Pennsylvania

By

Chris Linn

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CHAPTER 4

PENNSYLVANIA

Chris Linn

Delaware Valley Regional Planning Commission

CONTENTS

MAPS

FIGURE

TABLES

SUMMARY

Sea level is rising about 1 inch every 9 years (2.7 millimeters per year) along the coast of Pennsylvania. Sea level rise in this area will continue to be approximately 0.05 inches per year (1.2 mm/year) greater than the global rise in sea level because of land subsidence in the Mid-Atlantic region. Given the small amount of low-lying land along Pennsylvania's coast, rising seas threaten only a relatively small portion of the state's coastal communities. However, the impacts of sea level rise go beyond inundation to include increased erosion, increased flooding, and the migration of the salt line farther up tidal rivers and streams.

Land use is diverse along the Pennsylvania portion of the Delaware Estuary. Most of the coast is heavily developed; only about 18 percent of the coastal area is classified as undeveloped. Much of the natural shoreline has already been filled in or modified many times over with bulkheads, docks, wharfs, piers, riprap shorelines, and other hard structures during the past two centuries.

As a result of the developed and altered character of the Delaware Estuary, the natural ebb and flow of the tide is, in many places, already restricted by hard edges and vertical structures. Shoreline armoring with bulkheads establishes a vertical boundary that separates uplands on one side from open water, wetlands, or mudflats on the other. As the sea rises, these armoring structures prevent the high protected uplands from becoming progressively transformed into a wetlands or intertidal environment. If fronting marshes or tidal flats do not accrete enough sediment to keep pace with rising sea level, they will drown.

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. A key step in evaluating whether new policies are needed is to evaluate what would happen under current policies. The maps in this report represent neither a recommendation nor an unconditional forecast of what will happen, but simply the likelihood that shores would be protected if current trends continue. The author obtained land use and planning data from Delaware, Philadelphia, and Bucks County and consulted with county planners as well as participating agencies in the Pennsylvania Coastal Zone Management program.

"Shore protection" here means 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 does it 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, the study area includes lands within about 17–18 feet (about 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. "Expected shore protection" is an intermediate scenario in which the areas depicted in brown and red are protected, while those shown in blue and light green are submerged.

Map 4-1 shows our assessment of the likelihood of shore protection for the coastal zone of Pennsylvania. Table 4-1 quantifies the area of land within approximately 3 feet (1 meter) above the tides for each of the shore protection categories by county. Table 4-2 quantifies the length of shoreline along the Delaware River.

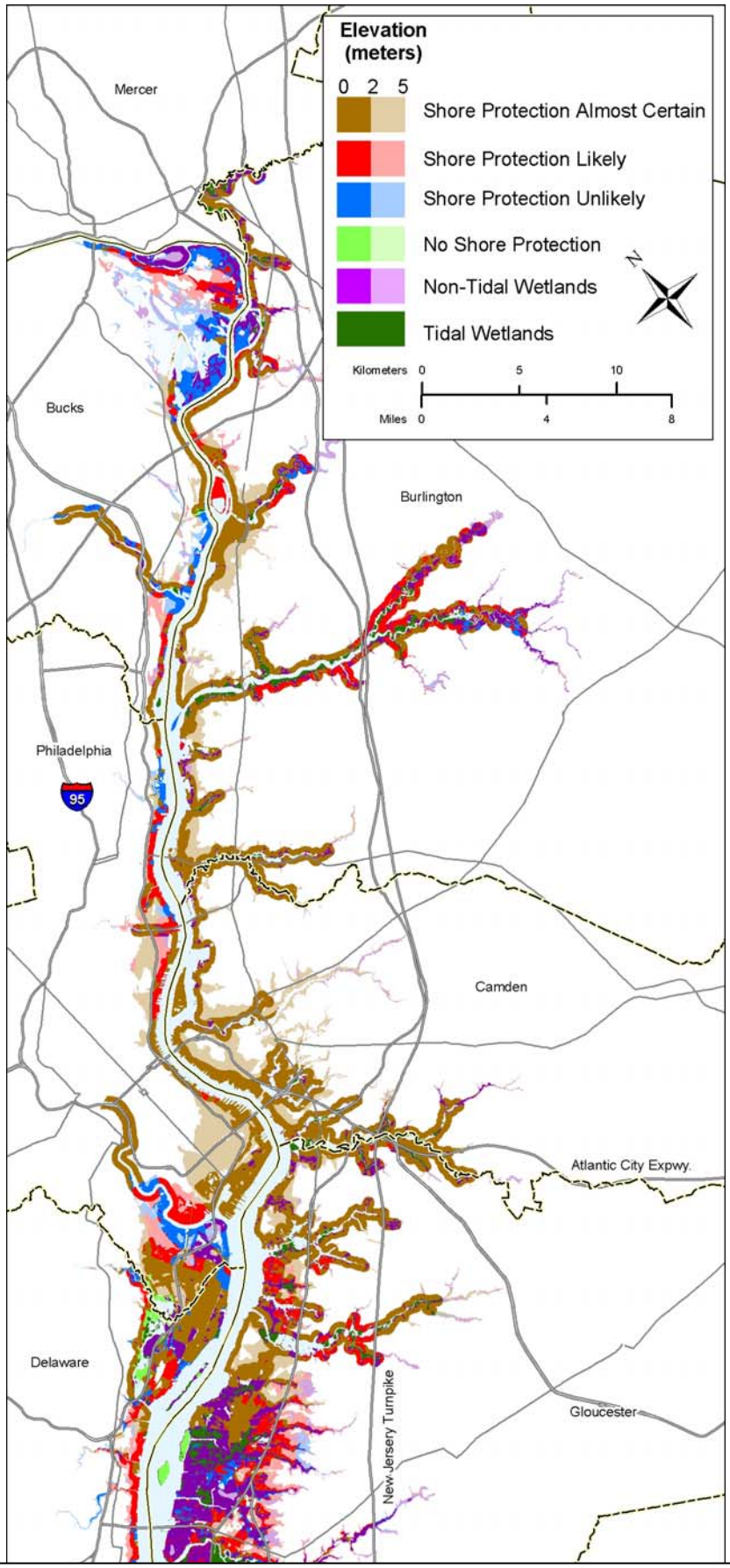
Conclusions

1. *Shore protection is likely or certain along most of the Pennsylvania coast.*

- All but 24 miles of the state's 60-mile Delaware River shore is likely or certain to be protected.
- Of the 10.5 square miles of dry land within approximately 3 feet above the tides, 6.1 square miles is likely or almost certain to be protected.

2. *Wetland migration will not be possible along a majority of the shores that our maps depict as likely or certain to be protected.*

- Development along the Delaware Estuary already restricts the natural ebb and flow of tides through hard edges and vertical armoring structures. Fronting marshes or tidal flats must accrete enough sediment to keep pace with rising sea levels, or be drowned.
- Approximately 40 percent of Pennsylvania's coastline is unlikely to be protected or abuts nontidal wetlands, allowing for the inland migration of tidal wetlands.



Map 4-1. Pennsylvania: 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 1,000 feet of the shore. The lighter shades show the rest of the study area. This map is based on data published in 2003 and site-specific changes suggested by planners in 2004.

Table 4-1.
Area of Land within 3.3 feet (1 meter) 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[3]
	Almost Certain	Likely	Unlikely	No Protection				
Delaware Estuary								
Bucks	0.5	0.6	1.2	0.01	0.5	3.0	46	0.7
Philadelphia	1.9	0.5	0.6	0.1	0.3	3.5	8	0.2
Delaware	1.9	0.8	0.5	0.2	0.5	3.9	25	1.4
Pennsylvania	**4.3**	**1.8**	**2.2**	**0.3**	**1.3**	**10.5**		**2.4**

1. Total Land includes the five categories listed plus land for which no data were 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-ft (1m) 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-m elevation contour.
3. Includes mudflats.

Table 4-2. Shoreline Length by Major Water Body and Likelihood of Shore Protection (miles)

County	Likelihood of Shore Protection				Nontidal Wetlands	Totals
	Almost Certain	Likely	Unlikely	No Protection		
Delaware River Total	21	15	19	<0.1	5	60
Bucks	5	2	10	<0.1	5	22
Delaware	2	7	4	0	0.7	13.7
Philadelphia	14	7	5	0	0	26
State Total[1]	61	37	52	17	20	186

[1] Includes tributaries to the Delaware River.

INTRODUCTION

Although not usually thought of as a coastal state, Pennsylvania has a 60-mile-long tidal coastline extending from its border with Delaware in the south to Morrisville, Pennsylvania, in the north. Collectively, the Delaware River and water-land interface along this stretch constitute the Pennsylvania portion of the Delaware Estuary. In the last century, sea level has risen at an average rate of 0.11 inches/year (2.7 mm/year) at Philadelphia, approximately 0.05 inches/year (1.2 mm/year) more rapidly than the global average rate of sea level rise during the same period.[1] With the rate of sea level rise expected to accelerate during the coming decades, coastal lands along the estuary will be vulnerable to erosion, flooding, and inundation unless the state or private property owners armor or elevate the land. The region's ecologically valuable tidal and coastal wetlands will be particularly vulnerable. Because tidal wetlands must periodically be washed over by the tides, the only way to ensure their survival in the face of rising seas is to allow their landward migration—a difficult mandate along Pennsylvania's heavily developed coast. In anticipation of these challenges, this report examines the likelihood that development will be protected from sea level rise along the estuarine shoreline of the state and the effects of sea level rise on the region's environmental resources.[2]

Purpose of this Study

This study develops maps that distinguish the areas likely to be protected[3] as the sea rises from the areas where shores are expected to retreat naturally, either because the cost of holding back 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.

This report also highlights issues that are unique to the counties along Pennsylvania's coast. For example, the report considers how sea level rise could affect and interact with extensive plans for waterfront redevelopment that have been, or are in the process of being, assembled for nearly the entire Pennsylvania coast. At the same time, the report addresses questions unique to the Delaware Estuary. How will rising sea levels affect ongoing efforts to restore the estuary and protect its sensitive environmental features? How would increased shoreline armoring affect the ecology of the estuary? What do rising seas bode for efforts to increase public access to

[1]The term "sea level rise" is used as shorthand for "relative sea level rise."

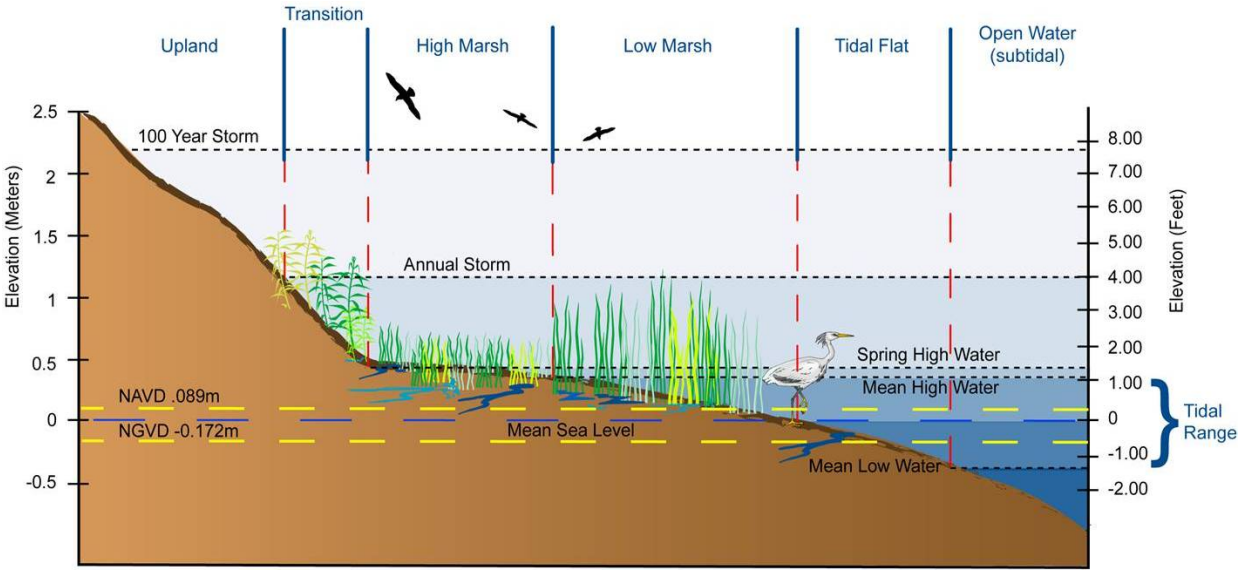
[2]See box on "Reference Elevations and Sea Level Rise" for an explanation of spring high water and sea level rise.

[3]For 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.

Box 4-1. TIDES, SEA LEVEL, AND EFERENCE 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, such as upper Albemarle Sound in North Carolina, 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. United States Geological Survey 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. NAVD88 and NGVD29 should not be used as equivalent to present-day LMSL.

the waterfront and create new open spaces and opportunities for waterfront recreation? State, county, and local authorities will need to consider all these questions in advance of rising seas.

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 inland,[4] 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.[5] 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.[6] Preparing for sea level rise requires society to decide which areas will be 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.[7] 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 cannot 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

[4] 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. In J.G. Titus and L. Strange (eds). *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, EPA 430R07004, Washington, DC: U.S. EPA.

[5] 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.

[6] 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.

[7] 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.

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 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; and[8]
- 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 chapter, 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:

- *existing conditions* in the Delaware Estuary*;*
- *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 the comments offered by planners during the stakeholder review meetings.

[8]For 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.

EXISTING CONDITIONS IN THE DELAWARE ESTUARY

To understand the impacts of sea level rise in the Pennsylvania portion of the Delaware Estuary and how coastal communities may respond, we highlight both the physical dynamics of sea level rise and the unique physical conditions present along Pennsylvania's estuarine shoreline.

Sea Level Rise in the Delaware Estuary

During the past century, global sea level rose about 6 inches (15 cm). Sea level along the shores of the Delaware Estuary rose about 1 foot (30 cm) during the same period due to both globally rising seas and subsidence in the Mid-Atlantic region. The Intergovernmental Panel on Climate Change predicts that seas will rise by between 7 and 23 inches globally during the twenty-first century. Presumably, the local rise in this area will continue to be approximately 0.059 inches/year (1.5 mm/year) greater than the global rise in sea level because of the rate of land subsidence in the Mid-Atlantic region.

Forecasting beyond 2100 is even more difficult because of uncertainties about the continuing buildup of greenhouse gases in the atmosphere and the many uncertainties related to the behavior of glaciers, but assuming "business-as-usual conditions," sea level will continue to rise, and if polar ice sheets begin to disintegrate, the rate at which seas are rising will accelerate more rapidly. Accordingly, a rise of 5 to 10 feet in the next 200 years is a distinct possibility, and a greater rise cannot be ruled out.

Compared to many other coastal states, Pennsylvania has a relatively small amount of low-lying land: only 3.1 square miles of land lie below 2 feet. North Carolina, by contrast, has nearly than 2,000 square miles of land below 2 feet in elevation.[9] Thus, with forecasts indicating a sea level rise of about 1 meter in the next 100 to 150 years, rising seas threaten to inundate only a small portion of Pennsylvania's coastal counties during the next century. The impacts of sea level rise, however, go beyond inundation to include increased erosion, increased flooding, and the migration of the salt line farther up tidal rivers and streams. Also, because the state has a large amount of heavily developed land below 20 feet (6 meters) in elevation, long-term thinking with regard to sea level rise will be just as important for Pennsylvania as it will be for other coastal states.

Pennsylvania's coast is influenced by relatively large tidal fluctuations. The tide range in the Delaware River and Bay is between 5.9 to 7.9 feet (1.8 to 2.4 meters). Since the elevation on U.S. Geological Survey (USGS) topographic maps is measured relative to the National Geodetic Vertical Datum (NGVD) of 1929, which is approximately 1 foot (0.4 meters) below the mean tide level of the Delaware River, a tide range of 7 feet (2 meters) means that all lands up to an elevation of 4.6 feet (1.4 meters) are already submerged at spring high water. The USGS 10-ft contour (3 meters) is thus a reasonable first approximation of the area that would be inundated at high tide if the sea rises 5.2 feet (1.6 meters), assuming that no measures to hold back the sea are implemented. Table 4-3 shows estimated area by county that would be inundated by a 2-foot rise in sea level. Figure 5 shows the lands within 20 feet (6 meters) above spring high water.

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[9]Titus, J.G., and E. Strange (eds.), 2008, *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, EPA 430R07004, Washington, DC: U.S. EPA.

