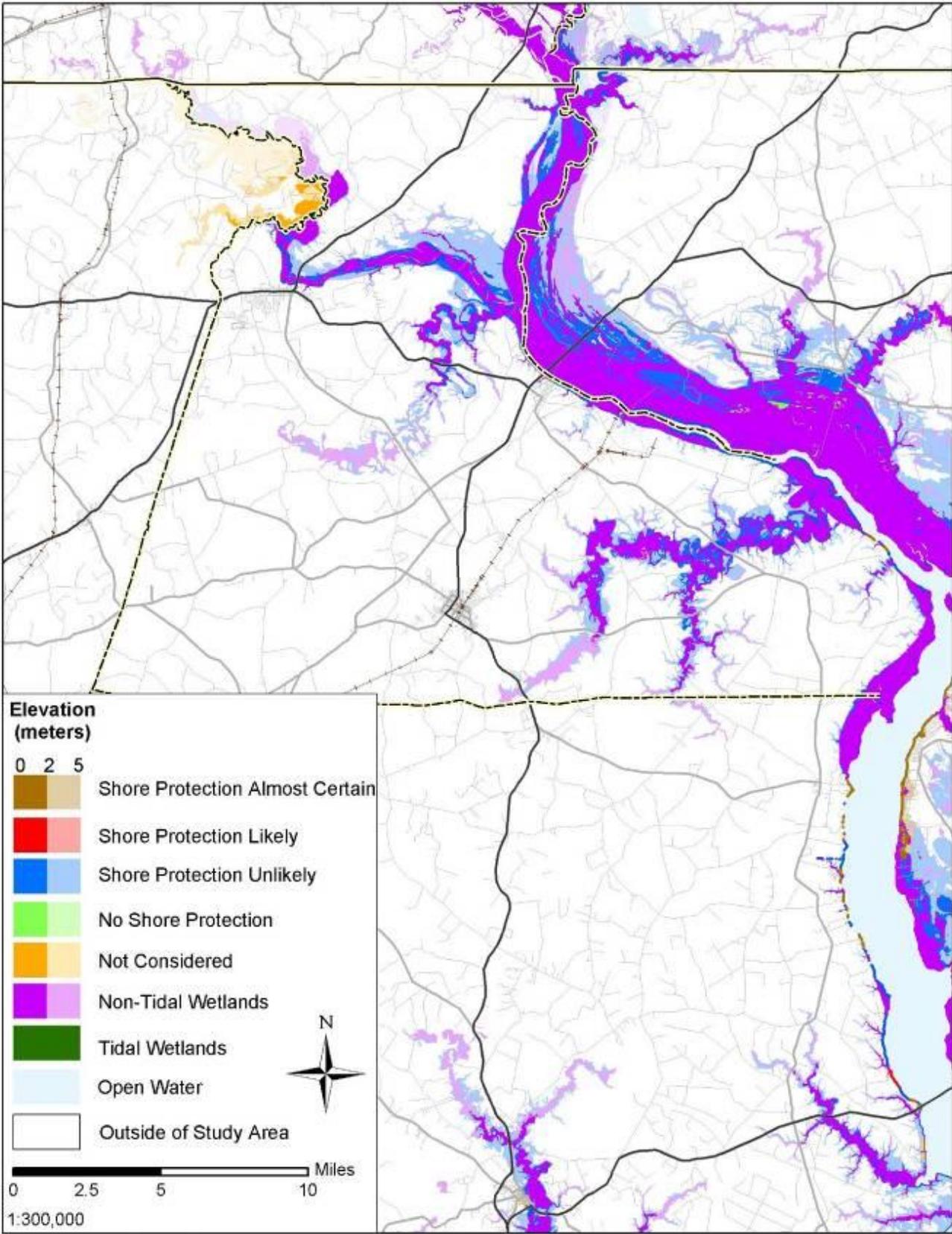
Map 7 shows the results for Hertford County.

⁷⁹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁸⁰ Edits made to the original map are hand-digitized at a 1:100,000 scale.

⁸¹ Based on both stakeholder review draft and county review.

⁸² The original stakeholder review draft concluded that the proposed site for the Nucor Steel facility is partly above and partly below a cliff and that the portion below the cliff would be vulnerable to inundation and possibly protected. The County indicated that the Chowan River is directly adjacent to the cliffs in that area and hence there is no dry land below the cliff that would require. Unfortunately, in their contacts with state and local officials, Clark and Kassakian neglected to mention that the study area includes all land within 1,000 feet of the shore. Therefore, we note that this facility will not be vulnerable to inundation, but would require protection if rising sea level caused these shores to erode significantly.



Map 9-7. Hertford County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

BERTIE COUNTY

Land Use Policies on Sea Level Rise

There was no information available on sea level rise planning in Bertie County's land use plan.

Because the majority of Windsor's planning jurisdiction is 10 to 20 feet above sea level, sea level rise is not expected to be a problem for Windsor. Some areas of the Cashie River floodplain, however, could be inundated. Therefore, Windsor will implement the following policies:

- The Town of Windsor will continuously monitor the effects of sea level rise and update the land use plan policies as necessary to protect the town's public and private properties from rising water levels.
- Windsor will support bulkheading to protect its shoreline areas from intruding water resulting from rising water levels.

Basis for these Maps

The following discussion and map of Bertie County are based on discussions with:

Jane Dautridge, district planning manager, Terry Moore, field representative, and David Moye, field representative, North Carolina Division of Coastal Management; and Allen Castelloe, EMS director, Bertie County

The maps are based on the original stakeholder review draft. The county reviewer agreed with all determinations made therein.⁸³

⁸³The EPA project manager gave several county officials and the mayor of Windsor a briefing on this project as part of a meeting on sea level rise held during the last week of June 2002, which primarily focused on The Nature Conservancy's project to ensure the survival of coastal ecosystems as sea level rises.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Much of the "high" shoreline along the lower portion of the Chowan River is developed and these lands will almost certainly be protected. Communities almost certain to be protected include Colerain, Edenhouse, and Mount Gould.

Very little of the shoreline in the southern part of the county has been developed or armored. The only exceptions are in the town of Windsor next to the Cashie River and along the western shore of the Albemarle just south of Morgan Swamp, which are already armored and certain to be protected.

North of Morgan Swamp the few existing fortified shorelines will continue to protect the adjacent areas.

The U.S. 17 bridge will almost certainly be protected. County planners assume that Highway 45 would also be protected where it crosses Bertie County near the mouth of the Roanoke River.

Protection Likely

Areas where protection is likely are depicted in red. The new residential development called Black Rock Farms, on the west shoreline of the Chowan River just north of the U.S. 17 bridge, is likely to be protected.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

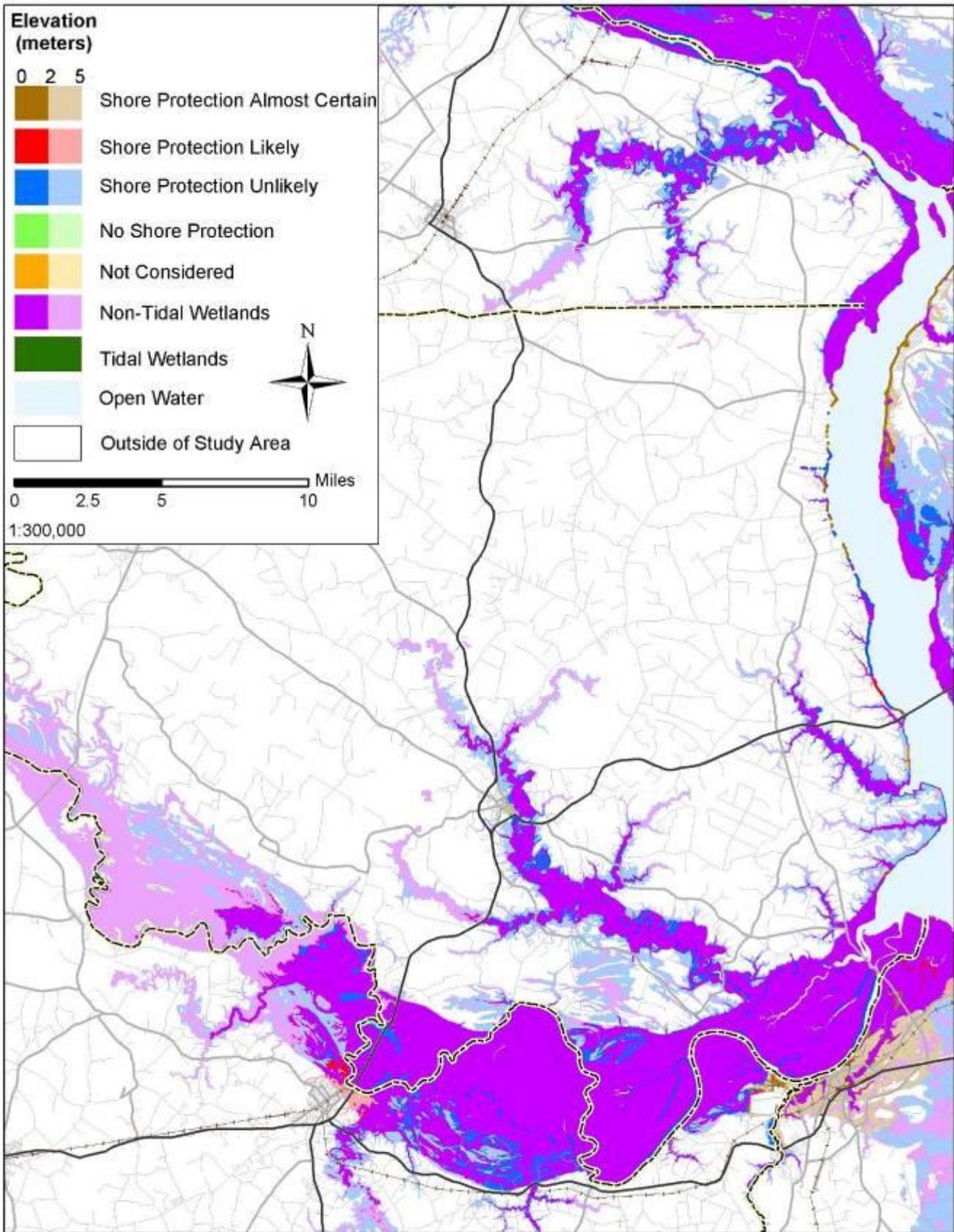


Photos 7–10. Batchelor Bay and the Roanoke River, Bertie County. Development along the Bertie County portion of Albemarle Sound/Bachelor Bay is sparse. Photos 7–9 show some of the few homes along Bachelor Bay. Cypress trees in the foreground of Photo 9 are growing in areas the were flooded more than 100 years ago. The stone revetments are entirely inland of the intertidal area. Photo 10 shows cypress trees along the Roanoke River near Plymouth. (June 2002).

No Protection

Wetlands are depicted in dark green. Note the vast area of wetland hardwood forest along the Roanoke River in southern Bertie County. It is assumed this area would continue to flood and broaden with rising sea level. Development in this area is likely to be restricted because of wetland regulations and riverine buffer/setback areas.

Map 8 shows the results for Bertie County, and Photos 7–10 shows the sparse development along Bachelor Bay, and the Roanoke River.



Map 9-8. Bertie County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

MARTIN COUNTY

Land Use Policy on Sea Level Rise

Martin County's land use plan makes no apparent reference to sea level rise.⁸⁴ Most of the county, however, is located well above the 5-foot contour line. The land under 5 feet is predominately wetlands.

Basis for these Maps

The following discussion and the map of Martin County are based on discussions with:

Jane Dautridge, district planning manager, Terry Moore, field representative, David Moye, field representative, North Carolina Division of Coastal Management

The maps are based on the original stakeholder review draft.⁸⁵

Anticipated Response Scenarios

Protection Almost Certain

Areas in brown are those that almost certainly will be protected. These are areas that are privately owned and are either already developed or will be developed in the very near future. Within the study area, the only area certain to be protected in Martin County is the current site of the Weyerhaeuser pulp and paper plant just west of Plymouth. Most of this facility is below the 5-meter elevation contour line on USGS 1:100,000 scale maps.

Protection Likely

Planners did not indicate any areas within the study area that are likely to be developed in the foreseeable future. It is possible that areas along the Roanoke River to the east of Jamesville could develop given their nonwetland status, proximity to the river, and access via Highway 64. The poor economy in this area and the availability of land on broader bodies of water, however, make this scenario unlikely in the near future.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

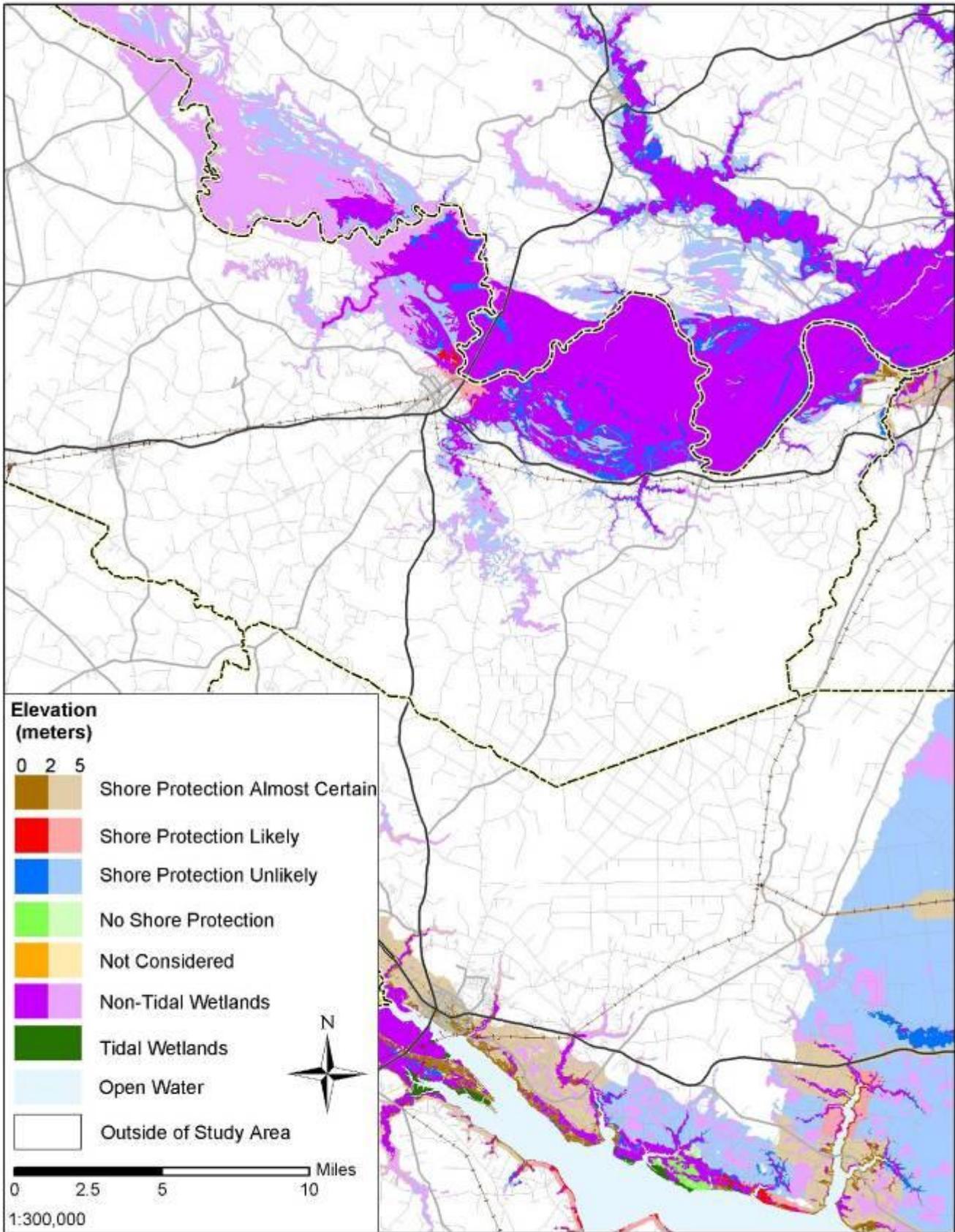
No Protection

Wetlands are depicted in dark green. County and state planners did not indicate any conservation lands within our study area in Martin County.

Map 9 shows the results for Martin County.

⁸⁴ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁸⁵ Tom Stroud of the Partnership for the Sounds and Jennifer Kassakian each made several unsuccessful attempts to secure comments on this draft.



Map 9-9. Martin County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

WASHINGTON COUNTY

Land Use Policies on Sea Level Rise

Washington County's plan references sea level by stating that a policy restricting development within areas up to 5 feet above mean high water that might be susceptible to sea level rise is not currently applicable to Washington County.

The Town of Plymouth updated its CAMA-mandated land use plan in 1992.⁸⁶ The plan has identical wording to Washington County's plan.

Basis for these Maps

The following discussion and the map of Washington County are based on discussions with:

Jane Dautridge, district planning manager, Terry Moore, field representative, David Moye, field representative, North Carolina Division of Coastal Management; and Ann Keyes, Department of Planning and Inspections, Debbie Askew, GIS director, Washington County

After reviewing the original stakeholder review draft, the County suggested using their Proposed Zoning Areas and Possible Waterfront Development Locations maps. The County asked us to make the following assumptions: (1) The entire floodplain is likely to be protected. (2) Existing and future development along Albemarle Sound is almost certain to be protected, as are the planning centers. (3) Along the river, existing planning centers and both planned and future development are almost certain to be protected. (4) Inland, the three areas of commercial/industrial zoning are likely to be protected. (5) All other areas in the county are unlikely to be protected.

⁸⁶ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

Unless otherwise stated, the discussion regarding which areas will be protected is based on these decision rules.

Anticipated Response Scenarios⁸⁷

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

The town of Plymouth, which is on the southern shore of the Roanoke River in western Washington County, is certain to be protected. Much of this area is fortified and is likely to be protected as a rising sea level pushes up the Roanoke River (see Photos 11 and 12).⁸⁸

The developed areas in and around the inland communities of Roper and Creswell will also almost certainly be protected.

More than half of the shoreline along the Albemarle Sound in Washington County is developed and would be protected as sea level rises. Lands that are designated for future shoreline development along the sound will also certainly be protected.

The major transportation corridors leading to Plymouth, U.S. 64 and state highway 45 will be protected. Highway 32, which crosses the Albemarle Sound, will be protected.⁸⁹

Protection Likely

Currently, Washington County expects protection for all structures that lie within the floodplain and thus are at risk of inundation due to sea level rise. Uncertainty about the feasibility of complete

⁸⁷Edits made to the original map are hand-digitized at a 1:100,000 scale.

⁸⁸Based on both original stakeholder review draft and county review.

⁸⁹Based on original stakeholder review draft.

protection, however, precludes these lands from being considered “almost certainly protected.”

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop. Much of the remaining Roanoke riverfront area to the east of the town of Plymouth is wetland and is unlikely to be developed. Although the County assumes that undeveloped lands will be abandoned, some larger corporate farms might ultimately be protected. That decision would be based on economic and engineering feasibility.

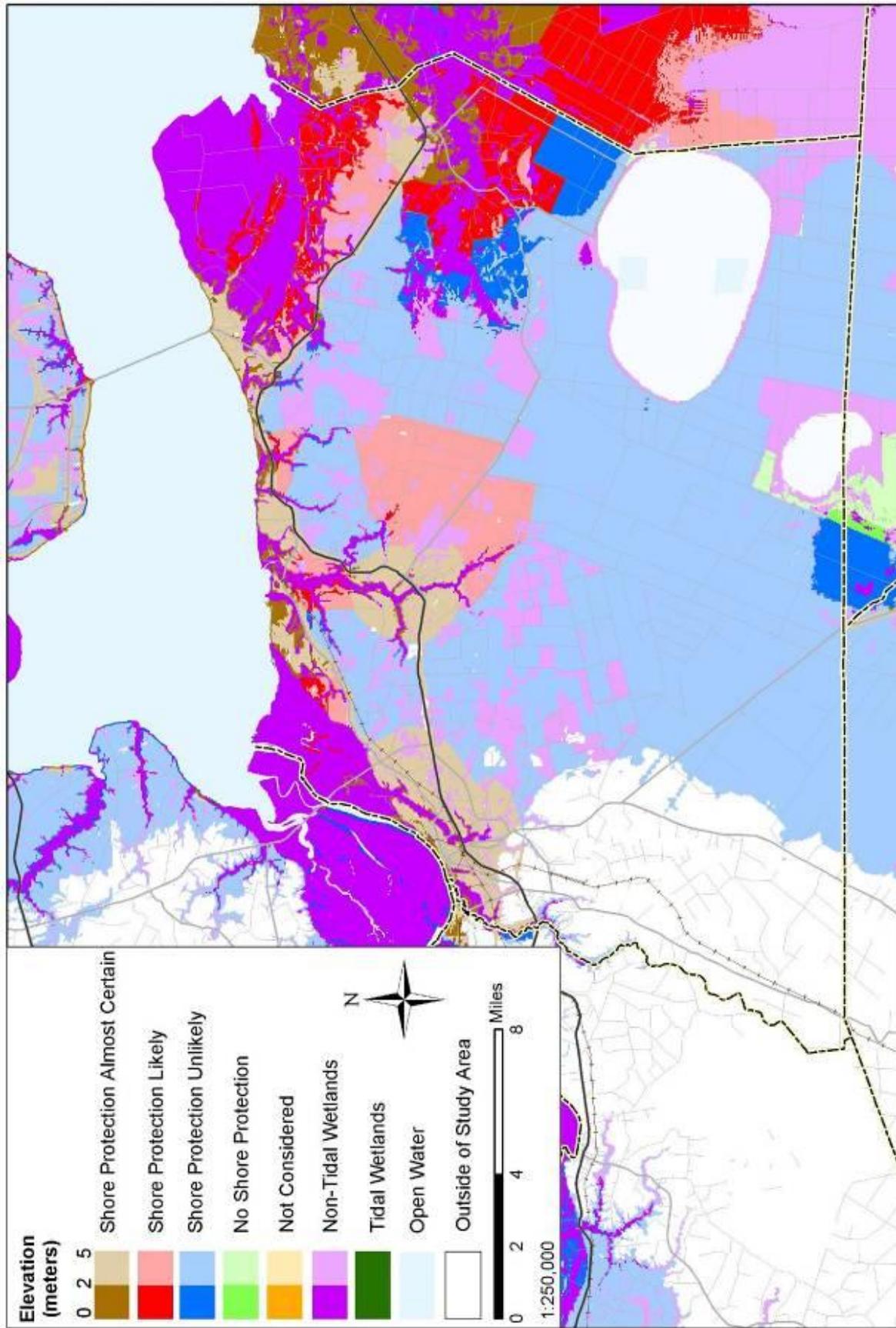
No Protection

Wetlands are depicted in dark green. County planners confirmed that there are no conservation lands in the county.

Map 10 shows the results for Washington County.



Photos 11 and 12. Plymouth. Photos 11 and 12 show the shoreline east of Plymouth from the water and land sides, respectively (June 2002).



Map 9-10. Washington County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

TYRRELL COUNTY

Land Use Policy on Sea Level Rise

Tyrrell County is one of three counties in North Carolina that is more than 95 percent below the 5-foot contour. (Dare and Hyde are the other two very low counties.) Almost all of the county relies on reverse osmosis for drinking water. The lack of an ocean shore makes Tyrrell less physically vulnerable to a rise in sea level, but also more economically vulnerable. Many tourists pass quickly through Tyrrell County on their way to Dare, Currituck, and Hyde counties, where most tourism dollars are spent. Meanwhile, as the rising sea submerges dry land that is barely above the ebb and flow of the tides, taxable private land transfers will convert to state-owned waters. Along Albemarle Sound and the Alligator River, one regularly sees cypress trees, which germinate only on dry land, growing in water a few feet deep.

Tyrrell County's CAMA-mandated land use plan indicates that the issue of sea level is not “solid” enough to propose a realistic policy statement, since it is still being debated in scientific circles.⁹⁰ NC-DENR staff are uncertain whether this viewpoint resulted from a full consideration of the available information on rising sea level or more from an absence of resources for considering long-term issues in a county that struggles to fund basic services.

Basis for These Maps

The following discussion and the map of Tyrrell County are based on discussions with:

Jane Dautridge, district planning manager, Terry Moore, field representative, David Moye, field representative, North Carolina Division of Coastal

Management; and J.D. Brickhouse, county manager, Tyrrell County

After reviewing the original stakeholder review draft and meeting with the EPA project manager, the county manager suggested numerous changes.⁹¹ He depicted the areas likely to be protected by drawing the rough boundaries on a USGS 1:100,000 scale map.⁹² Unless otherwise stated, the maps and discussion regarding which areas will be protected are based on those suggestions.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and in many cases already have some type of hard structure in place along the shoreline.

The community of Gum Neck is already protected by a dike with forced drainage (see Photo 13). This community consists mostly of farmland, but it also includes some homes. The dike surrounding Gum Neck was originally funded by a federal grant and the land inside the dike has forced drainage.⁹³ Given the substantial resources already invested

⁹⁰ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

⁹¹ Meeting between Jim Titus of EPA and J.D. Brickhouse of Tyrrell County at the county offices in Columbia, North Carolina. Summarized in “North Carolina Trip—Planning Study Implications” email sent October 24, 2003, from Jim Titus to Dan Hudgens.

⁹² Edits made to the original map are hand-digitized at a 1:100,000 scale.

⁹³ The general perception within the county is that highway projects elevated the water in this area, necessitating the dike; but Mr. Brickhouse also points out that the state highway department does not agree with that assessment. Regardless of the impact of infrastructure, sea level rise will continue to elevate the water tables in areas lacking forced drainage. The need for a dike in this area is also a useful reminder that in a flat area with largely natural drainage, sea level rise can elevate water tables and thereby essentially inundate lands that are a few feet above sea level.

and the community's willingness to pay for the maintenance and upkeep of this dike,⁹⁴ this community is sure to be protected for the foreseeable future.

Protected areas include all nonwetland areas along the Scuppernong River north of the town of Columbia to the Albemarle Sound.⁹⁵

Although the main street of Columbia is less than 2 feet above typical water levels, the town, which is also the county seat, is certain to be protected (see Photos 14 and 15).⁹⁶ The County will need to decide whether to encircle the community with a dike or elevate streets and encourage people to elevate yards with fill.⁹⁷

The roads from Columbia leading north to Soundside and northwest to Norman Beach and Legion Beach are fairly well populated. As a result, the entire area, including adjacent farmland, is almost certain to be protected with a dike.

