Maps that Depict the Business-As-Usual Response to Sea Level Rise in the Decentralized United States of America

By

James G Titus

OECD Global Forum on Sustainable Development
2004

Suggested citation: Titus, James G. 2004. Maps that Depict the Business-As-Usual Response to Sea Level Rise in the Decentralized United States of America, paper presented at the *OECD Global Forum on Sustainable Development: Development and Climate Change,* ENV/EPOC/GF/SD/RD(2004)9/FINAL, OECD, Paris.

Unclassified **ENV/EPOC/GF/SD/RD(2004)9/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

07-Feb-2005

English - Or. English

ENVIRONMENT DIRECTORATE
Environment Policy Committee

Global Forum on Sustainable Development

MAPS THAT DEPICT THE BUSINESS-AS-USUAL RESPONSE TO SEA LEVEL RISE IN THE DECENTRALIZED UNITED STATES OF AMERICA

by James G. Titus **http://risingsea.net**

Paris, 11-12 November 2004

JT00178101

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

English - Or. English

TABLE OF CONTENTS

MAPS THAT DEPICT THE BUSINESS-AS-USUAL RESPONSE TO SEA LEVEL RISE IN THE DECENTRALIZED UNITED STATES OF AMERICA[1]

James G. Titus[2]

1. Introduction and roadmap

1.1 Background

Over the last decade, numerous studies have demonstrated that rising sea level is serious enough to justify a response now, even though the most important impacts are still at least several decades away. Americans have—and continue—to develop areas that could be inundated by the tides within the next 50-100 years. In the coming decades, someone will have to decide whether to hold back the sea to protect these communities, or give them up to the rising sea.

Holding back the sea could undo one of the most important environmental accomplishments of the 20th century. By the 1970s, almost all tidal wetlands were placed off limits to development, which preserved an almost continuous strip of marshes, beaches, swamps, and mudflats along the US Coast. As the sea rises, those wetlands will be lost unless they are able to migrate inland, or environmental engineers can devise methods to allow them to be elevated in place.

Long-term approaches for managing low coastal lands as the sea rises can be broadly divided into three categories:

1. Protect the dry land with seawalls, dikes and other structures, eliminating wetlands and beaches (also known as *shoreline armoring*);

2. Elevate the land and perhaps the wetlands and beaches as well, enabling them to survive; and

3. Retreat by allowing the wetlands and beaches to take over land that is dry today

---

1. *Suggested citation:* Titus, James G. (2004), *Maps that Depict the Business-As-Usual Response to Sea Level Rise in the Decentralized United States of America*, paper presented at the OECD Global Forum on Sustainable Development: Development and Climate Change, ENV/EPOC/GF/SD/RD(2004)9/FINAL, OECD, Paris.

   The opinions expressed in this paper are those of the individual authors and do not necessarily reflect the views of their organisations or of the OECD.

2. Senior Policy Analyst, Project Manager for Sea Level Rise, Climate Analysis Branch, United States Environmental Protection Agency (USEPA). This draft paper does not represent the view of the Environmental Protection Agency.

Combinations of these three approaches are also possible.[3]

In the United States, elevating the land is the preferred approach along most developed ocean beach communities. Although it is the most expensive approach, both the development and the beach survive. Along estuaries, by contrast, shoreline armoring tends to be the preferred option.

The decentralized nature of environmental decision-making in the United States may be leading us to a result that no one chose. The national government prohibits destruction of most coastal wetlands. But the states, which own most of these tidal wetlands, have given property owners a near-universal permit to protect property by preventing wetlands from migrating onto dry land. Farmers rarely erect shore protection structures; but homeowners usually do. Counties allow most shorefront farms to be developed; many counties encourage residential shorefront development while preserving farms and forests inland. Thus, while America as a nation has chosen to save its existing wetlands, coastal states, counties, and property owners often choose to eliminate wetlands in the long run, by blocking their landward migration.

Figure 1 illustrates this paradox. The current momentum is mostly the result of a "business as usual" failure to plan for sea level rise. If the sea was not rising, current regulations would protect the wetlands--and shore protection costs would not increase. But the sea is rising. This situation suggests an urgent need for planning—perhaps not everywhere, but at least somewhere. For a given coastal area, either

- Planning is <u>not yet necessary</u>, because the time we have until important consequences occur is greater than the lead time required for preparation;

- Planning is <u>not necessary</u>, because an informed decision maker would choose the same course that we are following anyway; or

- <u>We should plan</u> because if we did, we would choose to save more ecosystems, and protect coastal communities more effectively.

The US coastal zone includes all three situations. (1) Some coastal areas will not be eroded or inundated for several centuries even in a worst-case scenario. (2) no matter how much we would like to keep our coastal wetlands or avoid expenditures for shore protection, we would never give up Boston, New York, Washington, Charleston, Miami, or Galveston to the sea.[4] And yet, (3) the land within one meter above high tide could be inundated within the next century. Land use decisions can determine which areas are developed for centuries; so it would be reasonable to incorproate the response to sea level rise within any land-use or infrastructure planning for areas within two meters above high water. If <u>keeping all</u> our wetlands was important enough to prohibit them from being filled for coastal development, <u>sustaining some</u> of the wetlands is probably important enough prevent future land use from eliminating them. Why would the United States go to the expense of protecting almost coastal wetlands in a given community

[3] Many barrier island communities elevate the ocean-side beach, while armoring the bay sides; conversely, after the catastrophic hurricane of 1900, Galveston was elevated 1-2 meters and a seawall was constructed along the Gulf of Mexico. Several IPCC reports propose an option called "accommodation", in which shores are allowed to retreat, but structures are protected through floodproofing and elevation. This approach is a common short-term response, but in the long run, homes resting on dry land would become docks standing over open water.