TABLE 4-3. AREA OF LAND VULNERABLE TO SEA LEVEL RISE IN PENNSYLVANIA (SQUARE MILES)[a]

Jurisdiction[b]	Vulnerable land[c]	Tidal wetlands	0-2 feet Elevation[d]		0-4 feet[d]		0-8 feet Elevation[d]	
			Dry land	Nontidal Wetland	Dry land	Nontidal Wetland	Dry land	Nontidal Wetland
Philadelphia[f]	3.1	0.7	2.2	0.2	4.8	0.4	10.8	0.6
Delaware	[e]	5.0	[e]	[e]	4.2	0.6	6.8	0.9
Bucks	[e]	0.7	[e]	[e]	[e]	[e]	6.4	1.5
Statewide totals	**7**	**0.4**	**6**	**1**	**12**	**2**	**24**	**3**

[a] J.G. Titus and J. Wang. 2008. 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. In Titus, J.G., and E. Strange (eds.), *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, EPA 430R07004, Washington, DC: U.S. EPA.

[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] Value omitted because the topographic information Titus and Wang used for this jurisdiction had poor vertical resolution.

[f] Dryland values for Philadelphia include 0.91 square miles of dry land currently below spring high water. Nontidal wetland values for Philadelphia include 0.15 square miles of nontidal wetlands currently below spring high water.

Physical Conditions in the Estuary

The *Delaware County Coastal Zone Compendium of Waterfront Provisions* (1998) describes its waterfront as a "scarce public resource of unique aesthetic, environmental, cultural, recreational, historic, and social value." Indeed, land uses along Pennsylvania's entire 57-mile coast are diverse. Industrial, commercial, residential, recreational, wooded, vacant, transportation, and environmental land uses all occupy the study area. Generally speaking, however, the Pennsylvania coastal zone is consistently and heavily developed. Only about 18 percent of the coastal area is classified as undeveloped.[10] In addition, much of the natural shoreline has already been filled in or modified many times over with bulkheads, docks, wharfs, piers, riprap shorelines, and other hard structures during the past two centuries.

As a result of the developed and altered character of the Delaware Estuary, the natural ebb and flow of the tide is, in many places, already restricted by hard edges and vertical structures. Accordingly, small changes in sea level would most immediately threaten remaining environmentally valuable areas that have natural shorelines or "soft edges" such as mudflats and tidal wetlands. Because the intertidal area will also rise with rising sea levels, it is likely that currently existing mudflats will progressively become subtidal (i.e., open water). In places like the Delaware River estuary where there can be substantial water inputs, the location and size of future intertidal areas will be difficult to predict.

In developed areas, such as along most of Pennsylvania's coast, shoreline armoring with bulkheads establishes a vertical boundary that separates uplands on one side from open water, wetlands, or mudflats on the other. As sea

[10] Delaware Valley Regional Planning Commission, *Year 2000 Land Use Survey*, August 2003. Undeveloped lands are those classified as agricultural, wooded, and vacant.

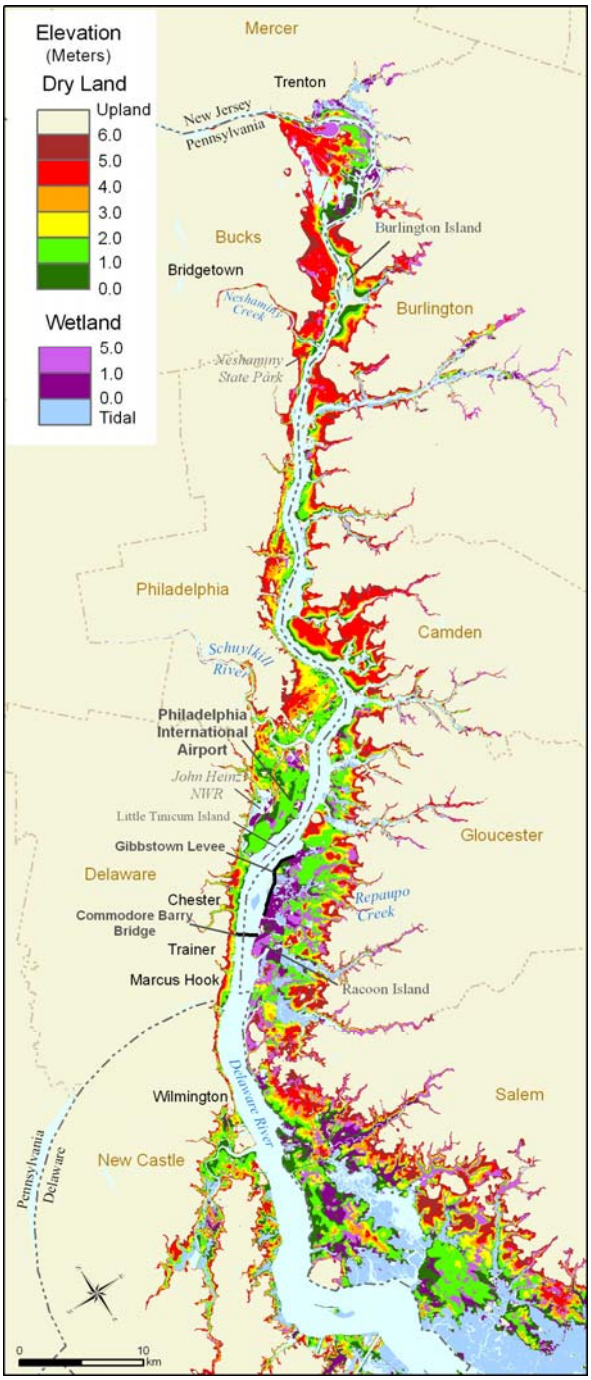

Figure 4.1. Lands Vulnerable to Sea Level Rise. Source: Titus and Wang (2008; see Table 5-3 for full reference). Elevations are relative to spring high water. Because the map has a contour interval of 1 meter (3.28 feet), we have not converted the legend from metric to the English units used in the text of this report.

level rises, a bulkhead or armoring structure becomes an impenetrable line that does not allow the high protected uplands to become progressively transformed into a wetlands or intertidal environment. If fronting marshes or tidal flats do not accrete enough sediment to keep pace with rising sea level, then they will drown.

According to Titus,[11] "Over the last several thousand years, the loss of wetlands from sea level rise has been more than offset by the formation of new wetlands as nearby low areas were flooded." In developed areas, however, the landward migration of wetlands is typically blocked to protect homes, businesses, industries, and infrastructure. Titus goes on to state, "Environmental programs have done little to stop the loss of wetlands and beaches as sea level rises. The wetlands regulatory program was designed to prevent people from filling—and hence drying out—land that is wet today. For wetlands to survive sea level rise, however, the entire ecosystem needs to migrate inland." The only way to ensure that tidal wetlands survive rising seas is to allow their landward migration. If migration were to occur along Pennsylvania's heavily developed coast, it would most likely occur in parks, in vacant or wooded areas, or in developed areas where the value of wetland migration is deemed greater than the value of existing development.

[11]Titus, J.G., Summer 2003, "Is rising sea level a problem for the Delaware Estuary," *Estuary News: Newsletter of the Delaware Estuary Program.*

METHODS

The findings of this report are based on discussions with state resource managers and county planning staff (Table 4-4); reviews of relevant state and local laws, regulations, and policies; and current land use patterns. This section provides detailed information on the approaches employed during this study.

Study Area

The study area for our analysis includes all land below the USGS 20-ft (NGVD) contour.[12] Given the prospect of, at most, a 3- to 4-ft (1-m) rise in sea level over the next century, the 20-ft contour may seem overinclusive. USGS maps are the only comprehensive set of elevation information for the entire study area, however, and their 10-ft contour interval implies that we had to choose between using the 10- or 20-ft contours. We chose the latter for several reasons.

First, although the impacts of rising seas in the "near term" are most relevant to current decision-making processes, it is useful to depict the entire area that could be affected by sea level rise over time. As discussed, a rise in sea level of 10 feet (3 meters) is possible over the next several centuries, and the 20-ft contour would become the approximate floodplain if such a rise were to occur. Second, because Pennsylvania has only a small amount of extremely low-lying land, a lower elevation threshold would have resulted in a study area that is marginal and ignores its overall land use context. Finally, the vertical and horizontal resolution of existing contour data is poor. Not only does the data have a wide contour interval, but also under National Mapping Standards those contours can have a vertical error of plus or minus 5 feet, i.e., the mapped 10-ft contour may really be as low as 5 feet in some places. Thus, a margin of error is required to ensure that our analysis includes all the lands that might be affected by rising seas. This large study area is not meant to suggest that sea level rise would inundate all of these lands. We merely are attempting to avoid the possibility that subsequent improvements in elevation data reveal areas we omitted to be vulnerable. *Although our study area extends to the 20-ft contour, those using our results need not include the higher elevations.*

Our study area also includes all dry land within 1,000 feet of tidal wetlands or open water to account for possible erosion[13] 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-ft study area along bluffs were difficult to read and did not convey the anticipated response.

The Pennsylvania coastal zone study area, as defined by the 20-ft contour, is approximately 69 square miles (180 square kilometers) and contains 22 square miles (58 square kilometers)

[12]Until 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 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.

[13]Like the 20-ft contour, the 1,000-ft 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.

of open water. The study area comprises portions of Delaware, Bucks and Philadelphia counties, including portions of 19 municipalities, and the City of Philadelphia. The gray shaded portions of Figure 4-1 depict the extent of the study area.

Protection Categories

Our evaluation of Pennsylvania's likely sea level rise responses was based on (1) state laws, policies, and regulations relevant to sea level rise; (2) current and anticipated land uses; and (3) discussions with county planners to determine local conditions, future plans, and areas of importance that would merit protection from rising seas if economically feasible. Using this information we developed decision guidelines for each county that identified the likelihood of protection for each type and category of land use.[14] Next, we modified our results based on where county planners anticipated area-specific departures from the general guidelines.

Within the study area, our maps use the following colors for the four categories depicting likelihood of shore protection:

Brown—areas that will **almost certain**ly 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 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.[15]

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 evaluated only whether dry land would be protected.[16]

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[14]The sea level rise response maps used the Delaware Valley Regional Planning Commission's *Year 2000 Land Use Survey*. This file is the most detailed and recent land use characterization for the region covering the entire Pennsylvania coastal study area.

[15]During the pilot testing of this multistate study, the initial approach was to obtain planner input on three scenarios of shoreline protection. Those scenarios included: 1) Enhanced Protection—Protection of all areas that can be protected under existing state and local policies); 2) Expected Protection—an assessment of current as well as anticipated behavior; and 3) Enhanced Wetland Migration—an assessment of alternative policies that would provide greater protection to natural resources (e.g., wetlands) or culturally significant resources.
This report uses the four map colors to—in effect—display all three scenarios on a single map. For additional information on the three scenarios and the relationship to the likelihood of shore protection, see the discussion of the project evolution in the Overview (Chapter 1) or New Jersey chapter (Chapter 3).

[16]Shore 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.

TABLE 4-4. GOVERNMENT PARTICIPANTS AND REVIEWERS

Name	Title and Affiliation	Role
Domenic Rocco	Civil Engineer Manager, Office of Water Management, PA DEP	State source of shore protection information
Kenneth Anderson	Water Pollution Biologist III, Office of Water Management, PA DEP	State source of shore protection information
Randall Brown	Office of Water Management, PA DEP	State source of shore protection information
Karen Holm	Manager of Environmental Planning, Delaware County Planning Department	County source of shore protection information and reviewer
Marty Soffer	Environmental Officer, Philadelphia City Planning Commission	County source of shore protection information and reviewer
Michael Roedig	County Planner, Bucks County Planning Commission	County source of shore protection information and reviewer

Basis for Category Delineations

Although the 20-ft contour was used as the boundary for the study area, the likelihood of protection for a given land use category is based on the assumption of an approximately 2- to 3-ft rise in sea level over the next century. No doubt, the capital and environmental costs as well as the risks associated with sea level protection efforts will rise as do sea levels; but because it is impossible for a single map to depict what would be a likely response to a wide range of sea level rise scenarios, we needed to key our maps to a specific level of rise, and we chose a scenario of between 2 and 3 feet. Even so, the same continuum of protection likelihood applies to greater levels of rise.[17]

Evaluations of sea level rise protection efforts in other states were based largely on examinations of existing land uses and development patterns, and on area-specific recommendations provided by county officials. A similar approach was taken for this study, adapted to reflect the unique conditions in, and issues confronting, the Delaware Estuary. For the most part, other states placed nearly all developed areas in the "shore protection almost certain" category and more sparsely developed and undeveloped areas in the "shore protection likely" or "shore protection unlikely" category. In Pennsylvania, nearly the entire coast is developed with homes, businesses, utilities, transportation infrastructure, and manufacturing facilities. Important cultural and historic features are located throughout the coastal region. Existing coastal parks are used predominantly for active recreation and to provide access to the water, not for conservation. Using the criteria employed by other states then would lead to a blanket conclusion that nearly the entire coast would be almost certainly protected from sea level rise.

[17]Given a greater level of rise, areas that are defined as "almost certain to be protected" will still be more likely to be protected than areas defined as "likely to be protected" even though the overall likelihood of protection for both categories will decrease as seas rise because of the overall cost of protection in the face of increased sea level rise.

The existing circumstances along Pennsylvania's coast, however, make us less certain that shores will be protected in all developed areas. The Pennsylvania coast is undergoing a dramatic transition from an industrial to a post-industrial landscape. Historically, the river's edge was a favorable location for the region's extensive manufacturing and industrial enterprises. Consequently, the study area today is still dominated by manufacturing and industrial land uses. Steady declines in the industrial economy over the past 60 years, however, have led to the abandonment of many industrial and manufacturing facilities. Some of these facilities sit empty and idle, and others have been adapted for more marginal uses. Warehousing facilities, scrap yards, materials recycling facilities, crumbling expanses of asphalt, abandoned rail lines, vacant areas, and other derelict lands now populate portions of the study area.

Although a majority of the study area is technically developed, sizable expanses are blighted and stressed—especially near the water. Because of the decaying industrial base, many residential portions of the study area suffer from below-average home values, a net loss of population, high vacancy rates, physical deterioration, and high levels of poverty and crime.[18] These trends, which are part of a larger regional pattern of sprawl, disinvestment in older communities, and urban decline, are evidenced up and down the Delaware Estuary coast. Furthermore, the current trend in global economic patterns indicates that the decline of the area's remaining industries will continue. Local planners with whom we spoke believe that the refineries, chemical processing plants, and other manufacturing facilities that operate profitably today could possibly be absent from our region in 50 to 100 years as the U.S. economy continues to shift away from a manufacturing and industrial base. Regardless of whether the manufacturing decline continues at its current pace, the coastal area is already well beyond its industrial prime and many facilities have long since been abandoned.

In response to industrial decline and creeping blight, new paradigms of waterfront development have emerged that offer fresh visions for southeastern Pennsylvania's waterfront. In late 2001, Philadelphia released the *Comprehensive Redevelopment Plan for the North Delaware Riverfront*—a 25-year redevelopment vision for a distressed 10-mile stretch of waterfront led by the design firm Field Operations. Delaware County, meanwhile, developed its *Coastal Zone Compendium of Waterfront Provisions* (1998) to guide revitalization efforts along its coast. Likewise, Bucks County just finished a national search for a design firm to create a comprehensive plan outlining the revitalization of its waterfront. Meanwhile, the Schuylkill River Development Corporation produced the *Tidal Schuylkill River Master Plan*, and community-based organizations in Philadelphia hired the firm of Wallace, Roberts & Todd to prepare a vision for the Center City waterfront.

All these plans and visions share common elements. They view the region's waterfronts as valuable public amenities that offer opportunities, and they view the estuary as something for the region to embrace rather than neglect. They emphasize public access along the water's edge, the creation of greenways and trails, open spaces, and the restoration of natural shorelines and wetlands where appropriate. Revitalization strategies also aim to take advantage of the quality of life benefits to be had from public access and an attractive, ecologically healthy waterfront by constructing vibrant mixed-use communities within the coastal zone.

