Part IV. Sensitivity to Sea-Level Rise at the Local Scale

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Previous chapters have provided region-wide perspectives on different effects, social impacts, and components of society's response to sea-level rise. The issue-by-issue presentation closely matches the separate professions involved in studying the effects and developing options for adapting to sea-level rise.

Many decisions, however, concern a specific location and require local andregional perspectives and information. Fortunately, much of the information that the previous chapters presented at the regional scale is also available at the state and local scale. Moreover, some information that is not available region-wide is available for some locations: For example, previous chapters did not look at the impacts of increased salinity on drinking water, but such information is available for the Philadelphia and New York metropolitan areas, which appear to be the primary areas where sea-level rise could harm water supplies.

This report does not recommend specific policies or actions in response to sea-level rise. Instead, it summarizes information on the options that are available. Impacts of sea-level rise on any specific community or local area will depend upon many factors and need to be carefully assessed as policy options and mitigation alternatives are examined.
Part IV is an overview of Appendices A-G, which provide state and local information similar to chapters 1-5 and 7, as well as information on some aspects of the effects of sea-

level rise that chapters 1-11 did not address but that may be important for specific locations.

IV.1 INFORMATION IN THE APPENDICES

There are separate appendices for each of seven sub-regions: Long Island, Greater New York City, New Jersey Shore, Delaware Estuary, Atlantic Coast of the Delmarva Peninsula, Chesapeake Bay, and North Carolina. These sub-regions generally track the sub-regional classifications of the results presented in the Chapters of this report. The data used in the discussion for these sub-regions are the same as those used in the thematic chapters and are explained there. The sub-regional presentation provides a more fine-grained analysis on certain themes (such as elevation and population), but for certain topics (such as wetland accretion) the data do not permit more site-specific conclusions for most locations.

The presentation of local-scale information in the appendices represents the best data available as this report was being prepared. Limited resolution and/or availability of data create some uncertainty in estimating land and population that could be vulnerable to sea-level rise. In addition, some data are several years old, leading to uncertainties regarding policies and expectations for land use.

IV.1.1 Effects of Sea-Level Rise

Depending on the size of the region discussed, each appendix includes one or more elevation maps similar to the elevation maps in Chapter 1. These maps generally have a contour interval of 50 centimeters, but in cases where the underlying data was less accurate, a 1-meter contour was used following the recommendations of the underlying study from which the map data was obtained. Tables are also included with county-specific uncertainty ranges for the amount of land below a particular elevation. As in Chapter 1, all elevations are measured relative to spring high water.

The Appendices discuss coastal erosion and the potential for the vertical buildup of wetlands. Those discussions serve as background for discussions of vulnerable ecosystems and species.

IV.1.2 Social Impacts

Discussions of wetland vertical buildup provide essential background for considering the environmental impacts of sea-level rise, but identifying specific areas where wetlands are likely and unlikely to migrate inland is a complex undertaking. Most appendices describe state and local policies on coastal development and response to a shifting shoreline, and illustrate examples of how these policies might affect wetland migration as well as estuarine ecosystems.

Finally, the appendices discuss unique aspects of each region’s vulnerability to sea-level rise, including population data on developed lands close to sea level, policy context, and — where applicable —responses. Some of these aspects do not fit neatly within the structure of the issues presented in Parts I-III, such as the vulnerability of the Path trains in the New York area to flooding from sea-level rise, the dikes along Delaware Bay dating back to the 17th century, or the vulnerability of areas in Washington, D.C. created by filling the Potomac River.

IV.2 EXAMPLES

The following excerpts come from the appendices of this report and provide examples of the analytical insights possible within the regions:

IV.2.1 Long Island (Appendix A)

Long Island has almost 1,350 miles of coastline along Long Island Sound, the Peconic bays, the south shore bays, and the Atlantic Ocean. On the north shore of the island, coastal bluffs presently protect structures from possible inundation by rising seas; however, measures may be taken in the future to protect structures at the top of the bluffs from erosion at the bottom. Along the Atlantic shore, most of the shoreline, especially along the mainland and areas of the south shore, particularly within Nassau County, is highly developed and, as a result, has already been hardened by bulkheads.

There has already been a significant loss of the historical area of vegetated tidal wetlands in Long Island Sound (Holst *et al.*, 2003), which some scientists partially attribute to sea-level rise (Mushacke, 2003). Beaches are far more common than tidal wetlands in the Long Island Sound study area, however; and if the shoreline is hardened by armoring then the potential for beach loss is increased.