The dry lands along U.S. 64 from Creswell (in Washington County) east and up to Colonial Beach will be protected. This area includes a new conference center.

The town of Frying Pan and the dry land surrounding NC-1307 will most likely be protected.

Other towns that will be protected are Dillon Ridge, Mills Ridge, Scotia, Pleasant View, and Jerry as well as Newfoundland and Buzzard Point. Ballast Bank and New Lands are also likely to be protected because of the high value of agricultural lands there.

U.S. 64 and the adjacent transportation corridor will be protected.⁹⁸ This two-lane highway is being expanded to a divided highway to improve access to the Outer Banks from Raleigh and other areas. In most areas the highway is higher than the surrounding land, often built on fill from adjacent drainage canals. As the sea rises and tidal flooding

of surrounding areas increases, the County will have to decide whether to continue to elevate the roadway with fill, convert to the bridge-style of causeway often found in Louisiana, or build a dike around the highway and the adjacent areas. Because this road may become an increasingly important evacuation route, it may be important to keep its elevation above flood levels.

All major roads will be protected. This analysis assumes that Highway 94 will be protected as a road that connects area communities.⁹⁹

Protection Likely

Areas where protection is likely are depicted in red. These are anticipated to be developed because they are adjacent to existing and expanding communities. Most of this area is currently either farmland or wetland.

The area from Goat Neck to Peartree Point is extremely vulnerable because it is surrounded by open water and swamp on two sides. Although it would be a good candidate for wetland migration, it recently received a substantial number of community block grants. Therefore, the County indicates that protection is possible.

The extensive agricultural lands in the southern part of the county near the Hyde County line may be protected should sea level rise affect them. These lands lie at a higher elevation than other agricultural lands within the county, so protection may not be necessary for a long time.

Protection Unlikely

Areas where protection is deemed unlikely by the County are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop. In these areas, protection is considered unlikely because of the high cost of constructing dikes and associated pumping systems compared with the relatively modest profits from forest products and agriculture.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green. Most of the western shore of the Alligator River is part of the Alligator

⁹⁴The property tax inside the dike is double the ad valorem rate of 1 percent to fund its operation and maintenance.

⁹⁵Based on original stakeholder review draft.

⁹⁶Based on both original stakeholder review draft and county review.

⁹⁷This issue was raised in the original stakeholder review draft.

⁹⁸Based on both original stakeholder review draft and county review.

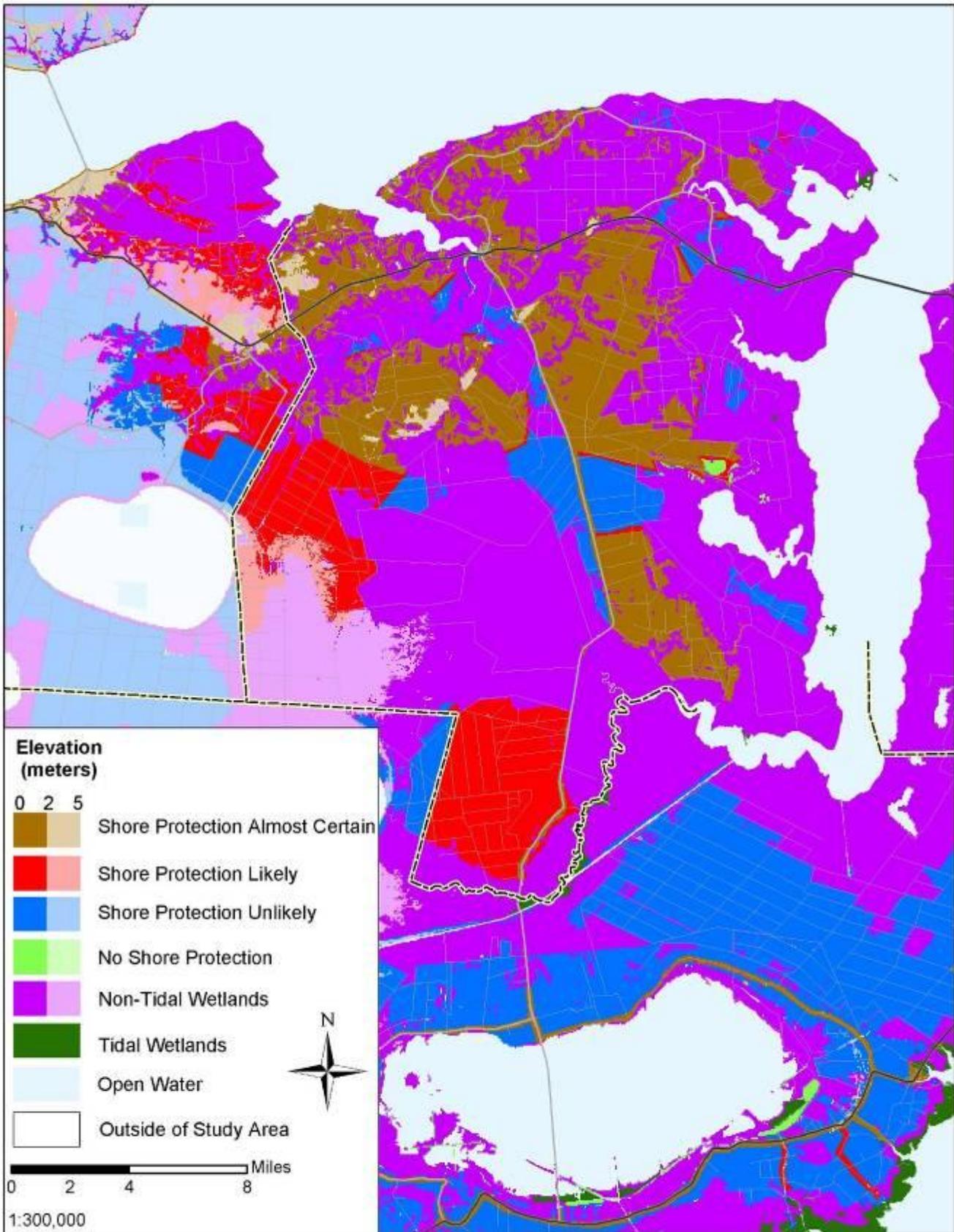
⁹⁹Based on original stakeholder review draft.

River National Wildlife Refuge or will be part of
the proposed Buck Island Coastal Reserve.

Map 11 shows the results for Tyrrell County.



Photos 13–15. Tyrrell County.
 Photo 13 shows the dike that protects Gum Neck (October 2002). Photos 14 and 15 show the small downtown area of Columbia, the county seat, which is entirely less than 1 meter above the mean water level (June 2002).



Map 9-11. Tyrrell County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

DARE COUNTY

Land Use Policy on Sea Level Rise

Dare County updated its CAMA-mandated land use plan in 1994.¹⁰⁰ The plan addresses sea level rise by stating that there is insufficient, reliable data to quantify the rate of sea level rise and that the phenomenon needs additional study. Until a more reliable and conclusive database has been established, Dare County will continue to rely on AEC standards for development limitations.

The Town of Southern Shores updated its CAMA-mandated land use plan in 1997. The town will rely on CAMA regulations, its local zoning and subdivision regulations, FEMA floodplain regulations, and other state and federal agencies to address this issue.

The Town of Kitty Hawk updated its CAMA-mandated land use plan in 1994. The town supports the restriction of development within areas up to 5 feet above mean high water susceptible to sea level rise and wetland loss.

The Town of Kill Devil Hills supports the restriction of development within areas up to 5 feet above mean high water susceptible to sea level rise and wetland loss.

Basis for these Maps

The following discussion and the maps of Dare County are based on discussions with:

John Thayer, district planning manager, Lynn Mathis, field representative, Denis Hawthorn, field representative, North Carolina Division of Coastal Management; Greg Ball, GIS coordinator, Ray

¹⁰⁰ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

Sturza, planning director, Donna Creef, chief planner, Dare County

For the mainland and Rodanthe, the maps are mostly based on the stakeholder review draft, with several changes based on the county's parcel data for existing land use, maps created for this project by the county GIS coordinator, and conversations with county planning staff.¹⁰¹ For the Outer Banks, the maps are mostly based on the overall judgments by county planning staff, with boundaries determined by county parcel data.

Anticipated Response Scenarios^{102,103}

Most of the land in Dare County is on the mainland, but most of the people live on Roanoke Island or the Outer Banks. We consider these areas separately.

Roanoke Island and the Mainland

Areas that will almost certainly be protected are depicted in brown. These areas are either already developed or will be developed in the very near future.

Roanoke Island was the first English settlement in what is now the United States, and the county itself is named after Virginia Dare, the first English child born in the New World. Manteo is

¹⁰¹ Meeting on June 6, 2003, at Dare County satellite office in Kill Devil Hills between Jim Titus, Ray Sturza, and Donna Creef.

¹⁰² Although North Carolina does not allow hardening of the ocean shorelines, the state does have a policy that allows beach nourishment. Consequently, we cannot assume retreat where development is substantial. Dare County is actively engaged in searching for sand resources for future nourishment, and its public officials have expressed the desire to move forward with nourishment.

¹⁰³ We identify the areas discussed in the following section using Dare County's GIS parcel data and property use classifications from the public tax files.

the largest year-round community in the county. The historic importance of Sir Walter Raleigh’s “Lost Colony” and the relatively intense development ensure that the northern part of Roanoke Island will be protected for the foreseeable future. A large portion of the northern end of Roanoke Island is highly developed with a fortified estuarine shoreline. Highway 64 connects to the northern end of the island near the Fort Raleigh National Historic Site; the new bridge connects U.S. 264 near the middle of the island. The community of Wanchese on the southern end of the island is also certain to be protected, including the state-owned Wanchese Seafood Industrial Park.

The primary question concerns some of the vacant land.¹⁰⁴ We show most of those lands as probably protected (red),¹⁰⁵ with the exception of nonprofit vacant lands, which we show as probably not protected (blue).¹⁰⁶ Because the northern and southern portion of the island is connected by wetlands, it is possible that eventually, as sea level rises, the road will be all that connects these two communities (see Photo 16).

Most of Dare County’s land area is on the mainland between the Alligator River and Albemarle, Roanoke, and Pamlico sounds. Most of the mainland is wetland, with a large fraction part of either the Alligator River National Wildlife Refuge or the Dare County Bombing and Electronic Combat Range. Almost all of the mainland is below 5 feet (NGVD).¹⁰⁷ Because of

¹⁰⁴The stakeholder review draft showed the entire island as developed and certain to be protected. The county’s land use data show a small amount of vacant land. The County offered no specific changes to the maps; hence we merely use the county data to refine—as best as we can—the boundaries and assumptions from the stakeholder review draft.

¹⁰⁵This assumption follows the approach of the stakeholder review draft, given that undeveloped land is expected to be developed on Roanoke Island.

¹⁰⁶Some of these lands are owned by The Nature Conservancy—although most of those lands are wetlands, not dry land. Those lands logically would be shown as conservation lands. Because it was impractical to obtain additional data, we show all nonprofit lands as probably not protected.

¹⁰⁷Until recently, most topographic maps provided contours that measured elevation above the National Geodetic Vertical Datum of 1929. That datum represented mean sea level for the tidal epoch that included 1929, at approximately 20

the very low elevation, opportunities for future development are limited by state prohibitions on draining wetlands for development, as well as requirements for functional septic systems.

State officials identified three areas on the mainland where protection is almost certain: East Lake, Manns Harbor, and Stumpy Point. U.S. 64 and U.S. 264 will almost certainly be protected to maintain the primary transportation routes between inland areas and the Outer Banks. Although it would be possible to convert these highways to long bridges through the wetlands, the preferred method of construction has been the use of fill. Given the protection of these roads, the settlements and businesses along these roads will be protected as well.

The largest area of mainland that seems certain to be protected is the closed landfill along U.S. 264 near the junction with U.S. 64. Given the need to prevent pollution seepage and runoff, the landfill has the same artificial drainage that one would expect to find in a very low farming community being protected from rising sea level.¹⁰⁸ Besides the drainage, the managers of this facility add topsoil periodically.¹⁰⁹ The landfill is currently used for disposing of construction debris.¹¹⁰

Because the land is supposed to be protected indefinitely for environmental reasons, Dare planners felt that it is most appropriate to color this facility brown.¹¹¹

Adjacent to the landfill lies the Creef Farm tract, a former farm that is now managed by U.S. Fish and Wildlife Service as a combination farm and wetlands complex. Roughly 5–6 miles to the west along U.S. 64 lies the Laurel Bay tract, which is

stations around the United States. The mean water level varied at other locations relative to NGVD, and inland tidal waters are often 3–6 inches above mean sea level from water draining toward the ocean through these rivers and bays.

Because sea level has been rising, mean sea level is above NGVD29 almost everywhere along the U.S. Atlantic Coast.

¹⁰⁸Meeting June 6, 2003, at Dare County satellite office in Kill Devel Hills; Jim Titus, Ray Sturza, Donna Creef.

¹⁰⁹Meeting June 6, 2003, at Dare County satellite office in Kill Devel Hills; Jim Titus, Ray Sturza, Donna Creef.

¹¹⁰Jeff DeBlieu, The Nature Conservancy (based on conversation with Dennis Steward, Refuge Biologist, Alligator River National Wildlife Refuge). Email from Jeff DeBlieu to Jim Titus, December 5, 2003.

¹¹¹Meeting June 6, 2003, at Dare County satellite office in Kill Devel Hills; Jim Titus, Ray Sturza, Donna Creef.

managed similarly by USFWS. The county land use data identified other similar areas, many of which are along U.S. 264. Because these areas are not currently being managed as conservation lands, and USFWS is not necessarily committed to allowing them to become submerged, this area is not shown as light green. Nevertheless, given the agency's commitment to conservation, these areas are not likely to be protected as sea level rises. Thus, the maps show them as blue.

Most of the bombing range is wetland and hence is not noticeable on our map. Nevertheless, a small portion appears to be dry land, approximately 3 miles east of the Alligator River. Following our general approach for secured installations, we color that dry land as red. The land depicted in light green immediately to the north is part of the Alligator River National Wildlife Refuge.

Finally, Dare County has a number of small islands that are large enough to support housing. The islands along U.S. 64 between Manteo and Nags Head are as intensely developed and as likely to be protected as Roanoke Island itself. A number of small islands between Roanoke Island and Oregon Inland are classified by Dare County as

“vacant unclassified” or “single family residential.” Given the absence of road access and the absence of any reason to expect it to be protected, the maps show these islands as probably not protected.

The Outer Banks

Portions of the Outer Banks have high erosion rates, which has led some federal and state agencies to adopt a policy of retreat. In the national seashore, the highway is regularly relocated inland—and even developed areas such as Kitty Hawk (Photos 17–20) and Nags Head (Photos 21–22) have seen their beaches erode under oceanfront homes that continue to stand for months and even years, before eventually falling into the water. This policy of acquiescence appears to be giving way in favor of a policy of coastal defense, at least in the area between Nags Head and Kitty Hawk.

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These areas are either already developed or will be developed in the very near future. Much of the estuarine shoreline in developed areas has been armored. This practice is likely to continue.

The Corps of Engineers now has an authorized beach nourishment project for the 13.6 miles from Nags Head to the southern end of Kitty Hawk; and county officials expect that the benefit/cost ratio will be revised to justify extending the project to Kitty Hawk. Therefore, this area clearly will almost certainly be protected from erosion.¹¹²

Protection Likely

State officials had a difficult time envisioning a retreat in any of the other communities along the Outer Banks. Nevertheless, the County pointed out that there are significant impediments for beach nourishment elsewhere. The communities north of Kitty Hawk do not have public access to the beaches; therefore they are ineligible for beach nourishment. Although that may change, it is not a certainty. Therefore, the areas seaward of the major coastal highway are likely—but not certain—to be protected north of Kitty Hawk.



Photo 16. Roanoke Island Wetlands. The Nature Conservancy and NC-DENR officials examine the wetlands south of Manteo. In the foreground along the street, *Spartina patens* is found because of relatively low salinity concentration caused by highway freshwater runoff. *Juncas* dominates more than 20 feet from the road. In the farground is a hommock, that is, an isolated stand of pine trees where the ground is still high enough to support terrestrial vegetation (June 2002).



17



18



19



20

Photos 17–20. Shore Erosion at Kitty Hawk. During June 2002, this home had large sand bags (geotextile containers) protecting the ground below the rear of the home, including the septic tank (Photo 17). By October the shore had eroded back to the garage, and the owners had moved the jet ski from under the home to the front yard. (Photo 18). By the following June, several homes had been removed as the shore continued to erode. The house with the dark green roof in the distance was still standing, but was unoccupied (Photo 19). All the while, people continued to use the beach, despite condemned homes and exposed septic tanks (Photo 20), (June 2002).

The towns of Avon, Buxton, Frisco, and Hatteras are almost entirely developed. There is little doubt that measures will be taken to prevent their inundation and erosion from baysides. Similarly, the unincorporated communities of Rodanthe, Waves, and Salvo will warrant bayside protection. The economics of beach nourishment for these communities, however, are less favorable than for Nags Head to Kitty Hawk. Long stretches of beach are always more cost-effective than short stretches to nourish: Because sand tends to move laterally along the shore, any project to nourish these isolated pockets of development would tend to lose sand to adjacent portions of the National

Seashore.¹¹³ Moreover, some of these communities have a very strong wave climate—Rodanthe has often seen erosion as great as 10 feet per year. Therefore, ocean side protection is much less

¹¹³Unless a terminal groin was put in place—which might tend to encourage an inlet breach.



21



22

Photos 21–22. Geotextile containers protecting homes along the shore at Nags Head (June 2003).



23



24

Photos 23–24. Hatteras Island. Photo 23 shows the Hatteras Lighthouse in the background with its original location in the foreground. Photo 24 shows typical water levels compared with the coastal highway (June 2002).

certain than for Nags Head to Kitty Hawk. Nevertheless, DENR planners believe that if beach nourishment costs are too great to be justified by property values and avoided flood damages, the state would either grant variances from the no-armoring policy or provide state funding to protect the shorefront homes in these towns. Along the sound side, portions of the highway and some lots in the Rodanthe area are less than 2 feet above the level of Pamlico Sound; elevating these low areas is far less expensive than beach nourishment on the ocean side.

In the case of Buxton, for the foreseeable future, the required protection would be on the bay side. Although the Cape Hatteras Lighthouse was recently relocated, the impetus for the move came from the federal level and was opposed by local government (Photos 23 and 24). Although the land

immediately next to the original location of the lighthouse is owned by the National Park Service and will continue to erode, most of the town of Buxton is well inland of the lighthouse and threatened more by soundside inundation than oceanside erosion. Low areas in these areas may have to be elevated with fill.

Soundside protection is almost certain for the other communities as well, regardless of the prospects for beach nourishment. The only exceptions are vacant lands in some of the communities, most of which will probably be developed in the next decade or so, but some of which might end up as conservation land. Within the Dare County Outer Banks, most of these lands are immediately south of the Wright Memorial Bridge or along the western shore of Kitty Hawk. All of these vacant lands are shown in red, except for those owned by

nonprofits, some of which are owned by The Nature Conservancy (which are colored blue).

We also show Highway 12 in undeveloped areas as likely to be protected because the state is committed to maintaining this road, but not necessarily in its current location. Highway 12 is the Outer Banks' connection to the mainland. The only other surface alternative is the state ferry system that crosses from Hatteras Island to Ocracoke Island and then from Ocracoke Island to the mainland. The highway is the commercial and evacuation route for the Outer Banks.

Consequently, the highway's protection is a high priority to the local communities and to state government. The North Carolina Department of Transportation and other state divisions are currently assessing various alternatives for protecting the highway. Future alternatives could include elevating the road or sand nourishment in vulnerable areas.

Historically, vulnerable areas of the highway have sometimes been protected with sandbags, but eventually the road has always been relocated inland. The abutments on the south end of Oregon Inlet were fortified under a variance granted from the state's nonhardening policy, but plans are under way for rebuilding the bridge inland. DENR staff believe that the highway is almost certain to be protected because of local and state protection priority—even if this requires hardening the shore.

No governmental agency has proposed the use of its own funds for beach nourishment simply to protect this road; and the Park Service, which owns much of the land through which this road passes, has a general policy of retreat. Given the tendency to relocate this road inland, as well as plans to build the bridge at Oregon Inlet well inland of its current location, a gradual inland

relocation of this road seems most likely. Our mapping convention does not offer an easy way to depict the concept of a barrier island rolling inland with all infrastructure moving inland as well. We color the map red as a compromise between brown (because the road will continue to exist) and green (because there is retreat policy in place).

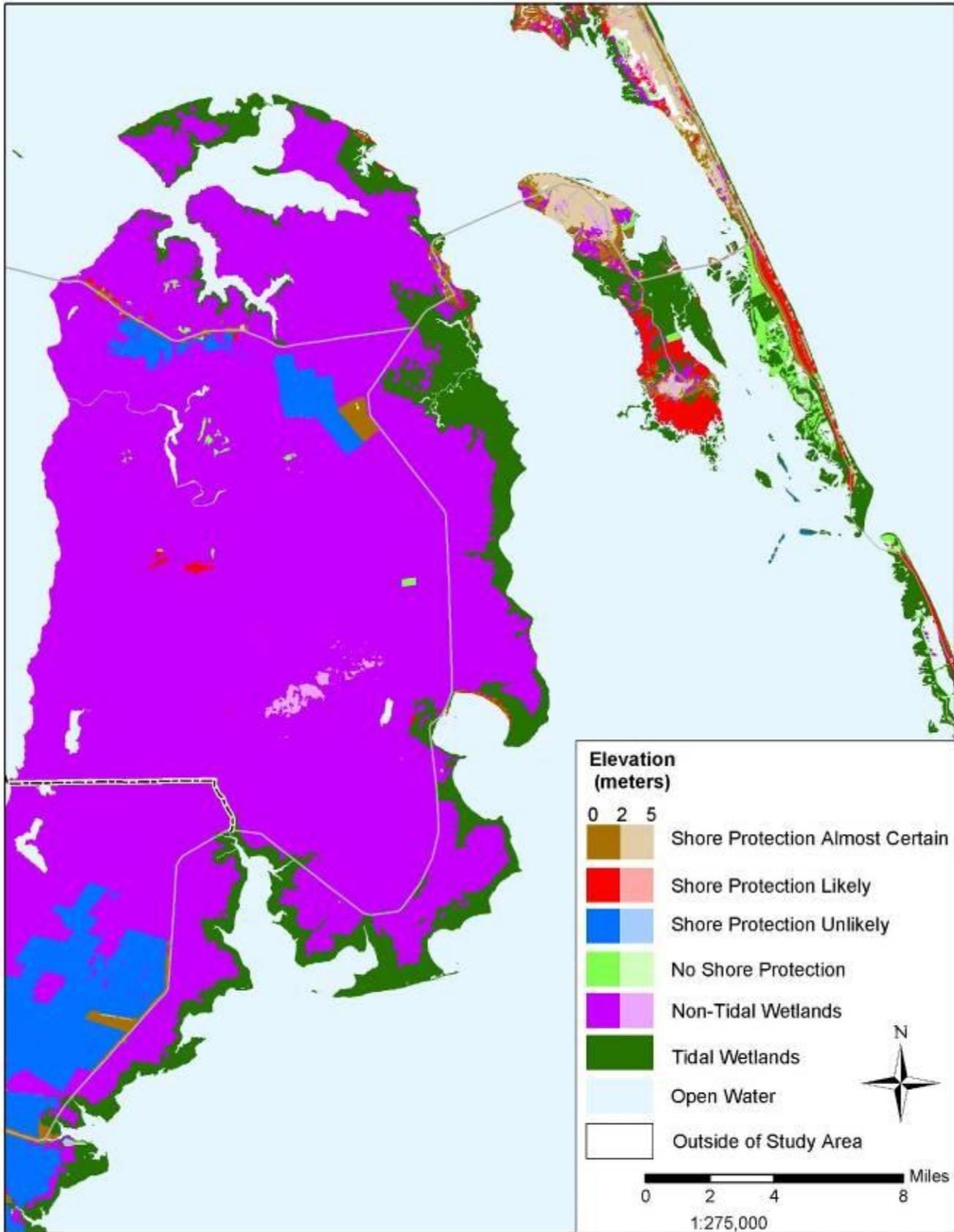
Protection Unlikely

Because The Nature Conservancy owns land along the Outer Banks, the maps treat nonprofit vacant land as unlikely to be protected. We also include land designated as horticultural, because farmland is not likely to be protected.

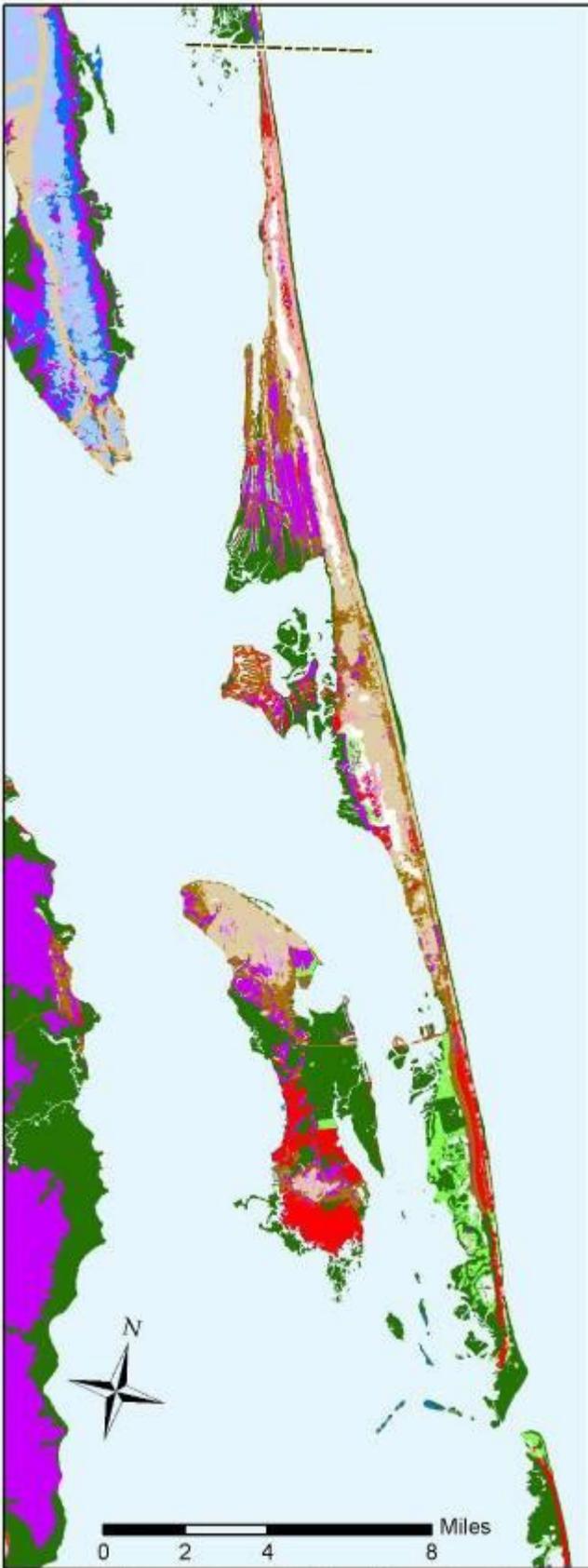
No Protection

The light green areas are undeveloped conservation areas and dark green areas are wetlands. Shown in light green are conservation lands held in public ownership (Nags Head Woods [state], Jockey's Ridge State Park Cape Hatteras National Seashore, and Pea Island National Wildlife Refuge). The maps assume that the National Seashore will not be protected, but this statement cannot be considered in isolation of plans for Highway 12. These areas also include Buxton Woods (a state reserve) and lands associated with the Wright Brothers Monument. With the exception of the monument, the maps assume that the public land would not be protected. It is possible that the monument would be protected under an exception for historically significant sites.