Given the transitional state of Pennsylvania's coastal area and the visions that have been proposed, it is safe to say that much of what is there today will probably not be there in 50 or 100 years. Although these areas will probably be developed, the reintroduction of public access, natural shorelines, and open spaces along the water's edge will be a key element of revitalization efforts. We do not currently foresee

[18] *Regional Data Bulletin No. 75: 2000 Census Profile by Minor Civil Division: Income and Poverty*, June 2003, Delaware Valley Regional Planning Commission, Philadelphia, PA; and *Census 2000*, October 2003, U.S. Census Bureau. http://factfinder.census.gov.

redevelopment being generally designed to allow ecosystems to migrate inland; nevertheless we cannot say with certainty that the shore will be maintained in its current location. Therefore, we view shore protection as likely for a large amount of the developed coast, a designation that the reader might construe as implying that while a portion of the shore will be protected and a portion will remain natural, it is currently impossible to distinguish these two areas.

Because planning has really just begun for nearly our entire study area, now is an excellent time for planners to address rising seas in their vision of the future. Thus, we hope that this will promote constructive dialogue on the choices that public officials, government agencies, citizens, and planning professionals will face as they confront rising seas over the coming decades and centuries.

This study organized land uses into four response categories. Unlike other states, we did not place all developed lands in the "protection certain" category because of (1) the declining character of many parts of the coastal area, (2) anticipation of the restoration of natural areas and open spaces along portions of the water's edge, and (3) the ability to consider rising seas when preparing future development plans. Instead, we attempted to differentiate stable developed land uses from developed land uses that could and probably will be reconfigured. Where developed areas are stable, we classified them as almost certain to be protected. Where developed areas are subject to wholesale revitalization, we classified them as likely to be protected, because it is here that parks, open spaces, and natural shorelines could be reintroduced, especially along the water's edge. These distinctions were made on the basis of existing land uses, inspections of aerial photos, general planning judgment, and the local knowledge and expertise of county planners. More specifically, land uses were assigned to the four response categories identified above according to the following guidelines:

Shore Protection Almost Certain

Areas where shoreline protection is almost certain are depicted in brown. These areas are stable developed areas that are not targeted for revitalization (although individual structures could be rehabbed). They include portions, but not all, of the following land use categories: residential, commercial, utility, community service, military, transportation, and associated parking. It should be noted that although some lands are classified as "military," the study area does not have any active military facilities. Even though several military bases and properties such as the Philadelphia Naval Base were decommissioned over the past decade, they are still coded as military by the *Year 2000 Land Use Survey* because they have yet to be fully converted to other uses.

Specifically, this category includes such areas as Philadelphia International Airport, major highways, commercial and retail centers, power generating stations, port facilities, stable residential areas, and regional destinations such as Penn's Landing. Areas that already have been redeveloped or are specifically targeted for redevelopment like the PECO power generating station in Chester, the former Philadelphia Naval Yard, and the future site of the Chester Downs Racetrack are also included in this category. Not insignificantly, many of these areas are already protected by existing bulkheads or otherwise armored, thereby adding an extra measure of certainty to their protection.[19]

Shore Protection Likely

Areas likely to be protected are depicted in red. They include the remaining developed land uses in the study area and all areas subject to potential revitalization. Light and heavy manufacturing, mining, and all parking associated with these land uses fall into this category. Commercial, residential, community service, and transportation land uses located in stressed communities may be part of future revitalization efforts and are included in this category.[20]

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[19]Existing bulkheads are usually more than 3 feet above the mean high water line and would provide protection from the riverbank erosion accompanying a 2- to 3-ft rise in sea level. However, a rise of 5 to 10 feet would probably overtop existing bulkheads.

[20]Most of the Delaware County coast and Philadelphia north of Penn Treaty Park are currently stressed. This assessment is based

Protection is also likely for vacant lands where revitalization would probably take place and for recreation lands that do not feature natural shorelines or that are surrounded by development. Protection of these areas is likely rather than certain for three reasons: (1) property values in blighted manufacturing and residential districts may not be high enough to offset the costs of protection, (2) most revitalization plans include provisions for public access and parks along the water's edge that may or may not require shoreline armoring, and (3) if redevelopment does take place, provisions for setbacks could be mandated in advance of rising seas.

Shore Protection Unlikely

This category comprises undeveloped lands, including wooded lands, vacant lands, and agricultural lands; they are depicted in blue. Most of these lands are undeveloped because they are not suitable for building and will probably not be developed in the future. Lands in this category may be privately or publicly owned. Given that these lands are unlikely to be developed and the public may want to promote wetland migration in these areas, protection of these lands is also unlikely. Public funds will probably not be allocated for shoreline armoring in these areas. Lands in this category are not typically bulkheaded or otherwise armored.

It should be noted that "vacant lands" refers to lands that have no discernable human use and are not wooded or otherwise used for agriculture. Vacant lands could be former industrial sites, wetlands (wetlands are usually classified as vacant for land use purposes), or other undeveloped lands. As such, vacant parcels are sometimes placed in the protection likely category if they are proximate to industrial land uses or if plans exist that specifically identify them as possible redevelopment sites. Remaining vacant lands are placed in the protection unlikely category.

This category also includes recreational and park areas that emphasize maintenance of a natural shoreline. Maintaining a natural shoreline would necessarily preclude protection. Recreation areas that require a certain amount of land area to provide access to and along the water's edge (i.e., a waterfront promenade, fishing pier, boat ramp, etc.) are placed in the protection likely category.

No Shore Protection

These are lands where current policies do not allow or strongly discourage protection. They are depicted in green. Only the John Heinz National Wildlife Refuge, Little Tinicum Island, parts of Neshaminy State Park, and lands owned and managed by The Nature Conservancy would fall into the conservation lands category in the Pennsylvania study area. The John Heinz Refuge is federally owned, and federal policy dictates that refuges be managed for a conservation objective that is incompatible with shore protection. Little Tinicum Island and portions of Neshaminy State Park are managed by the Pennsylvania Department of Conservation and Recreation for conservation purposes. The Nature Conservancy has a policy of allowing wetlands to migrate inland onto dry land. In terms of land use, lands classified as conservation lands are not a separate land use category. They are almost entirely classified as vacant and wooded.

Creation of Sea Level Rise Response Maps

The sea level rise response maps, which are based conceptually on the guidelines above, were assembled using the Delaware Valley Regional Planning Commission's (DVRPC's) *Year 2000 Land Use* file. DVRPC created the land use file by digitizing aerial orthophotography flown in spring 2000. DVRPC completed the heads-up digitizing of land-use polygons in summer 2003.[21] The maps were digitized at a scale of

on a variety of economic indicators such a median home values, housing vacancies, and income levels, as well as published planning reports and studies, including work done the by The Reinvestment Fund and The Brookings Institution Center on Urban and Metropolitan Policy.

[21]Heads-up digitizing is done on-screen using orthocorrected digital photos, as opposed to conventional digitizing, which uses paper enlargements of aerial photographs and a digitizing tablet. Also see DVRPC Regional Data Bulletin No. 78: 2000 Land Use by Minor Civil Division, March 2004.

1:2,400 for the entire nine-county Philadelphia metropolitan region, which encompasses the entire Pennsylvania coastal study area.[22]

To characterize land use, the entire region is digitized into polygons (of like land use), which are assigned to one of the following 13 major land use categories: (1) residential, (2) manufacturing, (3) transportation, (4) utility, (5) commercial, (6) community services, (7) military, (8) recreation, (9) agriculture, (10) mining, (11) wooded, (12) vacant, and (13) water. The residential land use category is further divided into single-family detached, multifamily, row homes, and mobile homes. The manufacturing category is subdivided into light and heavy industrial. A parking subcategory is also associated with each of the other land use categories, with the exception of single-family detached residential, wooded, vacant, and water.

All land use categories are represented in the Pennsylvania coastal study area with the exception of mobile homes, mobile home parking, row home parking, agricultural parking, and mining parking. Accordingly, 16 categories of nonparking land use and 9 categories of parking constitute the coastal study area. As a whole, the study area contains 2,730 individual land-use polygons.

The initial cuts of sea level rise protection maps were created by assigning the polygons in each land use category to either the protection almost certain, protection likely, or protection unlikely categories. Polygons comprising the John Heinz National Wildlife Refuge, Little Tinicum Island, and lands owned by The Nature Conservancy were hand-selected for inclusion in the no protection category, regardless of their land use designation. Land uses were then categorized according to the groupings shown in Table 4-5. The table shows each land use in the study area, its associated GIS attribute code, and the protection category to which it was assigned.

[22]An ArcGIS Personal GeoDatabase was created for each county in the region. Following completion, the Personal GeoDatabases were exported out to Arc shapefiles. The shapefiles for each county are identified as ***lu00.shp, where "***" represents the first three letters of the county.

The decision rules presented in Table 4-5 were only a starting point for assigning lands to protection categories. Following the first cut, area-specific refinements were made based on other factors. Land use polygons were assigned to protection categories other than the ones specified for their land use in Table 4-5 based on their size, neighboring land uses, or information specific to a particular site. For example, we considered protection for some residential areas to be likely, rather than almost certain, because of physical deterioration and location in the 100-year floodplain. General explanations for departures from the guidelines presented in Table 4-5 are provided in the protection category descriptions above. More precise explanations for the assignment of individual land use polygons to protection categories different from those in Table 4-5 are detailed in the individual county results sections in this report.

Additional Considerations

Existing bulkheads, as highlighted above, would probably provide protection from the increased erosion rates associated with a 2- to 3-ft rise in sea level. So it may be reasonable to state that all areas landward of existing bulkheads would certainly be protected. This study does not, however, precisely identify the locations of all bulkheads, the height of these bulkheads, the age and condition of the bulkheads, and the likelihood that these bulkheads would still be standing in 50 or 100 years. So although it is important to point out and consider existing bulkheads, they were not a deciding factor in the assignation of protection categories.

Another dynamic to consider is how shoreline armoring affects landward properties. For example, if the first row of structures along a shore is armored, then everything behind is protected from erosion as well. So the level of protection for all properties behind the shoreline should be at least as high as the level of protection for the first row of properties. We did not, however, completely reconfigure the maps to reflect this principle because protection categories can change, erosion does not always proceed perpendicular from the shore, and we wanted to show the likelihood of protection for

all areas as if they were located along the shoreline. We did, however, upgrade the level of protection certainty for some small parcels when they were completely surrounded by lands with a higher certainty of protection.

Ultimately, the costs associated with sea level rise protection will be a key factor in whether or not a piece of land is protected. This study focuses on a 2- to 3-ft rise in sea level, and clearly the costs of protection associated with greater rises would be higher. Protecting areas from a 10-ft rise, for example, would require raising the land or constructing sea walls or dikes. Estimating the costs of such projects is beyond the scope of this study, but these costs would be considerable and would play a pivotal role in determining whether or not an area would be protected or abandoned to the sea. When considering sea level rise of between 2 and 3 feet, the results of this study can be used to get a sense of which areas would be the most vulnerable to rising seas and which would warrant the greatest investments in protection based on their economic, cultural, and historic value. The protection categories developed for this study, however, would not necessarily apply to rises greater than 3 feet.

Shoreline armoring will exacerbate conflicts between ecological systems and the built environment. Historically, the filling of tidal wetlands and mudflats, the erection of vertical structures along the Delaware River's edge, and the channelization of the river caused by these activities have been primary factors contributing to the ecological degradation of the estuary. Environmental regulations are designed to address these problems by maintaining the river's remaining soft edges and restoring them where appropriate. However, the construction of seawalls or other barriers to hold back the sea would harden the land-water interface and would fly counter to current efforts to protect and restore the river's ecology. Such shoreline armoring would likewise block the landward migration of wetlands and mudflats. At the very least, the environmental costs of "straitjacketing" the estuary need to be considered along with the overall capital costs of protection efforts; and at the most, some protection efforts may, in themselves, be too environmentally disruptive to be feasible.

Protection efforts could also increase the risks associated with natural hazards and raise equity issues. Channelizing a river in one place by seawalls, for example, could result in more acute flooding in other places and may increase the overall severity of flooding events. Likewise, building a seawall in Pennsylvania would force New Jersey (at the Delaware River's eastern shore) to either construct a seawall of similar size or suffer harsher impacts from erosion and flooding than what would have otherwise occurred had Pennsylvania not armored its shoreline. Not insignificantly, all structures built to hold back the sea will have to be raised further as seas continue to rise, thereby raising capital expenditures and the intensity of physical, social, and ecological stress.

Map Scale

Our maps are based on decision rules and data created for other purposes. Therefore, the horizontal resolution at which one should reasonably display our maps is limited by the precision of the input data. The DVRPC's *Year 2000 Land Use* file used digital orthophotos with a pixel resolution of 1.5 square feet and a positional accuracy of $\pm$5 feet, which implies a scale of 1:2400 under map accuracy standards. Our hand edits were relatively few, and are hence unlikely to have deteriorated the scale by more than a factor of 4. Therefore, we consider the resulting scale of this layer to be generally 1:10,000 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.

Use of Experts

Like the other chapters in this report, this study uses data and experts. Our analysis uses published data following a basic approach, but we also rely on the site-specific understanding of the county planners. Unlike the other chapters in this report, however, this study was prepared by the regional planning commission responsible for coordinating coastal zone management in the portion of the state vulnerable to sea level rise.[23] The Delaware Valley Regional Planning Commission regularly coordinates with the counties on a variety of planning issues. While the other chapters in this report might be viewed as studies that rely on experts, this study could more precisely be viewed as a baseline analysis by a regional planning commission incorporating the concerns of local government following its standard procedure for doing so.

Like the other chapters, we start with the premise that lands will be protected if the cost of protection is less than the value of the resources being protected, except for where specific policies dictate otherwise. But estimating the costs and benefits of shore protection at every location would have been infeasible—and possibly involve wasted efforts for areas where the question is not close.

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 (given current policies). Second, we assume that residential, commercial, and other developed lands will be protected and that undeveloped lands are unlikely to be protected.[24]

We rely on local planners to help us correctly use land use, planning, and zoning data—and to apply current land use policies—to identify current and project future development. Third, we consider policies on public access to define developed lands where redevelopment may be set back from the shore, and hence shore protection would be likely, but not certain. Nevertheless, we had to rely on local planners to provide facts or opinions in those cases in which the necessary data are unavailable, are out of date, or provide an ambiguous result requiring a human tie-breaker. 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. Judgment-based map designations constitute a very small percentage of the land depicted in the maps in this study.

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 the 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.

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[23] Different agencies are responsible for coastal zone management along Lake Erie, which is above Niagara Falls and thus not vulnerable to sea level rise.

[24] The 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.

PENNSYLVANIA STATE POLICIES

The Commonwealth of Pennsylvania has no explicit policies, regulations, or directives that speak squarely to the issue of sea level rise. A number of state policies and regulations, however, could inform potential responses to rising seas. The Pennsylvania Department of Environmental Protection (PADEP) is the agency responsible for managing state-level environmental programs, including issuing any permits, licenses, and certifications, mandated by state environmental regulations. Although the state General Assembly enacted a number of its own environmental regulations, many of Pennsylvania's regulations are either mandated by or based on similar federal statutes (e.g., air quality, hazardous waste, floodplains, wetlands). The most important, as well as the most inclusive, body of regulations dealing with waterfront/waterway development in Pennsylvania is Chapter 105 (Dam Safety and Waterway Management Rules and Regulations), issued pursuant to Act 325 (Dam Safety and Encroachment Act of 1978).

Chapter 105 is extremely important in that it addresses almost every issue associated with water-related and shoreline development (including wetlands). This means that any construction in, or alteration of, the 100-year floodplain/floodway or wetlands requires permits from the Commonwealth of Pennsylvania. These regulations are designed to protect existing wetlands from development or from being "filled in," to protect the ecology of the river, and to manage development in the region's floodplains. They neither explicitly prohibit the erection of devices to hold back rising seas nor explicitly guarantee the right of landowners to protect themselves from rising seas.

Wetlands and Floodplains

Currently, if a property owner wants to erect a bulkhead or revetment seaward of the high-water mark, she must apply for a Water Obstruction and Encroachment Permit under the Dam Safety and Encroachment Act according to the provisions of Chapter 105. Although the regulations state that a project must not have a "significant adverse impact" on the "areal extent of a wetland" or on a "wetland's values and functions," these criteria are open to interpretation and are evaluated according to PADEP's judgment. Ignoring rising seas, a bulkhead constructed seaward of the high-water mark could eliminate coastal tidal wetlands landward of the location where the bulkhead is to be built. On rare occasion, PADEP may grant permits for the construction of bulkheads and revetments seaward of the high-water mark in areas dominated by intertidal habitat other marsh. Because the regulations were promulgated there has not yet been a case where bulkheads or other shore control structures have threatened landward tidal marsh.[25] It should also be noted that permits for the future construction of bulkheads and revetments that do affect wetlands could be granted on the condition that wetland mitigation projects be undertaken elsewhere.