Because the eastern part of Long Island is not as densely populated as the western part, some coastal lands in eastern Long Island are designated for preservation, conservation, or recreation and therefore for the foreseeable future will most likely be left in a natural state in the face of rising sea level.

IV.2.2 New York Metropolitan Area (Appendix B)

Although people generally think of the Southeast as the coastal area vulnerable to natural disasters, the New York metropolitan area is also susceptible. For example, in December 1992 a powerful nor'easter submerged parts of uptown Manhattan in 4 feet of water, shut down significant portions of the city's transportation system, and caused coastal flooding that damaged as many as 20,000 homes. Given New York's large population, the effects of hurricanes and other major storms combined with higher sea levels could be particularly severe. With much of the metropolitan area's transportation infrastructure at low elevation (most at 3 meters or less), even slight increases in the height of flooding could cause extensive damage and bring the thriving city to a relative standstill until the flood waters recede (Gornitz, 2002).

Although the New York metropolitan area is among the most densely populated and highly developed in the nation, there are local ecosystems being affected by sea-level rise as well. For example, the wetlands of Staten Island may not be able to migrate inland as sea level rises because of the relatively steep slopes that have formed near the shore. Jamaica Bay's wetlands may be able to respond naturally to sea-level rise, but wetlands in some parts of the bay already show substantial losses (Hartig, 2002).

IV.2.3 New Jersey Shore (Appendix C)

As far back as the 1800's, the dense development of the New Jersey shore led many people to take the view that people should not simply retreat in response to storm erosion, but instead hold back the sea. In 1898 the U.S. Army built a seawall between Sandy Hook and Sea Bright to protect the operations at Fort Hancock (NPS, 2007). Over time, the seawall was extended south as far as Long Branch, and as a result there was little or no beach along most portions of the New Jersey shore between Long Branch and Sandy Hook. During the 1970s, oceanographer Orrin Pilkey and coastal geologists began to warn people around the nation about the disadvantages of what they called "New Jerseyization", by which they meant replacing beaches with seawalls (Pilkey, *et al.*, 1978). The state has since reversed that trend and restored the beaches, although the seawalls remain.

The New Jersey shore continues to be vulnerable to storm erosion and rising seas. In several neighborhoods in the southern half of Long Beach Island, streets and yards are flooded by spring high tides whenever the bay is elevated by either strong winds from the East or a rainy period.

Though New Jersey has a well-established policy against shore armoring along the developed ocean shores, today beach nourishment is the preferred method for reversing beach erosion and protecting oceanfront land from coastal storms. In fact, the primary debate in New Jersey tends to be the level of public access required before a community is eligible to receive beach nourishment, not the need for nourishment itself.

IV.2.4 Delaware Estuary (Appendix D)

From the 17th through 20th centuries, more marsh was converted to dry land along the Delaware River and Delaware Bay than anywhere else in the United States. Today, however, efforts are under way to restore the wetlands to areas that were formerly diked (DDFW, 2007). Therefore, wetlands may be able to migrate inland along New Jersey sections of the Delaware Bay shores as sea level rises. In Delaware, the combination of floodplain regulations, preservation easements, and land purchases has created a major conservation buffer that will almost certainly be available for wetlands to potentially migrate inland as sea level rises.

Pennsylvania is the only state in the nation along tidal water without an ocean coast. The resulting lack of barrier islands and communities vulnerable to coastal erosion and life-threatening hurricanes has often led observers to ignore the impact of sea-level rise on Pennsylvania (USGS, not dated). Pennsylvania's sensitivity to sea-level rise is in fact different than other states. The Delaware River is usually fresh along almost all of the Pennsylvania shore. Because Philadelphia relies on freshwater intakes in the tidal river, the most important impact may be the impact of salinity increases from rising sea level on the city's water supply. Areas of Philadelphia (mostly near Philadelphia International Airport) are already below spring high water because of the long history of dike construction and may be prone to flooding (see Figure IV.1).