Map 12 shows the results for the mainland of Dare County and Roanoke Island. Maps 13 and 14 show the results for the Outer Banks: the Northern Spit and Hatteras.



Map 9-12. Dare County (Mainland and Roanoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.



Map 9-13. Dare County (northern spit): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see Map 9-2.



Map 9-14. Dare County (Hatteras Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see Map 9-2.

HYDE COUNTY

Land Use Policy on Sea Level Rise

There was no information available on sea level rise in Hyde County's land use plan.

Basis for these Maps

The following discussion is based on discussions with:

Kathy Vinson, district planning manager, Ted Tyndall, field representative, North Carolina Division of Coastal Management; Alice Keeney, county planner, Hyde County

The maps are based on the original stakeholder review draft, except for a few site-specific changes suggested by county staff.¹¹⁴

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Existing communities on the mainland of Hyde County will certainly be protected. The developed area around Fairfield and Carmur, along the north shore of Lake Mattamuskeet, will be protected as the lake level rises because of sea level rise. East of the lake, the Town of Engelhard and the Hyde County Airport are also certain to be protected. Other protected areas in Hyde County will include the waterfront towns of Middletown, Makleyville, Germantown, and Sladesville as well as three developed areas south of Mt. Olive along the eastern shore of the Pungo River.

Some of the shoreline in the brown areas is already armored – particularly along Swan Quarter Bay in the town of Swan Quarter. Swan Quarter is the

county seat for Hyde County and is the mainland port for one of the ferry routes to Ocracoke Island (Photos 25–28). In August 2002 the County, along with DNR and the USDA, published a plan for the construction of a dike to protect the area from flooding. For these reasons it will almost certainly be protected in the face of rising sea level.¹¹⁵

The town of Engelhard will certainly be protected.¹¹⁶

Considering its importance connecting area communities, Highway 94 will be protected. The most direct transportation corridor to this area is Highway 264 and it, along with offshoot roads to the coastal towns, will be protected.

North Lake Road, Piney Woods Road, and Turnpike Road along with 264 create a loop around Lake Mattamuskeet. All of these roads will be protected. Protection of Turnpike Road will extend to the section that connects the lake loop to Highway 264/45.¹¹⁷

The island of Ocracoke is mainly part of Cape Hatteras National Seashore. The community of Ocracoke is almost certain to be¹¹⁸ protected, given that high property values and the rapid development.¹¹⁹

¹¹⁵Based on both stakeholder review draft and county review. The dike was hand digitized based on a map included in the "Swan Quarter Supplemental Watershed Plan and Environmental Assessment" provided by the county as part of the stakeholder review.

¹¹⁶Based on county review.

¹¹⁷Based on county review.

¹¹⁸Although North Carolina does not allow hardening of the ocean shoreline, the state does have a policy that allows beach nourishment. Consequently, we cannot assume retreat in areas where development is substantial. On Ocracoke Island the ramifications of oceanfront erosion are not immediate since there is no development along the beach.

¹¹⁹In a meeting at the county seat, the county manager told the EPA project manager, with some regret, that property values are rising so rapidly that some long-time residents can no longer afford to pay property taxes or rent.

¹¹⁴Unless otherwise stated, boundaries of protected areas were hand-digitized from USGS 1:100,000 scale maps.



Photos 25–28. Swan Quarter and Vicinity. These photos show typical water levels around Swan Quarter, the county seat. Photo 25 is in the agricultural outskirts of town, within the area that would be protected by the planned dike. The other photos are all in town. The water in the wide ditches is essentially at sea level, and would be tidal were it not for the fact that Pamlico Sound has a negligible tide range (October 2002).

Protection Likely

Areas where development is expected and protection is likely are depicted in red.

Planners did identify an area along the Intracoastal Waterway where development is likely in the foreseeable future. Development is likely, however, to occur in an area near where spoil has been placed from dredging the waterway. The reasons for the development are elevated land and waterway access. If this area does develop, it is likely to be protected.

Because of the slow growth in Hyde County and the limited amount of “developable” land, there are limited areas for additional development. There is the potential for development (and protection) north of Quilley Point on the Pungo River. If developed, transportation corridors from Highway 264 would also be likely to be protected.

Highway 12 along the barrier island near Ocracoke is located within a COBRA area. As a result,

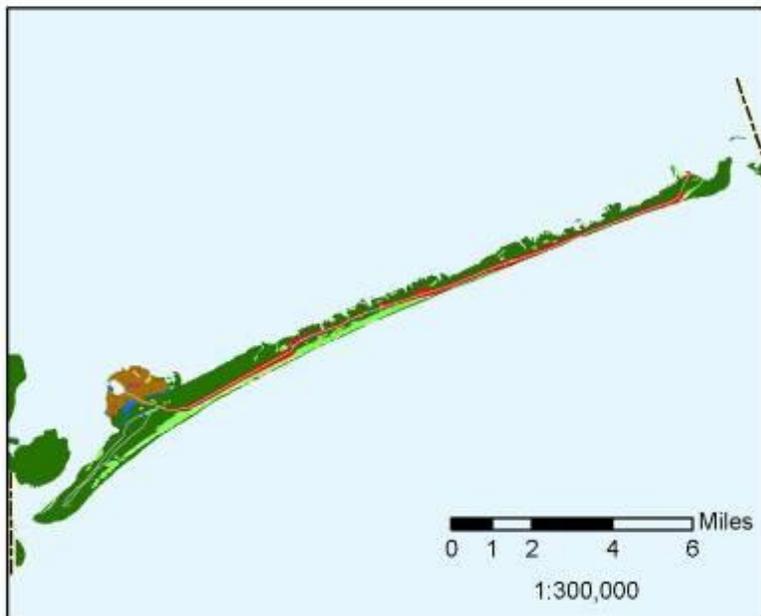
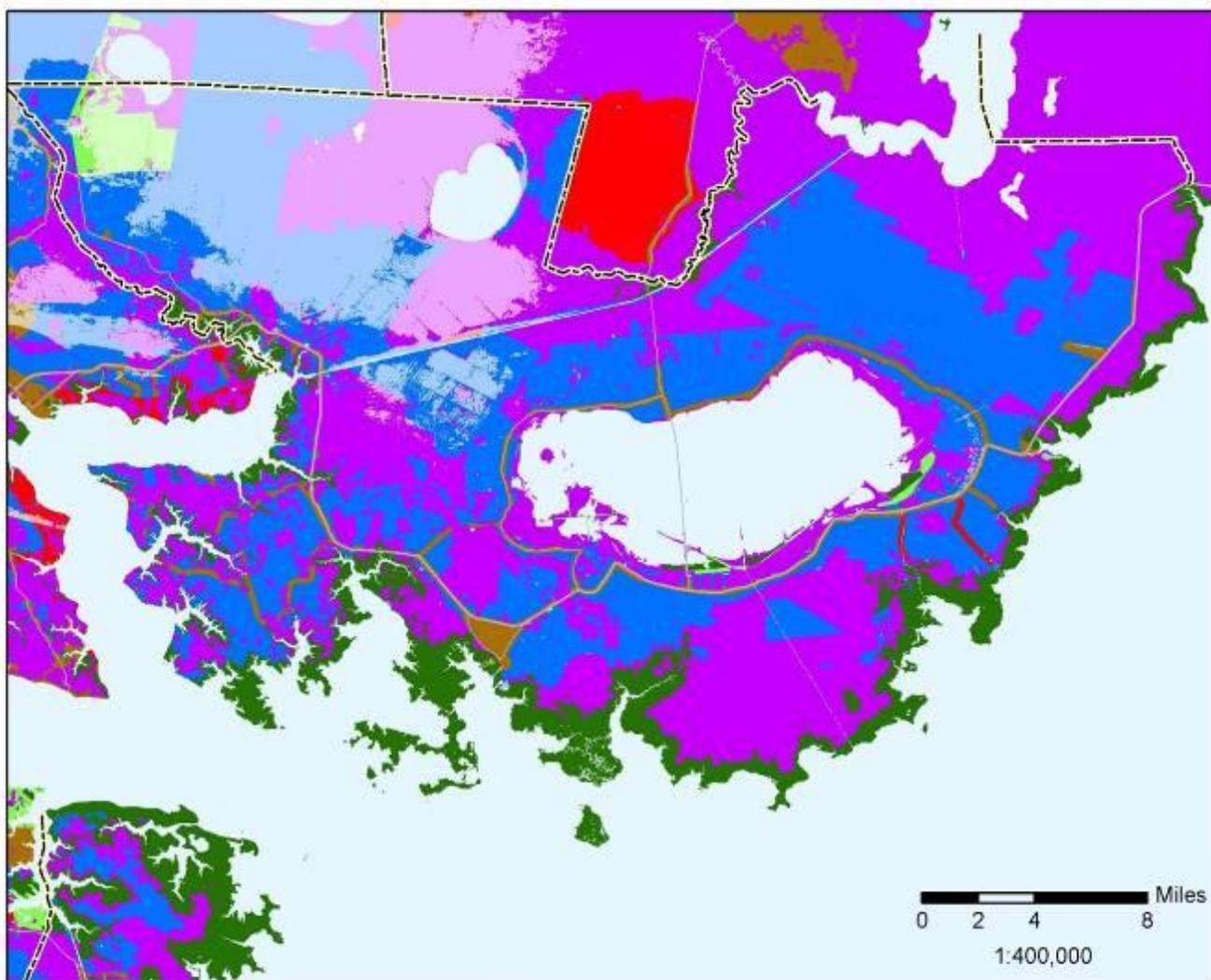
public funds are not likely to be used to protect this road. Because private funds might be used to protect the highway, however, we show the area as possibly protected.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. The Pungo National Wildlife Refuge is shown in light green in the northwest portion of the county. Additional conservation lands are predominantly wetlands and include the Mattamuskeet and Swan Quarter National Wildlife Refuges and the Gull Rock State Game Land. Wetlands are depicted in dark green.



Map 9-15. Hyde County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see Map 9-2.

BEAUFORT COUNTY

Land Use Policies on Sea Level Rise

Beaufort County updated its CAMA-mandated land use plan in 1997.¹²⁰ The County's stated position is that a policy restricting development that might be susceptible to sea level rise and wetland loss is worthy of continued research and investigation. As of 1997, however, no specific policy had been adopted.

The Town of Pantego updated its CAMA-mandated land use plan in 1994. The plan addresses areas where the elevation is below 5 feet. The plan recognizes that these areas could be susceptible to sea level rise but states that development in this area is minimal.

The Town of Aurora updated its CAMA-mandated land use plan in 1997. The plan recognizes that water levels change over time and that any rise in sea level will inundate areas in the Aurora planning area. Preparation for this requires looking at current land uses and projections. The plan suggests the following alternatives: (1) locate hazardous development outside low-lying areas, (2) locate all development outside low-lying areas, or (3) do not restrict development in low-lying areas. The plan's "policy choice" is to locate hazardous development outside of areas that may be affected by a 5-foot rise in sea level. The plan's strategy is to update its zoning ordinance to make necessary changes in industrial permitted uses.

The Town of Bath updated its CAMA-mandated land use plan in 1997. The plan's policy regarding sea level rise is to encourage shoreline development setbacks or vegetated buffers along the perimeter of fragile wetlands and water bodies and to allow only water-dependent uses in coastal wetlands, public trust waters, and other areas of environmental concern.

¹²⁰ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

Basis for these Maps¹²¹

The following discussion and the scenario depiction in this county area based on discussions with:

Kathy Vinson, district planning manager, Ted Tyndall, field representative, North Carolina Division of Coastal Management; Jeremy Smith, county planner, Gill Robbins, Beaufort County

After reviewing the original stakeholder review draft, county officials suggested using the county's 1997 land use plan to designate land use categories as certainly protected, likely to be protected, and unlikely to be protected. These rules confirmed the designations of areas that were highlighted in the stakeholder review draft. Thus the final maps are essentially the same as the maps from the stakeholder review draft, except that using the county's land use data enabled us to refine the boundaries.

Anticipated Response Scenarios

Protection Almost Certain

Areas in brown are those that will almost certainly be protected. These area areas that are privately owned and are either already developed or will be developed in the very near future. All areas that were designated as community, developed, urban transition, and municipal district in the Beaufort County 1997 Land Use Plan will certainly be protected. Areas that were specifically called out in the stakeholder review draft and which the county review confirmed appear below.

Substantial development and growth exist along the northern shore of the Pungo River, including the towns of Belhaven (Photo 29), Pantego, and Leechville. These areas will be protected as sea level rises.

The most direct transportation corridors to the county's developed areas are Highways 33 and 92

¹²¹Edits to original map are hand-digitized using the Beaufort County 1992 and 1997 CAMA land use plans.

and their offshoots. These corridors will be protected. Also, it is assumed that U.S. 264 and smaller area roads would be protected since they connect area communities.

Developed areas within the Town of Bath and along Bath Creek will be protected (these include much of the nonwetland shoreline of this area). Also included is the recreation site for PCS Phosphate—one of eastern North Carolina’s largest industries (in land mass), which is located on the shore of the Pamlico River, will also be protected. It should be noted that PCS Phosphate holds the “only” mining lease in North Carolina’s coastal area, which includes mineral rights to phosphate in the submerged lands of the Pamlico River.

The Town of Aurora located at the end of South Creek will be protected.

Protection Likely

Planners believe that development would occur in several areas in the foreseeable future and protection is likely there. These areas are shown in red on the map. Areas designated as limited transition in the 1997 land use plan are likely to be protected. These areas include the land along Blounts Creek, the land between Maules Point and Core Point, and the Long Point/Hickory Point area on the south banks of the Pamlico River. On the north side of the Pamlico River lands such as Gum Point and much of the land along the Pungo River are included in this category. Other areas noted in the stakeholder review draft that are confirmed by the land use-based decision rules include those points noted below.

Planners indicated several areas along the Pungo River that are likely to be developed (and therefore likely to be protected), including the vicinity of Lower Dowry Point, Satterthwaite Point, Windmill Point, and Woodstock Point.

Additional areas likely to be developed north of the Pamlico

River include the northern shores of North and Bath creeks. Transportation corridors to these developing areas are also likely to be protected.

South of the Pamlico River, areas likely to be developed include the shoreline along Blounts Bay north of Cotton Patch Landing, the area between Maules Point and Core Point, Hickory Point, and the south shore of Campbell Creek. Transportation corridors to these developing areas are also likely to be protected.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop. Areas designated as rural with services in the 1997 land use plan will most likely not be protected. There is one large agricultural area that might be protected if feasible from an economic and engineering perspective. Because of the uncertainty, however, we show the area as unlikely to be protected.

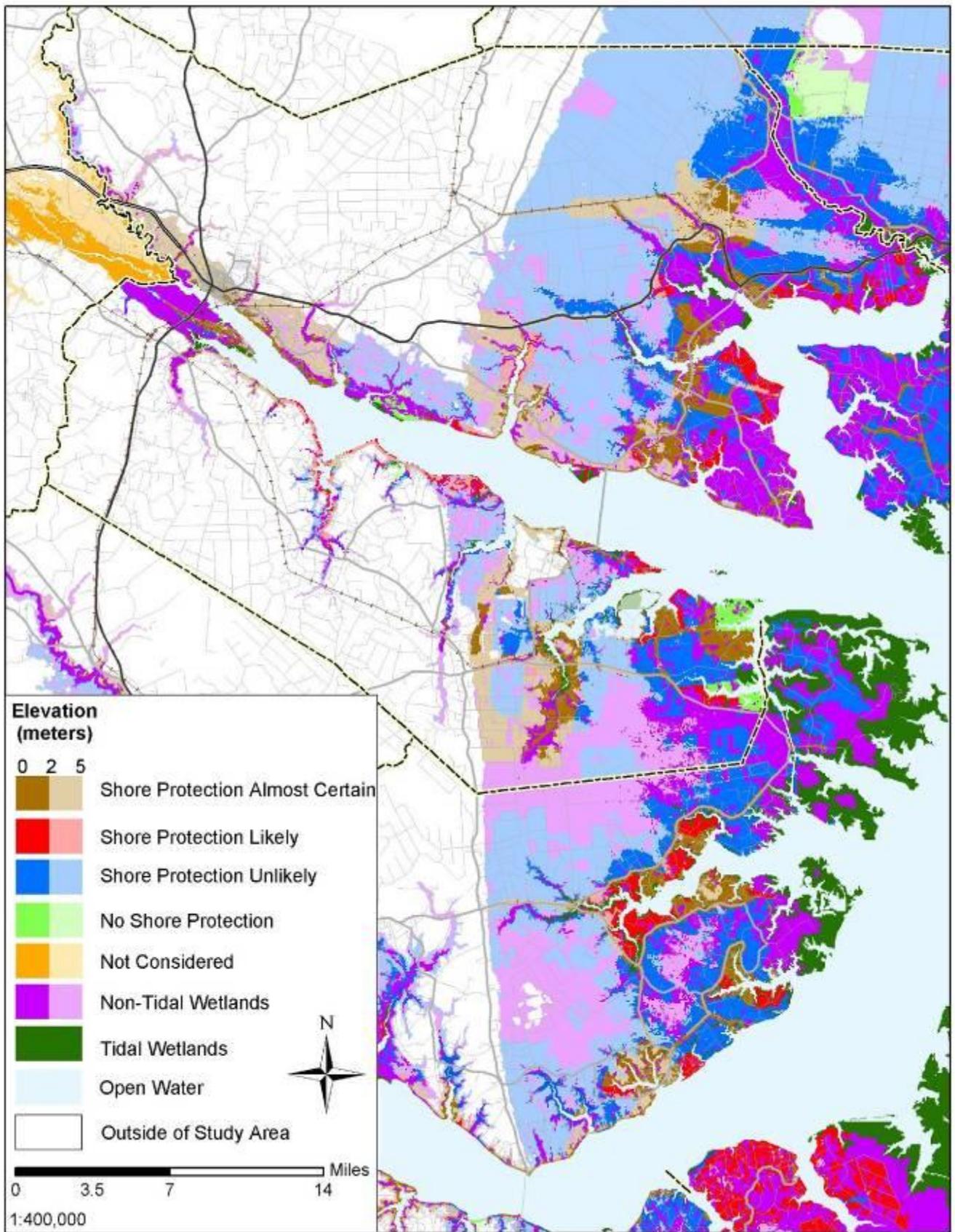
No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green. Creek State Park is located on southern edge of Beaufort County adjacent to the Pamlico River.

Map 16 shows the results for Beaufort County.



Photo 29. Belhaven City Hall (October 2002).



Map 9-16. Beaufort County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

PAMLICO COUNTY

Land Use Policies on Sea Level Rise

Pamlico County's CAMA-mandated land use plan states that the County will cooperate with local, state, and federal efforts to inform the public of the anticipated effects of sea level rise. It further states that the County will monitor sea level rise and consider establishing setback standards, density controls, buffer vegetation protection requirements, and building designs, which will facilitate the movement of structures.¹²² In addition, the Town of Oriental has an individual land use policy related to sea level rise.

The Town of Oriental's CAMA-mandated land use plan states that the town will adequately plan for uses located within wetland loss areas or sea level rise areas. The town will ensure compliance with all local, state, and federal guidelines, regulations, and inspections during analysis of a proposed development project lying in wetland loss and sea level rise areas.

Basis for these Maps

The following discussion is based on discussions with:

Kathy Vinson, district planning manager, Ted Tyndall, field representative, Scott Jones, field representative, North Carolina Division of Coastal Management; Miriam Prescott, map coordinator, Pamlico County

After reviewing the original stakeholder review draft, county officials suggested numerous changes. The county planner marked these changes on a county subdivision map, which was also used

¹²² A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

to help define the boundaries of the developed areas. Unless otherwise stated, the discussion regarding which areas will be protected is based on their suggestions. In all other cases, the County concurred with what was already in the stakeholder review draft.¹²³

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned. Generally speaking, areas that are already developed will certainly be protected (see Photos 30 and 31).

All subdivided development will certainly be protected.

The certainly protected areas are concentrated in the southern half of the county. The majority of the Greens Creek/Oriental area (with the exception of the southernmost shore of the creek) is subdivided and will certainly be protected (see Photo 30). The town of Pamlico will certainly be protected, as will the subdivided neck directly east of the town. Across Broad Creek to the north of Pamlico, there are a few areas of development, including the town of Whortonsville and the entire shore of Brown Creek, which will also be protected.

The county's direct transportation corridors (including Highways 304 and 55) will also be protected.¹²⁴

¹²³The map coordinator indicated that she was pleasantly surprised by how much of the situation was correctly captured by the stakeholder review draft. Email from Jim Titus to Jennifer Kassakian sent October 22, 2002, describing meeting with Miriam Prescott at Pamlico county offices on October 17, 2002.

¹²⁴Based on original stakeholder review draft.

Many areas along the Neuse River (with the exception of one area of undeveloped land west of Route 306) are either currently developed or will certainly be developed and protected in the future. This includes Kennel Beach as well as the area between Minnesott Beach (Photo 31) and Cooper Point.

In the Bay River area, Ball Creek is currently being developed and will certainly be protected.

Protection Likely

Areas where protection is likely are depicted in red. Generally, areas likely to be developed in the future are identified by planners as being likely to be protected.

Creek Point, in the southern part of the county along the Neuse River, may be developed and subsequently protected. Most other undeveloped lands west of 306 will also likely be developed and protected.

The southernmost shore of Greens Creek is likely to be subdivided and protected in the future.

Weyerhaeuser is currently planning a 400 home development (Gum Thicket Project) at the mouth of Broad Creek in the area of Tonney Hill Point. Weyerhaeuser will not be developing directly along the river, however, because of the high cost of maintaining the necessary bulkheading. If the new development is affected by sea level rise, it is expected that the land will be protected.¹²⁵

Development (in the proximity of Oriental) is also planned for the shorelines of Greens, Kershaw, and Smith creeks. As the property is sold, new owners obtain permits for bulkhead or rock stabilization.



Photos 30–31. Pamlico County. Low-lying homes sit next to marsh in the town of Oriental (Photo 30). Looking north from the ferry crossing the Neuse River, Minnesott Beach is losing its beach (Photo 31) (October 2002).

About 20 percent of the shoreline has already been stabilized.¹²⁶

Road access to these areas is via Highways 304 and 55. The primary corridors are certain to be protected, and the offshoots are likely to be protected.¹²⁷

Most undeveloped lands along the Bay River are likely to be developed and protected. The north and south shores of Bay River have many platted developments. When the property is sold, most new owners stabilize the shoreline. Currently,

¹²⁵Based on original stakeholder review draft.

¹²⁶Based on original stakeholder review draft.

¹²⁷Based on original stakeholder review draft.

about 15 percent of the southern shore area is hardened.¹²⁸

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. Although these areas tend to be undeveloped private lands that are unlikely to be developed, there is an important exception: Goose Creek Island, which has been developed. In the wake of Hurricane Floyd, FEMA is providing funding for residents to relocate to higher ground. This relocation—while motivated by flood risk reduction—may be the rare case where wetlands migrate landward into a formerly (albeit lightly) developed area. In addition:

Between Whitehurst Point and Cockie Point lie undeveloped forest lands that belong to a foundation that relies on timber sales and cannot sell the land. These lands will probably remain undeveloped and unprotected.

Across Broad Creek from Pamlico there is another large tract of undeveloped forest land owned by a foundation, which precludes it from development.