Constructing a revetment or shoreline control structure landward of the high water mark is not subject to current coastal wetland regulations.[26] When considered in advance of rising seas, however, Subchapter 105 could have significant

[25]Before those regulations went into effect, however, about 90 percent of Pennsylvania's original freshwater tidal marshlands were destroyed through this process.

[26]Such a revetment would usually be within the floodplain and hence fall within the jurisdiction of the statute.

implications. According to Subchapter 105.18b, the State cannot issue a permit for the construction of a "dam, water obstruction or encroachment located in, along, across or projecting into a wetland, unless the applicant affirmatively demonstrates that…the dam, water obstruction or encroachment will not have an adverse impact on the wetland.…"[27] Since shoreline armoring effectively results in the complete destruction of coastal wetlands over time by preventing their landward migration (when sea level is rising), Subchapter 105 seems to suggest that there could be some limits on the construction of shoreline protection measures even when they are built landward of the high-water mark. According to PADEP, however, current permit decisions do not consider the likelihood that the permitted structures will eventually eliminate the intertidal wetlands by blocking their landward migration as sea level rises and shores erode. PADEP did state that rising seas could potentially prompt new regulations that would address the effects of rising seas, including setbacks for development that would allow for shoreline erosion and the migration of wetlands.

Although the ways in which existing regulations might be applied to rising seas are not entirely clear, it can be said that a primary purpose of Chapter 105 is to protect existing wetland areas and to maintain the ecological health of the river. This is particularly germane to the Delaware Estuary, where a large portion of wetlands have already been filled or compromised by development over the past several hundred years. Wetlands are important because they play a crucial role in the function of natural systems through their ability to stabilize the water regime. Wetlands store floodwater and stormwater runoff and retain it for gradual release during drier periods. Wetlands act as a natural water purifier, improving water quality by removing and storing inorganic materials such as nitrogen and phosphorous compounds. In terms of food production per acre, wetlands are among the most productive ecosystems on Earth, furnishing excellent habitat for a wide range of species. For these reasons, state as well as federal and local regulations and policies aim to protect wetland areas.

It is possible to prevent a wetland from being filled or disturbed by development, but it is extremely difficult to protect a tidal wetland from rising seas. Protecting a tidal wetland from rising seas with a dike or seawall undermines its ability to function as a tidal wetland. Thus, the decision of whether or not to protect tidal wetlands from rising seas in their current location is somewhat moot. Although perhaps possible and permissible on limited scales, protecting tidal wetlands below the level of the tides with engineered structures (i.e., dikes, tide gates and pumps) is probably not feasible, cost-effective, or optimal in most cases. As noted earlier, "For wetlands to survive sea level rise…the entire ecosystem needs to migrate inland."[28]

The way in which Chapter 105 addresses floodplains presents problems similar to those posed by the relationship between wetlands and rising seas. For example, the floodplain regulations in Chapter 105 speak to development in "existing floodplains," not to the floodplains that would result from a 1-, 2-, or 5-ft rise in sea level. As such, the lands that might be included in the floodplain in the future are not currently regulated. Perhaps, future amendments will need to address rising seas by incorporating both existing and future floodplains into state regulations. In this manner, the costs associated with flooding both now and in a "rising sea future" could be avoided with sound land use decisions.

Overall, it can be generally stated that existing waterfront regulations and policies were put in place to protect the environment from development, to limit development in environmentally valuable or hazardous areas,

[27]Pennsylvania Code, 1997, Chapter 105. Dam Safety and Waterway Management, Pennsylvania Department of Environmental Protection.

[28]Titus, J.G., Summer 2003, "Is rising sea level a problem for the Delaware Estuary?" *Estuary News: Newsletter of the Delaware Estuary Program*.

and to reduce conflicts between ecological systems and human systems. Although the regulations do not specifically address the environmental harm that would result from armoring against rising seas, their intent seems to suggest that future sea level rise protection efforts could be constrained to limit damage to the region's already strained ecological resources.

Pennsylvania Coastal Zone Management Program

The Pennsylvania Coastal Zone Management (PA CZM) program, approved in 1980 under the authority of the federal Coastal Zone Management Act of 1972, seeks to protect and enhance the natural resources of the coastal zone while reducing conflicts between environmental protection and economic development. To achieve PA CZM goals, specific policies were formulated to guide state and local actions. These policies, which focus on defined areas, are as follows:

- *Coastal hazard areas*: protect coastal property from the damaging effects of bluff recession, coastal flooding, and erosion;
- *Fisheries management*: protect and enhance coastal aquaculture;
- *Wetlands*: preserve, protect, and, where possible, enhance or restore tidal and freshwater wetlands;
- *Public access for recreation*: provide, enhance, and maximize public access along coastal waters for active and passive recreational activities;
- *Historic sites and structures*: encourage the identification, restoration, and preservation of significant historic, architectural, and archaeological sites and structures in the coastal zones;
- *Dredging and spoil disposal*: promote environmentally responsible management of dredging and spoil disposal activity;
- *Intergovernmental coordination*: initiate a program of "state consistency" to ensure consultation and development of a unified state viewpoint before permits are issued;
- *Public involvement*: provide citizens and interest groups with opportunity for early and continuous involvement in the management of coastal resources through effective communication and participation;
- *Port activities*: develop and enhance coastal port infrastructure and the economic base of the urbanized waterfront;
- *Energy facilities placement*: place energy facilities in the coastal zone in an environmentally responsible manner; and
- *Control of invasive species*: promote and implement measures to check and reverse the spread of invasive species.

Although the PA CZM program is itself nonregulatory, its management authority is based on seven Commonwealth statutes, including the Dam Safety and Encroachments Act, the Floodplain Management Act, the Clean Streams Act, and the Bluff Recession and Setback Act. Implementation is based on executive order, memoranda of understanding with Commonwealth agencies, and the Environmental Rights Amendment of the Pennsylvania Constitution. A 1980 executive order directs state agencies to "enforce and act consistently with the goals, policies and objectives" of the state coastal program. Agencies subject to the executive order include PADEP and the departments of commerce, community affairs, and transportation. For state agencies not under jurisdiction of the governor's office, PA CZM established memoranda of understanding. These agreements provide a basis for cooperation, coordination, and implementation of program policies. Participating agencies are the Pennsylvania Fish Commission, Historical and Museum Commission, and Public Utility Commission.

PA CZM implements its policy structure primarily through monitoring, technical assistance, and financial assistance rather than explicit regulations and enforcement. Although it is possible to read between the lines and find

discouraged or encouraged uses within CZM policies, they do not explicitly prohibit any activities nor are they clear demarcations of state policy. Some activities are regulated, based on the state statutes mentioned above, but they may be permitted if certain conditions are satisfied.

The intent of the CZM program, like the state's environmental regulations, is to balance competing ecological and human demands. In an area like the Delaware Estuary, where human patterns have already superseded natural ones, the program strives to preserve existing natural resources and restore the ecological functions of the estuary while giving the public access to the river and its environs. The program aims to restore and protect the ecology of the river while being sensitive to existing development patterns and encouraging redevelopment that is compatible with its environmental goals.

MUNICIPAL AND COUNTY POLICIES

A study of the coastal zone management practices that may affect how Pennsylvania deals with sea level rise must consider the role of municipal and county governments.

Pennsylvania is a home-rule state, and land use decisions are made at the municipal level. County governments have (for practical purposes) no zoning authority or land use regulatory power in Pennsylvania. The Municipal Planning Code (MPC), Act 247 (as amended), is the enabling legislation that empowers municipal governments to plan and zone all land contained within their boundaries. Local governments plan for streets, public parks, open space, pedestrian rights-of-way, railroad and transit rights-of-way, floodplains, drainage easements, etc. They also review and decide whether residential or commercial developments are approved. Predicting the decisions of diverse local planning boards made up of transient membership is beyond the scope of this project, but it is important to recognize that local land use decisions will ultimately play a key role in how the region responds to rising seas. Currently, only Philadelphia addresses sea level rise in its codes.

Although county governments have no direct authority over land use (with the exception of Philadelphia, which is also a municipality), they play an important advisory role in shaping development patterns. Counties foster cooperative action among their municipalities and create an overall planning framework to guide future development and growth in the county. County governments have the power to impose taxes and raise funds for land acquisition, conservation, and protection through easements. Counties play an important role in providing the transportation, water, and wastewater infrastructure on which development depends. For these reasons, we met with representatives of the coastal counties to better understand current and anticipated conditions in the study area, and to better understand how those conditions and county policies may inform future responses to sea level rise.

COUNTY-SPECIFIC RESPONSES TO SEA LEVEL RISE

The sections that follow provide background information on each county's relative risk to the impacts of sea level rise, highlight current county-level policies regarding land use planning and sea level rise (if they exist), and describe anticipated future shoreline protection responses.

Given that there is no formula to determine precisely the areas that would be protected from rising seas and those that would not, we did not ask county planners to define exactly where land would be protected from sea level rise. We did, however, ask county planners to review conditions along their coasts based on aerial photographs; identify areas of economic, cultural, and historic importance that would warrant protection; discuss future plans and anticipated land uses; speculate as to how coastlines may be affected by rising seas; and comment on how future county policies and planning initiatives could be informed by sea level rise. Meetings were conducted separately with Delaware, Philadelphia, and Bucks counties.

DELAWARE COUNTY

Delaware County, located at the southern end of the study area, has 12 miles of coastline extending from the Borough of Marcus Hook northward to Tinicum Township. It is highly developed, with a large proportion of the coastal land area dedicated to manufacturing, industrial, transportation, port, and commercial land uses. Much of the coastline is already bulkheaded or protected with vertical structures. The Philadelphia airport is located in the northern portion of the county. The county also contains two significant natural areas, the John Heinz National Wildlife Refuge and Little Tinicum Island.

The Delaware County waterfront is an area in transition. As the economy of the region continues to move away from heavy industry, many parcels along the waterfront will eventually present opportunities for redevelopment. Recognizing that the waterfront is a unique natural, cultural, and aesthetic resource, the County has made a number of significant efforts to plan for development in this area. To this end, the County prepared the *Delaware County Waterfront Resources Management Plan* in 1992 and the *Delaware County Coastal Zone Compendium of Waterfront Provisions* in 1998. These documents aim to create a sound planning and management framework for the entire coastal zone. They provide guidance and decision-making tools for municipalities to more effectively address economic revitalization, brownfields, public access, transportation, and environmental and historical preservation. It is hoped that by employing the tools and concepts laid out in these documents, municipalities will be able to forge and implement a shared vision for redevelopment activities throughout the county's coastal zone.

The county's plans for coastal zone revitalization entail integrating multiple types of land uses and activities. They emphasize a transition away from a waterfront dominated by industrial uses with limited public access to the water to a waterfront with revitalized, vibrant, mixed-use communities that embrace the history and ecology of the river. The County aims to increase public access to the waterfront, create and preserve open space areas for active and passive recreation, protect environmentally valuable areas, promote mixed-use development of former industrial sites, reserve the waterfront for water-dependent uses, preserve and capitalize on historic resources, and promote economic development through strategic revitalization. It should be noted, however, that despite the emphasis on long-range planning, county plans do not specifically address sea level rise, nor do they give policy guidance as to how rising seas could be planned for or addressed.

Discussion Summary

Karen Holm, manager of environmental planning, Delaware County Planning Department

Based on visual inspections of aerial photos, Delaware County anticipates that sea level rise could pose serious problems for the county's coast, most of which is heavily developed. Ms. Holm pointed out that although much of the existing shoreline is already armored in some way, rising sea levels would steadily increase the risk of flooding and erosion and would eventually lead to inundation unless protection efforts were undertaken. She stated that elevating individual structures was not an economically feasible option for the county, and that if protection efforts were to be undertaken for greater rises in sea level, whole areas would have to be protected in their entirety either by

constructing walls to hold back the sea or by elevating the land. Ms. Holm could not estimate the costs associated with such protection efforts, but she did highlight land uses of economic, cultural, and historic importance along the coast that would warrant sea level rise protection, if feasible.

Starting at the southern end of the study area, Ms. Holm detailed existing conditions along the waterfront. In Marcus Hook, she identified two large refinery complexes, the Sun Oil Company and Phillips Petroleum. Sandwiched between these two industrial complexes is Market Square Memorial Park, an important public access point for community residents, which was recently expanded and improved with public funds. Immediately north of the refineries lie two large utility sites, the DELCORA sewage treatment plant and a trash-to-steam plant. Adjacent to these sites is the former PECO power generating station, a massive, architecturally significant, historic structure now being converted into class-A office space with provisions for public access to the water. The parcels to the north, also formerly owned by PECO, were recently acquired by the City of Chester and will become part of an expanded Barry Bridge Park. Adjacent to the park is a capped Superfund site and the Riverbridge Industrial Park (formerly a Ford Motor Company facility).

A series of active and abandoned industrial sites are located along the next section of coast, moving northward. The first of these is the Kimberly-Clark plant, an active facility, followed by an abandoned shipyard slated to become the Chester Downs Racetrack and Marina. The next sites are Penn Terminals, an active port facility, and some underused former industrial parcels that Eddystone Borough has plans to acquire for public access and recreation. The final sites along this stretch, south of Darby Creek, are an active PECO generating station and a Boeing Corporation helicopter manufacturing facility.

Philadelphia International Airport and the town of Essington occupy the northernmost portion of the Delaware County coastline. Essington is a historic neighborhood with several significant cultural and historic sites, including the Corinthian Yacht Club, the Lazaretto, and Governor Prinz Park. The airport is a key regional economic asset and a nationally significant hub for air travel. The extreme waterside edge of the airport, along Hog Island Road, is slated to become a link in the East Coast Greenway, an off-road, multiuse trail running from Florida to Maine. Numerous wetland and mudflat areas are also located along the airport shoreline.

Beyond the waterfront, most of the study area comprises older residential neighborhoods interspersed with smaller commercial districts and industrial sites. The area also contains portions of Interstate 95, the Northeast Amtrak and SEPTA rail corridors, and multiple freight rail lines, which serve the industries and ports along the waterfront. Immediately behind the airport and the town of Essington lies the John Heinz National Wildlife Refuge, the largest protected, intact wetland ecosystem in the Pennsylvania coastal zone. Located in the river channel across from the airport and Essington is Little Tinicum Island. The island is publicly owned and is surrounded by mudflats or sandy beaches on all sides. The remainder of Delaware County's coastal wetlands mostly consists of smaller tidal wetlands along the river's shore and some larger nontidal wetlands in and around the Philadelphia airport. The commercial development and tidal wetlands on the Pennsylvania side of the river are mirrored on the opposite shore in New Jersey, but New Jersey also has large extents of non-tidal wetlands because of a history of building levees and dikes for agriculture. The Gibbstown Levee was built more than 200 years ago in New Jersey's Gloucester County, and it prevents tidal inundation of several square miles of land that are below spring high water.

Although Delaware County has no formal policy to address sea level rise, it concedes that rising seas will pose some tough decisions. For example, the County has supported efforts to maintain the integrity of high value natural areas like the John Heinz Refuge and Little Tinicum Island in the face of human activities and ongoing development pressures, but there is little

that can be done to save them from rising seas. The only way to retain wetlands is to allow their inland migration and the formation of new wetland areas on what is now dry land. From a policy standpoint, this would place the county in a difficult position: choosing between wetland migration and the protection of existing development in some locations.[29]

The county's vision for revitalizing its waterfront includes restoring open spaces and opening up the waterfront for public access. Establishing parks along the shore would create a buffer between the river and developed areas where erosion could occur. Even so, if the parks eroded away entirely, the shoreline would eventually need to be armored, so it may make sense to armor waterfront parks before they erode. Furthermore, if the purpose of open space along the water's edge is to provide public access or to provide a certain amount of "play space," armoring may be required. Of course, such eventualities are a function of park width, the rate of erosion, and the amount of area needed for a park to fulfill its intended function. Assuming a landward erosion rate of 1 foot per year, a 200-ft wide park buffer would provide a considerable cushion, but a 12-ft wide promenade hard-pressed between the river and development would require immediate armoring. So, even if parks and public rights-of-way are established along the water's edge, critical decisions about whether and when to armor will need to be made.