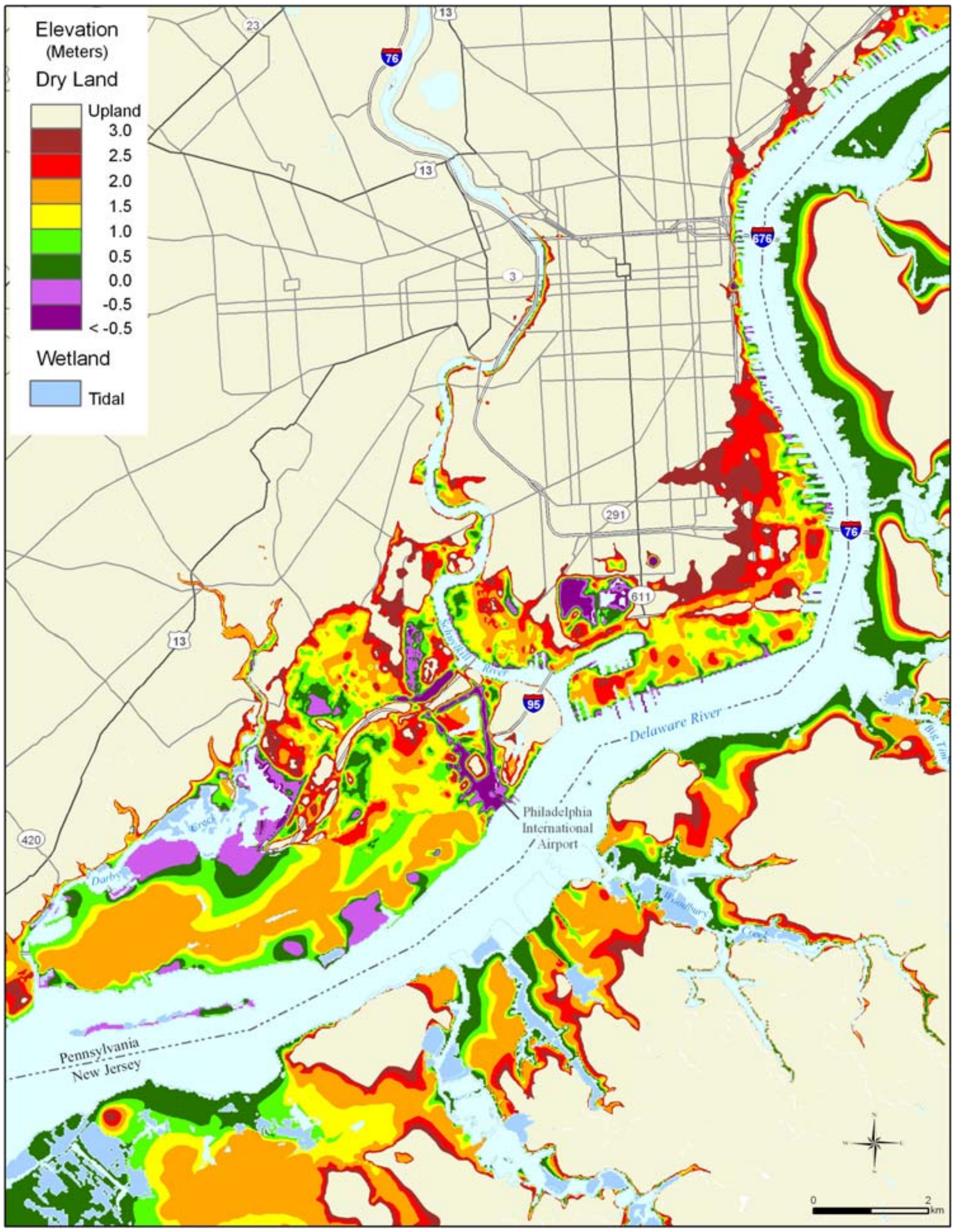


Figure IV.1 Philadelphia: Elevation relative to spring high water.