[4] A categorical statement about the fate of New Orleans is more difficult.

when the coast is being developed, but not protect of them in perpetuity? Planning for the future appears to be the only rational response.[5]

Communities with limited resources, however, are not irrational for failing to divert attention from pressing problems to address future sea level rise. The overhead cost of thinking about a new issue can be a full-time job, and thus beyond the reach of all but the largest or most flood-prone communities.[6] Moreover, some communities prefer waterfront housing over wetland protection, i.e., for them planning is not necessary because they would choose the same course as what we are following anyway.

Even though planning for sea level rise is not a part of local comprehensive plans, many levels of government have policies regarding coastal erosion, flooding, development, and preservation of open space. Those policies combined provide a *de facto*, albeit unofficial, baseline plan for sea level rise.

Until now, however, no one has attempted to discern that baseline plan for a large area. Assessment of sea level rise have had hypothetical shore protection scenarios, rather than determining what is likely to happen by asking the people who actually make the decisions.

1.2 Purpose and roadmap

This paper is an interim report of an ongoing study by the US Environmental Protection Agency to create maps that distinguish the lands that are likely to be protected from erosion and inundation as the sea rises, from those areas where shores are likely to retreat naturally. This author and various EPA contractors have obtained land use and zoning data, and discussed land use plans related to sea level rise and shore protection, with the planning staffs from approximately 100 local governments along the US Atlantic Coast. Maps have been completed and reviewed by 70 localities between New York and North Carolina; draft maps are being reviewed and revised for 30 jurisdictions in South Carolina, Georgia, and Florida.

This study is part of a continuing effort by the US Environmental Protection Agency to encourage the long-term thinking required to deal with the impacts of sea level rise. The nature of rising sea level prevents the issue from being a top priority; but it also gives us time to reflect upon how to address the impacts. Many researchers have developed maps that illustrate the areas that might ultimately be submerged; while informative, those maps can leave some coastal residents with the impression that the authors believe that submergence is beyond their control. Maps that illustrate alternative visions of the future may promote a more constructive dialogue.

These maps are intended for two very different audiences:

- *State and Local Planners and Others Concerned about Long-Term Planning of the Coastal Zones.* Whether one is trying to ensure that a small town survives, that coastal wetlands are able to migrate inland, or some mix of both, the most cost-effective means of preparing for sea level

---

5 A rational decision makes could conclude that waterfront housing will be more important than environmental protection in the next 50-100 years, but how does one reconcile such a conclusion with the decision to prevent wetlands from being converted to waterfront housing in the last 50 years.

6 This situation may create a mild bias against planning for sea level rise. If the costs of holding back the sea are great, it will be the federal or state government—not the local government—that funds the shore protection. It is the state that loses the wetlands that it holds for the people. Moreover, local governments rarely address an issue unless citizens demand action. In the case of rising sea level, local demand is not great because the people likely to be living in a community during the 22nd century generally have not been born.

rise often requires implementation several decades before developed areas are threatened. EPA seeks to accelerate the process by which coastal governments and private organizations plan for sea level rise. A key step in preparing for sea level rise is to decide which areas will be elevated or protected with dikes, and which areas will be abandoned to the sea.

- National and International Policy Makers, as well as anyone trying to decide upon the importance or reducing greenhouse gas emissions. National and international policies regarding the possible need to reduce greenhouse gas emissions require assessments of the possible impacts, and such an assessment depends on how people manage the impacts of sea level rise—and other consequences of climate change.

Section 2 of this paper shows that responding to sea level rise requires a relatively near-term decision among three fundamental pathways (retreat, elevation, and armoring), even if most of the work will not be required for a long time. The section briefly describes effects and responses to sea level rise. It then offers several examples where the appropriate action today depends on which of these long-term responses a community will follow.

Section 3 presents the mapping study of where people are likely to hold back the sea. In Florida, these maps are being prepared and formally adopted by the regional planning councils. In other states, these maps are not part of the comprehensive land use planning process, but they may be used as a reference for local officials responsible for infrastructure. We hope to ultimately prepare maps that show how people are likely to hold back the sea, but such distinctions were outside the scope of this study.

2. The three pathways for responding to sea level rise

2.1 Effects of sea level rise

The most important effects of sea level rise are the gradual inundation of wetlands and low dry land, erosion of beaches, increased flooding, and increases in the salinity of rivers, bays, aquifers, and wetlands. EPA has prepared a large map, available on the web, which shows the land vulnerable to inundation along the Atlantic and Gulf Coasts.[7] Each of the Gulf Coast states and the Atlantic coast states from New York southward has at least 180 square kilometers below the 1.5-meter contour. The land below the 1.5 meter contour includes 2000 square kilometers of developed barrier islands, 6000 square kilometers of farms, 7000 square kilometers of forests, 2000 square kilometers of residential lands, and 1200 square kilometers of urban and industrial areas.

Although the 1.5-meter contour provides an indication of the land vulnerable to sea level rise, it does not depict where the shore would be if the sea rose 1.5 meters, because (a) the sea has risen since 1929 when the map benchmark was established; (b) the tides flood areas that are above mean sea level; (c) wetlands vertically accrete as the sea rises; and (d) beaches erode. A study by EPA that considered all of these factors estimated that without human intervention, a one-meter rise in sea level would inundate 23,000 square kilometers of dry land, of which 8000 square kilometers would be converted to wetlands and the remainder to open water. The creation of 8000 square kilometers of new wetlands would partly offset the inundation of 26,000 square kilometers of existing wetlands, for a net loss of about 18,000 square kilometers. According to the Federal Emergency Management Agency, if the sea rose one meter, the 100-year floodplain would expand from 60,000 square kilometer today to 80,000 square kilometers.