For the present, the County identified a few actions that could be taken now in anticipation of rising seas. For example, existing codes, which require new structures built in the floodplain to be 1 foot above the 100-year flood elevation, could be increased, or the area in which they apply could be expanded beyond the floodplain as currently defined. By raising the "freeboard" an extra foot, new structures would be flood-proofed for another 50 to 100 years. The County could apply these same requirements to the renovation of existing structures. The County also points out that municipal zoning and land use codes could be adapted to define special "hazard areas" that encourage proactive planning for rising seas.

In summary, most of the study area in Delaware County is developed, but the character of this development ranges from abandoned industrial properties and blighted neighborhoods to regionally critical assets such as the Philadelphia Airport. The County is working to redefine and revitalize those portions of the waterfront that are marginal by capitalizing on its primary asset—the river itself. The goal of revitalization is not just to find a use for vacant industrial parcels, but also to energize waterfront communities. For such efforts to be a success, the County knows that quality-of-life enhancements need to be made, including providing public access and restoring natural areas along the water's edge. Accordingly, revitalization efforts may reduce the need for shoreline armoring.

Anticipated Response Scenarios

The sea level rise protection map for Delaware County was created using the process described in the methods section. Departures from the statewide rules were made for specific municipalities according to the categorization rules presented in Table 4-5. Other, polygon-specific departures from the general rules are described in the results discussion below. Map 4-2 depicts the study results for Delaware County.

Shore Protection Almost Certain

Areas that will almost certainly be protected are depicted in brown. These are developed areas where current uses are not likely to change. They include residential, utility, commercial, community service, and transportation land uses in the municipalities specified in Table 4-6, as well as associated parking. In addition, the following specific areas are identified for inclusion in this category: the former PECO power generating station and the site of the future Chester Downs Racetrack in Chester, the Boeing helicopter facility (a manufacturing land use) in Ridley, the Commodore Barry Bridge,

[29]State or federal policy would ultimately play an important role in guiding county and local actions, but the county would have a voice in shoreline armoring and abandonment decisions through its influence on local land use planning.

TABLE 4-5. STATEWIDE SEA LEVEL RISE SHORE PROTECTION CATEGORIES BY LAND USE

Protection Category[a]	Land Use	Land Use Code
Protection almost certain	Residential	01000, 02000, 02010
Protection almost certain	Transportation	04000
Protection almost certain	Utility	05000
Protection almost certain	Commercial	06000
Protection almost certain	Community services	07000
Protection almost certain	Military	08000
Protection almost certain	Parking	02009, 02029, 04009, 05009, 06009, 07009, 08009
Protection likely	Manufacturing–light industrial	03000
Protection likely	Manufacturing–heavy industrial	03010
Protection likely	Recreation	09009
Protection likely	Mining	11000
Protection likely	Parking	03009, 03019, 09009
Protection unlikely	Agriculture	10000
Protection unlikely	Wooded	12000
Protection unlikely	Vacant	12010

[a] Polygons comprising the John Heinz National Wildlife Refuge, Little Tinicum Island, and lands owned by The Nature Conservancy were hand-selected for inclusion in the no protection category, regardless of their land use designation.

and one polygon along the southeastern corner of the airport classified as manufacturing.

Shore Protection Likely

Areas likely to be protected are depicted in red They include manufacturing (with the exception of the Boeing facility), mining, and recreation land uses and their associated parking. There are a number of healthy industrial and manufacturing enterprises that may seem better placed in the almost certain category, but local planners looked at 100 years, and because redevelopment scenarios may include natural buffers, protection of these areas is not certain.

Recreation land uses in the Delaware County coastal region are, for the most part, surrounded by development and designed for active use, or are already bulkheaded (i.e., Market Square Memorial Park), so we deemed protection to be likely as opposed to unlikely for these areas.

Protection is also likely, as opposed to almost certain, for residential, utility, commercial, community service, and transportation land uses located in stressed communities.[30] Although

[30]Stressed communities in Delaware County include the boroughs of Trainer and Marcus Hook and the City of Chester. Evaluation is based on relative household income and percentage of

these areas are developed, they are likely targets for revitalization. The potential transformation of these areas to reflect new visions for the waterfront means that while protection is generally likely, future scenarios may allow shoreline retreat in some locations.

Shore Protection Unlikely

Areas where protection is unlikely are depicted in blue. This category includes wooded, agricultural, and vacant lands.[31] These fragmented, undeveloped lands have low development potential (typically because of environmental constraints), and it is doubtful that the benefits of shoreline armoring in these locations would outweigh the costs. The majority of vacant lands in Delaware County are not associated with former industrial sites or located along the shoreline. Because future development of these parcels is doubtful, we considered their protection to be unlikely. In addition, a portion of one polygon currently coded as utility, just to the north of the PECO power generating station, is being converted into a waterfront park. Because this future park, to be named Barry Bridge Park, will feature a natural shoreline, we deemed protection to be unlikely in this location.

No Protection

Lands that will not be protected from sea level rise are depicted in light green. Land use polygons comprising the John Heinz National Wildlife Refuge and Little Tinicum Island fall into this category.

County Review

Delaware County's review (see Appendix D) of the map did not result in any changes to the protection categories.

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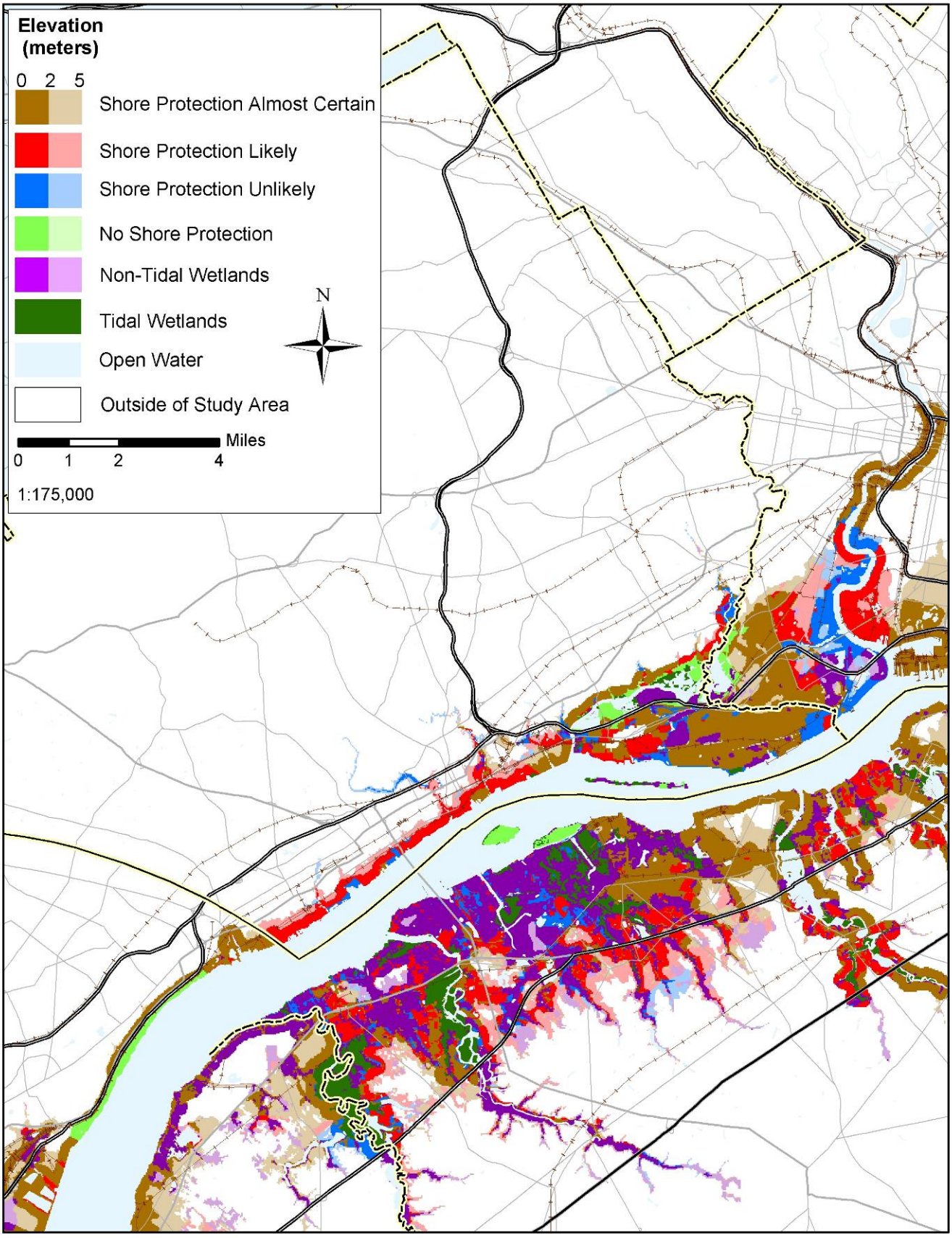
population below the poverty level. See DVRPC's Regional Data Bulletin No. 75: 2000 Census Profile by Minor Civil Division: Income and Poverty, June 2003.

[31]Delaware County has only one polygon classified as agriculture.

TABLE 4-6. DELAWARE COUNTY LAND USE SHORE PROTECTION CATEGORIES

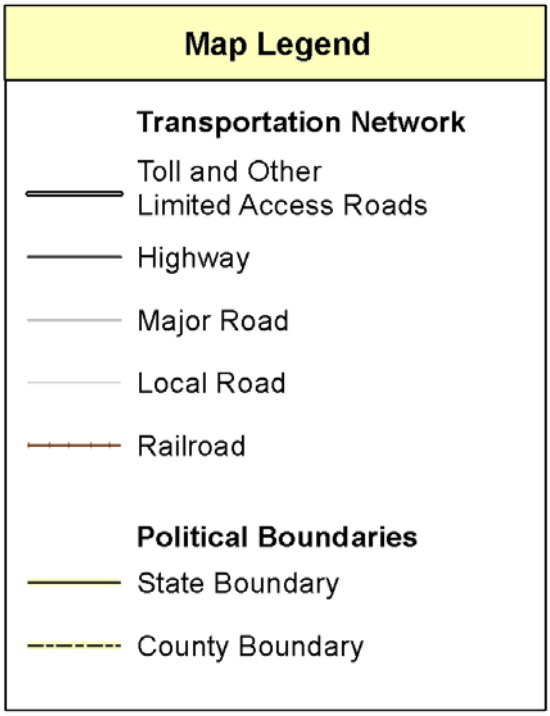
Land Use	Protection Category[1]			Land Use Code
	Unlikely	Likely	Almost Certain	
Municipality: Marcus Hook, Trainer, Chester City				
Residential		✓		01000, 02000, 02010
Manufacturing		✓		03000. 03010
Transportation		✓		04000
Utility		✓		05000
Commercial		✓		06000
Community services		✓		07000
Recreation		✓		09000
Parking		✓		02009, 03009, 03019, 04009, 05009, 06009, 07009, 09009
Wooded	✓			12000
Vacant	✓			12010
Municipality: Colwyn, Darby Borough, Darby Twp., Eddystone, Folcroft, Norwood, Prospect Park, Ridley, Ridley Park, Tinicum				
Residential			✓	01000, 02000, 02010
Transportation			✓	04000
Utility			✓	05000
Commercial			✓	06000
Community services			✓	07000
Parking			✓	02009, 04009, 05009, 07009
Manufacturing		✓		03000
Recreation		✓		09000
Mining		✓		11000
Parking		✓		03009, 03019, 06009, 09009
Agriculture	✓			10000
Wooded	✓			12000
Vacant	✓			12010

[a] Polygons comprising the John Heinz National Wildlife Refuge, Little Tinicum Island, and lands owned by The Nature Conservancy were hand-selected for inclusion in the no protection category, regardless of their land use designation. [Christine, please change footnote 1 in heading to a.



Map 4-2. Delaware 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 4-2. Delaware 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 1,000 feet of the shore. The lighter shades show the rest of the study area. For the basis of the shore protection categories in adjacent states, see the companion reports on New Jersey and Delaware. This map is based on Year 2000 land use data (published in 2003). Although the map also reflects site-specific changes suggested by planners in 2004, the intended use of this map is to convey countywide 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.



Map 4-2 (continued). Delaware County: Likelihood of Shore Protection. This legend defines the meaning for the transportation network and political boundary symbols used in the county-specific maps

PHILADELPHIA COUNTY

Philadelphia, located in the central portion of the study area, has 20 miles of coastline extending from Philadelphia International Airport in the south to its border with Bucks County at Poquessing Creek in the north. Philadelphia's coastal area is even more heavily developed than Delaware County's, and contains no natural areas or conservation lands of appreciable size other than the extreme northeast corner of the John Heinz National Wildlife Refuge. Most of the coastline is heavily altered, featuring a complex jumble of piers, wharfs, docks, and other hard structures. Nearly the entire shoreline south of the Betsy Ross Bridge is armored with vertical structures and bulkheads. Moving northward from the Betsy Ross Bridge, the vertical character of the shoreline becomes somewhat less pronounced and there are some larger undeveloped properties.

For the purposes of this study, we divide Philadelphia into four sections—north, central, south, and the Schuylkill—each of which has its own unique characteristics. The southern section extends from the airport to Washington Avenue. The northern section runs from Penn Treaty Park to the Bucks County border, and the central section lies in between—adjacent to Center City. The Schuylkill section borders either side of the Schuylkill River north of Bartram's Garden. Some of the state's largest areas less than 20 feet above sea level are located in the southern section. This district is almost exclusively nonresidential. It is dominated by refineries, port facilities, the Philadelphia airport, the former Philadelphia Naval Base, salvage yards, auto recycling facilities, big box retail, the stadium district, warehousing, vacant lands, wetlands, and mudflats. Much of this area is very low land created by filling wetlands, or otherwise in the floodplain.

The central portion of Philadelphia's shoreline is characterized by a continuous series of wharfs and finger piers. The piers have multiple uses, from warehousing and storage to ice skating rinks and luxury condominiums. Some of the piers, however, have been abandoned and are covered with vegetation. Behind these piers lie Columbus Boulevard and Interstate 95. Farther inland lie the dense residential neighborhoods of Center City, though most of these districts are on higher ground, beyond the boundaries of the study area. This stretch also includes Penn's Landing, which has been the site of multibillion dollar redevelopment proposals.

Heading north, the study area opens up somewhat and is more diverse. Manufacturing and industrial properties, residential neighborhoods, parks, institutional properties, utilities, former military bases, and municipally owned lands populate this section of the coast. This stretch of the Delaware River is the focus of the city's Comprehensive Redevelopment Plan for the North Delaware Riverfront, which presents a vision for a revitalized riverfront that includes a greenway along the river, open spaces, vibrant mixed-use development, and the preservation of historic structures.

The study area along the Schuylkill River north of the Gray's Ferry Avenue Bridge is relatively narrow and is characterized by manufacturing, transportation, recreation, and vacant land uses. The Schuylkill Expressway, the CSX rail tracks, and the Schuylkill River Trail, which extends along the river's eastern bank from Schuylkill River Park to the northern boundary of the study area, parallel the river for much of this stretch. Although the northern Schuylkill is revitalizing, this portion of the study area does not have large derelict tracts where natural shorelines could be restored. Furthermore, any erosion along the Schuylkill's eastern bank would jeopardize both

the new Schuylkill River Trail and the adjacent CSX rail tracks. Because the river throughout most of this stretch is already armored and because there are few areas where natural conditions might be restored, protection should be considered almost certain for this portion of the study area.

Discussion Summary

Marty Soffer, environmental planner, Philadelphia City Planning Commission

We discussed existing conditions along Philadelphia's waterfront and its potential responses to rising seas with Mr. Soffer. Although the city has no blanket policy regarding sea level rise, it did take rising seas into account when formulating its current floodplain regulations. Because of concerns about increased flooding associated with rising seas, the city added an additional foot of freeboard to its existing foot of freeboard; that is, new construction must be elevated 2 feet above the base flood elevation. The city, with the help of FEMA, is also updating its floodplain maps based on the city's 2-ft elevation contours. The city's existing stormwater controls, which are meant to prevent flooding and environmental degradation, also have the potential to mitigate some of the effects of rising seas, according to Mr. Soffer.