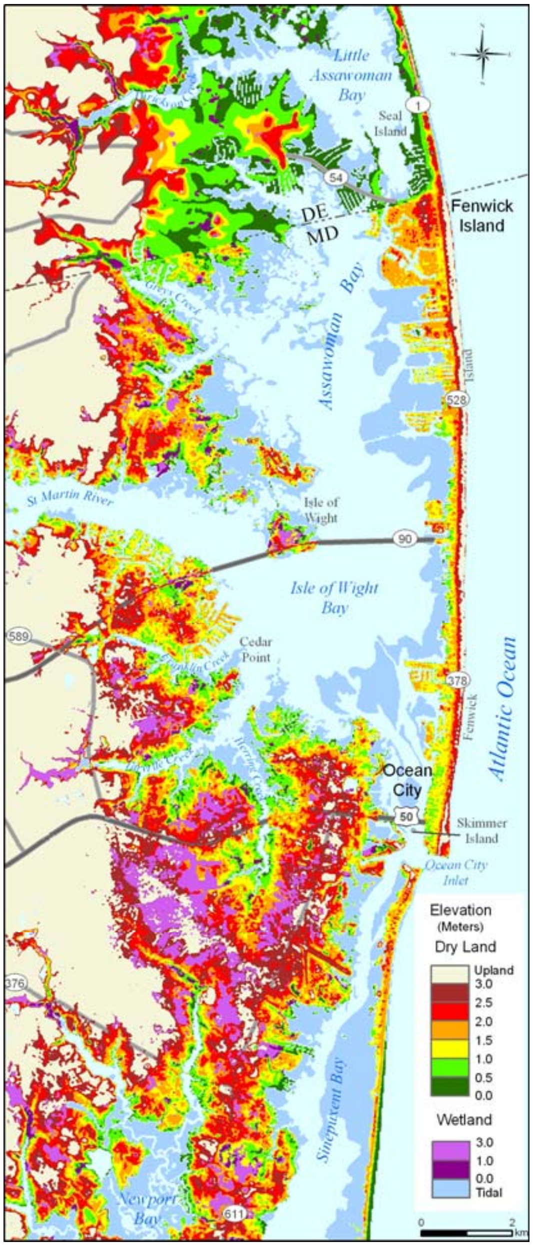
In addition, sea-level rise poses the risk of inundating dry land and reducing habitat for wildlife species along the bay. A sea-level rise modeling study estimated that a 2 foot rise in relative sea level over the next century could reduce shorebird foraging areas in Delaware Bay by 57 percent or more by 2100 (Galbraith *et al.*, 2002). If these foraging habitats are lost and prey species such as horseshoe crab decline, there are likely to be substantial reductions in the numbers of shorebirds supported by the bay (Galbraith *et al.*, 2002).

IV.2.5 DelMarVa (Appendix E)

Along the Atlantic Ocean between the mouths of the Chesapeake and Delaware bays lie approximately 200 kilometers of ocean beaches, only 30 kilometers of which have been developed. Unless conservation policies are reversed or conservation organizations change their priorities, the portion that is now developed is likely all that ever will be developed. All of the Virginia Eastern Shore's 124-kilometer ocean coast is owned by the U.S. Fish and Wildlife Service, The Nature Conservancy, or NASA. Of Maryland's 51 kilometers of ocean coast, 36 kilometers are Assateague Island National Seashore, and densely populated Ocean City occupies the other 15 kilometers. More than three-quarters of the barrier islands and spits in Delaware are part of Delaware Seashore State Park, while the mainland coast is about evenly divided between Cape Henlopen State Park and resort towns such as Rehoboth, Dewey Beach, and Bethany Beach.

With development accounting for a smaller portion of land area compared to other regions of the mid-Atlantic coast, the natural shoreline processes may dominate along much of the ocean shores. Counteracting shoreline erosion in developed areas with beach nourishment may continue as the primary shore preservation activity in the near term, but preventing the inundation of low-lying lands will eventually be necessary as well.

Maryland's Coastal Bays National Estuary Program has long included sea-level rise as a factor to be addressed in plans to protect the bays (MCBP, 1999), and the state of Maryland has the most stringent policies governing development along these coastal bays. The Virginia counties of the DelMarVa have shores along both the Atlantic Ocean and Chesapeake Bay, and setback rules that apply to both. Similarly, the Delaware Department of Natural Resources has proposed a 100-foot setback along their coastal bays (DNREC, 2007).



BOX IV.2: Elevating Ocean City as Sea Level Rises

Logistically, the easiest time to elevate low land is when it is still vacant, or during a coordinated rebuilding. Low parts of Ocean City's bay side were elevated during the initial construction. As sea level rises, the town of Ocean City has started thinking about how it might ultimately elevate.

Ocean City's relatively high bay sides make it much less vulnerable to inundation by spring tides than other barrier islands. Still, some streets are below the 10-year flood plain, and as sea level rises, flooding will become increasingly frequent.

However, the town cannot elevate the lowest streets without considering the implications for adjacent properties. A town ordinance requires property owners to maintain a 2% grade so that yards drain into the street. The town construes this rule as imposing a reciprocal responsibility on the town itself to not elevate roadways above the level where yards can drain, even if the road is low enough to flood during minor tidal surges. Thus, the lowest lot in a given area dictates how high the street can be.