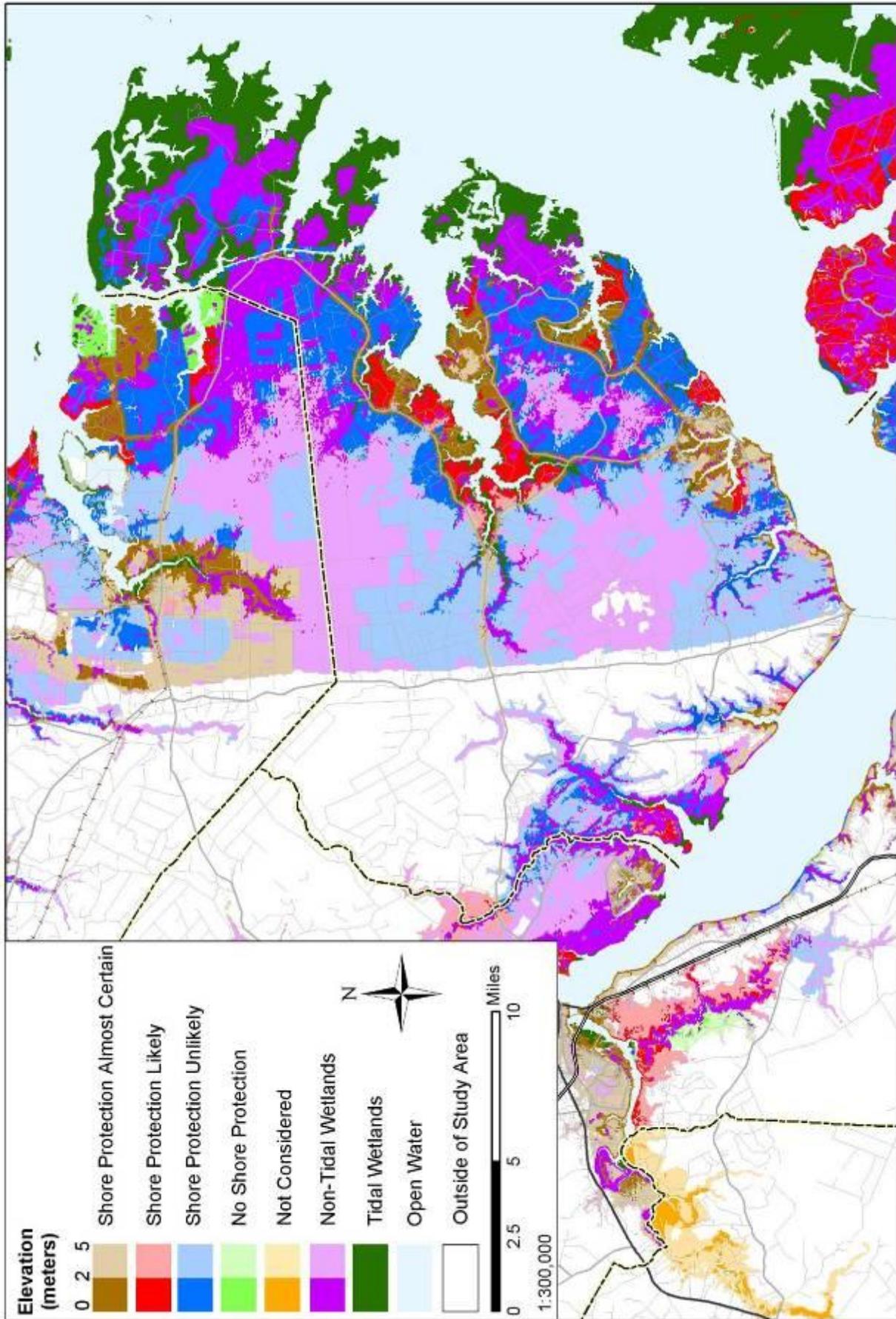
The area east of Kennel Beach will most likely not be developed and will remain unprotected.

No Protection

Wetlands are depicted in dark green. Much of the area in the north around Goose Creek Island is wetland. Areas farther to the south around Boar Point, Bay Point, Deep Point, Piney Point, and Swan Island are also wetland. Within these areas, artificial lagoons were created to promote duck hunting. There would be little incentive to secure these areas.

Map 17 shows the results for Pamlico County.

¹²⁸Based on original stakeholder review draft.



Map 9-17. Pamlico County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

CRAVEN COUNTY

Land Use Policies on Sea Level Rise

Craven County updated its CAMA-mandated land use plan in 1996.¹²⁹ The plan contains a policy that states that the County will implement the following policies to respond to sea level rise:

- Craven County will continuously monitor the effects of sea level rise and update the land use plan policies as necessary to protect the county's public and private properties from rising water levels;
- Craven County will support bulkheading on the mainland to protect its shoreline areas from intruding water resulting from rising sea level.

Basis for these Maps

The maps are based on the original stakeholder review draft. The county planner, Don Baumgardner, agreed with all determinations made therein.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

On the north side of the Neuse River is a large residential development called Fairfield Harbor. There is substantial development and infrastructure in Fairfield Harbor, and most of the shoreline (which consists of Northwest Creek and many artificial canals) is armored.

The south shore of the Neuse River (north of Croatan National Forest) has been developed as residential. This area has easy access to New Bern and Havelock (home of the Cherry Point Air Station) via Highway 70. There are a substantial number of permanent (full-time) residences in this area.

Protection Likely

Areas where protection is likely are depicted in red. This area, however, does not apply to Craven County since most of the buildable land is already developed. The remaining vacant land is either wetland or part of the Croatan National Forest.

Protection Unlikely

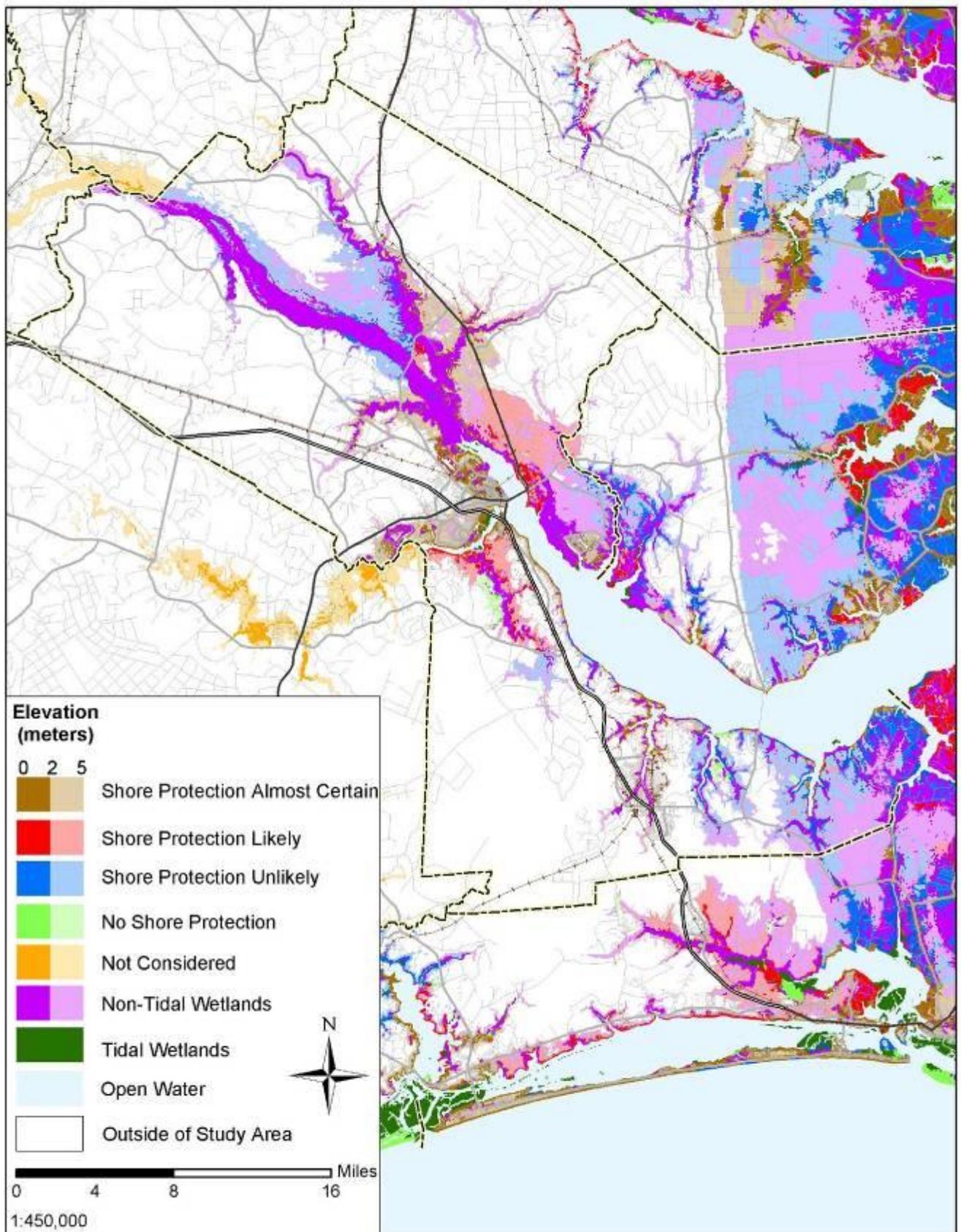
Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green.

Map 18 shows results for Craven County.

¹²⁹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.



Map 9-18. Craven County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

CARTERET COUNTY

Land Use Policies on Sea Level Rise

Carteret County updated its CAMA-mandated land use plan in 1996.¹³⁰ The County will monitor sea level rise and consider establishing setback standards, density controls, bulkhead restrictions, buffer vegetation protection requirements, and building designs, which will facilitate the movement of structures.

Carteret County is one of the most vulnerable counties in the state. Carteret has substantial amounts of very low land, most vividly evident in the towns of Atlantic and Sea Level (Photos 32–35). As in Dare, Hyde, and Tyrrell counties, the main roads in Carteret have wide drainage ditches that are regularly full of water. Because the sounds in Carteret have substantial tides, however, these ditches rise and fall with the tides, like the tidal ditches along Chesapeake Bay. Therefore, the appropriate means for holding back the sea in Carteret might better resemble techniques used along Chesapeake Bay (e.g., tide gates) than the measures used elsewhere in North Carolina.

The Town of Cape Carteret updated its CAMA-mandated land use plan in 1997. The town does not feel it is in a position to develop specific policy statements related to sea level rise because of uncertainties surrounding the issue.

Basis for these Maps¹³¹

The following discussion and the maps are based, in part, on discussions with:

Kathy Vinson, district planning manager, Ted Tyndall, field representative, North Carolina

¹³⁰ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

¹³¹ Edits to original map are hand-digitized at a 1:100,000 scale.

Division of Coastal Management; Katrina Marshall, director of Planning and Inspections, Carteret County; Gabriele Onorato, assistant general manager, Open Grounds Farm, Inc.

Unless otherwise stated, the maps are based on the original stakeholder review draft. Nevertheless, major changes were made based on meetings with Open Grounds Farm, the largest coastal landowner in the county, and county planning staff. Some changes were also suggested by the EPA project manager based on a trip through the county, with county concurrence.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Bogue Banks (which includes the Town of Emerald Isle and Atlantic Beach) is certain to be protected. This area is highly developed with residential (primarily vacation) and commercial property.¹³² In 2002, the County conducted a beach renourishment project for the area beaches.

The Town of Cape Carteret is also certain to be protected. The shoreline in this area is developed and mostly fortified. Most of the estuarine shoreline is already fortified or will be in the near future.

Other areas certain to be protected include East Carteret High School near the community of North

¹³² Although North Carolina does not allow hardening of the ocean shorelines, the state does have a policy that allows beach nourishment. Consequently, we cannot assume retreat in areas where development is substantial. Much of Bogue Banks has been nourished and Carteret County recently held a bond referendum to raise local funds for nourishment of the beaches. Although the referendum failed, the County and its local officials support nourishment.



Photos 32–35. Sea Level, North Carolina and Vicinity. Tidal ditches next to the Sea Level United Methodist Church (Photo 32). In the wake of Hurricane Floyd, most homes were being elevated between North River Corner and North River. Photo 33 shows a home resting on steel flange beams, which are in turn resting on wooden blocks. The truck in the foreground has a hydraulic compressor, with hoses leading to each of six jacks inside the blocks. Although most owners simply elevate their homes, some choose to elevate the ground immediately next to the home (Photo 34), while others do not (Photo 35) (October 2002).

River, a retirement community serving more than 100 residents at the northern end of Nelson Bay, and all of Harker's Island. Harker's Island is entirely developed at the maximum density allowed by the state.¹³³

The major state and county roads in Carteret County will certainly be protected. These roads include, but are not limited to, Merrimon Road running north that provides access to the towns of South River and Merrimon¹³⁴ and Laurel Road, which is a connector between Merrimon Road and Route 101.¹³⁵

Protection Likely

Areas where protection is likely are depicted in

red. They include areas that are likely to be developed in the future as well as large corporate farms.

Open Grounds Farm, Inc., is a large corporate farm that accounts for the majority of dry land within the study area in Carteret County. Dikes and tide gates already protect a few low areas, and a drainage system is already in place. The onsite management believes that the economics would justify protection of this farm.¹³⁶ Therefore, this large area was changed from blue to red. Because it is agricultural land, it may be a better target for a conservation buyout than other developed areas. Accordingly, the County believes that protection

¹³³Based on county review.

¹³⁴EPA's project manager had suggested that the road be changed from blue to red (email from Jim Titus of EPA to Katrina Marshall of Carteret County, October 31, 2002). The County, however, responded that it should be changed from blue to brown (county review).

¹³⁵Based on county review.

¹³⁶Meeting between Jim Titus of EPA and Gabriele Onorato, assistant general manager, Open Grounds Farm, Inc., October 17, 2002.

likely is more accurate than protection almost certain.¹³⁷

The residential and commercial lots on either side of the road from North River Corner north to North River will probably be protected. In the aftermath of Hurricane Floyd, homes are being elevated, which is consistent with the assumption that land and structures will simply be elevated as the sea rises.¹³⁸ The road itself will almost certainly be protected. The County doubts that this low-income area would be a focus of protection in the future.¹³⁹ Therefore, it is possible that the area will be given up to the sea.

The north shore of Bogue Sound is likely to be developed and therefore also likely to be protected.

Along the Neuse River, the towns of South River and Merrimon are both likely to be protected. Access to the communities will be ensured through the protection of the state road and branches serving the towns.¹⁴⁰

Some areas of dense development along the White Oak River in the westernmost portion of the county will certainly be protected.

State and county staff generally expect that the U.S. military reservation (Bogue Airfield) is certain to be protected. Following the convention of this study, however, it is depicted in red.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to be developed. There is a public maritime forest that is the home of one of the state aquariums (the other two are on Roanoke Island and at Ft. Fisher). If the actual facility becomes threatened the state might decide that protection is a feasible option. Much of the land around the facility, however, would not be protected.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. This includes the Cape Lookout National Seashore on the Core Banks. Wetlands are depicted in dark green.

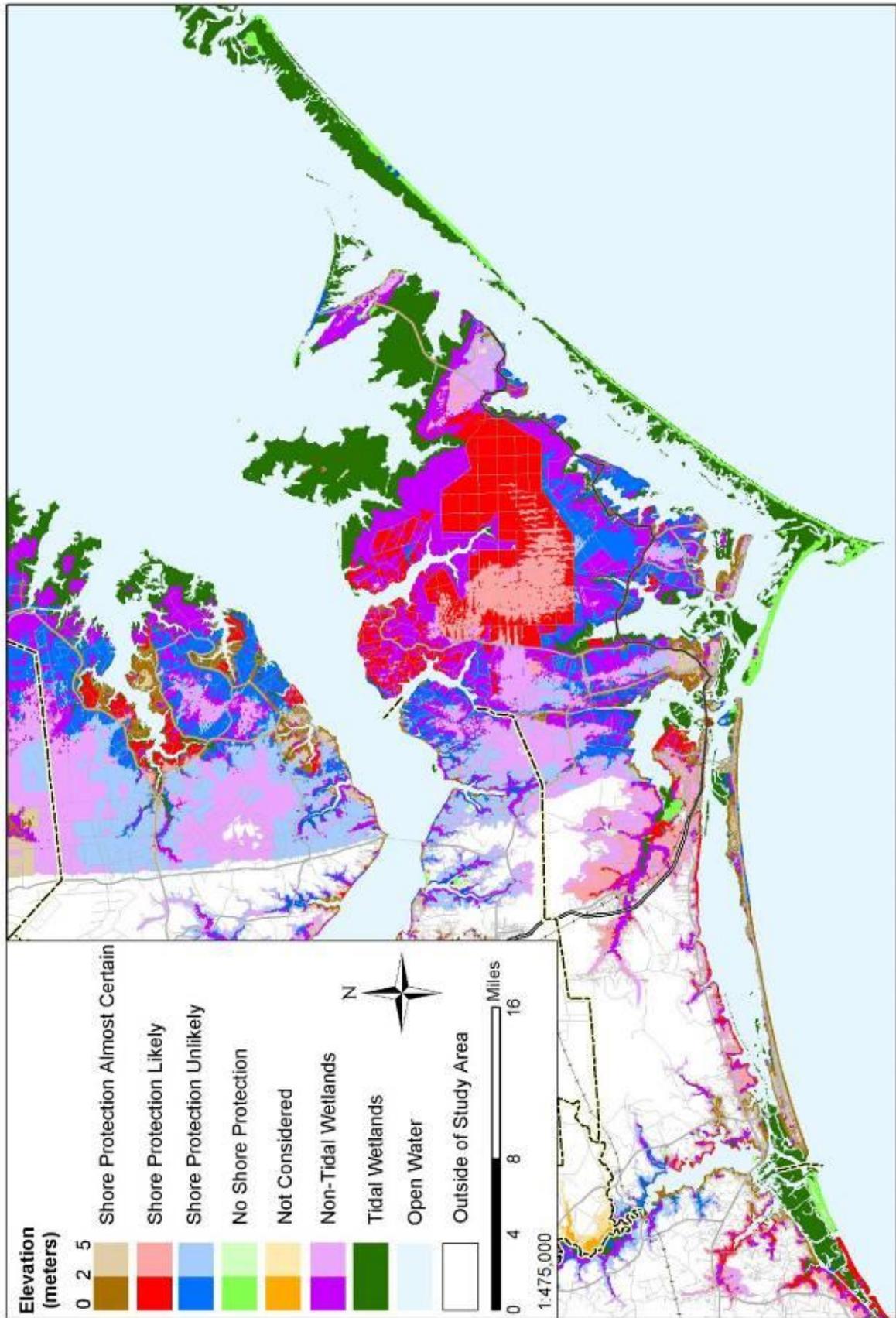
Map 19 shows results for Carteret County.

¹³⁷Based on county review (concurring with October 31, 2002, email from Jim Titus of EPA to Katrina Marshall of Carteret County).

¹³⁸Based on county review (concurring with October 31, 2002, email from Jim Titus of EPA to Katrina Marshall of Carteret County).

¹³⁹An October 31, 2002, email from Jim Titus of EPA to Katrina Marshall of Carteret County suggested that perhaps the County would want to assume that this area is almost certain to be protected, given the resources recently devoted to elevating land and/or structures. In a subsequent conversation with Jennifer Kassakian, the County indicated that they disagreed with this assumption, and felt that as sea level rises this area is unlikely to obtain resources for additional elevation. Property owners may undertake the required expenditures themselves.

¹⁴⁰Based on county review.



Map 9-19. Carteret County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

ONSLow COUNTY

Land Use Plans on Sea Level Rise

Onslow County updated its CAMA-mandated land use plan in 1991.¹⁴¹ The plan states that the County will monitor sea level rise and respond accordingly.

The Town of Swansboro updated its CAMA-mandated land use plan in 1999. The town feels it is unable to develop specific policies related to sea level rise because of the uncertainty surrounding the extent and magnitude of the problem.

Basis for these Maps¹⁴²

The following discussion and the maps are based, in part, on discussions with:

Angie Manning, staff planner, Onslow County

The maps are based on the original stakeholder review draft, with a few minor adjustments to development boundaries and site-specific changes identified by the county reviewer.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

On the barrier islands and ocean beaches, the only area certain to be protected is the West Onslow Beach portion of the incorporated town of North

Topsail Beach, on Topsail Island along the border with Pender County.¹⁴³

The City of Jacksonville, the Town of Swansboro, the nearby area extending up the White Oak River to the town of Stella, and the area in the vicinity of Sneads Ferry are all almost certain to be protected.

Most of the inland estuarine shoreline is within the Camp Lejeune military reservation. The developed portions of the reservation are certain to be protected.¹⁴⁴

Protection Likely

Areas where protection is likely are depicted in red.

There is some commercial development around the bridge crossing U.S. 17 near the town of Belgrade. This area may be protected.¹⁴⁵

Most of the northern portion of North Topsail Island is part of the system of “undeveloped barrier islands” under the Coastal Barriers Resources Act. This area is commonly recognized as the most densely developed portion of the system, and likely to justify beach nourishment. Nevertheless, the fact that the area is ineligible for federal subsidies makes shore protection less likely than the part of the island that is eligible for federal subsidies.

Close to one-half of the county’s ocean coast is within the Camp Lejeune Marine Base. Although the state officials expect the Marines to choose retreat over coastal defense, we color the barrier islands red consistent with our approach to secured

¹⁴¹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

¹⁴² Edits to the original map are hand-digitized at a 1:100,000 scale.

¹⁴³ Although North Carolina does not allow hardening of the ocean shoreline, the state does have a policy that allows beach nourishment. Consequently, we cannot assume retreat in areas where development is substantial. Much of the estuarine shoreline on the back side of North Topsail will probably be fortified and protected.

¹⁴⁴ Based on county review.

¹⁴⁵ Based on county review.

installations. For the same reason, we color the undeveloped portion of the base's estuarine shore as red.

Protection Unlikely

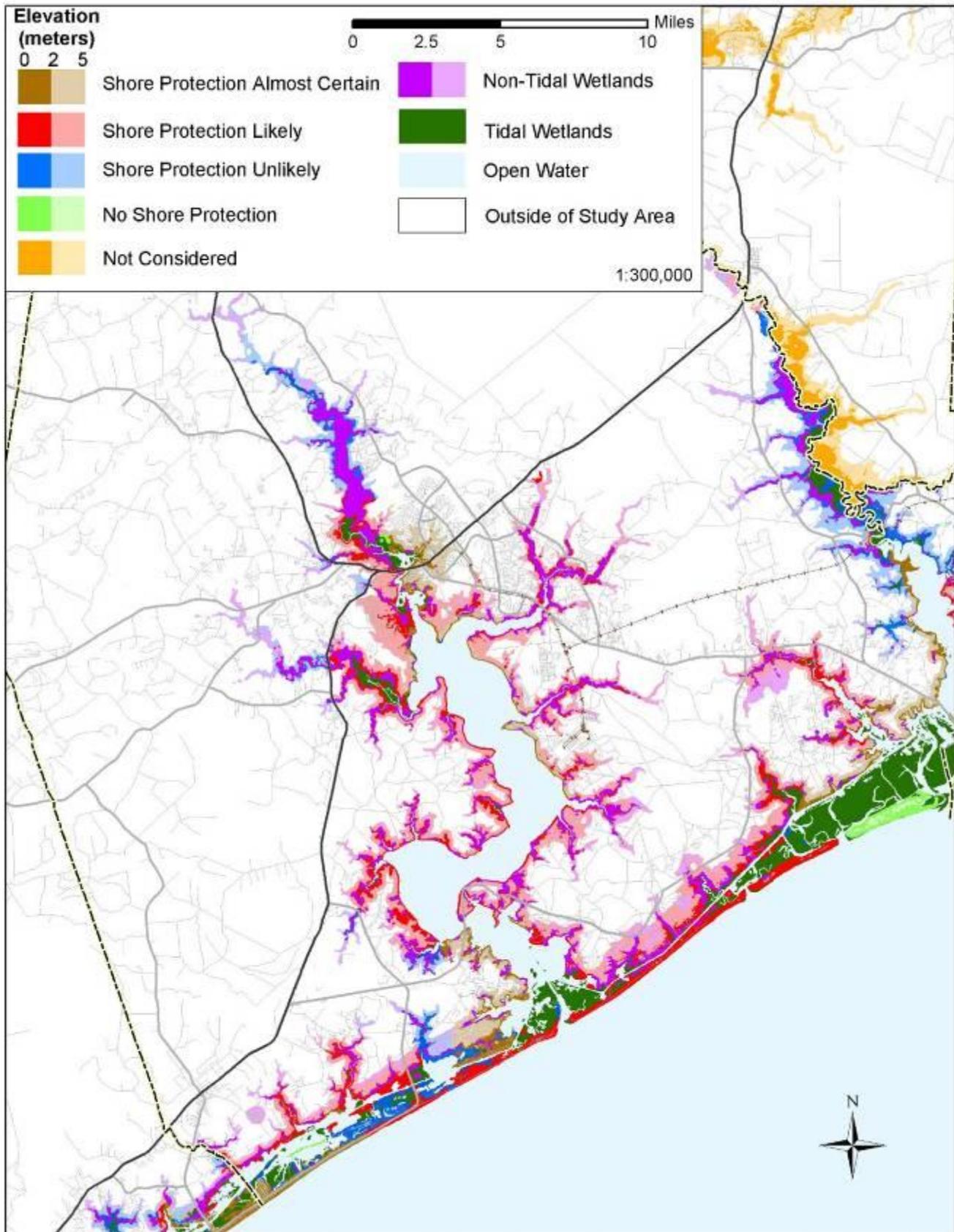
Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed. With development pressures low, this land is likely to remain undeveloped (and therefore also unlikely to be protected). In addition, Browns Island is used as a bombing range and the area south of Browns Inlet has been developed as a military recreation area. These areas also will not be protected.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Bear Island is part of Hammocks Beach State Park. Because natural shore migration does not threaten the recreational and conservation purposes of this project, it will almost certainly not be protected.

Wetlands are depicted in dark green.

Map 20 shows the results for Onslow County.



Map 9-20. Onslow County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

PENDER COUNTY

Land Use Plans on Sea Level Rise

Pender County updated its CAMA-mandated land use plan in 1991.¹⁴⁶ The County will restrict development in areas up to 5 feet above mean high water using existing CAMA, local, state, and federal regulations.

The Town of Topsail Beach updated its CAMA-mandated land use plan in 1990. The town considers its existing policies based on FEMA and flood insurance regulations adequate to deal with the issues of sea level rise.

The Town of North Topsail Beach updated its CAMA-mandated land use plan in 1996. The town supports the construction of bulkheads along estuarine shorelines to protect structures from rising sea level.

The Town of Surf City updated its CAMA-mandated land use plan in 1992. The town states that it will monitor sea level rise.

Basis for these Maps

The following discussion and the map of Pender County are based on discussions with

Alex Marks, former district planning manager for the North Carolina Division of Coastal Management.

The maps are based on the original stakeholder review draft.¹⁴⁷

¹⁴⁶ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

¹⁴⁷ Jennifer Kassakian made several unsuccessful attempts to secure comments on this draft from Pender County representatives. Johnny Sutton, Planning and Community Development Coordinator for Pender County, declined to

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future.

Topsail Island is highly developed. The portion in Pender County includes Topsail Beach, Surf City, and Del Mar Beach.

Along the estuarine shoreline, Hampstead and Watts Landing are almost certain to be protected.