As in Delaware County, Philadelphia is still transitioning away from its manufacturing and industrial base, and active industrial facilities and refineries in the study area will most likely cease operations in the next 50 years or so. Mr. Soffer also indicated that former industrial parcels will be attractive sites for redevelopment. He was unsure of the extent to which redevelopment efforts would entail the creation of waterfront parks and the reintroduction of natural areas along the water's edge, but he did not rule these out either.[32]

Beginning at the southern end of the county, Mr. Soffer described some areas of economic, cultural, and historic importance that are vulnerable to rising seas where the city would support protection. He identified Philadelphia International Airport, the Kvaerner Shipyard, the former Navy Base (now the Naval Business Center), the western edge of Center City along the Schuylkill River, the Old Swedes Church, Penn's Landing, the Frankford Arsenal, Fort Mifflin, and Bartram's Garden. Mr. Soffer also pointed out that the migration of the salt line up the Delaware could threaten the Baxter water intake near the Philadelphia Detention Center at the mouth of Pennypack Creek.

Finally, Mr. Soffer highlighted some examples of development projects in the city's coastal areas that are indicators of future trends. A new parking garage is under construction at 30th Street Station along the Schuylkill and there are plans for a high-rise office tower in this location as well. The airport is conducting an expansion study that includes the filling of some floodplain areas. New residential development has been proposed for the Philadelphia Coke site, St. Vincent's School, and the Dodge tract along the northern Delaware. New housing and office space are under construction at the Naval Business Center, and filling in the eastern third of the Business Center for development has been proposed. Protection for most of these development sites is classified as almost certain.

Anticipated Response Scenarios

The sea level rise protection map for Philadelphia was created using the process described in the methods section. Departures from the statewide rules are detailed in Table 4-7. Other, polygon-specific departures from the general rules are described in the results discussion below. Map 4-3 depicts the study results for Philadelphia.

Protection Almost Certain

In the southern section of the study area, protection is almost certain for the airport, the Kvaerner Shipyard, the former Navy Base, the Packer Avenue Marine Terminal, the stadium district, FDR park, and the area's piers,

[32]The Comprehensive Plan for the North Delaware Riverfront as well as the Schuylkill River Development Corporation's Tidal Schuylkill River Master Plan both contain extensive provisions for greenways, the restoration of natural shorelines, and the creation of larger open space nodes along the Schuylkill and Delaware rivers.

warehouses, retail centers, and transportation infrastructure.

Protection is almost certain along both sides of the Schuylkill River north of the Gray's Ferry Avenue Bridge. Although a greenway is being established along the east bank of the river, its shoreline is already armored and any erosion here would jeopardize the new public right-of-way, which is hard-pressed between the river's edge and rail tracks belonging to CSX. The Schuylkill Expressway runs parallel to the river on its western edge and is currently armored.

With the exception of a few vacant piers and waterfront parcels, the central section of the study area, running the length of Center City's eastern edge, will be protected in its entirety.

For the northern section, which is the focus of the Comprehensive North Delaware Riverfront Plan, protection is almost certain for residential, transportation, utility, commercial, and community service areas, most of which are located landward of I-95. Protection is also almost certain for regionally important features such as I-95, the Tioga Marine Terminal, and the Philadelphia Correctional Center, as well as recreational land uses located within residential neighborhoods.

Protection Likely

Protection is likely for a portion of existing and former industrial facilities, for parking and storage areas, and for commercial areas, recycling facilities, salvage yards, and vacant lands along the mouth of the Schuylkill River in the southern section of Philadelphia. Although most these areas are currently "developed," it is unclear whether or not public or private entities would invest in their protection. Assuming the area is eventually vacated by its current industrial tenants, it is not known if, when, or how the area will be adapted for new uses, because no revitalization plans are proposed for this section of the city.

Protection is also likely for large portions of the northern section of Philadelphia's shoreline. Land here, particularly near the river, is used primarily for manufacturing, storage, and parking, or is vacant. Because this area is targeted for widespread revitalization, future land uses are not certain. Some areas may in the future require protection, while others could be left to erode. Therefore, protection for most of the area seaward of I-95 should be considered likely, but not certain. The only exceptions to this rule include the parcels for which certain protection was identified above, such as the Tioga Marine Terminal, and parcels that will in all likelihood be left to erode, such as vacant, wooded, and recreation areas along the water's edge.

Protection Unlikely

Protection is unlikely for wooded lands and some vacant, industrial, and commercial parcels along the southern reaches of the Schuylkill River. Protection for these vacant, industrial, and commercial parcels is unlikely rather than likely because of proximity to wetlands, wooded lands, mudflats, open water, and the area's floodplain. Accordingly, we judge the likelihood of future development in these areas to be highly uncertain, and if no future development were to occur, these shores would probably be allowed to erode.

Protection is also unlikely for wooded and some vacant and recreation parcels along the northern Delaware River. These tracts are not developed and would not be likely locations for future development, either because they are environmentally constrained or because they are open space in public ownership with natural shorelines.

No Shore Protection (Conservation Areas)

Conservation lands include the northeast corner of the John Heinz National Wildlife Refuge.

County Review

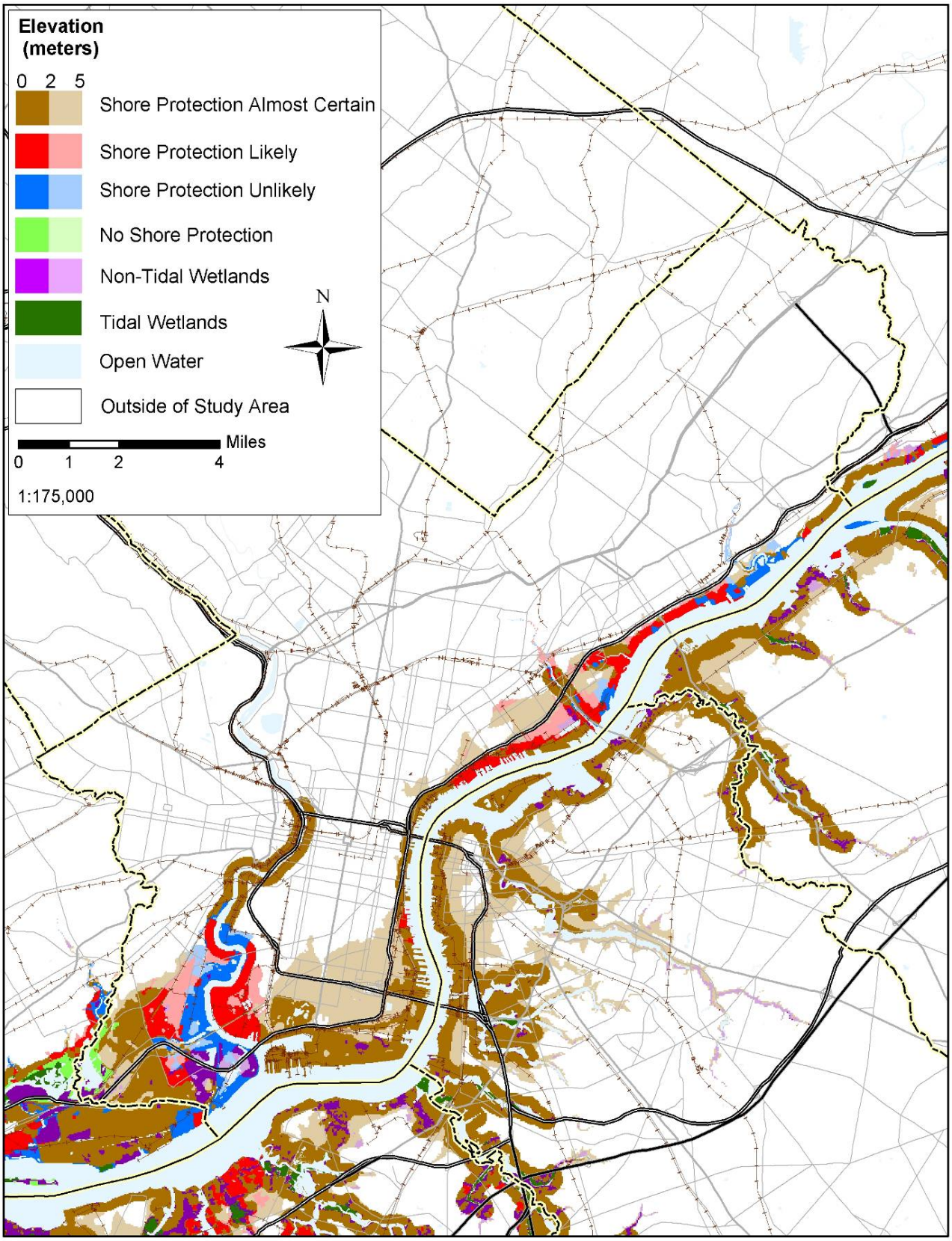
Philadelphia's review (see Appendix D) of the Philadelphia sea level rise protection map did not result in any changes to the protection categories.

TABLE 4-7. PHILADELPHIA LAND USE SHORE PROTECTION CATEGORIES

Land Use	Protection Category[a]			Land Use Code
	Unlikely	Likely	Almost Certain	
North Schuylkill River and Central Section of Philadelphia				
All categories			✓	02000, 02009, 02010, 03000, 03009, 03010, 04000, 04009, 05000, 05009, 06000, 06009, 07000, 07009, 09000, 09009, 12000, 12010
Southern Section of Philadelphia				
Residential, manufacturing,[b] transportation, utility, commercial[b] community services, military, recreation, vacant[b]			✓	01000. 02000. 02010, 03000, 03010, 04000, 05000, 06000, 07000, 08000, 09000, 12010,
Parking			✓	02009, 02019, 03009, 03019, 04009, 05009, 06009, 07009
Manufacturing[b]		✓		03000, 03010
Commercial[b]		✓		06000
Vacant[b]		✓		12010
Parking		✓		09009
Manufacturing[b]	✓			03000, 03010
Commercial[b]	✓			06000
Wooded	✓			12000
Vacant[b]	✓			12010
Northern Section of Philadelphia				
Residential, transportation, utility, community services, recreation			✓	01000, 02000, 02010, 04000, 05000, 06000, 07000, 09000
Parking			✓	02009, 04009, 05009, 06009, 07009, 09009
Manufacturing, vacant, parking		✓		03000, 03010, 12000, 03009, 03019
Recreation, wooded, vacant	✓			09000, 12000, 12010

[a] Polygons comprising the John Heinz National Wildlife Refuge were hand-selected for inclusion in the no protection category, regardless of their land use designation.

[b] Protection can be almost certain, likely, or unlikely for manufacturing, commercial, and vacant land use polygons in the southern section of the Philadelphia study area. This distinction is based on the proximity of polygons to the mouth of the Schuylkill River. Either side of the lower Schuylkill is dominated by manufacturing and vacant land uses, with some commercial land uses mixed in. This region, like most of the study area, will probably transition away from its industrial base. However, no plans exist to redevelop this area with new residential and commercial uses. Much of the area faces possible contamination issues and is in the floodplain, making redevelopment that much less likely. Accordingly, we concluded that future protection is unlikely or likely, but not certain. The distinction between unlikely and likely is based on proximity to the river and on visual inspections of aerial photos, more so than on rigid land use decision rules. The remainder of the southern section of the city is heavily developed and less transitional in character than the heavy industrial areas near the Schuylkill. The land is also less flood-prone and is not characterized by derelict and transient uses such as junkyards and materials recycling facilities. As a result, protection for nearly all land uses in the southern section beyond the vicinity of the lower Schuylkill is almost certain.



Map 4-3. **Philadelphia County: Likelihood of Shore Protection .** For additional details, see the legend and caption accompanying Map 4-2.

BUCKS COUNTY

The study area in Bucks County extends 25 miles from the border with Philadelphia in the south to the height of the tide at Morrisville, Pennsylvania, in the north. Overall, Bucks County's coastal area features more residential districts and the shoreline is less heavily armored than in Philadelphia and Delaware counties. Most of Bucks County's coast is developed in some way, but there are some natural areas of significant size as well. The study area is home to several large industrial properties, including what was once the largest steel manufacturing site in the country: the Fairless Hills Steel Works (or more recently, USX Steel), although that facility is now closed. This same area, located in the southeastern corner of Bucks County, is also the county's largest low-lying area. Although this corner of the county, which is sometimes referred to as the "Great Bend," was home to the large steel manufacturing facility, it also contains sizable wooded tracts and wetlands and features a predominantly natural shoreline.

The County recently has undertaken a revitalization plan for the coastal areas of southern Bucks County. Currently, the potential of the Delaware River as a public amenity and as a boost to the overall quality of life in the region is not realized. Few locations exist where the public can access the river. Bucks County's revitalization plan aims to capitalize on the river's assets by creating better public access, introducing more public open spaces, and improving ecological conditions along the river's edge. By doing so, the County hopes the river can become a catalyst for revitalization and the creation of economically healthy, vibrant mixed-use communities.

Discussion Summary

Michael Roedig, environmental planner, Bucks County Planning Commission

We met with Mr. Roedig, who as an environmental planner for the county is focusing on the waterfront, to discuss the county's potential responses to rising seas. Mr. Roedig informed us that the County has never formally considered sea level rise nor has it addressed rising seas in its adopted policies and plans. He agreed that rising seas would affect the county and that this study could serve as a starting point for the county to begin planning for rising seas. Mr. Roedig thought that a rise of less than 2 feet poses only a small threat for developed portions of the shoreline, but he expressed concern over the loss of wetlands and natural areas that he predicted would accompany any rise in sea level. Although Mr. Roedig identified some bulkheaded areas, he did not know how rising seas would affect erosion rates along unprotected portions of the shoreline.

As is the case in Delaware and Philadelphia, the Bucks County's waterfront revitalization plan will present a vision for the reuse of underused areas in the coastal zone and will include provisions for public access along the water's edge. Mr. Roedig thought that incorporating setbacks and buffers into the plan might be appropriate in anticipation of more extreme flooding as seas rise. Likewise, he stated that it would be in the county's best interest to "hedge its bets" by planning to place development farther from the shore than they otherwise would were seas not rising.

To inform this study, Mr. Roedig described existing land uses and ownership patterns along the shore. Beginning in the south, the shoreline is occupied by a five-hole golf course and a private marina associated with an adjacent multifamily development. A series of large estate homes occupy the shoreline moving northward. The last of these homes is the privately owned Pen Ryn Mansion, which is surrounded by publicly owned wooded lands. The next section of

shoreline is occupied by Echo Beach and the Delaware Expressway Industrial Park, which is partly vacant. Landward of Echo Beach is the Cornwells Heights neighborhood. North of the industrial park are a series of riverfront homes and Neshaminy State Park. The rest of the coastline up to Bristol Borough's border is mostly wooded or vacant. Most of this property is owned by Rohm & Haas or is part of a water treatment works serving Bristol Township. The shoreward areas of the Rohm & Haas property are mostly wooded or open and contain numerous wetlands. The Nature Conservancy acquired a portion of former Rohm & Haas property containing some wetlands along the southern edge of Bristol Borough in the 1980s. More recently, discussions have taken place among Rohm & Haas, Bristol Borough, The Nature Conservancy, and the Natural Lands Trust regarding the transfer of additional wetlands owned by Rohm & Haas to a conservation organization for permanent protection. Part of the shoreline just south of Bristol Borough, along what is known as Maple Beach, is bulkheaded or diked. According to the PADEP, however, most of these structures run perpendicular, not parallel, to the shoreline.

Bristol Borough is an older town that is built up to the river's edge. Residential development located near the shore also extends for several miles north of the borough. The next section of the Bucks County study area is the Great Bend region mentioned previously. This area is home to two major active landfills—the Tullytown Landfill and the GROWS Landfill—as well as a capped landfill now referred to as Money Island. Also included in this district are the Novolog Port facility, Quaker Penn Park, and Pennsbury Manor—the former home of William Penn. The massive former USX Steel plant and a number of large wooded tracts and wetlands adjacent to the river occupy most of the remainder of the Great Bend. The Borough of Morrisville lies at the northern terminus of the study area, just upriver of the Great Bend region. The southern portion of the borough, up to the railroad bridge, is mostly vacant and wooded along the river and includes an underused manufacturing/warehouse site. The remainder of the borough is developed with commercial and residential uses.

Anticipated Response Scenarios

The sea level rise protection map for Bucks County was created using the process described in the methods section. Departures from the statewide rules are detailed in Table 4-8. Other, polygon-specific departures from the general rules are described in the results discussion below. Map 4-4 depicts the study results for Bucks County.

Protection Almost Certain

In Bucks County, protection would be almost certain for all residential, commercial, utility, and community service areas, with the exception of the Tullytown and GROWS landfills, for which protection would be unlikely (see below). The majority of the county's transportation land uses would be protected, as would the Novolog Port, currently coded as manufacturing, and historic Pennsbury Manor, currently coded as a combination of wooded and vacant. Protection is also almost certain for some recreation areas such as those found in Bristol Borough, which are surrounded by dense development and are primarily active recreation sites. Finally, the golf course and marina near Poquessing Creek would almost certainly be protected, because the County identified these as significant private facilities warranting protection.