As sea level rises, failure by a single property owner to elevate could prevent the town from elevating its streets, unless it changes this rule. Yet public health reasons require drainage, to prevent standing water in which mosquitoes breed. Therefore, the town has an interest in ensuring that all property owners gradually elevate their yards so that the streets can be elevated as the sea rises without causing public health problems.

Ocean City has developed draft rules that would require that, during any significant construction, yards be elevated enough to drain during a 10-year storm surge for the life of the project, considering projections of future sea-level rise. The draft rules also state that Ocean City's policy is for all lands to gradually be elevated as the sea rises.

Note: 1. This discussion is based on the presentation by Terry McGean, city engineer, Town of Ocean

Box Figure IV.2-1

IV.2.6 Chesapeake Bay (Appendix F)

Rising sea level has been altering the Jamestown peninsula in Virginia since at least colonial days. Two hundred years ago, the narrow strip of land that connected the peninsula to the mainland eroded, creating Jamestown Island (Johnson and Hobbs, 1994). Shore erosion also threatened the location of the historic town itself, until a stone revetment was constructed (Johnson and Hobbs, 1994). As the sea rose, the shallow valleys between the ridges on the island became freshwater marsh, and then tidal marsh (Johnson and Hobbs, 1994). Maps from the 17th century show agriculture on lands that today are salt marsh. The National Park Service may eventually have to decide whether to allow the rising sea to convert the island to open water or to continue to armor the shoreline.

Other shorelines along Chesapeake Bay have also been retreating over the last four centuries. Several bay island fishing villages have had to relocate to the mainland as the islands on which they were located eroded away (Leatherman, 1992). Low-lying farms on the eastern shores are converting to marsh, while the marshes in wildlife refuges convert to open water. As sea level rises, the risk of flooding is increasing from Poquoson, Virginia, to Fells Point in Baltimore, Maryland.

Coastal elevations and sensitivity to sea-level rise vary at a local scale along the Chesapeake Bay. Each area confronts unique issues and must design site-specific responses.

For example, between the Choptank River and Ocohannock Creek along the Eastern Shore of Chesapeake Bay lies that nation's fifth largest concentration of land close to sea level (see Figure IV.3). Water levels in roadside ditches rise and fall with the tides in some sections of Dorchester and Somerset Counties in Maryland. Tidal wetlands are gradually encroaching onto many farms. Narrow sandy beaches with gradual sloping shoreline throughout the area could accommodate moderate sea-level rise, assuming no armoring or other barriers exist. Many of the beaches provide critical nesting habitat for the diamondback terrapin (*Malaclemys terrapin*), and proximity of these nesting beaches to nearby marshes provides habitat for new hatchlings. Erosion control and shoreline stabilizing practices block access to the beach, forcing females to travel around the obstructions, or to deposit their eggs below the high tide line.

On the other hand, Lewisetta, Virginia, appears to be the only community along the Potomac River vulnerable to tidal inundation with a 50–100 cm rise in sea level. With a fairly modest rise in sea level, wetlands may begin to take over portions of Lewisetta's homeowners' yards and flooding will be more frequent. But outside a small number of other communities in this area, shore erosion–not inundation–will almost certainly be the primary factor forcing people to choose between shore protection and land loss.

Although each state has conducted assessments, neither Maryland nor Virginia has adopted an explicit policy to address the consequences of rising sea level. Nevertheless, both states have policies designed to protect wetlands, beaches, and private shorefront property and collectively create an implicit policy.