Protection Likely

Areas where protection is likely are depicted in red. The entire shoreline of Pender County is certain to be developed in the near future and therefore also likely to be protected—except for wetland areas. This part of the North Carolina coast will continue to develop at a rapid pace.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop. In particular, land along the Cape Fear River is unlikely to be developed or protected. The coastal barrier to the southwest of Topsail Island is critical piping plover habitat.¹⁴⁸

No Protection

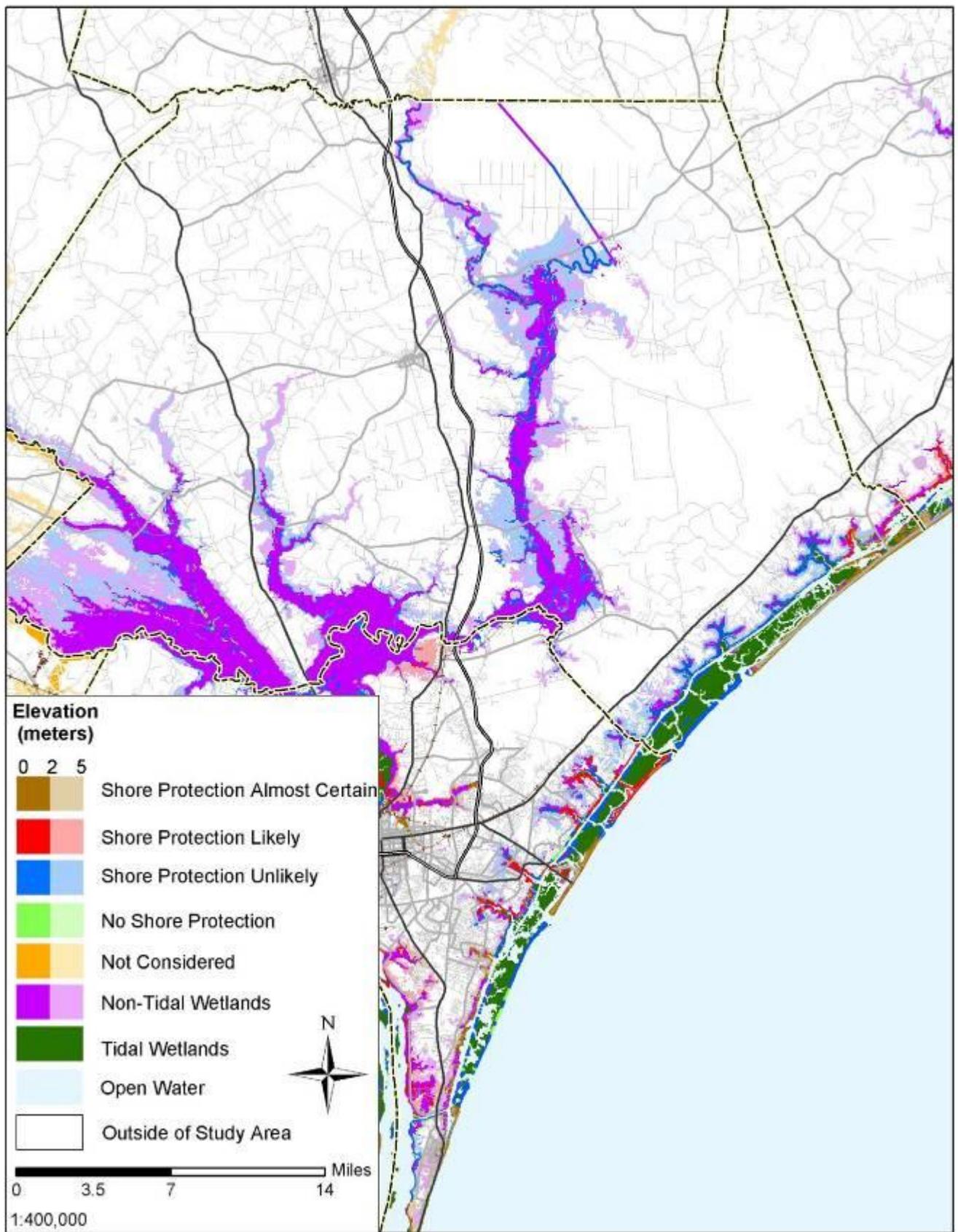
Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green. These natural areas

comment on the report or maps for this study on November 4, 2002.

¹⁴⁸Federal Register Vol. 66, No. 132, Tuesday, July 10, 2001, Rules and Regulations, at 36087.

include a private ocean island that is not likely to be developed and large amounts of salt marsh between the barrier islands and the mainland.

Map 21 shows results for Pender County.



Map 9-21. Pender County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

NEW HANOVER COUNTY

Land Use Plans on Sea Level Rise

New Hanover County last updated its CAMA-mandated land use plan in 1999.¹⁴⁹ New Hanover County's plan contains background information on sea level rise and includes a list of various responses to the issue. Policy 4.13 specifically states that the County will "pursue a policy of retreat along our estuarine shorelines in order to accommodate future sea level rise and wetland migration." A number of other policies demonstrate that New Hanover is committed to reducing development along the erodible shoreline and within the 100 year floodplain.¹⁵⁰ Though not a specific policy, New Hanover has had a conservation ordinance in place since the mid-1980s that requires a 75-foot setback from the estuarine shorelines for residential structures. Greater setbacks are required for commercial uses.

The Town of Carolina Beach updated its CAMA-mandated land use plan in 1997. The plan states that the town will consider state and federal policies before formulating specific local policies regarding sea level rise (specifically, decisions regarding development within areas up to 5 feet above sea level). No specific policies are mentioned.

The Town of Wrightsville Beach updated its CAMA-mandated land use plan in 1996. The town supports a policy of regular beach renourishment as the most practical means of balancing the public's interest in the beach shoreline with the protection of private property

¹⁴⁹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

¹⁵⁰ New Hanover's land use policies are available at www.nhcgov.com/PLN/PLNsteercomm.asp.

investments. In the absence of renourishment, the town's next policy of choice is relocation of threatened structures.

Basis for these Maps

The following discussion and the New Hanover County map are based on discussions with:

Chris Okeef, New Hanover County Planning Department; Zoe Bruner, director of Planning and Inspections, Town of Wrightsville Beach and former district planning manager for the North Carolina Division of Coastal Management's southern district; Alex Marks, former district planning manager for the North Carolina Division of Coastal Management; Dexter Hayes, planning director, New Hanover County

The map is based on the original stakeholder review draft. The county reviewer agreed with determinations made therein. He also requested minor edits to the report, none of which altered the maps.

Anticipated Response Scenarios

Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are areas that are privately owned and are either already developed or will be developed in the very near future. The county's beach communities are highly developed and will be protected.

Extensively developed areas, including Wilmington and Carolina Beach (including the Carolina Beach State Park), are certain to be protected.

Fort Fisher, the ferry departure point at Federal Point, Kure Beach, and the North Carolina Aquarium will be protected. In fact, a variance has been granted from the state's ocean shoreline hardening rules to allow a hardened

structure (rock rip rap) to protect the historic Fort Fisher. This structure also protects U.S. 421, which provides access to the area and the ferry connection to Southport, North Carolina.

Much of the land between Carolina Beach and Masonboro along the Intracoastal Waterway is developed and fortified.

Although North Carolina does not allow hardening of the ocean shoreline, the state does have a policy that allows beach nourishment. Consequently, we cannot assume retreat in areas where development is substantial. In fact, all the beach communities of New Hanover County support beach nourishment as their preferred option for dealing with sea level rise.

Wrightsville Beach and Carolina Beach have a long history of beach nourishment. The County collects a room occupancy tax that supports their beach nourishment projects. Recent revenues average about \$3.5 million annually.

Protection Likely

Areas where protection is likely are depicted in red.

Substantial areas of new development along the Cape Fear River (north and south of Wilmington) are likely to be protected.

The estuarine shoreline along the northeast portion of the county is developing and is therefore likely to be protected in the future.

Figure Eight Island is privately owned and not eligible for federal funding, thus protection is less than certain, but still likely, given the high property values.

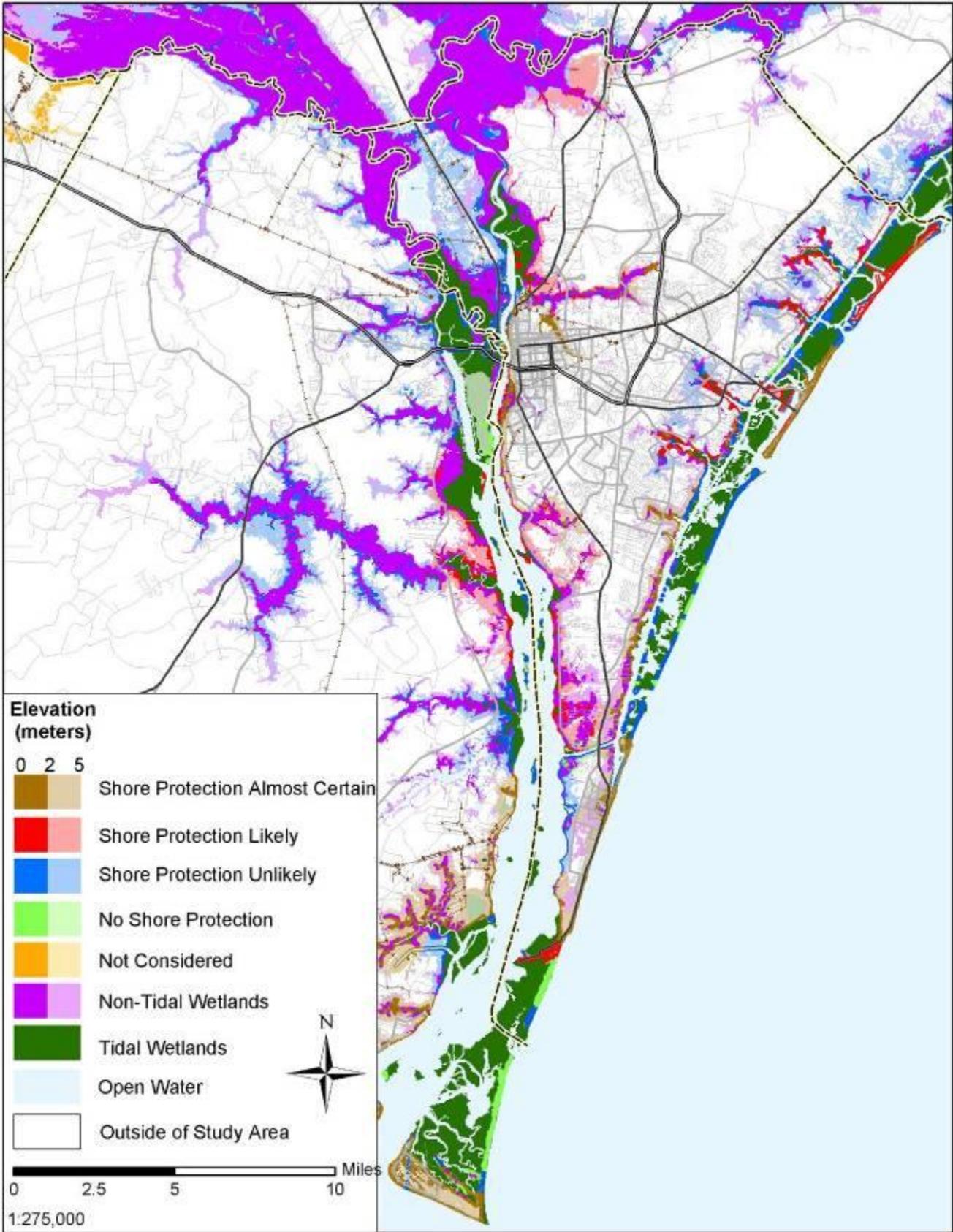
Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green.

Map 22 shows results for New Hanover County.



Map 9-22. New Hanover County (mainland and Ocracoke Island): Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

BRUNSWICK COUNTY

Land Use Plans on Sea Level Rise

Brunswick County updated its CAMA-mandated land use plan in 1997.¹⁵¹ According to the plan, the County supports current AEC use standards governing shoreline protection and management in the face of sea level rise. The County will not permit efforts to harden the shoreline in an attempt to counteract such conditions (sea level rise); however, this policy will not preclude the use of innovative shoreline preservation techniques as approved by the Coastal Resources Commission. (Note: Current AEC standards forbid hardening of the ocean shoreline but permit hardening of the estuarine shoreline.)

The City of Southport updated its CAMA-mandated land use plan in 1997. According to the plan, the city does support a review of all local building and land use related ordinances to establish setback standards, long-term land use plans, density controls, bulkhead restrictions, buffer vegetation requirements, and building designs that will facilitate the movement of structures. That being said, the policy states that the city supports bulkheading to protect its shoreline areas (estuarine) from intruding water resulting from rising sea level.

The Town of Yaupon Beach updated its CAMA-mandated land use plan in 1997. The text is the same as Southport's.

The Town of Ocean Isle Beach updated its CAMA-mandated land use plan in 1997. According to the plan, the town will respond to sea level rise by implementing the CAMA regulations applicable to development within areas of environmental concern. The town strongly supports beach renourishment as the appropriate means to minimize the impacts of beach erosion. In the absence of renourishment, the town's next policy of choice is the relocation of threatened structures. (The plan does not address the estuarine shoreline.)

The Town of Shallotte updated its CAMA-mandated land use plan in 1992. According to the plan, the town will restrict development in areas up to 5 feet above mean high water using existing CAMA, local, state, and federal regulations as applicable.

The Town of Sunset Beach updated its CAMA-mandated land use plan in 1997. According to the plan, the town defers primary response to sea level rise to CAMA regulations. The town does strongly support beach renourishment as the appropriate means to minimize the impacts of beach erosion. In the absence of renourishment, the town's next policy of choice is the relocation of threatened structures.

The Town of Calabash updated its CAMA-mandated land use plan in 1994. According to the plan, the town will consider state and federal policies before issuing statements regarding sea level rise.

Basis for these Maps

The following discussion and the Brunswick County map are based on discussions with:

Zoe Bruner, director of Planning and Inspections, Town of Wrightsville Beach and

¹⁵¹ A more recent version of the land use plan may now be available. To the extent that policies have changed, actual shore protection may deviate from the likelihoods depicted in this map.

former district planning manager for the Division of Coastal Management’s southern district; Alex Marks, former district planning manager, North Carolina Division of Coastal Management; Leslie Bell, planning director, Brunswick County

The map is based on the original stakeholder review draft. The county reviewer agreed with all determinations made therein.

Anticipated Response Scenarios

Protection Almost Certain

Areas in brown are those that will almost certainly be protected. These are areas that are privately owned with current development of where development is imminent. Although North Carolina does not allow hardening of the ocean shoreline, the state does employ beach renourishment. Consequently, we cannot assume retreat in areas where development is substantial. In fact, all the beach communities in Brunswick County support beach renourishment as their preferred option for dealing with sea level rise on the ocean side. Therefore, with the exception of Bird Island, all buildable land along oceanfront beach communities is almost certain to be protected.

The community of Bald Head Island sits on the southern end of Smith Island. This is a community of private homes with limited ferry connection to the mainland. There are no private vehicles (autos) on Bald Head and the ferry transports is for passengers only. Although nonresidents can visit the island, there is a fee for using the ferry system. Much of Bald Head is developed. New construction is ongoing within the East Beach and Middle Island portions of the island. Given the semi-private nature of Bald Head Island, funding for future beach renourishment “may” have to come from private sources. Portions of the island have a significant erosion problem. In fact, within the last 5 years, Bald Head Island was granted a variance from the state’s shoreline hardening policy allowing the installation of large sand tubes along a threatened portion of the resort. We assume that the developed portions of the island will be protected.

Much of the estuarine shoreline is developed and fortified. Consequently, these areas will almost certainly be protected.

On the west shore of the Cape Fear River, the Sunny Point Military Ocean Terminal and the large industrial facility there will be protected.

The Town of Southport is home to Carolina Power and Light’s Nuclear power generating facility. This facility has the only ocean discharge permit for the state—a permit to discharge hot water. This area will be protected.

Protection Likely

Areas where protection is likely are depicted in red. Within the county, lands developed in the future will likely be protected. Because most beach community land is already developed, however, only a few areas are expected to develop in the future.

A portion of Yaupon Beach will be further developed and hence protected.

Shoreline areas in the eastern portion of the county (landward of Long Beach) will continue to develop as the development pressure from Myrtle Beach and Wilmington spreads north and south.

Much of the west shore of the Cape Fear River will experience some growth in the foreseeable future.

Protection Unlikely

Areas where protection is legal, but considered unlikely because of the economic cost of armoring or nourishment, are depicted in blue. These areas are predominantly private lands that are not extensively developed or currently expected to develop.

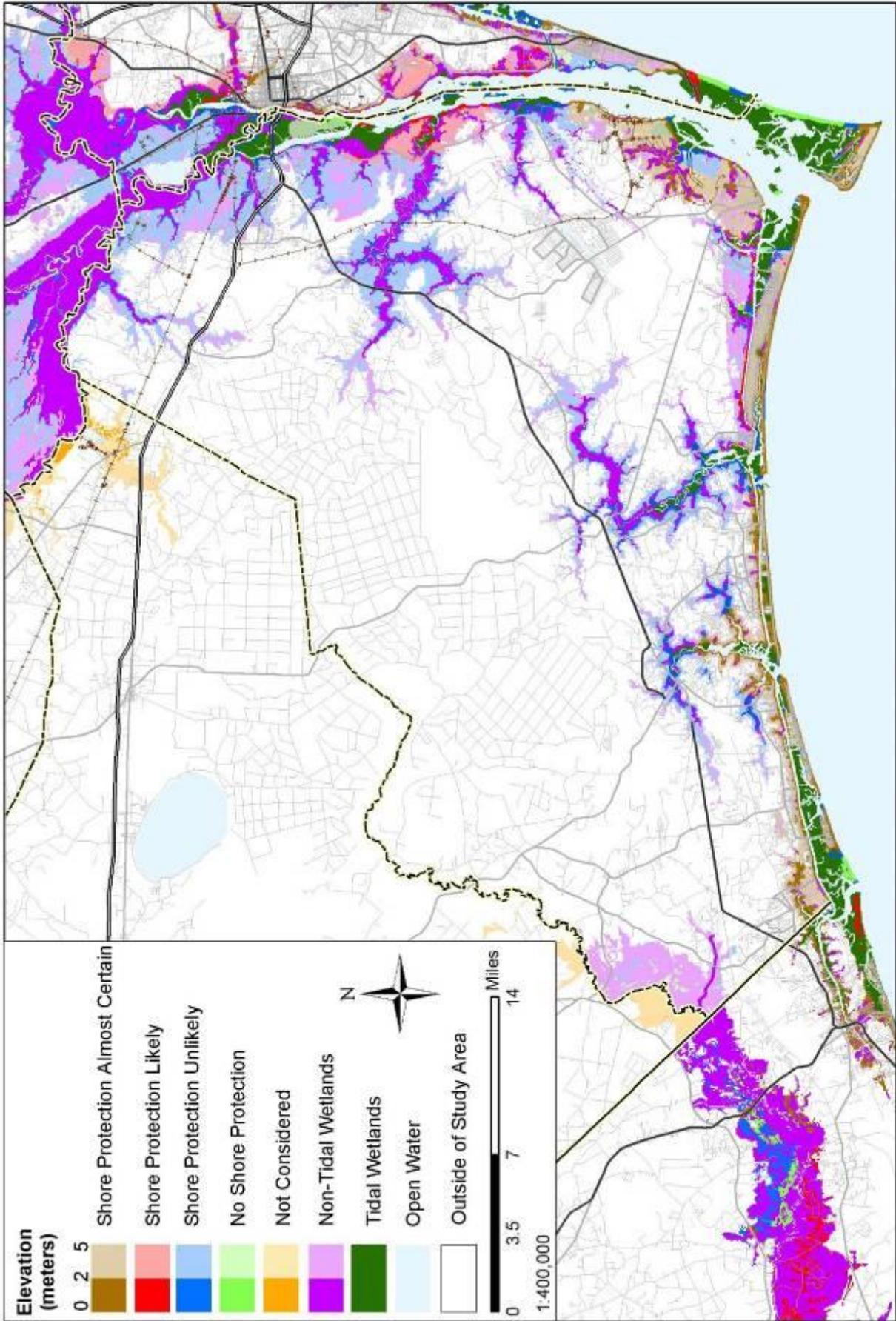
No Protection

Conservation lands that would not be protected as sea level rises are depicted in light green. Wetlands are depicted in dark green. The northern portion of Smith Island is publicly owned or under conservancy protection. The island has a very large complex of salt marsh. After the stakeholder review, Bird Island became a North Carolina Coastal Refuge, and

hence we have changed it from blue to green.¹⁵² Until recently, Bird Island was a privately owned island at the North Carolina/South Carolina border. Efforts had been under way for several years to acquire this undeveloped barrier island for preservation.

Map 23 shows results for Brunswick County.

¹⁵²See, e.g., *Coastlines* “Governor dedicates Bird Island as North Carolina coastal reserve.” Newsletter of the North Carolina Coastal Land Trust. (winter 2003) As of September 15, 2003, available at http://www.coastallandtrust.org/images/homepage/coastlines_winter_2003.pdf.



Map 9-23. Brunswick County: Likelihood of Shore Protection. For an explanation of the shading and symbols on this map, please see the caption that accompanies Map 9-2.

Appendix A

LENGTH OF SHORELINES BY LIKELIHOOD OF SHORE PROTECTION

Authors: John Herter and Daniel Hudgens

Table of Contents: List and description of tables included in this appendix

Table Name	Description	Table Number
Definitions: Water body categories used in this Appendix	Descriptions of the water body categories used in this Appendix.	A-1
Shoreline length by County	Total shoreline length for each county.	A-2
Shoreline length of primary water bodies	Shoreline length reported for Primary Water Bodies by Water Body Name.	A-3
Shoreline lengths for all bodies of water by county	Shoreline length reported by unique County, Water Body Category, and Water Body Name.	A-4
Military lands	Shoreline length reported by unique County, Water Body Category, and Water Body Name where the shoreline is located within a Military Facility.	A-5
Islands with roads	Shoreline length reported by unique County, Water Body Category, and Water Body Name where the shoreline is located on an island that contains roads.	A-6

Notes

This appendix estimates the lengths of tidal shoreline for each of the categories of shore protection likelihood. By “shoreline” we mean the land immediately adjacent to tidal open water or tidal wetlands. We provide several alternative summaries of our tidal shoreline estimates, including shoreline length by county, type of water body, and major body of water. For information on how we created, categorized, and measured the shoreline, see Annex 1 of this report.

Table A-1: Definitions: Water body categories used in this Appendix

Water Body Category¹	Description
Anthropogenic Shores	
Dredge and Fill	Shoreline characterized by multiple "finger" canals that run from the primary shoreline area inland and provide access to the water for the local community development.
Other/Road	A general term used for land that might not always be considered to be land. In particular, 1) dry land located at the base of causeways leading to barrier islands and 2) docks and piers that extend into the water are included in this category.
Shorelines Along Primary Water Bodies²	
Barrier/Bayside	The side of a barrier island (or spit) adjacent to the back barrier bay
Primary Sound	Shoreline located along a major sound such as Pamlico Sound or Albemarle Sound, except for those on the bay sides of a barrier island or spit.
Barrier Bay/Mainland	Mainland shore along a back-barrier bay. This includes all land immediately adjacent to the barrier bay absent any inflow from rivers, tributaries or creeks.
Primary River	The portion of a major river that flows either into the Atlantic Ocean or a Primary Sound where the river is wider than one kilometer. In this case, major rivers are subjectively determined but represent the most significant waterways in the region based on relative size (e.g., Neuse or Chowan River).
Barrier/Oceanside	The side of barrier islands adjacent to the Atlantic Ocean.
Ocean Front	Land located immediately adjacent to the Ocean. Excludes land located along a barrier island (which is characterized as Barrier/Oceanside).
Other Types of Shores	
Island	A piece of land completely surrounded by water except for a barrier island. Shores along Primary Water Bodies are not included in the "Island" category.
Secondary Sound	Shoreline located along a smaller sound or bay that is further sheltered from the wave action of a major sound or Ocean.
Secondary River	A river that is smaller in relative size than the major rivers identified as Primary River, or where the width of a major river falls below one kilometer.
Tributary ³	Small tributaries, creeks, and inlets flowing into a Primary Water Body. The water body name reflected in the GIS data is either the actual name of the tributary or the name of the water body into which the tributary flows.

Notes:

1. These categories reflect the order in which we assign shoreline categories. For example, "Barrier/Bayside" is above "Primary Sound" which is above "Island" in this table. Therefore, the portions of the Outer Banks along Albemarle Sound (a Primary Sound) are considered "Barrier/Bayside". The portion of Roanoke Island along Albemarle Sound is considered a "Primary Sound" shoreline; but the portion along Roanoke Sound (a Secondary Sound) is classified as "Island".
2. For the purpose of this study, "Primary Water Body" distinguishes larger water bodies less sheltered by land barriers and offering a more favorable environment for the promotion of wave action caused by wind.
3. When categorizing the shoreline, we identify "Unclassified Tributaries" where the water body name reflects the name of the water body into which the tributary flows. For the results presented in this appendix, we combine the "Unclassified Tributaries" within the "Tributary" category and aggregate the shoreline lengths.

County	Shoreline Length (Kilometers)						Totals
	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Beaufort	260	156	116	50	334	4	921
Bertie	11	4	190	2	318	12	537
Brunswick	368	27	199	53	224	0.4	871
Camden	65	4	158	0	0	0	227
Carteret	362	196	263	239	334	3	1396
Chowan	32	2	12	0.3	107	0	153
Craven	146	27	107	12	419	1	713
Currituck	90	11	398	26	75	0	600
Dare	316	173	40	209	441	0	1179
Gates	0	0	41	8	119	0	168
Hertford	1	0	80	0.6	111	2	195
Hyde	50	37	198	43	561	0	890
Martin	4	0	24	0	45	0	74
New Hanover	83	117	165	16	131	0.1	512
Onslow	155	323	102	21	223	<0.1	825
Pamlico	213	119	212	0.3	351	0	895
Pasquotank	47	9	74	0	39	0	169
Pender	60	9	251	36	326	1	683
Perquimans	47	15	20	0	153	0	234
Tyrell	18	1	13	0.6	304	0	336
Washington	20	12	0	<0.1	86	0	118
Totals	2346	1243	2663	716	4701	24	11695

* Excludes Bladen, Columbus, Duplin, Jones, Lenoir, Northampton, Pitt, and Sampson Counties.

Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Out of Study Area	
Barrier Bay/Mainland	Albemarle Sound	3	1	0	3	16	0	23
Primary Sound	Albemarle Sound	49	3	29	0	66	0	148
Primary River	Alligator River	0.7	0	<0.1	<0.1	104	0	105
Barrier/Oceanside	Atlantic Ocean	181	85	41	170	<0.1	0	477
Ocean Front	Atlantic Ocean	8	0	0	0	0	0	8
Barrier Bay/Mainland	Back Sound	11	0	0	0	0.1	0	11
Barrier/Bayside	Back Sound	0	0	0	26	<0.1	0	26
Barrier Bay/Mainland	Bogue Sound	15	21	1	0	3	0	41
Barrier/Bayside	Bogue Sound	40	0	0.3	1	1	0	44
Barrier Bay/Mainland	Cape Fear River	6	0	3	0	0.5	0	9
Barrier/Bayside	Cape Fear River	5	1	2	12	0.2	0	20
Primary River	Cape Fear River	13	17	20	<0.1	25	0	75
Primary River	Chowan River	18	1	14	0	38	5	76
Barrier Bay/Mainland	Core Sound	12	0.4	21	3	7	0	44
Barrier/Bayside	Core Sound	0	0	0	33	0	0	33
Barrier Bay/Mainland	Currituck Sound	18	5	64	0.6	1	0	89
Barrier/Bayside	Currituck Sound	20	0.8	5	2	34	0	63
Barrier Bay/Mainland	Intracoastal Waterway	57	37	32	0.3	20	0	147
Barrier/Bayside	Intracoastal Waterway	81	31	42	14	3	0	170
Barrier/Bayside	Kitty Hawk Bay	6	0.1	0.4	0.2	2	0	8
Primary River	Little River	7	3	2	0	15	0	26
Primary River	Neuse River	57	17	16	3	36	0	128
Primary River	North River	4	0.7	51	0	0	0	56
Primary River	Pamlico River	51	25	8	6	21	0	111
Barrier Bay/Mainland	Pamlico Sound	8	1	16	0.7	156	0	181
Barrier/Bayside	Pamlico Sound	28	58	1	48	4	0	139
Primary Sound	Pamlico Sound	0.2	3	2	0	0	0	6
Primary River	Pasquotank River	31	5	16	0	0	0	51
Primary River	Perquimans River	14	10	0.3	0	31	0	56
Barrier/Bayside	Roanoke Sound	9	3	<0.1	14	6	0	32
Totals		753	330	388	337	590	5	2403

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Beaufort	Secondary River	Goose Creek	13	6	13	32	4	4	72
Beaufort	Dredge and Fill	Pamlico River	0.3	0	0	0	0	0	0.3
Beaufort	Island	Pamlico River	0	0.5	0	0	1	0	2
Beaufort	Other	Pamlico River	0	2	0	0	0	0	2
Beaufort	Primary River	Pamlico River	51	25	4	6	13	0	98
Beaufort	Secondary River	Pamlico River	3	0	0	0	8	0	12
Beaufort	Tributary	Pamlico River	92	45	32	12	144	0	325
Beaufort	Secondary River	Pungo River	58	67	33	0	153	0	311
Beaufort	Secondary River	South Creek	43	10	35	0	11	0	99
Bertie	Primary Sound	Albemarle Sound	0.4	0	5	0	4	0	9
Bertie	Primary River	Chowan River	6	1	12	0	7	5	31
Bertie	Tributary	Chowan River	0	0	13	0	19	0	32
Bertie	Secondary River	Roanoke River	5	3	160	2	288	6	465
Brunswick	Barrier/Oceanside	Atlantic Ocean	55	0	2	8	0	0	65
Brunswick	Barrier Bay/Mainland	Cape Fear River	6	0	3	0	0.5	0	9
Brunswick	Barrier/Bayside	Cape Fear River	5	0	0.6	9	0.2	0	15
Brunswick	Island	Cape Fear River	0.3	1	22	6	3	0	33
Brunswick	Other	Cape Fear River	0	0	0	0.4	0	0	0.4
Brunswick	Primary River	Cape Fear River	7	4	11	<0.1	13	0	35
Brunswick	Secondary River	Cape Fear River	0	0	9	5	12	0.2	27
Brunswick	Tributary	Cape Fear River	59	7	50	3	102	0	221
Brunswick	Barrier Bay/Mainland	Intracoastal Waterway	35	9	1	0.3	5	0	50
Brunswick	Barrier/Bayside	Intracoastal Waterway	52	0	8	4	2	0	66
Brunswick	Dredge and Fill	Intracoastal Waterway	43	0.2	<0.1	0	<0.1	0	43
Brunswick	Island	Intracoastal Waterway	10	0.4	7	1	0.2	0	19
Brunswick	Other	Intracoastal Waterway	2	0	1	2	0	0	5
Brunswick	Tributary	Intracoastal Waterway	49	5	6	3	17	0	80
Brunswick	Tributary	Little River	0	0	0.4	11	31	0.2	43
Brunswick	Island	Mullet Creek	0.3	0	0.8	0	0	0	1
Brunswick	Secondary River	Mullet Creek	4	0	43	0	30	0	77
Brunswick	Island	Shalotte River	0	0	0	0	<0.1	0	<0.1
Brunswick	Secondary River	Shalotte River	41	0	34	0	8	0	83
Camden	Dredge and Fill	Albemarle Sound	4	0	6	0	0	0	10
Camden	Primary Sound	Albemarle Sound	2	0	8	0	0	0	9
Camden	Island	North River	0	0	1	0	0	0	1
Camden	Primary River	North River	0	0	19	0	0	0	19
Camden	Secondary River	North River	0	0	26	0	0	0	26
Camden	Tributary	North River	0	0	35	0	0	0	35

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Camden	Primary River	Pasquotank River	15	3	10	0	0	0	28
Camden	Secondary River	Pasquotank River	34	0.5	40	0	0	0	75
Camden	Tributary	Pasquotank River	9	0	13	0	0	0	22
Carteret	Barrier/Oceanside	Atlantic Ocean	40	0	0.4	69	0	0	110
Carteret	Island	Atlantic Ocean	0	0	0	3	0	0	3
Carteret	Tributary	Atlantic Ocean	26	2	63	0.1	28	0	120
Carteret	Barrier Bay/Mainland	Back Sound	11	0	0	0	0.1	0	11
Carteret	Barrier/Bayside	Back Sound	0	0	0	26	<0.1	0	26
Carteret	Dredge and Fill	Back Sound	0.7	0	0	0	0	0	0.7
Carteret	Island	Back Sound	0	0	0	3	0	0	3
Carteret	Other	Back Sound	0	0	0	3	0	0	3
Carteret	Tributary	Back Sound	0	0	0	18	0.9	0	19
Carteret	Barrier Bay/Mainland	Bogue Sound	15	21	1	0	3	0	41
Carteret	Barrier/Bayside	Bogue Sound	40	0	0.3	1	1	0	44
Carteret	Dredge and Fill	Bogue Sound	24	0	0	0	0.2	0	24
Carteret	Island	Bogue Sound	0.2	0	8	2	0	0	10
Carteret	Other	Bogue Sound	0.7	0	3	0	0.2	0	4
Carteret	Tributary	Bogue Sound	32	27	1	4	15	0	79
Carteret	Barrier Bay/Mainland	Core Sound	12	0.4	21	3	7	0	44
Carteret	Barrier/Bayside	Core Sound	0	0	0	33	0	0	33
Carteret	Island	Core Sound	0	0	0	6	1	0	7
Carteret	Tributary	Core Sound	0	0	0	2	0	0	2
Carteret	Island	Nelson Bay	0	0	0	0	1	0	1
Carteret	Secondary Bay	Nelson Bay	8	0.3	1	0	2	0	12
Carteret	Primary River	Neuse River	0	8	2	0	1	0	12
Carteret	Island	Newport River	7	0.5	4	0	3	0	16
Carteret	Secondary River	Newport River	48	28	57	6	54	0	193
Carteret	Island	North River	4	2	1	0	3	0	11
Carteret	Secondary River	North River	25	6	38	0	37	0	106
Carteret	Barrier/Bayside	Pamlico Sound	0	0	1	19	<0.1	0	20
Carteret	Island	Pamlico Sound	0	0.5	14	29	6	0	49
Carteret	Other	Pamlico Sound	18	0	0	0	3	0	20
Carteret	Tributary	Pamlico Sound	2	79	19	3	110	0	214
Carteret	Dredge and Fill	The Straits	3	0	0	0	0	0	3
Carteret	Island	The Straits	17	0	0	0	0.3	0	17
Carteret	Secondary River	The Straits	4	0	0.6	0	0.1	0	5
Carteret	Secondary Bay	Thorofare Bay	0	0	0.7	0	4	0	5
Carteret	Secondary Bay	Turnagain Bay	0	0.8	0	0	11	0	12
Carteret	Secondary Bay	West Bay	0	3	0	1	26	0	30
Carteret	Island	Whiteoak River	0.2	2	0	1	0.9	0	4
Carteret	Secondary River	Whiteoak River	22	14	24	5	14	3	83
Chowan	Primary Sound	Albemarle Sound	11	2	3	0	13	0	29

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Chowan	Tributary	Albemarle Sound	5	0	3	0	32	0	41
Chowan	Primary River	Chowan River	12	0	1	0	24	0	37
Chowan	Tributary	Chowan River	4	0	4	0.3	38	0	46
Craven	Island	Neuse River	2	1	0	0	0.7	0	4
Craven	Primary River	Neuse River	34	5	7	3	19	0	68
Craven	Secondary River	Neuse River	11	0.4	11	0	281	1	304
Craven	Tributary	Neuse River	96	20	64	9	108	0	297
Craven	Secondary River	Newport River	2	0	2	0	0.7	0	5
Craven	Tributary	Pamlico Sound	2	0	23	0	10	0	35
Currituck	Island	Albemarle Sound	0	0	0.4	0	0	0	0.4
Currituck	Other	Albemarle Sound	4	0.2	4	0	0	0	9
Currituck	Primary Sound	Albemarle Sound	3	0	4	0	0	0	7
Currituck	Tributary	Albemarle Sound	0	0	8	0	0	0	8
Currituck	Barrier/Oceanside	Atlantic Ocean	15	2	16	4	0	0	37
Currituck	Barrier Bay/Mainland	Currituck Sound	18	5	64	0.6	1	0	89
Currituck	Barrier/Bayside	Currituck Sound	3	0	5	1	31	0	42
Currituck	Dredge and Fill	Currituck Sound	9	0	22	0	0.2	0	31
Currituck	Island	Currituck Sound	25	2	52	12	32	0	122
Currituck	Other	Currituck Sound	6	0	0.7	7	2	0	15
Currituck	Tributary	Currituck Sound	3	1	118	2	8	0	132
Currituck	Island	North River	0	0	6	0	0	0	6
Currituck	Primary River	North River	4	0.7	32	0	0	0	36
Currituck	Secondary River	North River	0	0	36	0	0	0	36
Currituck	Tributary	North River	0	0	28	0	0	0	28
Dare	Barrier Bay/Mainland	Albemarle Sound	3	1	0	3	16	0	23
Dare	Dredge and Fill	Albemarle Sound	17	2	0	0	<0.1	0	20
Dare	Island	Albemarle Sound	12	11	2	5	38	0	67
Dare	Other	Albemarle Sound	3	0.8	0.2	0.1	4	0	9
Dare	Primary Sound	Albemarle Sound	4	0	0	0	0.5	0	5
Dare	Tributary	Albemarle Sound	0.6	0	0	2	4	0	6
Dare	Primary River	Alligator River	<0.1	0	0	<0.1	43	0	43
Dare	Tributary	Alligator River	0	<0.1	0	10	30	0	40
Dare	Barrier/Oceanside	Atlantic Ocean	38	40	0.3	59	0	0	138
Dare	Island	Atlantic Ocean	0	0	0	0.2	0	0	0.2
Dare	Tributary	Atlantic Ocean	0	0	0	6	0	0	6
Dare	Island	Croatan Sound	12	11	9	0.8	14	0	46
Dare	Secondary Bay	Croatan Sound	2	0.8	0	0	32	0	35
Dare	Barrier/Bayside	Currituck Sound	17	0.8	<0.1	0.4	3	0	21
Dare	Tributary	Currituck Sound	13	<0.1	0.2	0	3	0	16
Dare	Other	East Lake	0	0	0	0.1	25	0	25
Dare	Barrier/Bayside	Kitty Hawk Bay	6	0.1	0.4	0.2	2	0	8
Dare	Dredge and Fill	Kitty Hawk Bay	1	0.3	0	0	0	0	1

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Dare	Island	Kitty Hawk Bay	6	2	<0.1	0	4	0	13
Dare	Other	Kitty Hawk Bay	1	1	0	0	<0.1	0	2
Dare	Tributary	Kitty Hawk Bay	20	2	3	6	13	0	44
Dare	Barrier Bay/Mainland	Pamlico Sound	5	1	0.2	0.6	52	0	60
Dare	Barrier/Bayside	Pamlico Sound	28	38	0.2	21	2	0	89
Dare	Dredge and Fill	Pamlico Sound	7	0	0	0	0.2	0	7
Dare	Island	Pamlico Sound	6	5	5	12	6	0	34
Dare	Other	Pamlico Sound	3	0.2	0	0	0	0	4
Dare	Primary Sound	Pamlico Sound	0.2	3	2	0	0	0	6
Dare	Tributary	Pamlico Sound	62	24	0.6	14	75	0	175
Dare	Barrier/Bayside	Roanoke Sound	9	3	<0.1	14	6	0	32
Dare	Dredge and Fill	Roanoke Sound	7	0.5	0.2	0	0	0	8
Dare	Island	Roanoke Sound	18	14	15	9	6	0	62
Dare	Other	Roanoke Sound	9	3	1	0	0	0	13
Dare	Tributary	Roanoke Sound	5	7	0	45	2	0	60
Dare	Other	South Lake	0	0	0	0	61	0	61
Gates	Primary River	Chowan River	0	0	0.3	0	0.6	0	0.9
Gates	Secondary River	Chowan River	0	0	31	3	69	0	103
Gates	Tributary	Chowan River	0	0	10	5	49	0	64
Hertford	Primary River	Chowan River	0	0	1	0	6	0	7
Hertford	Secondary River	Chowan River	1	0	78	0.6	100	2	183
Hertford	Tributary	Chowan River	0	0	1	0	5	0	5
Hyde	Primary River	Alligator River	0	0	0	0	15	0	15
Hyde	Secondary River	Alligator River	0	0	3	0	17	0	19
Hyde	Barrier/Oceanside	Atlantic Ocean	0	7	0	18	0	0	24
Hyde	Barrier Bay/Mainland	Pamlico Sound	2	0	14	0.1	91	0	107
Hyde	Barrier/Bayside	Pamlico Sound	0	20	0	9	1	0	30
Hyde	Island	Pamlico Sound	3	0.4	0.5	9	23	0	37
Hyde	Other	Pamlico Sound	12	5	8	5	0.4	0	30
Hyde	Tributary	Pamlico Sound	12	3	32	2	203	0	253
Hyde	Secondary River	Pungo River	20	2	141	0.9	211	0	376
Martin	Secondary River	Roanoke River	4	0	24	0	45	0	74
New Hanover	Barrier/Oceanside	Atlantic Ocean	9	7	14	6	0	0	37
New Hanover	Ocean Front	Atlantic Ocean	8	0	0	0	0	0	8
New Hanover	Barrier/Bayside	Cape Fear River	0	1	1	3	0	0	5
New Hanover	Island	Cape Fear River	2	3	10	0.3	4	0	19
New Hanover	Other	Cape Fear River	0	6	1	0	0.2	0	8
New Hanover	Primary River	Cape Fear River	6	12	9	<0.1	12	0	40
New Hanover	Secondary River	Cape Fear River	11	8	42	0	69	0	129
New Hanover	Tributary	Cape Fear River	0.4	11	5	0.5	27	0.1	44
New Hanover	Barrier Bay/Mainland	Intracoastal Waterway	12	11	10	<0.1	1	0	34
New Hanover	Barrier/Bayside	Intracoastal Waterway	7	6	16	4	0	0	34

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
New Hanover	Dredge and Fill	Intracoastal Waterway	1	2	2	0	<0.1	0	4
New Hanover	Island	Intracoastal Waterway	0.5	6	35	1	0.7	0	43
New Hanover	Other	Intracoastal Waterway	2	5	3	1	0.5	0	12
New Hanover	Tributary	Intracoastal Waterway	24	38	16	0.2	17	0	95
Onslow	Barrier/Oceanside	Atlantic Ocean	7	29	1	6	0	0	43
Onslow	Island	Atlantic Ocean	0	0	0.2	0	0	0	0.2
Onslow	Island	Bell Swamp Creek	0	0.4	0	0	2	0	3
Onslow	Secondary River	Bell Swamp Creek	10	27	0.5	0	10	0	48
Onslow	Island	Bogue Sound	0	0	0	0.4	0	0	0.4
Onslow	Tributary	Bogue Sound	0	0	0	2	0	0	2
Onslow	Barrier Bay/Mainland	Intracoastal Waterway	8	15	3	0	12	0	38
Onslow	Barrier/Bayside	Intracoastal Waterway	5	25	9	6	0.8	0	45
Onslow	Dredge and Fill	Intracoastal Waterway	11	<0.1	8	0	0	0	19
Onslow	Island	Intracoastal Waterway	2	18	15	5	4	0	44
Onslow	Other	Intracoastal Waterway	1	4	2	0	0.3	0	7
Onslow	Tributary	Intracoastal Waterway	6	59	20	0	22	0	107
Onslow	Secondary River	New River	75	145	20	2	147	<0.1	389
Onslow	Secondary River	Whiteoak River	30	0	26	0	24	0	80
Pamlico	Secondary River	Bay River	72	72	39	0	81	0	265
Pamlico	Island	Goose Creek	0	0	3	0	0	0	3
Pamlico	Secondary River	Goose Creek	0.7	0	15	0	56	0	71
Pamlico	Tributary	Goose Creek	0	0	0	0	0.6	0	0.6
Pamlico	Island	Neuse River	0	1	0	0	3	0	4
Pamlico	Primary River	Neuse River	23	3	6	0	15	0	48
Pamlico	Tributary	Neuse River	18	4	56	0	53	0	130
Pamlico	Island	Pamlico River	0	0	0	0	<0.1	0	<0.1
Pamlico	Primary River	Pamlico River	0	0	4	0	8	0	12
Pamlico	Tributary	Pamlico River	0	0	8	0	8	0	16
Pamlico	Barrier Bay/Mainland	Pamlico Sound	0	0	2	0	13	0	15
Pamlico	Island	Pamlico Sound	0	0	7	0	7	0	15
Pamlico	Tributary	Pamlico Sound	100	38	73	0.3	105	0	316
Pasquotank	Primary Sound	Albemarle Sound	1	0.2	8	0	0.2	0	9
Pasquotank	Tributary	Albemarle Sound	2	0	28	0	3	0	33
Pasquotank	Dredge and Fill	Little River	1	0	0	0	1	0	2
Pasquotank	Primary River	Little River	4	1	2	0	7	0	14
Pasquotank	Secondary River	Little River	4	0	1	0	21	0	26
Pasquotank	Tributary	Little River	2	0	1	0	7	0	11
Pasquotank	Dredge and Fill	Pasquotank River	5	3	0	0	0	0	7
Pasquotank	Primary River	Pasquotank River	15	2	6	0	0	0	23
Pasquotank	Secondary River	Pasquotank River	7	0	0.7	0	0	0	8
Pasquotank	Tributary	Pasquotank River	5	3	27	0	0	0	36
Pender	Barrier/Oceanside	Atlantic Ocean	17	0	7	0	<0.1	0	23

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)						Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Outside Study Area	
Pender	Island	Atlantic Ocean	0	0	0.2	0	0	0	0.2
Pender	Secondary River	Cape Fear River	0	0	147	36	310	1	495
Pender	Barrier Bay/Mainland	Intracoastal Waterway	2	3	19	0	2	0	25
Pender	Barrier/Bayside	Intracoastal Waterway	17	0	9	0	0.4	0	26
Pender	Dredge and Fill	Intracoastal Waterway	5	0	1	0	0	0	6
Pender	Island	Intracoastal Waterway	13	0.6	10	0	0.2	0	24
Pender	Other	Intracoastal Waterway	1	0	0.7	0	0	0	2
Pender	Tributary	Intracoastal Waterway	5	6	57	0	13	0	81
Perquimans	Primary Sound	Albemarle Sound	8	1	1	0	3	0	14
Perquimans	Tributary	Albemarle Sound	15	<0.1	2	0	29	0	46
Perquimans	Primary River	Little River	2	2	0.2	0	8	0	12
Perquimans	Secondary River	Little River	2	1	1	0	16	0	20
Perquimans	Tributary	Little River	0.5	0	<0.1	0	<0.1	0	0.7
Perquimans	Primary River	Perquimans River	14	10	0.3	0	31	0	56
Perquimans	Secondary River	Perquimans River	5	<0.1	14	0	59	0	78
Perquimans	Tributary	Perquimans River	<0.1	0	1	0	7	0	8
Tyrell	Primary Sound	Albemarle Sound	6	0	0.4	0	25	0	32
Tyrell	Tributary	Albemarle Sound	10	0.3	10	0.6	49	0	70
Tyrell	Tributary	Alligator Creek	0.2	0.6	0.4	0	42	0	44
Tyrell	Primary River	Alligator River	0.6	0	<0.1	0	47	0	47
Tyrell	Secondary River	Alligator River	2	0	2	0	93	0	97
Tyrell	Tributary	Alligator River	0	0	0	0	47	0	47
Washington	Primary Sound	Albemarle Sound	13	0	0	0	21	0	34
Washington	Tributary	Albemarle Sound	5	7	0	<0.1	49	0	61
Washington	Secondary River	Roanoke River	2	5	0	0	16	0	23
Totals			2346	1243	2663	716	4701	24	11695

* Excludes Bladen, Columbus, Duplin, Jones, Lenoir, Northampton, Pitt, and Sampson Counties.

Table A-5: Military lands						
County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)			
			Shore Protection Certain	Shore Protection Unspecified ¹	Non-Tidal Wetlands	Totals
Carteret	Barrier Bay/Mainland	Bogue Sound	0.9	3	2	5
Carteret	Tributary	Bogue Sound	5	7	2	14
Dare	Tributary	Pamlico Sound	0	0.7	8	9
Onslow	Barrier Bay/Mainland	Intracoastal Waterway	0	5	8	13
Onslow	Barrier/Bayside	Intracoastal Waterway	0	18	0.7	18
Onslow	Barrier/Oceanside	Atlantic Ocean	0	18	0	18
Onslow	Island	Intracoastal Waterway	0	12	3	15
Onslow	Other	Intracoastal Waterway	0	1	0	1
Onslow	Secondary River	New River	0.5	131	95	227
Onslow	Tributary	Intracoastal Waterway	0	15	13	28
Perquimans	Primary River	Perquimans River	4	0	1	5
Perquimans	Primary Sound	Albemarle Sound	4	0	0.7	5
Totals			14	211	134	359
<p>Note:</p> <p>1. The general approach of this study was to not speculate on the intentions of the military, but to avoid an excessive number of map colors. The protection response maps depict unclassified military lands in red, however, the protection response for the shoreline was classified as "Unspecified". Military lands in urban areas were classified as shore protection certain in those cases where county officials indicated that the land would be developed and protected even if the installation were to close.</p>						

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					Totals
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	
Brunswick	Barrier/Bayside	Cape Fear River	5	0	0.6	9	0.2	15
Brunswick	Barrier/Oceanside	Atlantic Ocean	8	0	1	6	0	15
Brunswick	Island	Cape Fear River	0	0	0.5	0.3	<0.1	0.8
Brunswick	Other	Cape Fear River	0	0	0	0.4	0	0.4
Brunswick	Tributary	Cape Fear River	9	0	1	3	0.9	14
Carteret	Barrier Bay/Mainland	Back Sound	6	0	0	0	0.1	6
Carteret	Barrier Bay/Mainland	Core Sound	6	0	6	3	5	20
Carteret	Dredge and Fill	The Straits	3	0	0	0	0	3
Carteret	Island	Newport River	7	0	4	0	0	11
Carteret	Island	North River	4	0	<0.1	0	0.8	5
Carteret	Island	Pamlico Sound	0	0	10	0	0	10
Carteret	Island	The Straits	16	0	0	0	0.3	16
Carteret	Secondary Bay	West Bay	0	0	0	1	7	8
Carteret	Tributary	Atlantic Ocean	4	0	16	0	2	22
Carteret	Tributary	Pamlico Sound	<0.1	0	2	0.7	9	12
Currituck	Dredge and Fill	Currituck Sound	6	0	0.7	0	0	7
Currituck	Island	Currituck Sound	25	2	27	5	27	86
Currituck	Other	Currituck Sound	0	0	0	7	2	9
Dare	Dredge and Fill	Roanoke Sound	3	0.3	0.2	0	0	3
Dare	Island	Croatan Sound	11	10	9	0.2	7	37
Dare	Island	Roanoke Sound	17	8	9	4	6	44
Dare	Other	Roanoke Sound	7	1	1	0	0	10
Dare	Primary Sound	Albemarle Sound	4	0	0	0	0.5	5
Dare	Primary Sound	Pamlico Sound	0.2	3	2	0	0	6
New Hanover	Island	Intracoastal Waterway	0.1	5	4	0	0	9
Pamlico	Barrier Bay/Mainland	Pamlico Sound	0	0	0	0	9	9
Pamlico	Primary River	Pamlico River	0	0	4	0	8	11
Pamlico	Secondary River	Goose Creek	<0.1	0	12	0	54	65
Pamlico	Tributary	Goose Creek	0	0	0	0	0.6	0.6
Pamlico	Tributary	Pamlico River	0	0	7	0	5	12
Pamlico	Tributary	Pamlico Sound	0.9	0	0.9	0	25	26
Totals			142	30	119	40	168	500

Appendix B

AREA OF LAND BY SHORE PROTECTION LIKELIHOOD

Authors: James G. Titus, Russ Jones, and Richard Streeter

The following tables were created by overlaying the shore protection planning maps developed in this report, with EPA's 30-meter digital elevation data set.

The EPA data set used the North Carolina Department of Environment and Natural Resources wetlands data to distinguish dry land, nontidal wetlands, tidal wetlands, and open water. See Appendix 2 of this report for additional details on how these tables were created.