Protection Likely

With the notable exception of the former USX Steel site, most of Bucks County's manufacturing and industrial districts are healthier, with fewer vacancies and less blight, than those found in Delaware and Philadelphia counties. Nevertheless, the long-term prognosis for industry in Bucks County is not strong. Accordingly, we treated manufacturing land uses in Bucks County the same as in the other counties. We considered protection in these areas to be likely. We also consider protection to be likely for vacant and transportation land uses associated with manufacturing sites.

Protection Unlikely

Protection is unlikely for the study area's wooded lands, most vacant tracts, and a single polygon coded as agricultural. Some of these lands are privately owned and others are under public control, such as those found within Neshaminy State Park. There is also a chance that the large assemblage of natural lands located in the Great Bend will be acquired by public entities. Even if they are not, these areas are still unlikely to be protected, because development here would be doubtful because of both natural constraints and possible contamination issues. Erosion along the undeveloped wooded shorelines of the region's active and former landfills could occur as long as this erosion did not present significant environmental or public health threats. Barring toxic contamination issues, protection for the Tullytown and GROWS landfills is unlikely because the County stated that they will probably reach capacity in the next 10 years and will not be redeveloped for other uses.

Protection would also be unlikely for the area's mining operations. Mining in the coastal area consists mostly of sand and gravel mining, and these operations result in the conversion of dry land to open water even under normal conditions. In fact, sizable portions of Van Sciver and Manor lakes are the result of past mining operations. Accordingly, rising seas would only hasten the conversion of existing or former sand and gravel mines to open water.

No Shore Protection (Conservation Areas)

Lands owned and eased by The Nature Conservancy and portions of Neshaminy State Park constitute Bucks County's conservation areas. The Nature Conservancy lands occupy approximately 18 acres of marshy ground just to the southwest of Bristol Borough.[33] The Nature Conservancy's policy of allowing wetlands to migrate means that protection would be prohibited in these areas. A portion of Neshaminy State Park up Neshaminy Creek away from the river contains forested wetlands and is managed by the state for conservation purposes.

County Review

Bucks County reviewed the sea level rise protection map and specified several changes to the protection categories (see Appendix D). The County requested that shore protection for the golf course adjacent to the Poquessing Creek be changed from likely to almost certain. This recoding reflects the golf course's role as part of a successful residential enclave that would armor itself to prevent erosion. The County stated that vacant land south of The Nature Conservancy's wetland should be coded blue (shore protection unlikely). This is consistent with the area's current and expected future status as vacant land. According to the county, protection for an area in north Bristol Borough, which was originally classified as unlikely, should be reclassified as almost certain. Part of this area has been redeveloped as senior housing, and the County indicated that the remaining industrial parcels along this stretch will be redeveloped in the near future. Finally, the County stated that the Tullytown and Grows landfills will reach capacity and close within the next 10 years. After closing, the landfills will be capped and become areas of passive use. The landfills therefore will not require shoreline armoring and should be coded blue (shore protection unlikely) as opposed to brown (shore protection almost certain).

Upon review (see Appendix D), Pennsylvania's CZM program requested a single change to Bucks County's sea level rise protection map. The program recommended that a forested area of Neshaminy State Park north of Neshaminy Creek and immediately above the marina be coded as green (no shore protection) rather than blue (shore protection unlikely). Such a designation is consistent with the management of these lands by the Pennsylvania Department of Conservation and Natural Resources for conservation purposes.

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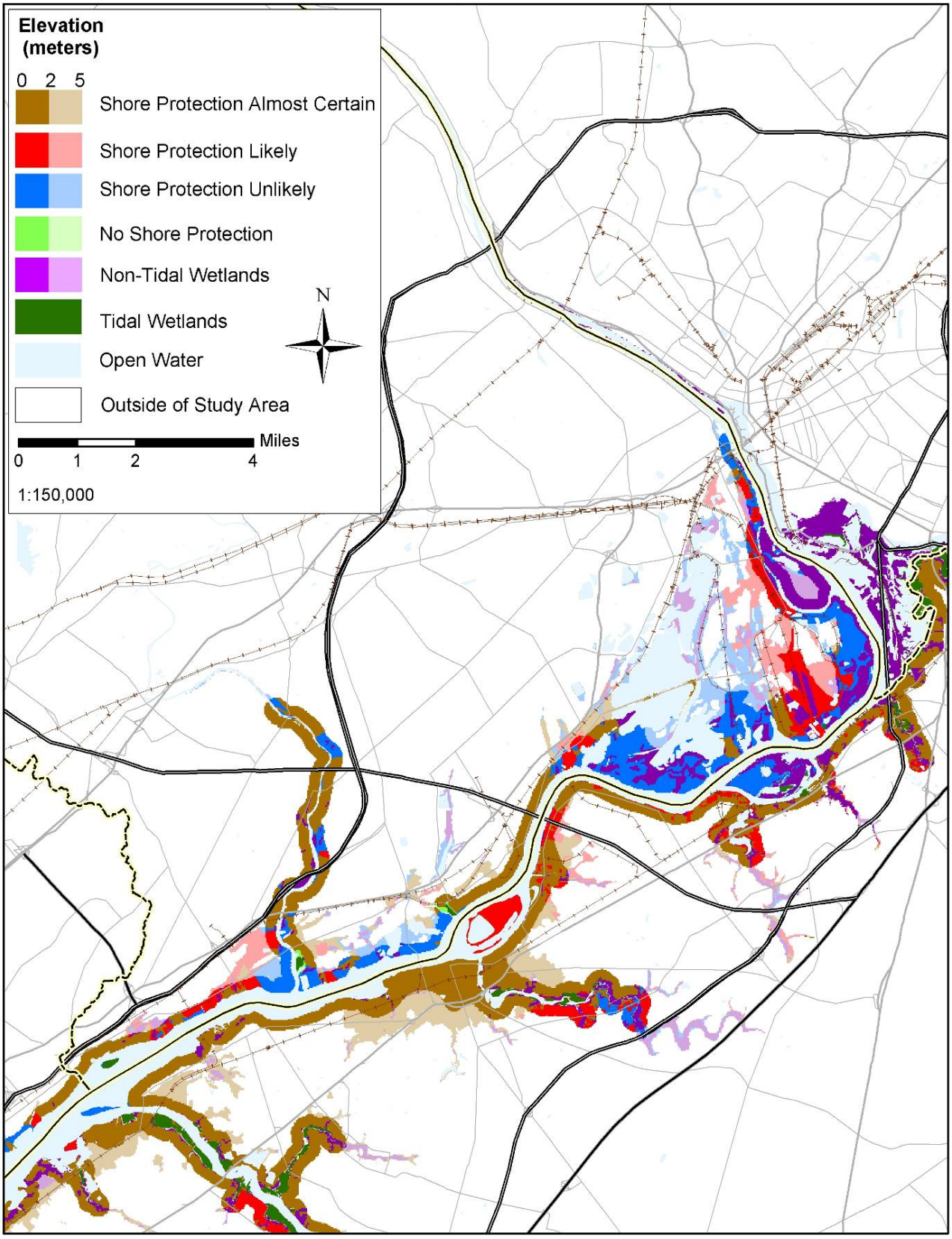
[33]The Nature Conservancy, *http://nature.org/wherewework/northamerica/states/pennsylvania/*.

TABLE 4-8. BUCKS COUNTY LAND USE SHORE PROTECTION CATEGORIES

Land Use	Protection Category[a]			Land Use Code
	Unlikely	Likely	Almost Certain	
Residential			✓	01000, 02000, 02010
Transportation[b]			✓	04000
Utility			✓	05000
Commercial			✓	06000
Community services			✓	07000
Recreation[b]			✓	09000
Wooded[b]			✓	12000
Parking			✓	02009, 04009, 05009, 06009, 07009
Manufacturing		✓		03000, 03010
Transportation[b]		✓		04000
Recreation[b]		✓		09000
Vacant[b]		✓		12010
Parking		✓		03009, 03019
Recreation[b]	✓			09000
Agriculture	✓			10000
Mining	✓			11000
Wooded[b]	✓			12000
Vacant[b]	✓			12010
Parking	✓			09009

[a] Polygons comprising lands owned by The Nature Conservancy were hand-selected for inclusion in the no protection category, regardless of their land use designation.

[b] Protection for the transportation, recreation, wooded, and vacant land use categories can vary. These variations are described in the individual protection category discussions.



Map 4-4. Bucks County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 4-2

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

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 Appendix 1 of this report.

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

Water Body Category[1]	Description
Shorelines Along Primary Water Bodies [2]	
Primary Bay	Shoreline located along a major bay such as Chesapeake Bay.
Barrier/Bayside	The side of barrier islands adjacent to the inner coastal bay.
Primary River	The portion of a major river that flows either into the Atlantic Ocean or a Primary Bay where the river is wider than one kilometer. In this case, a major river is subjectively determined but represents the most significant waterways in the region based on relative size (e.g., Potomac River, Delaware River, Nanticoke River, etc.).
Barrier Bay/Mainland	Shoreline that is located along the major county landmass and, at least partially, shielded by a barrier island.
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/Oceanfront).
Other Types of 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.
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 Bay	Shoreline located along a smaller bay that is further sheltered from the wave action of a major bay 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. With the exception of shoreline identified as "Dredge and Fill", all Water Body Categories are mutually exclusive. Dredge and Fill areas are identified separately and are associated with shoreline that would otherwise be identified as Tributary.

2. For the purpose of this study, "Primary Water Body" distinguishes larger water bodies where the more immediate effects of sea level rise are likely to occur. These areas are less protected by land barriers and offer 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.

Table A-2: Shoreline length by County

County	Shoreline Length (Kilometers)					
	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Bucks	23	5	36	3	16	**84**
Delaware	12	24	18	17	13	**84**
Philadelphia	63	31	30	6	2	**132**
Totals	**98**	**60**	**83**	**27**	**32**	**300**

Table A-3: Shoreline length of primary water bodies

Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Primary River	Delaware River	34	25	30	<0.1	9	**98**
Totals		**34**	**25**	**30**	**<0.1**	**9**	**98**

Table A-4: Shoreline lengths for all water bodies

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Bucks	Island	Delaware River	0	0	0.3	0	0	**0.3**
Bucks	Primary River	Delaware River	9	3	16	<0.1	8	**36**
Bucks	Tributary	Delaware River	15	2	19	3	9	**48**
Delaware	Island	Delaware River	0	0.1	0	4	3	**7**
Delaware	Other	Delaware River	1	1	0.3	0	0.1	**3**
Delaware	Primary River	Delaware River	3	11	7	0	1	**21**
Delaware	Tributary	Delaware River	8	12	11	13	9	**54**
Philadelphia	Other	Delaware River	15	7	0.8	0	0	**23**
Philadelphia	Primary River	Delaware River	23	11	7	0	0	**41**
Philadelphia	Tributary	Delaware River	25	13	22	6	2	**68**
Totals			**98**	**60**	**83**	**27**	**32**	**300**

Appendix B

AREA OF LAND BY SHORE PROTECTION LIKELIHOOD

(Counties in Same Order as Discussed in the Text)

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 USGS 1:24,000 scale topographic maps for Delaware and Bucks Counties. The City of Philadelphia, however, provided EPA with its 2-ft contour elevation data set, which has numerous contours with negative elevations, particularly in the area near Philadelphia International Airport. Therefore, the results include negative elevations only for Philadelphia.

The EPA data set used the National Wetlands Inventory (NWI) to distinguish dry land, nontidal wetlands, tidal wetlands, and open water. The boundaries of that wetlands data set do not perfectly match the boundaries of the land use data used in this report. Some areas that the wetlands data treated as dry land, for example, are wetlands or open water according to the land use data sets. This table treats such lands as "not considered" because our planning study did not estimate shore protection likelihood there. Most of these lands are along the shore and are as likely as not to be wetlands or open water today, even if they were still dry land when the wetlands data were created. See Appendix 2 of this report for additional details on how these tables were created.

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

Pennsylvania

Elevation above Spring High Water (m)		Area (square kilometers)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
-4.0	-2.5	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.02
-2.5	-2.0	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.03
-2.0	-1.5	0.00	0.00	0.01	0.00	0.01	0.03	0.01	0.04
-1.5	-1.0	0.14	0.00	0.02	0.00	0.02	0.18	0.03	0.21
-1.0	-0.5	0.34	0.03	0.12	0.04	0.09	0.61	0.20	0.81
-0.5	0.0	0.63	0.19	0.40	0.13	0.14	1.49	0.15	1.64
0.0	0.5	4.58	2.21	2.56	0.34	0.51	10.21	1.46	11.68
0.5	1.0	5.32	2.36	2.68	0.32	0.45	11.13	1.52	12.64
1.0	1.5	7.83	3.54	2.87	0.31	0.42	14.96	1.65	16.62
1.5	2.0	6.30	3.76	2.76	0.21	0.37	13.41	1.55	14.96
2.0	2.5	5.01	3.29	2.58	0.07	0.33	11.28	1.13	12.40
2.5	3.0	5.11	3.24	2.52	0.11	0.34	11.31	0.99	12.30
3.0	3.5	4.31	2.69	2.38	0.06	0.40	9.84	0.97	10.81
3.5	4.0	3.94	2.51	2.25	0.05	0.47	9.23	0.95	10.18
4.0	4.5	3.92	2.33	1.95	0.04	1.07	9.31	0.81	10.12
4.5	5.0	2.76	1.29	0.46	0.02	4.53	9.07	0.34	9.41
5.0	5.5	1.77	0.59	0.30	0.01	5.68	8.34	0.36	8.71
5.5	6.0	1.14	0.51	0.26	0.00	6.25	8.17	0.37	8.54

Delaware

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	242.3	99.3	59.7	27.1	16.3	444.7	61.8	506.5
0.5	1.0	242.3	99.3	59.7	27.1	16.3	444.7	61.8	506.5
1.0	1.5	242.3	99.3	59.7	27.1	16.3	444.7	61.8	506.5
1.5	2.0	163.7	89.8	42.6	17.2	13.6	326.8	38.7	365.5
2.0	2.5	27.9	73.6	13.9	1.6	9.1	126.2	0.6	126.8
2.5	3.0	27.9	73.6	13.9	1.6	9.1	126.2	0.6	126.8
3.0	3.5	27.9	73.6	13.9	1.6	9.1	126.2	0.6	126.8
3.5	4.0	27.9	73.6	13.9	1.6	9.1	126.2	0.6	126.8
4.0	4.5	27.9	73.6	13.9	1.6	9.1	126.2	0.6	126.8
4.5	5.0	23.2	57.5	11.7	1.2	30.6	124.2	0.6	124.8
5.0	5.5	10.3	8.9	5.3	0.2	91.2	115.9	0.6	116.5
5.5	6.0	10.3	8.9	5.3	0.2	91.2	115.9	0.6	116.5

Philadelphia

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
-4.0	-3.5	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.09
-3.5	-3.0	0.00	0.00	0.09	0.00	0.36	0.45	0.00	0.45
-3.0	-2.5	0.00	0.00	0.27	0.00	1.53	1.80	0.00	1.80
-2.5	-2.0	0.45	0.00	0.18	0.00	2.43	3.06	0.00	3.06
-2.0	-1.5	0.45	0.00	1.26	0.00	1.35	3.06	0.81	3.87
-1.5	-1.0	13.59	0.27	1.89	0.00	2.07	17.82	2.97	20.79
-1.0	-0.5	33.57	2.52	12.24	3.87	8.73	60.93	20.43	81.36
-0.5	0.0	63.45	18.90	39.60	13.23	13.86	149.04	14.67	163.71
0.0	0.5	148.68	45.81	41.31	6.03	15.21	257.04	15.21	272.25
0.5	1.0	222.75	60.48	52.92	3.33	9	348.48	20.43	368.91
1.0	1.5	473.04	168.66	67.68	2.43	5.67	717.48	27.45	744.93
1.5	2.0	398.16	181.8	65.25	3.06	4.05	652.32	28.44	680.76
2.0	2.5	404.73	150.75	76.23	4.23	3.96	639.90	24.03	663.93
2.5	3.0	414.54	145.71	70.11	7.83	5.4	643.59	10.44	654.03
3.0	3.5	335.07	90.99	56.16	2.97	10.89	496.08	8.73	504.81
3.5	4.0	297.9	72.99	43.38	2.07	18.54	434.88	6.75	441.63
4.0	4.5	301.95	70.11	41.4	1.53	40.14	455.13	5.49	460.62
4.5	5.0	226.98	54.72	25.65	1.26	131.13	439.74	4.14	443.88
5.0	5.5	141.12	33.12	15.48	0.99	184.86	375.57	6.66	382.23
5.5	6.0	78.3	25.29	12.06	0	242.46	358.11	6.93	365.04