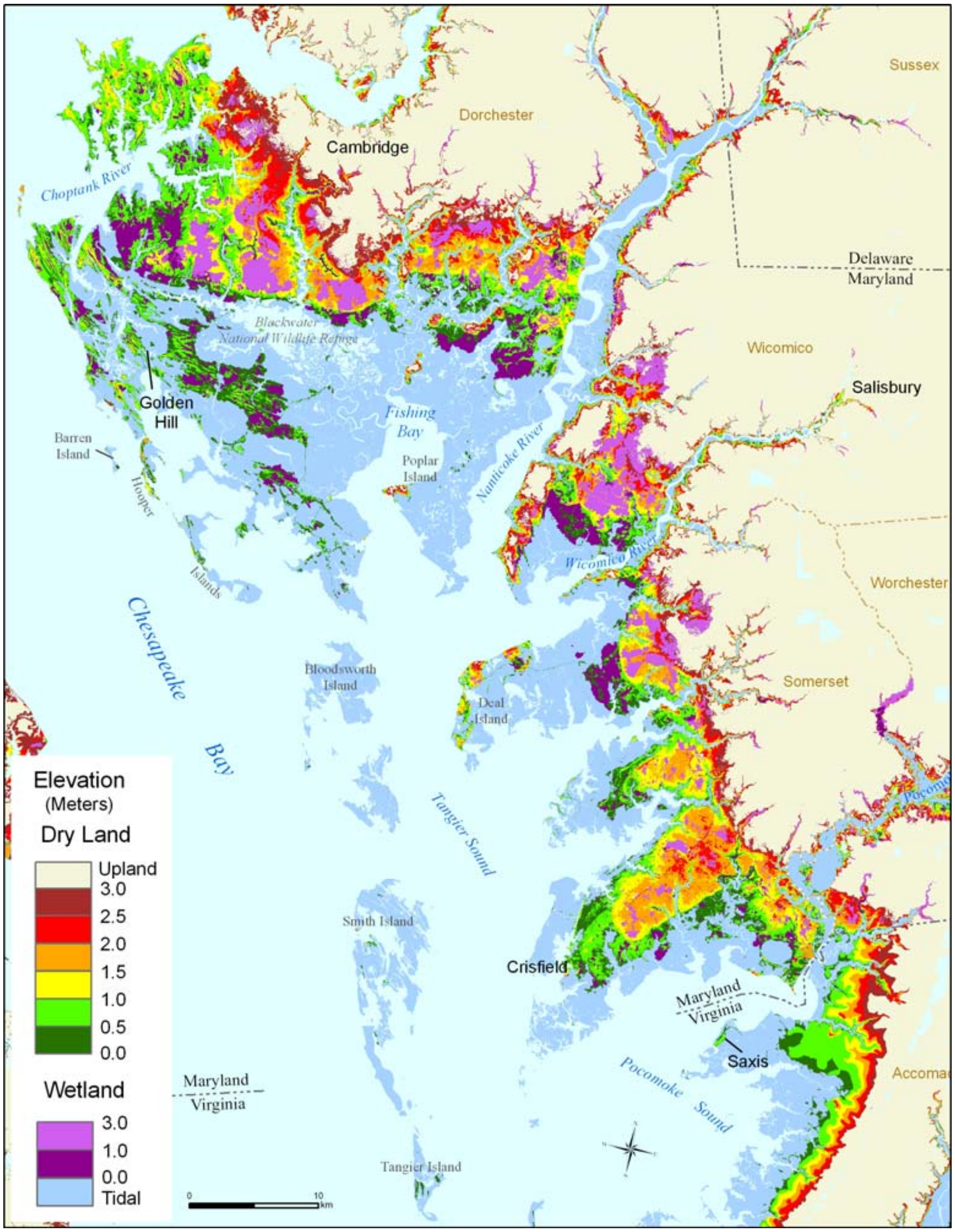


Figure IV.2 Lower Eastern Shore: Lands Close to Sea Level.

IV.2.7 North Carolina (Appendix G)

The third largest area of land vulnerable to rising sea level in the United States lies between Cape Lookout and the mouth of Chesapeake Bay (Figure IV.4). In North Carolina alone, between 1300 and 1800 square kilometers of dry land is within one meter above the tides (Titus and Cacela, 2008) —approximately half the total for the entire Mid-Atlantic. Another 3000 to 3400 square kilometers of non-tidal wetlands are within one meter above the tides —again approximately half the total for the entire Mid-Atlantic. The state of North Carolina alone has as much vulnerable ocean shore as all of the shores from Virginia to New York combined.

Many ocean shores in the state are gradually eroding, claiming shorefront homes and prompting officials to relocate the coastal highway (NC 12) and the Cape Hatteras lighthouse inland. Several studies have estimated increases in future shoreline erosion as sea level rises, and some researchers also believe that the islands off the coast of North Carolina may be in jeopardy if sea-level rise accelerates.

Some wetland systems in North Carolina are already at the limit of their ability to keep pace with rising sea level. Altered drainage patterns appear to be limiting their ability to build upward—and saltwater intrusion could cause subsidence and conversion to open water. Rather than helping the ecosystem respond to rising sea level, human activities appear to be disabling the processes that could otherwise allow these wetlands to stay ahead of the rising sea.