[7] See http://www.epa.gov/globalwarming/publications/impacts/sealevel/maps/maps.html

In addition to the direct inundation of low land, higher sea level can cause land above sea level to erode approximately 50-200 meters for every meter of sea level rise. Along densely developed ocean shores, beach nourishment protects shorefront development without sacrificing the beach. Along estuarine shores, however, the beaches are being eliminated by the construction of bulkheads and revetments, effectively privatizing shores to which the public is legally entitled to access, and eliminating critical habitat for horseshoe crabs, terrapins, and a number of endangered birds and insects.

2.2 Opportunities to prepare for rising sea level

Coastal communities have three fundamental responses to sea level rise:

- shoreline armoring, i.e. seawalls and dikes to hold back the sea;
- elevate land and structures (includes beach nourishment); and
- retreat/no shore protection, tolerating whatever erosion and flooding occurs.

Rising sea level has numerous implications for current activities. In most cases, however, the appropriate response depends on whether and which of these three courses of action a particular community intends to follow. (See Table 1.)

Coastal Drainage Systems. Sea level rise slows natural drainage and the flow of water through drain pipes that rely on gravity. If an area will not be protected from increased inundation, then larger pipes and pumping may be necessary. If an area will be protected with a dike, then larger pipes are less important than underground storage, check valves, and making sure that the system can be retrofitted to allow for pumping. If the land surfaces are going to be elevated, then sea level rise will not impair drainage.

Road Maintenance As the sea rises, roads flood more frequently. If a community plans to elevate land with the sea, then repaving projects should elevate the roadway accordingly. If a dike is on the horizon, then repaving projects should consciously avoid elevating the street above people's yards, lest the projects prompt people to spend excess resources on elevating their yards when doing so is not necessary in the long run.

As an example, Ocean City, Maryland currently has policies in place that would be appropriate if the long-term plan was to build a dike and pumping system—but the town intends to elevate instead. Currently, the town has an ordinance that requires property owners to maintain a 2 percent grade so that yards drain into the street. The Town has construed 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, the town will be unable to elevate 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. The town has developed draft rules that would require that during any significant construction, yards to 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.

Sewer. Rising sea level can elevate the water table to the point where septic systems no longer function properly. If areas will be protected with a dike, then all the land protected must eventually be artificially drained and sewer lines further such a response by facilitating drainage. On the other hand, extending sewer would be entirely incompatible with allowing wetlands to migrate inland, because the

high capital investment tends to encourage coastal protection; a mounds based septic system is more compatible. If a community's long-term plan is to elevate the area, then either a mounds-based system or extending public sewage will be compatible.

Subdivision and Setbacks. If a dike is likely, then houses need to be set back enough from the shore to allow room for the dike and associated drainage systems. Setbacks and larger coastal lot sizes are also desirable in areas where a retreat policy is preferred, for two reasons: First, the setback provides open lands onto which wetlands and beaches can migrate inland without immediately threatening property. Second, larger lots mean lower density and hence fewer structures that would have to be moved—as well as less justification for investments in central water and sewer. By contrast, in areas where the plan is to elevate the land, sea level rise does not alter the property available to the homeowner, and hence would have minor implication for setbacks and lot sizes.

Covenants and Easements Accompanying Subdivision. Although setbacks are the most common way to anticipate eventual dike construction or the landward migration of wetlands and beaches, a less expensive method would often be purchase of (or regulatory conditions requiring) rolling easements, which allow development but prohibit hard structures that stop the landward migration of ecosystems. Figure 2 shows how a rolling easement might work over time. The primary advantage is that society makes the decision to allow wetlands to migrate inland long before the property is threatened, so that people can plan around the assumption of migrating wetlands, whether that means leaving an area undeveloped or building structures that can be moved.

Local governments can also obtain easements for future dike construction. Both of these types of easements would have very low market prices in most areas, because the fair market value is equal to today's land value discounted by the rate of interest compounded over the many decades that will pass before the easement would have any effect. As with setbacks, a large area would have to be covered if wetlands are going to migrate inland, a narrow area would be required along the shore for a dike, and no easements are needed if the land will be elevated in place.

Locations of Roads. As the shore erodes, any home that is only accessed by a road seaward of the house could lose access before the home itself is threatened, and even homes seaward of the road might lose access if the road is washed out elsewhere. If the shore is expected to erode, it is important to ensure that all homes are accessible by shore-perpendicular roads, a fact that was recognized in the layout of early beach resorts along the New Jersey and other shores. But if a dike is likely, then a road along the shore would be useful for dike construction and maintenance. If all land is likely to be elevated, then sea level rise may not have any significant impacts on the location of new roads.

3. Sea level rise planning maps

Many other decisions may be affected by sea level rise, but from these examples, one thing is clear: neither property owners nor government project managers can incorporate the risk of sea level rise into their decisions unless they know whether–and in most cases how–the land will be protected from the sea. Nevertheless, planning directors and other local officials have generally told EPA staff that incorporating sea level rise into their master plans is not something that they are likely to do for the foreseeable future, because there is currently no significant demand from the public to do so. There is no opposition to such planning either, but with limited time, local government must focus on problems that the public wants solved.

What is to be done when there is little local demand for an activity that would accomplish important policy goals in a cost-effective fashion? The first question is whether, without any planning at all, we are likely to "muddle along" and reach the same result that the most farsighted planner would have

reached anyway. Therefore, EPA's Sea Level Rise Planning Project is developing GIS-based maps illustrating which low-lying coastal lands would be protected from rising sea level, and which lands would gradually be eroded or inundated as the sea rises.

Within the study area, our maps use the following colors:

- Brown—areas that will almost certainly be protected if and when the sea rises enough to threaten them;

- Red—areas that will probably be protected, 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 that probably will not be protected, 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—but if property values increase these areas might be protected;

- Light Green—areas where existing policies would preclude holding back the sea. These areas include both publicly and privately owned lands held for conservation purposes.