The LIDAR data used to estimate these elevations has a root mean square error of approximately 20-25 cm, with the exception of Gates (32.3 cm) and Hertford (33.7 cm). (See e.g. North Carolina Cooperating Technical State Flood Mapping Program, 2001, LIDAR Accuracy Assessment Report—Hyde County.) In many cases, the standard is based on the RMS error for the best 95% of points, but the actual RMS error may be 50-100% greater. Therefore most of these negative elevations represent land that is slightly above spring high water, but negative measurement error resulted in an estimated elevation lower than SHW. In some cases, the negative elevations may represent over-estimates of the elevation of SHW or lands that are truly above the level of the tides but classified as dry land due to flood control structures or land use normally associated with dry land in spite of periodic flooding.

Table B-1. Area of Land by Shore Protection Likelihood

North Carolina (jurisdictions within the study area only)

Elevation above Spring High Water (m)		Area (square kilometers)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	2.8	0.5	1.8	0.5	0.3	5.9	0.5	6.5
-1.0	-0.5	2.2	1.0	11.3	1.5	1.2	17.1	11.2	28.4
-0.5	0.0	27.4	11.9	96.0	6.5	3.5	145.3	606.0	751.3
0.0	0.5	145.4	58.5	343.0	19.5	4.1	570.5	1723.6	2294.1
0.5	1.0	196.7	120.3	289.8	12.6	4.1	623.5	708.3	1331.8
1.0	1.5	138.1	131.6	291.9	12.1	4.2	577.9	384.4	962.3
1.5	2.0	140.9	132.8	343.4	11.4	3.4	631.9	309.1	941.0
2.0	2.5	136.2	117.4	353.8	15.5	2.6	625.5	281.5	907.0
2.5	3.0	98.9	60.7	383.5	16.6	2.9	562.6	243.6	806.2
3.0	3.5	91.6	72.4	429.8	8.0	3.7	605.5	214.8	820.3
3.5	4.0	83.8	79.5	523.7	4.9	5.5	697.5	216.9	914.4
4.0	4.5	68.9	49.8	414.2	4.0	7.1	544.0	199.4	743.4
4.5	5.0	50.7	36.1	282.4	3.6	8.8	381.7	208.2	589.9
5.0	5.5	34.4	21.9	191.7	3.0	11.2	262.2	141.7	403.9
5.5	6.0	18.8	10.5	72.3	1.8	10.2	113.5	44.6	158.0

1008

Beaufort

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	216	0	53	0	3	272	29	301
-1.0	-0.5	4	1	4	1	1	11	12	23
-0.5	0.0	164	62	357	41	10	633	1539	2173
0.0	0.5	1310	793	1448	552	18	4121	5216	9337
0.5	1.0	2571	835	2422	254	16	6099	4090	10189
1.0	1.5	2422	610	3507	73	9	6620	3234	9855
1.5	2.0	2972	380	4781	49	5	8187	3236	11423
2.0	2.5	3381	353	4713	21	5	8473	4458	12932
2.5	3.0	2491	186	5391	14	7	8088	3704	11792
3.0	3.5	2147	150	6015	11	11	8335	2420	10755
3.5	4.0	2124	174	7341	7	20	9666	1641	11307
4.0	4.5	1935	106	4801	7	36	6886	1528	8414
4.5	5.0	1368	56	3391	7	55	4878	1270	6148
5.0	5.5	680	38	1604	6	100	2428	791	3218
5.5	6.0	214	31	316	4	109	673	207	880

Bertie

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
-1.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
-0.5	0.0	2.8	0.0	9.2	0.0	0.4	12.3	5156.1	5168.4
0.0	0.5	6.4	0.0	157.8	0.0	0.8	165.0	5887.4	6052.4
0.5	1.0	6.5	0.4	283.8	0.0	0.9	291.5	1683.3	1974.8
1.0	1.5	7.5	0.4	341.6	0.2	0.5	350.1	831.9	1182.0
1.5	2.0	7.3	0.5	382.5	1.8	0.6	392.8	1126.3	1519.0
2.0	2.5	12.7	0.5	461.2	2.2	0.7	477.2	1162.9	1640.1
2.5	3.0	12.8	0.5	489.6	33.0	1.2	537.1	1255.1	1792.2
3.0	3.5	13.2	0.6	553.6	50.6	0.6	618.7	981.6	1600.3
3.5	4.0	9.8	0.5	664.6	11.9	1.1	687.9	969.4	1657.3
4.0	4.5	10.5	0.7	871.0	14.4	1.2	897.8	1728.2	2626.0
4.5	5.0	9.1	0.4	1167.8	37.2	2.5	1217.0	1726.9	2943.9
5.0	5.5	10.4	0.4	1331.0	24.8	3.8	1370.4	1290.3	2660.8
5.5	6.0	12.5	0.8	1222.7	1.6	4.0	1241.6	675.9	1917.5

Brunswick

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	30	3	6	16	9	63	2	66
-1.0	-0.5	71	9	41	15	19	155	607	761
-0.5	0.0	153	24	173	27	28	405	1548	1953
0.0	0.5	234	46	316	37	22	655	1697	2351
0.5	1.0	456	40	366	21	15	898	873	1771
1.0	1.5	576	46	459	27	10	1118	740	1858
1.5	2.0	512	65	567	19	5	1168	613	1781
2.0	2.5	451	87	670	17	4	1230	627	1857
2.5	3.0	437	102	790	13	3	1345	619	1964
3.0	3.5	467	92	911	11	5	1487	567	2054
3.5	4.0	502	88	1046	8	6	1650	589	2239
4.0	4.5	523	94	1155	10	7	1789	501	2289
4.5	5.0	537	81	1088	11	11	1727	482	2209
5.0	5.5	483	70	804	10	12	1378	496	1874
5.5	6.0	409	43	567	9	14	1042	311	1353

Camden

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	2	0	0	2	0	2
-1.0	-0.5	2	0	1	0	0	3	4	7
-0.5	0.0	32	31	139	0	1	204	6166	6370
0.0	0.5	278	125	1068	0	0	1470	8080	9551
0.5	1.0	351	137	643	0	0	1131	746	1877
1.0	1.5	1135	840	3027	0	0	5003	1063	6066
1.5	2.0	904	614	2385	0	0	3903	761	4665
2.0	2.5	711	877	3063	0	0	4651	1020	5671
2.5	3.0	296	947	4038	0	0	5281	1178	6460
3.0	3.5	119	315	2211	0	0	2645	716	3361
3.5	4.0	60	542	1708	1	0	2313	739	3052
4.0	4.5	282	1215	2080	7	0	3584	1254	4839
4.5	5.0	127	532	1564	5	0	2228	3008	5236
5.0	5.5	14	138	1659	6	0	1817	1502	3319
5.5	6.0	0	0	326	0	4	330	389	720

1010

Carteret

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	2	1	5	17	3	28	0	28
-1.0	-0.5	16	4	57	76	18	170	17	187
-0.5	0.0	250	138	839	270	113	1610	527	2137
0.0	0.5	735	759	1465	220	131	3310	2888	6198
0.5	1.0	1204	3346	1889	390	151	6980	5302	12282
1.0	1.5	1232	4897	2340	437	95	9002	4812	13814
1.5	2.0	1142	6892	2319	350	46	10750	4470	15220
2.0	2.5	977	5521	1089	292	34	7913	3618	11531
2.5	3.0	808	699	494	150	22	2172	2045	4218
3.0	3.5	557	592	260	87	17	1513	1061	2574
3.5	4.0	448	815	278	93	16	1651	1093	2743
4.0	4.5	395	993	245	91	19	1743	1561	3304
4.5	5.0	323	783	120	63	39	1328	1266	2594
5.0	5.5	244	372	64	37	67	784	774	1558
5.5	6.0	134	124	33	23	33	347	125	472

Chowan

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	0	0	0	0	2	2
-1.0	-0.5	0	0	0	0	0	0	8	8
-0.5	0.0	8	5	46	0	1	60	1103	1162
0.0	0.5	41	7	192	0	1	240	1839	2080
0.5	1.0	62	5	286	0	2	356	444	799
1.0	1.5	78	8	374	0	2	463	418	880
1.5	2.0	94	13	499	0	1	607	352	960
2.0	2.5	121	19	779	0	1	920	399	1319
2.5	3.0	192	23	1349	1	0	1565	539	2105
3.0	3.5	307	17	1966	1	0	2290	772	3062
3.5	4.0	481	5	3023	0	0	3510	1141	4650
4.0	4.5	486	0	3233	0	0	3719	1396	5115
4.5	5.0	259	0	3393	0	1	3652	1182	4834
5.0	5.5	84	0	1796	0	0	1880	1096	2975
5.5	6.0	36	0	348	0	0	384	113	498

Craven

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	18	1	2	0	0	21	5	26
-1.0	-0.5	3	1	1	0	0	4	5	10
-0.5	0.0	119	13	21	2	1	156	2682	2837
0.0	0.5	319	64	228	23	3	637	3379	4016
0.5	1.0	484	125	471	34	6	1121	2056	3177
1.0	1.5	675	242	809	33	5	1764	1958	3721
1.5	2.0	747	444	1093	38	4	2324	2169	4494
2.0	2.5	758	466	1280	44	4	2551	2088	4639
2.5	3.0	849	478	1156	55	6	2544	1654	4198
3.0	3.5	922	655	1250	84	11	2922	1454	4376
3.5	4.0	983	1143	1370	120	14	3629	1451	5080
4.0	4.5	1105	701	1483	137	27	3453	1445	4898
4.5	5.0	1171	388	1492	146	67	3263	1421	4683
5.0	5.5	1069	326	1420	158	193	3167	1421	4588
5.5	6.0	608	193	723	102	252	1878	556	2434

Dare

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	11	10	0	7	0	29	3	32
-1.0	-0.5	10	27	35	22	2	96	34	130
-0.5	0.0	129	61	505	35	12	742	3363	4105
0.0	0.5	921	1073	990	687	6	3677	36824	40501
0.5	1.0	1209	634	69	306	4	2223	16219	18442
1.0	1.5	956	546	17	270	1	1790	6135	7925
1.5	2.0	909	311	12	286	0	1519	3376	4894
2.0	2.5	865	312	6	338	1	1522	496	2018
2.5	3.0	686	248	8	227	3	1172	107	1279
3.0	3.5	553	176	7	140	8	883	44	927
3.5	4.0	304	121	4	92	10	532	20	552
4.0	4.5	169	78	4	66	13	331	12	342
4.5	5.0	98	48	3	43	18	210	7	217
5.0	5.5	53	30	2	28	14	126	4	129
5.5	6.0	40	19	2	17	9	88	3	91

1012

Gates

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9
-1.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	15.1	15.1
-0.5	0.0	0.0	0.0	57.0	16.7	1.3	75.0	3499.6	3574.5
0.0	0.5	0.0	0.0	514.0	35.2	1.1	550.3	4934.4	5484.7
0.5	1.0	0.0	0.0	573.7	9.0	0.0	582.7	545.0	1127.6
1.0	1.5	0.0	0.0	552.3	0.5	0.0	552.9	424.3	977.1
1.5	2.0	0.0	0.0	536.9	4.9	0.1	541.9	515.1	1057.0
2.0	2.5	0.0	0.0	546.3	16.4	0.0	562.7	405.5	968.2
2.5	3.0	0.0	0.0	947.3	17.5	0.0	964.7	512.6	1477.4
3.0	3.5	0.0	0.0	1583.0	21.5	0.1	1604.6	759.2	2363.9
3.5	4.0	0.0	0.0	2040.6	19.1	0.1	2059.7	619.1	2678.9
4.0	4.5	0.0	0.0	1455.9	14.2	0.3	1470.4	430.0	1900.4
4.5	5.0	0.0	0.0	1986.1	12.9	0.1	1999.1	320.6	2319.7
5.0	5.5	0.0	0.0	3166.1	12.1	17.0	3195.2	288.7	3483.9
5.5	6.0	0.0	0.0	896.3	12.4	69.3	978.0	177.8	1155.9

Hertford

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.0	-0.5	0.0	0.0	0.1	0.0	0.2	0.3	6.1	6.4
-0.5	0.0	0.0	0.0	66.2	0.5	36.1	102.7	2749.6	2852.3
0.0	0.5	0.4	0.0	213.5	1.6	104.9	320.4	2089.7	2410.1
0.5	1.0	0.5	0.0	252.1	0.0	115.8	368.5	640.4	1008.8
1.0	1.5	0.3	0.0	295.1	0.0	196.3	491.7	397.5	889.2
1.5	2.0	0.4	0.0	314.2	0.0	215.7	530.3	347.8	878.0
2.0	2.5	0.5	0.0	329.3	0.0	124.9	454.7	418.1	872.8
2.5	3.0	0.6	0.0	335.7	0.1	111.5	447.9	267.4	715.3
3.0	3.5	0.4	0.0	356.9	0.3	112.9	470.4	238.4	708.8
3.5	4.0	0.0	0.0	372.4	0.1	197.7	570.2	323.6	893.9
4.0	4.5	0.6	0.0	398.8	0.2	279.4	679.0	307.9	986.9
4.5	5.0	0.3	0.0	405.5	0.2	265.2	671.1	204.1	875.3
5.0	5.5	0.6	0.0	403.7	0.1	193.6	598.0	184.6	782.6
5.5	6.0	0.4	0.0	343.9	0.2	124.7	469.2	119.1	588.2

Hyde

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	0	0	0	0	0	0
-1.0	-0.5	3	2	704	10	0	719	121	841
-0.5	0.0	217	14	5555	121	10	5917	3746	9663
0.0	0.5	1735	180	20795	213	9	22932	30689	53620
0.5	1.0	1962	142	11889	126	16	14135	15328	29463
1.0	1.5	594	84	4690	250	27	5645	5294	10939
1.5	2.0	221	52	4778	235	2	5288	2750	8038
2.0	2.5	25	31	4481	625	0	5162	1975	7137
2.5	3.0	3	24	2917	1003	0	3947	2215	6161
3.0	3.5	2	32	2287	199	0	2519	1802	4321
3.5	4.0	1	23	1800	17	0	1840	2241	4081
4.0	4.5	0	9	1189	4	0	1202	1367	2570
4.5	5.0	0	1	565	0	0	567	1018	1585
5.0	5.5	0	0	306	0	0	308	466	773
5.5	6.0	0	0	4	0	0	4	127	131

Martin

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-0.5	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1700.7	1701.7
0.0	0.5	2.0	0.0	56.1	0.0	0.3	58.3	4147.8	4206.2
0.5	1.0	10.2	0.4	200.0	0.0	0.3	210.8	1566.4	1777.1
1.0	1.5	28.8	25.4	408.7	0.0	0.6	463.5	1963.1	2426.6
1.5	2.0	60.1	44.7	527.8	0.0	0.5	633.1	1292.5	1925.6
2.0	2.5	49.3	33.9	484.0	0.0	0.7	568.0	1100.4	1668.4
2.5	3.0	19.4	34.8	422.3	0.0	1.4	477.9	842.0	1319.9
3.0	3.5	9.5	43.4	307.8	0.0	2.0	362.6	634.0	996.6
3.5	4.0	7.2	37.3	255.0	0.0	2.5	302.0	507.3	809.3
4.0	4.5	3.8	20.5	254.8	0.0	2.8	281.9	432.9	714.8
4.5	5.0	2.4	9.5	273.1	0.0	3.2	288.3	531.2	819.5
5.0	5.5	1.7	8.8	269.4	0.0	4.1	284.0	367.1	651.1
5.5	6.0	1.8	7.5	213.8	0.0	3.6	226.6	206.9	433.5

1014

New Hanover

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	2.8	2.6	10.6	12.2	12.4	40.7	0.1	40.8
-1.0	-0.5	11.9	9.9	32.8	10.6	17.5	82.6	10.4	93.0
-0.5	0.0	52.8	38.5	87.9	18.7	28.2	226.2	626.9	853.0
0.0	0.5	111.8	87.6	167.2	8.8	23.0	398.4	2266.7	2665.2
0.5	1.0	182.0	161.6	243.7	16.0	29.2	632.5	736.5	1369.0
1.0	1.5	218.7	198.2	264.1	21.7	26.4	729.0	384.8	1113.8
1.5	2.0	196.3	254.3	239.9	8.0	37.0	735.4	322.7	1058.1
2.0	2.5	181.8	264.4	209.4	6.8	47.2	709.7	285.6	995.2
2.5	3.0	205.3	304.7	232.9	5.0	66.0	813.8	294.3	1108.1
3.0	3.5	219.6	382.0	251.9	5.5	84.9	943.8	260.5	1204.3
3.5	4.0	181.8	367.3	294.4	5.5	110.7	959.7	236.0	1195.7
4.0	4.5	178.4	318.2	346.9	4.3	133.0	980.8	259.1	1239.9
4.5	5.0	132.9	260.7	404.5	4.0	164.9	967.0	243.4	1210.3
5.0	5.5	105.0	196.4	300.6	3.9	161.5	767.3	176.4	943.7
5.5	6.0	81.9	138.5	224.9	3.0	109.8	558.1	130.8	688.9

Onslow

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	17	45	0	1	63	0	63
-1.0	-0.5	27	40	48	7	58	181	156	336
-0.5	0.0	244	552	442	36	52	1326	1595	2921
0.0	0.5	270	416	167	6	29	888	728	1616
0.5	1.0	222	576	166	23	20	1007	734	1741
1.0	1.5	212	549	175	23	27	988	487	1474
1.5	2.0	225	716	148	48	16	1153	451	1604
2.0	2.5	234	919	251	41	21	1467	540	2007
2.5	3.0	204	646	260	20	27	1156	368	1524
3.0	3.5	232	986	271	28	36	1554	511	2065
3.5	4.0	221	1106	391	19	53	1790	543	2333
4.0	4.5	219	714	364	12	55	1364	422	1786
4.5	5.0	294	1285	455	15	129	2178	443	2621
5.0	5.5	250	968	366	12	184	1780	273	2053
5.5	6.0	138	461	130	6	94	829	109	939

Pamlico

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	0	0	0	0	0	0
-1.0	-0.5	0	0	1	0	0	1	0	1
-0.5	0.0	7	5	77	0	4	94	582	675
0.0	0.5	313	215	1788	2	8	2325	4697	7022
0.5	1.0	932	608	1995	0	5	3541	2079	5620
1.0	1.5	1383	768	3066	0	3	5220	1210	6430
1.5	2.0	1313	515	3511	0	3	5342	2079	7421
2.0	2.5	877	230	2749	0	1	3858	2556	6414
2.5	3.0	427	145	2910	0	1	3482	1644	5126
3.0	3.5	110	64	2893	0	1	3068	2251	5319
3.5	4.0	65	34	2162	0	4	2266	2211	4477
4.0	4.5	66	23	1470	0	9	1568	1299	2867
4.5	5.0	79	21	805	0	15	920	1518	2438
5.0	5.5	55	22	412	0	53	543	1504	2047
5.5	6.0	45	19	180	0	44	288	270	558

Pasquotank

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	9	15	0	0	24	1	25
-1.0	-0.5	0	2	4	0	0	7	3	10
-0.5	0.0	19	5	47	0	1	71	2527	2598
0.0	0.5	268	15	678	0	1	961	2510	3471
0.5	1.0	435	38	2405	0	1	2879	1220	4099
1.0	1.5	941	172	3225	0	0	4338	866	5204
1.5	2.0	1441	155	3276	0	0	4872	731	5603
2.0	2.5	1817	88	2828	0	0	4733	943	5677
2.5	3.0	950	160	2944	0	1	4055	800	4855
3.0	3.5	820	1310	5053	0	0	7184	1024	8207
3.5	4.0	492	1944	6935	0	1	9372	965	10338
4.0	4.5	38	154	4587	0	1	4780	474	5253
4.5	5.0	25	21	2482	0	1	2529	298	2827
5.0	5.5	8	3	203	0	0	214	57	271
5.5	6.0	2	1	7	0	0	10	1	10

1016

Pender

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	26	0	0	26	5	31
-1.0	-0.5	10	0	25	0	4	39	0	40
-0.5	0.0	40	8	75	0	24	147	999	1146
0.0	0.5	87	18	187	2	38	332	7714	8046
0.5	1.0	113	14	411	5	18	560	2815	3375
1.0	1.5	103	7	595	8	9	723	1796	2518
1.5	2.0	73	6	829	15	7	930	1753	2683
2.0	2.5	47	5	1110	13	17	1192	1462	2654
2.5	3.0	31	3	1478	19	36	1568	1435	3003
3.0	3.5	22	3	1807	12	75	1919	1360	3279
3.5	4.0	13	5	1901	17	114	2050	1312	3362
4.0	4.5	4	4	1997	20	130	2155	1394	3549
4.5	5.0	2	5	1860	14	113	1993	1218	3212
5.0	5.5	1	5	1490	7	103	1606	917	2523
5.5	6.0	2	4	1054	2	75	1138	644	1782

Perquimans

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	5	0	0	0	5	0	5
-1.0	-0.5	1	1	0	0	0	2	2	4
-0.5	0.0	18	16	61	0	2	97	2453	2549
0.0	0.5	78	102	221	0	1	403	1375	1778
0.5	1.0	148	146	366	0	2	663	844	1507
1.0	1.5	279	231	662	0	2	1174	865	2039
1.5	2.0	758	366	1734	0	1	2860	1041	3900
2.0	2.5	955	341	3200	0	0	4496	1274	5770
2.5	3.0	656	353	3671	0	0	4681	1196	5876
3.0	3.5	933	761	6785	0	0	8478	1219	9697
3.5	4.0	1014	869	9072	0	0	10956	2208	13164
4.0	4.5	509	411	5657	0	0	6577	1951	8528
4.5	5.0	51	90	2238	0	0	2378	2324	4702
5.0	5.5	1	0	584	0	1	586	1608	2193
5.5	6.0	0	0	96	0	1	97	74	171

Tyrrell

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	4	0	3	0	0	8	4	12
-1.0	-0.5	52	3	157	1	0	213	117	329
-0.5	0.0	1255	205	762	69	0	2291	14132	16423
0.0	0.5	7457	1576	2360	90	0	11483	29085	40568
0.5	1.0	8576	4224	1534	3	0	14338	9570	23907
1.0	1.5	2132	2612	216	0	0	4960	3227	8186
1.5	2.0	1325	1273	15	0	0	2613	1067	3680
2.0	2.5	405	845	7	1	0	1258	1140	2398
2.5	3.0	118	217	2	16	0	353	1065	1417
3.0	3.5	86	221	4	6	0	317	1276	1593
3.5	4.0	43	80	3	1	0	127	968	1095
4.0	4.5	8	43	0	0	0	51	496	547
4.5	5.0	0	1	0	0	0	2	107	109
5.0	5.5	0	0	0	0	0	0	0	0
5.5	6.0	0	0	0	0	0	0	0	0

Washington

Elevation above Spring High Water (m)		Area (hectares)							
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
Above	Below								
	-1.0	0	0	0	0	0	0	0	0
-1.0	-0.5	0	0	0	0	0	0	1	1
-0.5	0.0	11	15	0	1	0	26	2618	2643
0.0	0.5	145	366	7	4	0	521	4424	4946
0.5	1.0	336	977	376	1	0	1690	1511	3200
1.0	1.5	382	1309	1042	3	0	2736	1013	3749
1.5	2.0	548	1168	1339	45	0	3101	989	4091
2.0	2.5	1036	1340	2168	79	0	4623	1215	5838
2.5	3.0	854	1488	4052	36	0	6431	1731	8161
3.0	3.5	1000	1440	5625	103	0	8168	1715	9884
3.5	4.0	911	597	10103	51	0	11662	1579	13241
4.0	4.5	736	86	9152	5	0	9979	1235	11214
4.5	5.0	496	28	4105	0	0	4629	1172	5802
5.0	5.5	339	15	2414	0	9	2776	741	3517
5.5	6.0	143	5	334	0	55	537	149	686

1018

Table B-2. Area of Land Vulnerable to a One Meter Rise in Sea Level (square kilometers)

By County by Likelihood of Shore Protection

County	Likelihood of Shore Protection						Total Nontidal Land	Tidal Wetlands
	Certain	Likely	Unlikely	No Protection	Nontidal Wetlands			
Beaufort	42.6	16.9	42.8	8.5	108.9	220.2	35.1	
Bertie	0.2	0.0	4.5	0.0	127.3	132.0	0.3	
Brunswick	9.4	1.2	9.0	1.2	47.3	69.0	108.7	
Camden	6.6	2.9	18.5	0.0	150.0	178.1	7.1	
Carteret	22.1	42.5	42.6	9.7	87.3	208.3	331.7	
Chowan	1.1	0.2	5.2	0.0	34.0	40.5	0.0	
Craven	9.4	2.0	7.2	0.6	81.3	100.7	12.1	
Currituck	6.6	0.4	37.3	1.5	150.1	196.3	123.5	
Dare	22.8	18.0	16.0	10.6	564.4	632.1	165.3	
Gates	0.0	0.0	11.4	0.6	89.9	102.0	0.0	
Hertford	0.0	0.0	5.3	0.0	54.9	62.8	0.0	
Hyde	39.2	3.4	389.4	4.7	498.8	935.9	198.6	
Martin	0.1	0.0	2.6	0.0	74.1	76.9	0.0	
New Hanover	3.6	3.0	5.4	0.7	36.4	50.2	55.3	
Onslow	7.6	16.0	8.7	0.7	32.1	66.8	68.3	
Pamlico	12.5	8.3	38.6	0.0	73.6	133.2	111.6	
Pasquotank	7.2	0.7	31.5	0.0	62.6	102.0	0.3	
Pender	2.5	0.4	7.2	0.1	115.3	126.4	38.0	
Perquimans	2.4	2.7	6.5	0.0	46.7	58.4	0.0	
Tyrrell	173.4	60.1	48.2	1.6	529.1	812.4	3.8	
Washington	4.9	13.6	3.8	0.0	85.5	107.9	0.3	
North Carolina ²	374.5	192.3	741.9	40.5	3049.7	4412.0	1259.9	

1. Total includes the five categories listed plus the "not considered" category.
2. Excludes Bladen, Columbus, Duplin, Jones, Northampton, and Pitt Counties which have about 5.7 square kilometers of dry land and 41.2 square kilometers of nontidal wetlands within one meter above spring high water, as well as 3.5 square kilometers of tidal wetlands.