However, several North Carolina laws and regulations have an impact on response to sea-level rise: Buildings being constructed or reconstructed are required to be set back a certain distance from the shoreline, and property owners are not allowed to build seawalls, bulkheads, or dikes to hold back the sea.

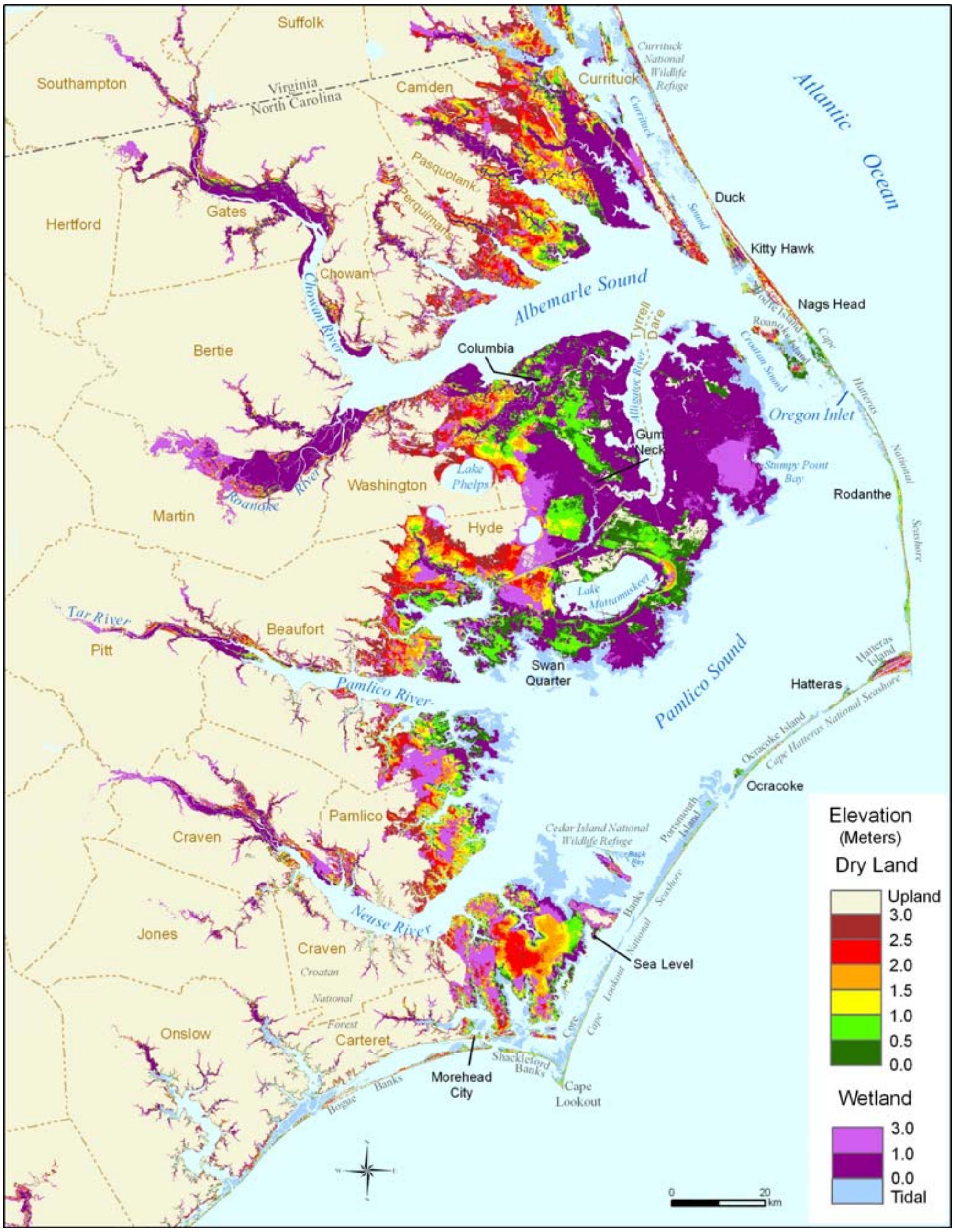


Figure IV.3 Elevation of lands close to sea level: Cape Lookout to Virginia Beach.

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