Outside the study area, we generally show nontidal wetlands as purple and tidal wetlands as dark green. Note: For purposes of this discussion, the term "protection" refers to engineering efforts to prevent land from being eroded or flooded.

This information may help to promote planning for several reasons: First, a baseline planning scenarios is often a first step needed before local governments can incorporate an issue into their master plans. Second, even if master plans do not formally incorporate sea level rise, the availability of maps based on local planner's best judgment may help to ensure that infrastructure decisions are based on internally consistent assumptions about the future. Third, permits for shoreline armoring sometimes require environmental assessments of cumulative impacts; the cumulative impact depends on how much of the shore will be protected. Fourth, private and public conservancies considering the purchase of coastal ecosystems need to know where the wetlands would otherwise be able to migrate inland, and where they would otherwise be squeezed between the rising sea and developed areas.

3.1 Methods

3.1.1 Study Area

The study area consists of dry lands that are either below the 20-foot (6 meter) contour, or land within 300 meters of the shore. We used the 20-foot contour because in many areas, it is the lowest contour available and we wanted a relatively uniform study area. For various reasons, the 20-foot contour is approximately 5 meters above the upper edge of tidal wetlands.[8] For the lay public, which might construe the study area boundary as a prediction that sea will rise 5 meters, we plan to prepare maps that only depict those areas that might be inundated within the foreseeable. Nevertheless, the over-inclusive study area has some advantages: over several centuries, the sea may rise 5 meters, storm surge flooding may warrant

[8] The spring high tide tends to be almost one meter above the National Geodetic Vertical Datum of 1929, for two reasons. First, the spring high tide tends to be 30-100 cm above the mean tide level. Second, mean tide level tends to be about 15-30 cm above NGVD, mostly because the sea has risen 15-30 cm since 1929 along the Atlantic Coast.

consideration of lands not vulnerable to tidal flooding, and elevation data is poor but improving. It is easier to reformat maps by excluding some areas that were part of the study area, than to include areas that were mistakenly omitted in the study. High ground within 300 meters of the shore accounts for possible erosion.

3.1.2 Draft maps: General approach

We first researched state and county laws and plans for development to determine the policies that affect coastal management decisions. Next, we met with state regulators and county planners to investigate existing and anticipated coastal policies and land uses.[9] Their knowledge about local priorities and wishes allowed us to glean broad policy directions based upon land use.

State and local officials had not previously assessed the areas that might ultimately be protected, aside from the heavily developed recreational barrier island resorts, a few important bay beach resorts, and a few areas where wetland erosion is severe or policies exist to limit shoreline armoring for environmental purposes.[10] Nevertheless, the primary question for this study involves many of the same issues that planners routinely consider, most importantly: which areas will become densely developed, which areas will be placed off-limits to development, and which areas are conservation lands. Because the results of such considerations are increasingly published as a GIS data layer, we have tried wherever possible to rely on available land use data, especially data on land use plans, existing land use and land cover, and boundaries of conservation areas.[11]

During the meetings, state and local staff explained which policies would have an effect on the eventual response to sea level rise. We then asked state and local planners to consider the anticipated planning responses given rising seas of 30-90 cm in the next 100 years and as much as 3 meters over the next few hundred years. We also discussed public access to the water, economic conditions, areas of cultural or historical importance, and flood-prone areas.

Most importantly, we also asked the planners to identify the lands that would be protected or lost under different scenarios. Where appropriate, they suggested general categories of land, which often would correspond to a designation in a GIS dataset, enabling us to create a generalized sea level rise planning map by applying a "decision rule" to the data. *We use the term "decision rule" in this report because our processing of land use data treats the county-specified general categories as geographical information system decision rules; we do not mean to suggest that those categories represent policy decision rules*. Those general categories consider existing policies that influence both future development and shoreline armoring and nourishment and the likelihood of future shoreline protection. For example, a decision rule might be that all development outside of designated growth areas will probably be protected (red).

---

9 Because this assessment is intended to reflect the general consensus of officials within the area depicted, we rely heavily on the informed opinions of local planners. Although available land-use and land planning data guide the results and often defined the boundaries in these maps, the expert judgment of local officials generally were the most important source of information.

10 Calvert County, Maryland prohibits shoreline armoring along most of its cliffs, to protect the endangered tiger beetle and ensure sediment supply. Outside of our study area, several New England states also prohibit shoreline armoring to maintain traditional uses of the shore, and Washington State prohibits armoring in some areas to protect salmon shallow water habitat.

11 For example, we use 1997 land use data provided by Maryland Department of Planning to delineate presently developed lands (i.e., residential, commercial, industrial lands).

Table 2 is a generalized version of the decision rules local officials suggested. The actual approach in a given county depended on land values, shore protection costs, existing land use policies, and the availability of data needed to apply a specific general rule.

In general, densely developed areas along the ocean, and moderate to high-density communities along rivers and bays are almost certain to be protected (brown). Nevertheless, several areas have specific policies that make protection less likely. Along the ocean, shore protection is only cost-effective if undertaken for a long stretch of shore, which rarely occurs without government subsidies. A federal statute in the early 1980s designated most remaining undeveloped barrier islands and spits as ineligible for federal subsidies. Some of those areas became densely developed anyway, and private shore protection may be cost-effective; some of those islands lack bridges or road access, and have not developed enough for shore protection to even be likely.

At the other end of the spectrum, a small number of communities have regulations prohibiting shore protection for environmental purposes (light green). Other areas where the general rule would be to assume no protection include wildlife refuges, parks managed for conservation purposes, and private conservation lands.