Table B-3. Area of Lands Close to Sea Level By County
Jurisdictions not included in study (hectares)

County	Meters above Spring High Water										
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
	-----Dry Land, by half meter elevation increment-----										
Bladen	0.0	0.0	0.1	1.7	6.8	12.2	33.7	112.2	225.0	691.0	
Columbus	0.2	2.1	2.8	8.8	13.9	18.5	21.2	22.9	32.9	39.3	
Duplin	0.2	0.1	0.1	0.0	0.5	2.3	6.2	13.7	19.3	55.2	
Jones	190.4	116.3	140.3	178.4	224.2	312.0	388.4	525.8	676.4	762.9	
Lenoir	0.0	0.0	0.0	0.0	0.5	5.1	11.3	21.2	50.9	96.2	
Northampton	6.5	10.4	11.1	19.8	47.7	83.2	114.2	124.7	131.6	140.1	
Pitt	105.8	137.0	230.2	303.5	421.4	508.0	710.1	973.0	1106.3	1233.4	
Sampson	0.0	0.0	0.0	0.0	0.0	2.5	5.0	8.2	11.4	34.1	
Wetlands	Tidal	-----Nontidal Wetlands, by half meter elevation increment-----									
Bladen	0.0	0.3	20.3	70.1	125.9	214.1	277.6	432.4	644.7	461.4	895.1
Columbus	0.0	20.1	58.2	104.9	134.7	126.8	108.1	86.3	58.1	47.3	143.5
Duplin	0.0	0.0	0.0	0.0	0.0	5.0	9.5	65.3	134.6	112.4	221.9
Jones	351.3	811.1	332.6	246.7	263.8	244.8	251.8	241.0	271.4	242.4	220.7
Lenoir	0.0	0.0	0.0	13.6	40.3	108.4	168.4	246.9	205.3	361.9	405.4
Northampton	0.0	119.8	85.7	73.5	125.2	224.1	192.9	194.0	133.7	82.8	80.3
Pitt	0.0	2142.9	526.3	490.1	479.3	497.3	497.0	500.9	557.6	550.0	456.0
Sampson	0.0	0.0	0.0	0.0	0.0	0.1	70.1	99.5	115.9	100.5	202.1

Appendix C

ELEVATION UNCERTAINTY

Authors: James G. Titus, Russ Jones, and Richard Streeter

C-1. Low and High Estimates of the Area of Land Close to Sea Level, by County: North Carolina¹ (square kilometers)

County	Meters above Spring High Water																			
	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
	0.5		1.0		1.5		2.0		2.5		3.0		3.5		4.0		4.5		5.0	
-----Cumulative (total) amount of dry land below a given elevation-----																				
Beaufort	49	93	109	156	177	235	257	317	341	401	422	482	505	576	600	655	672	711	722	744
Bertie	1.8	3.4	4.7	6.8	8.2	10	12	15	17	20	22	26	28	32	35	40	44	51	56	65
Bladen	0	0	0	<0.01	<0.01	0.01	0.02	0.06	0.1	0.2	0.2	0.4	0.5	1.1	1.5	3	4	8.2	10	16
Brunswick	14	20	24	31	36	43	48	55	60	68	74	83	89	98	105	116	123	134	140	149
Camden	11	21	26	46	59	100	115	147	157	189	201	232	241	256	262	282	290	313	321	336
Carteret	56	95	127	179	220	287	326	379	402	421	427	437	443	452	459	470	476	485	490	496
Chowan	2.9	5.0	6.5	9.2	11	15	17	22	27	35	42	55	65	85	100	122	137	159	173	188
Columbus	0.00	0.01	0.02	0.04	0.05	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.5	1.6	1.9
Craven	7.9	16	20	32	37	54	60	78	85	104	111	132	140	165	175	201	210	234	243	267
Currituck	23	38	50	71	87	119	143	178	201	234	252	273	285	300	306	313	316	320	322	326
Dare	47	65	71	86	91	102	106	117	121	131	133	140	143	147	148	151	152	153	154	155
Duplin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.03	0.07	0.1	0.2	0.2	0.3	0.4	0.8	0.9	1.5
Edgecombe	0	0	0	0	0	0	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.02	0.03
Gates	5.3	11	11	16	17	22	22	27	28	35	36	50	52	69	72	85	87	103	107	130
Greene	0	0	0	0	0	0	0	0	0	0	0	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	0.02
Halifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<0.01	<0.01	0.06
Hertford	3.7	6.9	7.4	11	12	17	17	21	22	26	26	31	31	36	37	42	43	49	50	55
Hyde	280	410	433	482	496	533	548	586	600	632	641	660	666	682	686	695	698	702	704	707
Jones	1.8	2.7	3.0	4.0	4.4	5.6	6.1	7.7	8.4	11	11	14	15	19	20	25	27	32	35	41

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

Lenoir		0	0	0	0	0	0	0	0.01	0.02	0.05	0.06	0.1	0.2	0.3	0.4	0.7	0.9	1.5	1.7	2.8
Martin		0.5	1.8	2.6	5.6	7.0	11	13	18	19	23	24	27	28	30	30	33	33	35	36	38
New Hanover		8.3	13	15	20	22	28	30	35	37	43	45	52	55	61	64	71	74	81	84	90
Northampton		0.05	0.1	0.2	0.3	0.3	0.4	0.4	0.8	0.9	1.5	1.6	2.6	2.8	3.8	4.0	5.1	5.3	6.5	6.7	8.0
Onslow		25	33	35	43	46	55	58	68	71	81	85	96	100	111	116	128	133	147	152	166
Pamlico		27	48	64	95	116	150	170	194	209	230	243	263	274	289	296	307	312	319	322	325
Pasquotank		11	26	40	65	83	112	131	161	178	202	221	259	290	350	382	418	432	449	457	460
Pender		5.9	9.9	12	17	19	25	28	36	40	51	55	69	74	89	94	110	116	131	136	149
Perquimans		5.0	8.8	12	18	24	39	52	79	97	124	145	189	227	296	335	381	402	420	427	432
Pitt		1.1	1.8	2.4	3.7	4.7	6.5	7.8	10	12	15	17	21	24	30	34	40	45	52	57	65
Sampson		0	0	0	0	0	0	0	0	0	0.02	0.03	0.06	0.07	0.1	0.15	0.2	0.3	0.5	0.6	0.9
Tyrrell		131	235	269	321	331	351	358	369	371	374	375	378	378	379	380	380	380	380	380	380
Washington		5.6	14	22	38	49	68	81	106	128	165	192	238	272	340	387	452	484	519	535	556
Statewide		780	1275	1495	1936	2177	2675	2935	3409	3633	4036	4231	4645	4872	5351	5590	5999	6176	6487	6614	6845

	low	high low		high low		high low		high low		high low		high low		high low		high low		high low				
		0.5		1.0		1.5		2.0		2.5		3.0		3.5		4.0		4.5		5.0		
Wetlands	Tidal	-----Cumulative (total) amount of Nontidal Wetlands below a given elevation-----																				
Beaufort	35	65	95	105	131	139	162	171	202	215	244	252	272	278	290	294	306	310	320	323	330	
Bertie	0.3	110	123	127	132	136	142	147	153	159	167	171	177	181	186	191	200	207	219	225	234	
Bladen	0	<0.01	0.1	0.2	0.6	0.9	1.8	2.1	3.3	4.1	6.3	7.3	10	11	15	16	21	23	29	31	36	
Brunswick	109	38	44	47	52	55	58	61	65	67	71	73	77	79	82	85	88	90	93	95	98	
Camden	7.1	137	146	149	155	157	165	168	175	177	184	187	194	197	201	203	210	214	233	243	258	
Carteret	334	34	67	87	117	136	164	180	202	216	231	237	243	247	254	258	267	273	281	286	293	
Chowan	0	29	32	34	37	38	40	42	44	46	49	51	56	59	64	70	79	84	91	96	104	
Columbus	0	0.2	0.5	0.8	1.3	1.9	2.7	3.2	3.9	4.4	5.1	5.5	6.1	6.4	6.7	7	7.3	7.5	8.0	8.9	11	
Craven	12	59	74	80	94	100	115	121	137	142	154	159	170	173	184	188	198	202	213	217	227	
Currituck	125	129	144	150	159	164	172	178	184	188	194	196	199	201	203	204	206	209	215	219	221	
Dare	168	376	525	553	604	619	651	659	664	664	665	666	666	666	666	666	666	666	666	666	666	
Duplin	0	0	0	0	0	0	0	0	0.01	0.03	0.1	0.2	0.5	0.7	1.4	1.8	2.9	3.4	4.7	5.3	6.7	
Edgecombe	0	0	0	0	0	0	0	0	0	0	0	0	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.03	0.05	0.09
Gates	0	78	89	89	93	94	98	99	102	103	107	108	114	115	121	122	126	126	129	129	132	
Greene	0	0	0	0	0	0	0	0	0	0	0	0	<0.01	<0.01	0.01	0.01	0.02	0.03	0.1	0.1	0.2	
Halifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<0.01	0.03	0.3	0.5	1.6	
Hertford	0	45	53	54	58	58	61	62	65	66	69	69	71	71	74	74	77	78	79	80	81	
Hyde	199	325	461	488	538	549	571	578	592	598	614	619	634	638	653	660	672	675	682	685	689	
Jones	3.5	7.8	10	11	13	14	16	16	18	19	21	21	23	24	26	26	28	29	31	31	33	
Lenoir	0	0	0	0	0.07	0.13	0.38	0.5	1.1	1.5	2.8	3.3	4.9	5.6	7.6	8.4	11	12	14	15	17	
Martin	0	58	67	73	88	93	103	106	114	117	124	126	130	132	136	137	140	142	145	147	150	
New Hanover	56	28	35	36	39	40	42	43	45	46	48	49	51	52	53	54	56	57	58	59	60	
Northampton	0	0.9	1.9	2.0	2.6	2.7	3.5	3.7	5.9	6.0	7.3	7.6	9.6	9.9	11	11	12	12	13	13	14	
Onslow	69	25	30	31	35	36	40	41	45	46	49	51	54	55	59	60	64	65	68	69	72	
Pamlico	112	52	67	73	81	86	97	106	123	131	142	148	161	171	186	192	201	206	215	221	232	

Pasquotank	0.3	50	58	62	68	71	75	79	84	88	93	96	102	106	113	116	119	121	122	124	124
Pender	38	83	107	113	128	132	145	150	161	165	175	179	189	192	202	206	216	219	229	232	239
Perquimans	0.04	38	44	47	52	55	61	66	74	79	86	90	98	103	113	124	137	144	158	167	180
Pitt	0	21	25	27	30	32	35	36	39	41	44	46	49	51	54	57	60	62	65	67	70
Sampson	0	0	0	0	0	0	0	0	<0.01	0.02	0.4	0.6	1.4	1.6	2.3	2.6	3.6	4.0	5.2	5.7	6.8
Tyrrell	3.8	422	502	523	554	559	569	571	579	582	591	593	601	606	614	616	620	621	622	622	623
Washington	0.3	70	78	86	92	96	101	106	112	118	128	134	145	152	162	168	175	180	188	192	197
Statewide	1606	2314	2946	3134	3472	3601	3857	3974	4193	4303	4500	4583	4752	4830	4995	5076	5236	5314	5479	5559	5698
		Cumulative (total) amount of land below a given elevation ⁵																			
Dry Land		780	1275	1495	1936	2177	2675	2935	3409	3633	4036	4231	4645	4872	5351	5590	5999	6176	6487	6614	6845
Nontidal Wetlands	1606	2314	2946	3134	3472	3601	3857	3974	4193	4303	4500	4583	4752	4830	4995	5076	5236	5314	5479	5559	5698
All Land	1606	3094	4221	4629	5408	5778	6532	6910	7602	7936	8536	8814	9397	9702	10346	10667	11235	11490	11966	12173	12542

C-2. Likelihood of Shore Protection in North Carolina, High and Low Estimates of the Land within One Meter above Spring High Water¹ (square kilometers)

County	Likelihood of Shore Protection								Nontidal Wetlands		Total ²	
	Certain		Likely		Unlikely		No Protection					
	low	high	low	high	low	high	low	high	low	high	low	high
Beaufort	41	59	17	22	42	65	8.6	9.3	105	131	215	287
Bertie	0.16	0.2	<0.01	0.01	4.5	6.5	0	0	127	132	132	139
Brunswick	10	14	1.4	1.6	9.9	13	1.4	1.6	47	52	71	83
Camden	5.9	11	2.6	5.6	17	29	0	0	149	155	174	200
Carteret	23	31	44	71	44	58	11	14	87	117	214	297
Chowan	1.1	1.6	0.17	0.22	5.2	7.4	0	0	34	37	40	46
Craven	9.3	14	2	3.5	7.6	13	0.6	0.8	80	94	99	126
Currituck	6.7	9.4	0.4	0.5	40	58	1.9	2.4	150	159	200	229
Dare	23	31	19	24	16	16.2	13	15	553	604	624	690
Gates	0	0	0	0	11	16	0.6	0.61	89	93	101	109
Hertford	<0.01	0.01	0	0	5	7.4	0.02	0.02	54	58	61	69
Hyde	38	44	3.5	4.4	386	426	5.5	7.1	488	538	922	1020
Martin	0.1	0.3	<0.01	0.1	2.5	5.1	0	0	73	88	76	94
New Hanover	3.6	5.2	3.5	5	5.9	8	0.7	0.9	36	39	51	60
Onslow	7.6	9.2	16	21	8.9	10	0.7	1	31	35	66	78
Pamlico	13	21	9.1	14	42	59	0.02	0.02	73	81	137	176
Pasquotank	7.3	12	0.7	1.6	32	51	0	0	62	68	102	133
Pender	2.7	3.5	0.4	0.5	7.4	12	0.07	0.13	113	128	125	144
Perquimans	2.5	4	2.7	4	6.5	10	0	0	47	52	58	70
Tyrrell	165	189	56	80	47	50	1.63	1.64	523	554	792	875
Washington	4.9	7.2	14	22	3.8	9.4	<0.05	0.05	86	92	108	131
North Carolina³	366	467	193	281	744	929	46	54	3007	3307	4369	5056

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

2. Total includes the five categories listed as well as a small amount of low land that the authors did not analyze.

3. Excludes Bladen, Columbus, Duplin, Jones, Northampton, and Pitt Counties.

C-3. Likelihood of Shore Protection in North Carolina, High and Low Estimates of the Land within Two Meters above Spring High Water¹ (square kilometers)

County	Likelihood of Shore Protection								Nontidal Wetlands		Total ²	
	Certain		Likely		Unlikely		No Protection					
	low	high	low	high	low	high	low	high	low	high	low	high
Beaufort	95	120	28	30	124	156	9.9	10	171	202	428	519
Bertie	0.3	0.38	0.01	0.02	12	14	0.02	0.03	147	153	159	167
Brunswick	22	25	2.5	3	20	24	1.9	2	61	65	109	120
Camden	26	32	17	23	71	92	0	0	168	175	283	322
Carteret	47	53	162	200	91	98	19	21	180	202	506	581
Chowan	2.9	3.5	0.4	0.5	14	18	0	<0.01	42	44	59	66
Craven	23	29	8.7	12	26	35	1.3	1.6	121	137	181	215
Currituck	18	22	0.6	0.7	122	151	3.1	3.3	178	184	321	362
Dare	43	49	28	30	16	16	19	21	659	664	765	781
Gates	0	0	0	0	22	26	0.7	0.8	99	102	121	129
Hertford	<0.02	0.02	0	0	11	14	0.02	0.02	62	65	79	87
Hyde	48	48	5.1	5.4	485	518	10	14	578	592	1126	1179
Martin	1	1.4	0.7	1	12	15	0	0	106	114	119	132
New Hanover	7.8	9.2	8.1	10	11	13	1.08	1.13	43	45	73	81
Onslow	12	14	30	36	12	14	1.5	1.8	41	45	100	112
Pamlico	40	46	22	23	107	124	0.02	0.02	106	123	276	317
Pasquotank	31	42	4	4.5	96	115	0	0	79	84	210	245
Pender	4.5	4.9	0.57	0.61	21	29	0.3	0.4	150	161	178	197
Perquimans	13	19	8.7	11	30	49	0	0	66	74	118	153
Tyrrell	207	211	98	106	51	51	1.64	1.64	571	579	929	948
Washington	14	20	38	47	28	38	0.5	1	106	112	186	218
North Carolina³	657	750	463	544	1383	1612	70	80	3732	3920	6327	6931

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error.

For a discussion of these calculations, see Annex 3 of this report.

2. Total includes the five categories listed as well as a small amount of low land that the authors did not analyze.

3. Excludes Bladen, Columbus, Duplin, Jones, Northampton, and Pitt Counties.

C-4. Area of Land by Elevation by Shore Protection Likelihood, High and Low Estimates: North Carolina¹

Elevation relative to Spring High Water (m)	Area (square kilometers)															
	Dry land: likelihood of shore protection										Dry Land	Non Tidal Wetlands		All Land ²		
	Shore Protection Certain		Shore Protection Likely		Shore Protection Unlikely		No Shore Protection		Not Considered							
low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	
0.5	170	313	73	147	437	661	31	41	13	18	724	1179	2280	2879	3004	4093
1.0	366	467	193	281	744	929	46	54	20	25	1368	1757	3048	3354	4415	5119
1.5	512	609	327	415	1033	1264	58	67	28	34	1957	2388	3465	3694	5422	6087
2.0	657	750	463	544	1383	1612	70	80	36	43	2609	3030	3794	3992	6404	7023
2.5	791	861	575	619	1734	1982	86	98	46	54	3232	3615	4087	4269	7319	7887
3.0	893	956	640	688	2110	2387	102	109	58	69	3803	4208	4347	4509	8150	8717
3.5	985	1042	713	768	2542	2880	111	114	74	89	4425	4894	4582	4740	9007	9633
4.0	1068	1117	789	826	3060	3349	116	119	98	118	5131	5529	4818	4969	9949	10493
4.5	1138	1176	841	869	3474	3681	120	123	127	153	5699	6001	5041	5198	10740	11193
5.0	1190	1216	879	897	3766	3914	124	126	165	196	6124	6349	5273	5405	11397	11750

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

2. Excludes Bladen, Columbus, Duplin, Jones, Northampton, and Pitt Counties.

APPENDIX D: SUMMARY OF DATA SOURCES

This appendix describes data used to create the GIS-based maps accompanying this report. Data descriptions are organized by data source. Within each section we provide a brief summary of each layer obtained from that source. Summary information includes a description of how the data were developed, identifies the key elements of the data used in our analysis, and provides the date of publication.

HAND EDITS BASED ON PLANNER INPUT

Original Planning Judgments

Key Data Elements: State and county representatives from the NC Division of Coastal Management delineated three levels of protection on 1:100,000 USGS paper maps: shoreline protection almost certain, shoreline protection likely, or shoreline protection unlikely. These anticipated responses to sea level rise were then hand-digitized by ICF Consulting.

Scale: 1:100,000

Date of Publication: 1999-2000

Counties applicable: All

Source: Discussions with state and county representatives conducted by Walter Clark; notes on paper maps were then hand-digitized by ICF Consulting.

County Planning Judgments

Key Data Elements: County representatives made revisions to the maps created from the Original Planning Judgments data. These planners were able to categorize the likelihood of shoreline protection for specific parcels of land. The revisions to anticipated sea level rise response categories were then hand-digitized by IEC.

Scale: 1:100,000 or better

Date of Publication: 2001-2003

Counties applicable: Currituck, Camden, Pasquotank, Perquimans, Hertford, Washington, Beaufort, Tyrrell, Hyde, Pamlico, Carteret, Onslow, and New Hanover

Source: Discussions with county representatives conducted by Jim Titus and IEC; notes on paper maps were then hand-digitized by IEC.

Barrier Beaches

Key Data Elements: Paper maps delineate areas protected by the Coastal Barrier Resources Act. The EPA manager drew the boundary of undeveloped coastal barrier areas onto paper maps based on the Original Planning Judgments data. These anticipated responses to sea level rise were then hand-digitized by IEC.

Scale: hand-digitized on 1:100,000 USGS maps

Date of Publication: 2001

Counties applicable: Currituck, Onslow

Source: Jim Titus outlined barrier beaches on paper map, which were then hand-digitized by IEC.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE

Highways

Key Data Elements: Used to create 300 foot buffers indicating shoreline protection along major roads and important transportation corridors, per county representatives' stakeholder review judgments.

Scale: 1:50,000 (largest possible scale)

Date of Publication: 2002

Counties applicable: Currituck, Camden, Pasquotank, Perquimans (using county-specific roads data), Hertford, Washington, Beaufort, Tyrrell, Hyde, Pamlico, Carteret, Onslow, and New Hanover

Source: ESRI

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Wetlands

Key Data Elements: Areas identifying wetland types as determined by the NC Division of Coastal Management. Used to delineate between tidal and non-tidal wetlands.

Scale: 1:24,000

Date of Publication: 1999

Counties applicable: All

Source: BasinPro dataset developed by the Center for Geographic Information and Analysis

Conservation Lands

Key Data Elements: Used to delineate lands in North Carolina managed for conservation and open space relating to many purposes, including recreation, wildlife habitat, water quality, and farmland preservation. This is a composite layer from 13 sources, representing an integrated depiction of lands that have been permanently protected or designated for open space.

Scale: Based on the density of vertices, we estimate the scale as 1: 24,000 or better.

Date of Publication: Obtained in 2000.

Counties applicable: All

Source: BasinPro dataset developed by the Center for Geographic Information and Analysis

COUNTY-SPECIFIC DATA

Pasquotank County Zoning

Key Data Elements: Zoning data were used to delineate areas of existing development and areas where future development is planned.

Scale: Based on the density of vertices, we estimate the scale as 1:10,000 or better.

Date of Publication: County parcels were digitized from paper maps in 1998. Updated zoning data provided in 2003.

Source: Parcels were digitized by an outside contractor. Dataset maintained by Pasquotank County planning office.

Perquimans County Subdivisions

Key Data Elements: Subdivision data were used to delineate areas of existing development and areas where future development is planned.

Scale: 1: 4,800

Date of Publication: County parcels were digitized from paper maps in 2002.

Source: Parcels were digitized by an outside contractor. Dataset maintained by Perquimans County planning office.

Camden County Zoning

Key Data Elements: Zoning data were used to delineate areas of existing development and areas where future development is planned.

Scale: 1: 4,800

Date of Publication: County parcels were digitized from paper maps in 2000. Updated zoning data provided in 2003.

Source: Parcels were digitized by an outside contractor. Dataset maintained by Camden County planning office.

Dare County Parcels-Land Use

Key Data Elements: Land use planning data were used to delineate areas of existing development and areas where future development is planned. Each polygon was assigned a land use code according to a county-specific classification system. Exhibit A-1 lists the land use codes and descriptions used for these data.

Scale: Based on the density of vertices, we estimate the scale as 1: 4,800 or better.

Date of Publication: Updated land use data provided in 2003.

Source: Dataset maintained by Dare County planning office.

Table A-1. Dare County Property Use Codes and Descriptions

Code	Description	Code	Description
0001	In Process	2200	Wholesale Distributors
0010	Vacant Land	2300	Service
0020	Vacant Land (Religious)	3000	Private Museum, Gallery, Etc
0025	Vacant Land (Non-Profit)	3800	Warehouse
0030	Vacant Land (Prop Owner Assoc)	4000	Restaurant
0035	Vacant Land (Public Utility)	5000	Recreational
0040	Vacant Land (Federal Government)	5099	Boatslip
0050	Vacant Land (State of NC)	5100	Hotel/Motel/Ctg Court
0060	Vacant Land (Dare County)	5500	Professional
0070	Vacant Land (Town of Manteo)	6200	Hospital/Nursing Home
0080	Vacant Land (Town of Nags Head)	7200	Manufacturing
0085	Vacant Land (Town of Kitty Hawk)	7400	Horticultural
0090	Vacant Land (Town of KDH)	7500	Use-Value
0095	Vacant Land (Town of Shores)	7600	Private Schools
0099	Leasehold	7800	Aircraft
0100	Residential-SFR	8000	Religious Bldgs
0500	Residential Condo	8600	Public Utility Bldgs
0550	Condo Mastercard	8700	Property Owners Assoc Bldgs
0575	Condo-Future Development	8800	Non-Profit Organizations
0600	Townhouse	8900	Cemetery
0700	Timeshare	9000	Federal Govt Bldgs
0800	Co-Ownership	9100	State of NC Bldgs
0900	Resid w/Mobile Home	9200	County of Dare Bldgs
1000	Residential MH Park	9300	Town of Manteo Bldgs
1500	Commercial Condo	9400	Town of Nags Head Bldgs
1900	Multi-Use	9500	Town KDH Bldgs
1999	Vacant Comm Bldg	9600	Town of Kitty Hawk Bldgs
2000	Retail	9700	Town of Southern Shores Bldgs
2100	Sales/Service	9900	Secondary Improvements

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Walter Clark of the North Carolina Sea Grant Program conducted initial discussions with regional representatives from the North Carolina Division of Coastal Management and local officials along the Outer Banks, prepared the initial draft of the maps showing areas certain and likely to be protected, and wrote the first draft of this report. Daniel Hudgens of Industrial Economics, Inc. (IEc) and Jim Titus, EPA project manager, revised the maps to include areas protected by the Coastal Barrier Resources Act, and to distinguish areas where shore protection is unlikely from those areas with policies against shore protection. Leslie Katz reformatted the Clark report to a county-specific format, and Jim Titus revised that draft to reflect local concerns in the most vulnerable communities. Paul Meyer of the North Carolina Association of County Commissioners sent the resulting “stakeholder review draft” report to all 20 coastal counties analyzed by this study.

Jim Titus briefed officials from Bertie, Camden, Currituck, Pamlico, Beaufort, Washington, Perquimans, Pasquotank, Hyde, Tyrrell, and Dare counties on the objectives and draft results of the project, and obtained their suggestions for map revisions; Tom Stroud of the Partnership for the Sounds set up about half of those meetings. Jennifer Kassakian, Industrial Economics, Inc., consulted with Currituck, Chowan, Hertford, Bertie, Martin, Hyde, Onslow, Carteret, New Hanover, and Brunswick counties on their suggested changes, kept the complete record of the stakeholder review, and revised the maps based on

the county responses. Jim Titus revised the methods section and the county-specific sections for those counties where he had met with officials, and Jennifer Kassakian revised the county-specific sections for the remaining counties. Daniel Hudgens and James E. Neumann reviewed the reports and provided technical support in creating the maps, and strategic advice in the presentation of results. The diagram on tides, wetlands, and reference elevations was produced by collaboration between EPA and NOAA. Titus prepared the rough sketch and dimensions of the diagram on, by adapting a graphic originally prepared in 1988 for EPA by Tim Kana of Coastal Science and Engineering. Deb Misch of STG, Inc did the artwork, under contract to NOAA's National Climatic Data Center

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