Shore protection is possible but not likely (blue) for most lands where development is not expected. The owners of riparian farms and forests generally tolerate modest shore erosion, and the gradual conversion of lands to marsh. Nevertheless, current state policies generally give property owners permits to hold back the sea, and occasionally dikes are constructed to protect farm communities from inundation. Land use plans often identify areas where development is not expected.[12] In addition, conservation easements prevent development of some farms and forests (while often reserving the right to armor the shore), and the managers of some large parks often tolerate the gradual erosion or inundation of shorefront property.

Most local planners had the greatest difficulty in distinguishing areas where shore protection is likely, from those where it is either certain or unlikely. Defining this category tends to be a judgment call. These include the areas where the need for planning is greatest. In some cases, it is possible to conceive of either allowing wetlands to migrate inland or not—but if no policy is enacted soon, protection will be inevitable—including undeveloped lands where development is expected but not certain, as well as some lightly developed areas where retreat is possible. In other cases, the land is similar to areas that will be protected, but the lack of federal subsidies makes shore protection less certain—such communities need a plan for defending the shore without federal assistance, or risk losing neighborhoods to the rising sea even though the land values are greater than the shore protection cost.

[12] Existing data probably overestimates the areas that will not be developed. Most rural jurisdictions do not have zoning ordinances preventing development for the sake of rural preservation; rather they have land use plans that encourage development in specific areas for the sake of providing services. Planners for those jurisdictions do not officially expect development in other areas. But they would not deny a permit, and when pressed to think about development over the next 50 years, tend to expect much of their shores to be developed. Suburban jurisdictions often have identified a few areas where the county actively seeks to persuade developers not to build close to the shore. Some jurisdictions have regulations limiting development. Maryland's statute designates a few areas where development is limited to one home for every 20 acres, and some counties actively discourage development in flood-prone coastal areas. But that is the exception—it is more common for local jurisdictions to encourage waterfront development, because it helps the property tax base.

3.1.3 County-specific changes

We then identified area-specific exceptions to these general rules. For example, a county might be quite certain that specific towns will be protected (brown), even though they are not within the designated growth areas. These site-specific exceptions sometimes required hand-editing of the map. Based upon this information, we then developed the maps depicting the relative likelihood of shoreline protection within each county.

To ensure that our maps correctly conveyed the expectations of county officials, we sent the draft report and maps to each of the counties. We then conducted follow-up "stakeholder review" meetings at which we obtained suggested changes to both the maps and the report. Those changes were then incorporated into this draft of the report and into the accompanying maps. In many cases, we had additional follow-up conversations to clarify issues raised during the stakeholder review meetings.

The interviews for this study were conducted by different individuals, and thus to some extent, similarities and differences may reflect the different approaches. Some members of the team tended to start with a consistent set of GIS decision rules for all of the counties, and make county-specific and site-specific changes as requested. Others took an individualistic approach, in which they discussed sea level rise at length with counties and prepared decision rules for each, based on specific—and sometimes idiosyncratic--situations. This writer tended to re-examine issues again and again, and was the most inclined of the team to go back and look at a particular shoreline to ensure that the locality understood the ramifications of how a particular area was mapped.

Counties had at least one--and usually two to four--opportunities to revise the maps. Therefore, the ultimate result should reflect what they actually believe, rather than our individual approaches for determining what they expect—especially for those lands that matter most. Nevertheless, for areas where county officials had little or no basis to predict the future, or small areas where their concern was the least, the maps may reflect a residual from the respective approaches, try as we did to prevent our own subjective expectations from influencing the results.

4. Interim results and next steps

Figures 3 shows the resulting map for an illustrative county, Worcester County, Maryland. Depending on where you obtained this paper, you may either have the color map produced by the project, or a simplified black-and-white map that lumps brown with red, and blue with light green. The northern barrier island is Ocean City, which has many high rises along the ocean and single family homes elsewhere. This area, as well as many mainland communities, are certain to be protected (brown). The central part of the mainland shore along the back-barrier bay is still mostly farm and forest—but development is expected; hence this area will probably be protected (red). In the southern part of the county, the Lower Shore Conservancy and others are obtaining conservation easements to prevent housing developments from replacing the shorefront farms and forests. Shore protection is unlikely (blue), but it is still possible in those areas, because the standard conservation easement in Maryland explicitly states that the owner can armor the shore. The southern barrier island is part of Assateague Island National Seashore. The National Park Service generally is committed to allowing natural processes to work; hence the map assumes "no protection" (light green). At the western side of the county, private lands are expected to remain agricultural and not protected (blue) along the Pocomoke River, and portions of the shore are within conservation lands (light green).

Figures 4 and 5 show Maryland and North Carolina, respectively. We are in the process of bringing the various state-specific studies into a common GIS data base. We only have complete statistics

for North Carolina; Table 3 shows shore protection likelihood by elevation. Table 4 summarizes the statistics for the entire study area for several other states.

In addition to completing these maps for the rest of the coastal states, we plan two other efforts. First, we are supporting an effort by the National Academy of Sciences to examine the ecological consequences of shore protection, and to examine the least environmentally disruptive means for shore protection. Second, we plan to prepare a parallel set of maps depicting the means by which shores will be protected

Table 1. **How the best way to prepare for sea level rise depends on whether and how a community intends to hold back the sea**

	Fundamental Response Strategy		
Activity	**Shoreline Armoring (Dike or Seawall)**	**Elevate Land**	**Retreat (No Protection) Wetland Migration**
Rebuilding drainage systems	Checkvalves, holding tanks room for pumps	No change needed	Install larger pipes, larger rights of way for ditches
Replace septics with public sewer	Extending sewer helps improve drainage	Mounds systems elevate septic system; extending sewer also okay	Extending sewer undermines policy; mounds system ok
Rebuild roads	Keep roads at same elevation; owners will not have to elevate lots	Rebuild road higher, motivates property owners to elevate lots	Elevate roads to facilitate evacuation
Location of roads	Shore-parallel road needed for dike maintenance	No change needed	Shore parallel road will be lost; all must have access to shore-perpendicular road,
Setbacks/ Subdivision	Setback from shore to leave room for dike	No change needed	Erosion-based setbacks
Easements	Easement or option to purchase land for dike	No change needed	Rolling easements to ensure that wetlands and beaches migrate

Table 2. **General approach for identifying likelihood of shore protection**[1]

Likelihood of Protection	Land-Use Category
Shore Protection Almost Certain (brown)	Existing developed land (commercial/ industrial/residential/governmental) within extensively developed areas or designated growth areas (including areas with central water and sewer)
	Extensively used state parks operated for purposes other than conservation, in areas that are certain to be protected, and have current shore protection.
	Future development within extensively developed areas and/or designated growth areas
	Publicly owned developed (e.g., historical landmarks) and military lands
	Military Lands in urban areas where land would be protected even if base closed
	Existing development within less densely developed areas or outside of growth areas (in the majority of counties)
Shore Protection Likely (red)	Existing development within less densely developed areas or outside of growth areas (in a minority of counties)
	Lightly developed areas with no central water or sewer—or mobile homes—in areas not expected to gentrify
	Projected future development outside of growth areas
	Moderately used parks operated for purposes other than conservation in areas likely to be protected, or shorefront parks with no current protection in areas certain to be protected.
	Military Lands in areas where protection is not certain
	Moderately Developed Oceanfront lands ineligible for federal subsidies, or surrounded by areas that will not be protected
	Conservation Easements in some areas where shore protection would be certain even if land remained as farmland
Shore Protection Unlikely (blue)	Undeveloped privately owned land in areas expected to remain sparsely developed (i.e., not in a designated growth area[3] and not expected to be developed)
	Lightly developed unbridged or roadless barrier islands ineligible for federal subsidies
	Resource Conservation Area (Critical Areas Act)
	County-owned lands
	Conservation Easements in most locations
No Shore Protection (light green)	Private lands owned by conservation groups, and some conservation easements
	Publicly owned natural lands
	Developed Areas where environmental regulations prohibit shore protection

Table 3. **Likelihood of shore protection in North Carolina, by elevation**

(square kilometers)

Elevation (cm)	Protection Certain	Likely	Unlikely	No Protection	Non-Tidal Wetland
30	111	47	283	15	1418
60	106	53	213	12	774
90	114	74	173	9	498
120	87	81	172	9	334
150	80	79	191	8	242
180	86	83	213	8	198
210	88	77	223	7	183
240	81	66	208	7	169
270	65	43	231	10	161
300	61	38	254	10	157
330	57	42	274	5	155
360	55	48	311	4	141
390	49	44	312	3	130
420	44	33	296	3	135
450	38	31	230	3	122
480	33	29	196	3	145
510	29	25	189	3	149
540	26	22	137	3	110
570	24	22	124	3	100

Note: Elevations are in 30-cm increments above mean spring high water, which is generally the upper edge of tidal wetlands.

Table 4. **Likelihood of shore protection within study area (square kilometers)**

Will Land Be Protected?		New Jersey	Penn-sylvania	Delaware	Maryland	District of Columbia	North Carolina
Shore Protection Certain	N	660	53	267	875	19	1078
Shore Protection Likely	N	158	30	44	524	3.0	802
Shore Protection Unlikely	Y	264	23	323	1584	1.4	3342
No Shore Protection	N	104	0.7	93	235	0	107
Non Tidal Wetlands	Y	no data	15	119	440	0	4676
Tidal Wetlands	N	1360	6	347	1166	0.47	1271

Note: Study area includes all dry land that is either within 300 meters of the shore, or less than 6 meters above the National Geodetic Vertical Datum of 1929. See text for explanation for why we use such an over-inclusive study area.

ANNEX. FIGURES

Figure 1. **The failure to plan for sea level rise could/may lead the United States to unwittingly repeal wetland protection policies.** The public trust doctrine of English Common Law, and US wetland-protection policies prevent people from filling mudflats, marshes, swamps and intertidal beaches. As a result, new construction is generally set back inland from the high water mark and wetlands are protected. Because these policies do not consider shoreline erosion, however, the shore will eventually erode up to the development, leaving us with the same situation that would have resulted had developers been allowed to fill the wetlands in the first place.

Figure 2. **How a rolling easement might work over time.** A rolling easement allows construction near to the shore, but requires the property owner to recognize nature's right of way to advance inland as sea level rises. In this case, the high marsh reaches the footprint of the house 40 years hence. Because the house is on pilings, it can still be occupied (assuming that it is hooked to a sewerage treatment plant-a flooded septic system would probably fail). After 60 years, the marsh has advanced enough to require the owner to park the car along the street and construct a catwalk across the front yard. After 80 years, the marsh has taken over the entire yard; moreover, the footprint of the house is now seaward of mean high water and hence on public property. At this point, additional reinvestment in the property is unlikely. Twenty years later, the particular house has been removed, although other houses on the same street may still be occupied. Eventually, however, the entire area returns to nature.

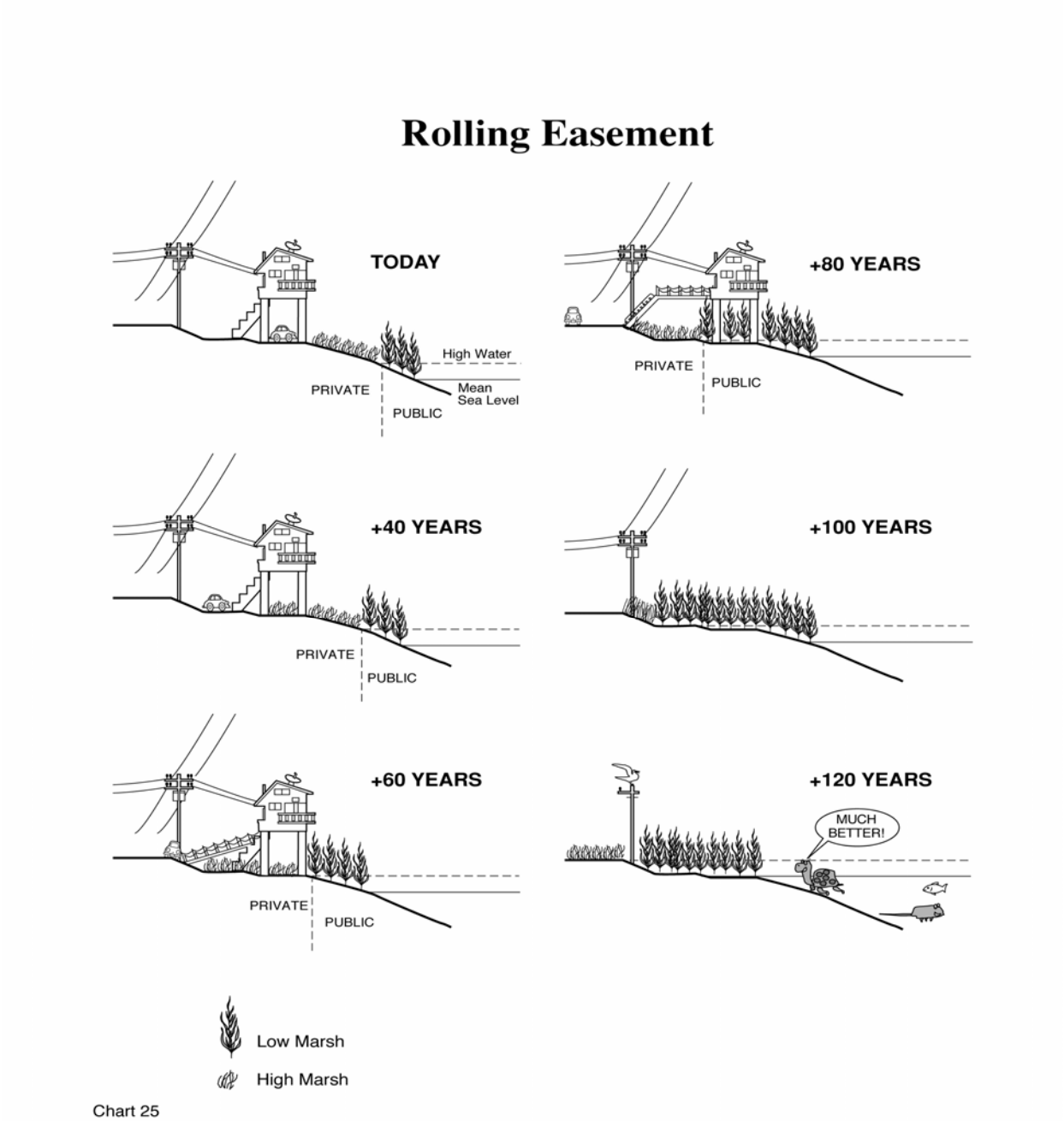

Figure 3. **Worcester County, Maryland: Long-term shore protection plan as sea level rises given business as usual.**

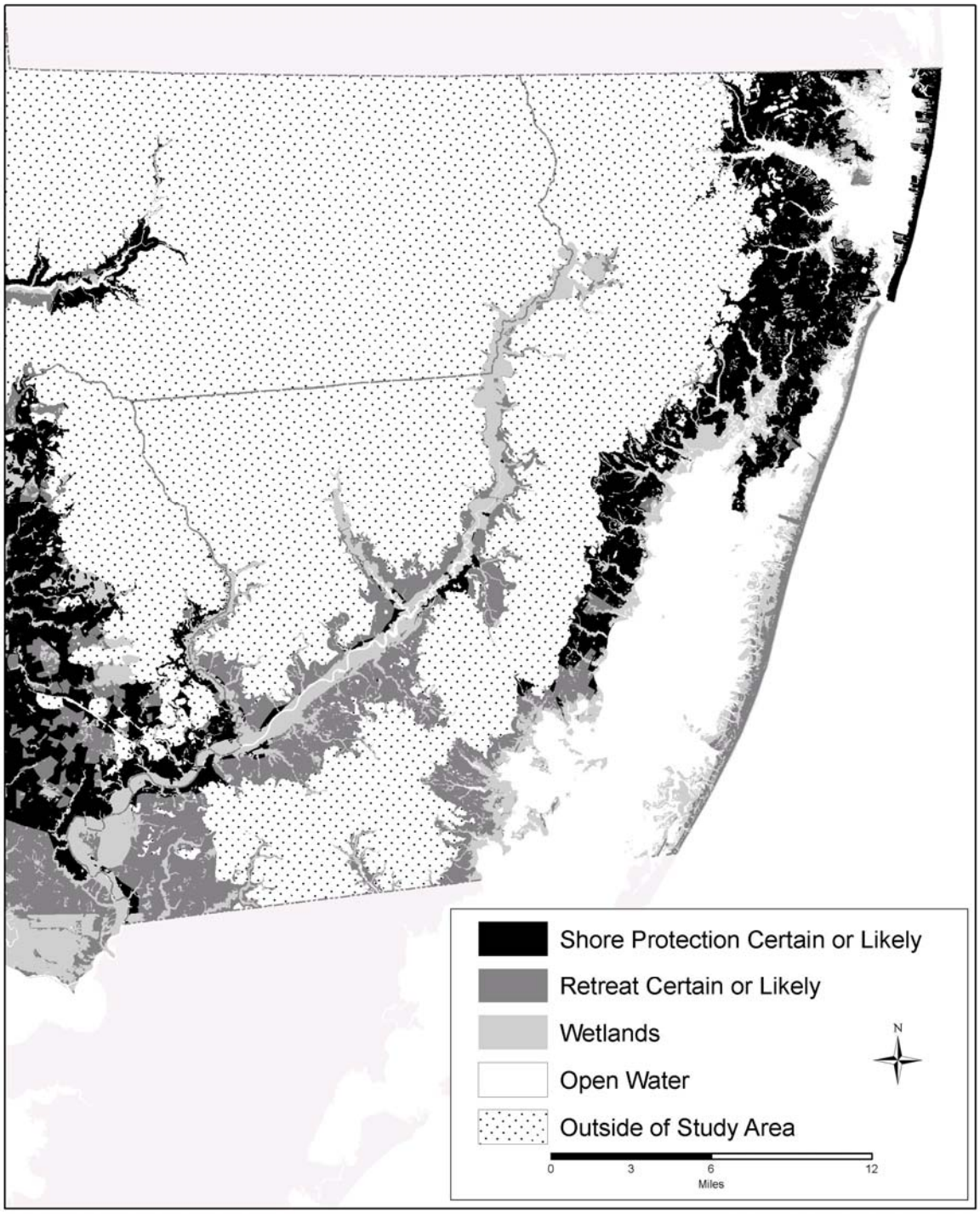

Figure 4. **Maryland: Long-term shore protection plan as sea level rises given business as usual.**

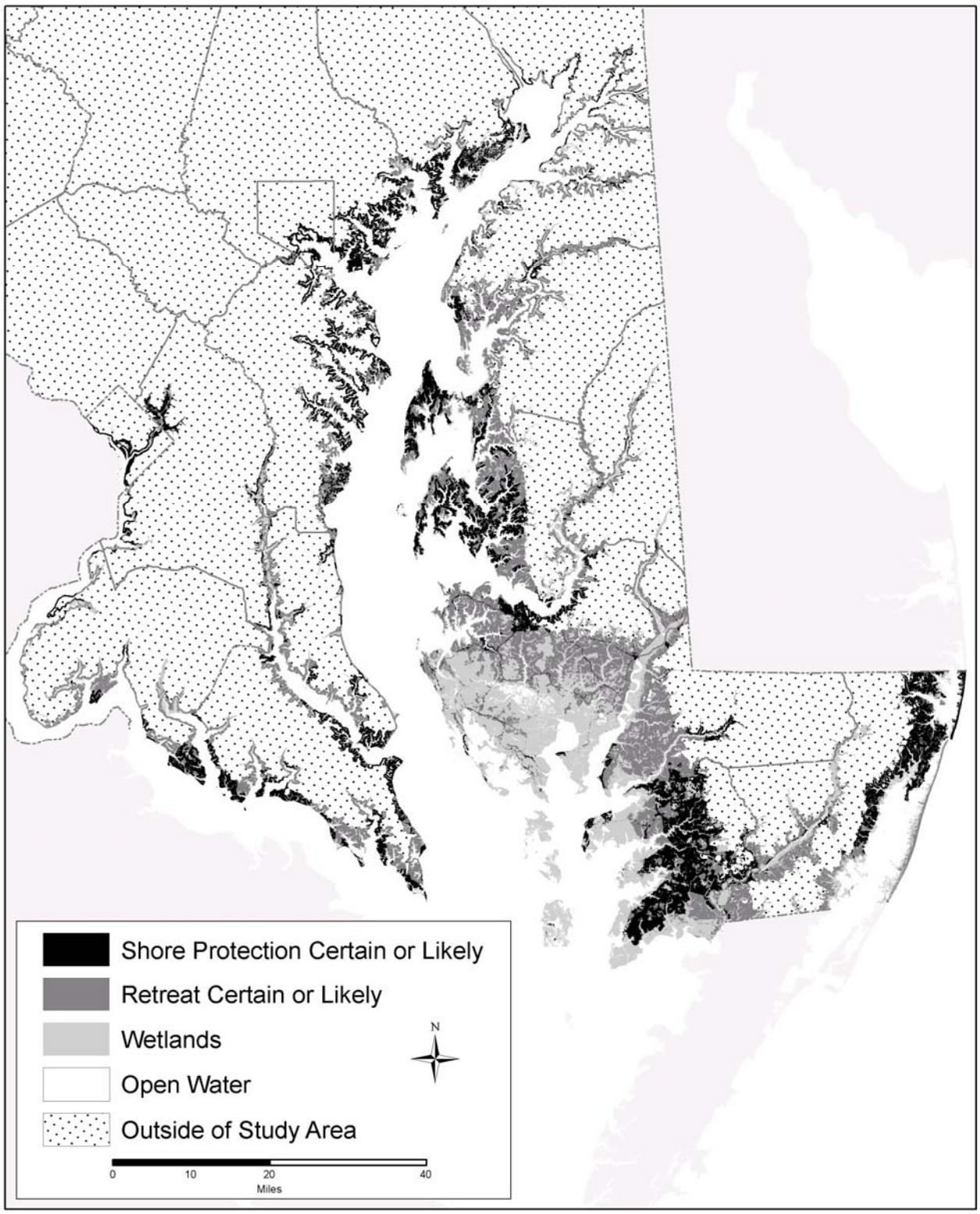

Figure 5. **North Carolina: Long-term shore protection plan as sea level rises given business as usual.**