Bucks

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	67.3	76.2	155.3	1.2	19.7	319.6	69.3	389.0
0.5	1.0	67.3	76.2	155.3	1.2	19.7	319.6	69.3	389.0
1.0	1.5	67.7	86.1	159.7	1.2	19.7	334.2	75.8	410.1
1.5	2.0	68.3	104.8	167.8	1.2	19.6	361.6	88.0	449.6
2.0	2.5	68.3	104.8	167.8	1.2	19.6	361.6	88.0	449.6
2.5	3.0	68.3	104.8	167.8	1.2	19.6	361.6	88.0	449.6
3.0	3.5	68.3	104.8	167.8	1.2	19.6	361.6	88.0	449.6
3.5	4.0	68.3	104.8	167.8	1.2	19.6	361.6	88.0	449.6
4.0	4.5	62.0	89.1	139.7	1.1	57.8	349.6	74.7	424.4
4.5	5.0	25.8	16.5	9.0	0.0	291.6	342.9	29.2	372.1
5.0	5.5	25.8	16.5	9.0	0.0	291.6	342.9	29.2	372.1
5.5	6.0	25.8	16.5	9.0	0.0	291.6	342.9	29.2	372.1

Table B-2. Area of Land Vulnerable to a One Meter Rise in Sea Level (square kilometers)
By Watershed and County by Likelihood of Shore Protection

County	Likelihood of Shore Protection						Tidal Wetlands[1]
	Certain	Likely	Unlikely	No Protection	Nontidal Wetlands	Total Nontidal Land	
Delaware Estuary							
Bucks	1.3	1.5	3.1	0.0	1.4	7.8	1.9
Philadelphia	4.8	1.3	1.5	0.3	0.7	9.2	0.6
Delaware	4.8	2.0	1.2	0.5	1.2	10.1	3.6
Total	11.0	4.8	5.8	0.8	3.4	27.1	6.1
Pennsylvania	11.0	4.8	5.8	0.8	3.4	27.1	6.1

1. Includes mudflats.

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: Pennsylvania[1]
(square kilometers)

		Meters above Spring High Water																	
		low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
County		**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----------																	
Bucks		0.04	4.4	0.2	8.5	2.5	13	5.3	18	9	23	12	27	15	32	19	36	22	39*	25	42*
Delaware		0.4	6.1	4	12	7.9	17	12	18	15	19	17	21	18	22	20	24	21	25	22	26
Philadelphia		3.6	6.1	6.8	12	13	19	20	25	26	31	32	37	37	42	42	46	47	51	51	55
Statewide		**4**	**17**	**11**	**33**	**24**	**49**	**37**	**61**	**50**	**73**	**61**	**85**	**71**	**96**	**81**	**106**	**90**	**115***	**99**	**123***
Wetlands	Tidal	---------Cumulative (total) amount of Nontidal Wetlands below a given elevation---------																	
Bucks	1.9	0.04	0.9	0.1	1.9	0.6	3	1.2	4.1	2	5.2	2.9	6.3	3.7	7.2	4.5	7.6	5.4	7.9*	6.2	8.2*
Delaware	3.6	0.1	0.8	0.6	1.7	1.1	2.2	1.6	2.2	2.1	2.2	2.2	2.3	2.2	2.3	2.2	2.3	2.25	2.27	2.26	2.28
Philadelphia	0.6	0.5	0.6	0.6	0.9	0.9	1.2	1.2	1.4	1.5	1.61	1.62	1.69	1.71	1.78	1.79	1.84	1.85	1.89	1.89	1.93
Statewide	**6.1**	**0.6**	**2.4**	**1.3**	**4.5**	**2.7**	**6.4**	**4.1**	**7.7**	**5.6**	**9.1**	**6.7**	**10**	**7.7**	**11**	**8.6**	**12**	**9.5**	**12***	**10**	**12***
		Cumulative (total) amount of land below a given elevation																	
Dry Land		4	17	11	33	24	49	37	61	50	73	61	85	71	96	81	106	90	115*	99	123*
Nontidal Wetlands		1	2	1	4	3	6	4	8	6	9	7	10	8	11	9	12	9	12*	10	12*
All Land	6	11	25	18	44	32	61	47	75	62	88	74	101	85	113	95	124	106	133*	115	141*

*This value is probably too low because of a data limitation. See Annex 3 of this report

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.

C-2. Likelihood of Shore Protection in Pennsylvania, High and Low Estimates of the Land within One Meter above Spring High Water[1] (square kilometers)

	Likelihood of Shore Protection											
County	Certain		Likely		Unlikely		No Protection		Nontidal Wetlands		Total[2]	
	low	high	low	high	low	high	low	high	low	high	low	high
Delaware Estuary	**6**	**16**	**1.9**	**6.8**	**1.9**	**7.6**	**0.5**	**1**	**1.3**	**4.5**	**12**	**37**
Bucks	<0.01	1.8	0.1	2	0.1	4.2	0	0.03	0.1	1.9	0.3	10
Philadelphia	3.8	7.7	1	2.1	1.3	1.8	0.25	0.28	0.6	0.9	7.5	13
Delaware	2.2	6.6	0.9	2.7	0.5	1.6	0.2	0.7	0.6	1.7	4.6	14
Pennsylvania	**6**	**16**	**1.9**	**6.8**	**1.9**	**7.6**	**0.5**	**1**	**1.3**	**4.5**	**12**	**37**

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 the authors did not analyze.

C-3. Likelihood of Shore Protection in Pennsylvania, High and Low Estimates of the Land **within Two Meters above Spring High Water**[1] (square kilometers)

	Likelihood of Shore Protection											
County	Certain		Likely		Unlikely		No Protection		Nontidal Wetlands		Total[2]	
	low	high	low	high	low	high	low	high	low	high	low	high
Delaware Estuary	**20**	**28**	**8**	**15**	**6.7**	**14**	**1**	**1.4**	**4.1**	**7.7**	**41**	**68**
Bucks	1.1	3.6	1.3	4.7	2.6	8.5	0.02	0.06	1.2	4.1	6.6	22
Philadelphia	12	15	4.2	5.5	2.6	3.1	0.31	0.33	1.2	1.4	21	26
Delaware	6.3	9.2	2.6	4.7	1.5	2.4	0.7	1	1.6	2.2	13	20
Pennsylvania	**20**	**28**	**8**	**15**	**6.7**	**14**	**1**	**1.4**	**4.1**	**7.7**	**41**	**68**

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 the authors did not analyze.

C-4. Area of Land by Elevation by Shore Protection Likelihood, High and Low Estimates: Pennsylvania[1]

Elevation relative to Spring High Water (m)	Area (square kilometers)															
	Dry land: likelihood of shore protection										Dry Land		Non Tidal Wetlands		All Land	
	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	1.9	7.6	0.6	3.3	0.9	4.1	0.2	0.6	0.4	1	4	17	0.6	2.4	4.6	19
1.0	6	16	2	7	2	8	0.5	1	0.7	1.5	11	33	1.3	4.5	12	37
1.5	13	23	5	11	4	11	0.8	1.3	1	2	24	49	2.7	6.4	26	55
2.0	20	28	8	15	7	14	1	1.4	1.4	2.4	37	61	4.1	7.7	41	68
2.5	26	33	11	18	9	17	1.3	1.5	1.7	2.8	50	73	5.6	9.1	55	82
3.0	31	38	14	22	12	20	1.4	1.6	2.1	3.3	61	85	6.7	10	67	95
3.5	36	43	17	25	14	22	1.5	1.6	2.4	4.8	71	96	7.7	11	79	107
4.0	40	46	20	26	16	23	1.6	1.7	2.8	8.3	81	106	8.6	12	89	117
4.5	44	49*	22	27*	19	24*	1.6	1.7*	3.4	13*	90	115*	9.5	12*	100	127*
5.0	48	52*	25	28*	21	24*	1.6	1.7*	4.6	18*	99	123*	10	12*	109	135*

*This value is probably too low because of a data limitation. See Annex 3 of this report

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.

APPENDIX D: STAKEHOLDER COMMENTS

Bucks County Comments

Comments from Michael Roedig, County Planner, Bucks County Planning Commission (Please note: page, map, and table numbers are different than those in the final text)

The following are some brief comments and additions to the Bucks County section of the Sea Level Rise Protection study. I have no comments for the remainder of the study as its objectives and methods appear to be sound.

Delaware Estuary Sea Level Rise Protection Study – Comments on Potential Bucks County Responses:

- Page 34, 2nd paragraph, 1st sentence. I suggest this sentence be changed to: "The county recently has undertaken a revitalization plan for the coastal areas of southern Bucks County." The study has begun and we might as well include the most recent information on it.
- Page 34, 4th paragraph, 1st sentence. Again, this can be changed to "... the preparation of Bucks County's waterfront revitalization plan began in March 2004 and is scheduled to finish by the middle of 2005."
- Page 35, 2nd paragraph. The golf course and marina are associated with the adjacent multifamily development. I think this should be clarified so that the impression is not given that this is a normal 18-hole course covering many acres, but a 4- to 5-hole course for the benefit of the development's residents and their guests. Also, technically, the area north of Pen Ryn Mansion is known as Echo Beach, but if you're just referring to the area in general, Cornwells Heights is fine.
- Page 35, 3rd paragraph. Since Morrisville is included in the study, a brief description of its riverfront conditions should be included. The south part of the borough, up to the railroad bridge, appears mostly vacant and wooded along the river and includes an underutilized manufacturing/warehouse use.
- Map 4: Bucks County. The following areas should be recoded:
  - ✓ I agree that the golf course and marina adjacent to the Poquessing Creek should be brown (Certain). These are private facilities and I believe every effort would be taken to protect them.
  - ✓ The vacant land south of the Nature Conservancy's wetland should be blue (Unlikely). Unless this was coded red because of existing shoreline protection (I don't know how far the dike extends), these areas would be unlikely to be protected, especially given the state of manufacturing in the region.
  - ✓ The blue area in north Bristol Borough should be brown (Certain). This appears to be the Riverfront North redevelopment area, which has been redeveloped into a senior housing development. Other former industrial sites along this area will be redeveloped. I suggest the entire area be coded brown, as these sites are within a borough setting with existing shoreline protection.
  - ✓ I suggest coding the Tullytown Landfill (the landfill east of Tullytown) and the GROWS Landfill (the landfill west of USX) red (Likely) or even blue (Unlikely). Lale Byers, our recycling coordinator, understands that both landfills will reach capacity in less than 10 years, although Waste Management has filed an application for the expansion of the GROWS Landfill. Lale indicates that after the landfills close, initially they would be sources of methane gas; afterwards, the uses would become passive and thus would not represent areas that would demand protection.

Delaware County Comments

Comments from Karen Holm, Manager of Environmental Planning, Delaware County Planning Department (Please note: page and table numbers are different than those in the final text)

I took a look at the Sea Level Rise Study. It was very interesting. I have just a handful of questions/comments. Here they are:

- Page 4, last paragraph before Report Structure: substitute examine or some other word for analyze (after analysis).
- Page 6, Table 1: Delaware County Planning Department
- Page 10, first paragraph: the text says that "...manufacturing facilities which operate profitably today 'will likely' be absent from our region..." "could possibly" might be better.
- Page 14 (and Table 3): Residential land use is listed for almost certain protection. Not all residential land use, particularly depending on condition and whether or not it is already in the 100-year floodplain, would necessarily be considered certain for protection in Delco. Maybe the text could make a similar statement.
- Page 19: The CZM Program has two more policies: Dredging and Spoil Disposal and Control of Invasive Species (new).
- Page 24, first paragraph: Karen Holm, manager of the Environmental Planning Section of the Delaware County Planning Department.
- Page 24, first paragraph (middle): elevating individual structures was not "an economically" viable option…
- Page 25, second full paragraph (middle): It says that the county has worked hard to maintain the integrity…. It might be better to say that the county has supported efforts to maintain…
- Page 25, second full paragraph (end): I don't know if the county would ever be put in the position of choosing between wetland migration and protection. I would think that federal or state policy, or at the very least local government would have the authority to decide.

Philadelphia County Comments

Comments from Martin Soffer, Environmental Officer, Philadelphia City Planning Commission (Please note: page numbers are different than those in the final text)

The study poses no problems at this end.

I had a few thoughts- - -

- Phila. reviews and approves all development in flood plains. The Commonwealth has a role when development is "over/in" water (p-17).
- Wetlands have been transferred from one location to another. Ex.- small isolated wetland within an industrial area was "transferred" to more viable location (Bartram's Garden) which would support such a growing ecosystem. etc. (p-18).
- City has stormwater controls - flooding, siltation, channel enlargement, which are meant to prevent degradation and flooding etc. since 1975.
- Trend indicators: (a) 30th St. - new garage under construction - future office building, (b) ongoing airport expansion study which includes filling of flood plain, (c) new residential proposals (Coke site at Orthodox St., St. Vincent's and the Dodge tract are under consideration in the north Delaware), (d) discussion of filling the eastern third of the Naval Business Center for development. There is new housing, office buildings at the base and there is a projected 25-year build out.
- Baxter water intake facility is north of Pennypack St.; the Police and the Fire Academies are between the Baxter water plant and the Pennypack Creek (p-30). There is city park land investment along both sides of the creek at the mouth of the stream.

Pennsylvania Coastal Zone Management Program Comments

Comments from Kevin Hess, Program and Technical Assistance Planner, Pennsylvania Coastal Zone Management Program, Office of Water Planning, Pennsylvania Department of Environmental Protection (Please note: page numbers are different than those in the final text)

My comments are fairly minimal, I think you did a great job - especially as a first step at addressing this socially and scientifically very complex issue . . .

- General comment - just wondering how it would work when a small section of unarmored, natural shoreline amidst armored or elevated shoreline would be dealt with. What I'm referring to is if there is one gap in the wall the water gets through it will flood from behind. I guess in a situation like John Heinz where they'll let the waters rise, they'll have to have additional diking to protect adjacent areas. There are other areas that are smaller, more heavily developed, but have a similar circumstance.
- Page 8 - top two paragraphs. At a recent wetland mitigation training they emphasized being careful with using USGS datums when planning tidal wetland mitigation or mitigation near tidal areas. I attached a link if you're interested. From using GIS, I have a fundamental understanding of using different datums, but just how it relates to USGS vs. NOAA charts (which I think was their point at training) I do not yet fully understand. I guess this isn't really a comment, but an FYI. It appears your MSL is consistent with NGVD 29, and I guess you've been all through this a few times.
- Page 16 and 17. Within the No Shore Protection category that includes John Heinz National Wildlife Refuge, Little Tinicum Island, and lands owned and managed by TNC, I thought Neshaminy State Park - or at least parts of it and especially that portion north of the Neshaminy Creek - would fit into this category also.
- Page 22, Wetlands and Floodplains. I'm not sure what you are trying to say at the end of the first paragraph but how it reads now is a bit misleading (at least to me). Wetland mitigation routinely occurs elsewhere from the impact. There is a hierarchy, and on-site replacement is the first choice, then within the same watershed (size of watershed left to interpretation). Chapter 105.20a(a)(3) does state that wetland losses in the coastal zone should be replaced in the coastal zone.
- Page 30, 3rd paragraph. Your description of Little Tinicum is close, but the channel side of the island is more sandy beach than mudflat.
- Page 35, 1st paragraph. I love your description "...a complex jumble of piers, wharfs, docks and other manmade features." How else could it be described...
- Page 35, last sentence. Is it really multibillion as opposed to multimillion?
- Page 42, 3rd paragraph. TNC has been involved with Bristol Marsh since 1986 so it's not really "recent." Rohm and Haas has some additional redevelopment type work/planning for it's facility here that includes wetlands - under this plan additional wetlands may be protected by the donation of some sort of ownership interest to either Natural Lands Trust or TNC. I'm doing my best to try to stay current on this. I'm not sure if two stories are getting mixed here or not - but it sort of seemed that way when I read it. Feel free to call me on this, I'm curious if you are correct and I just don't know the latest.
- Page 45, Conservation Areas. Wondering if Neshaminy State Park (especially existing tidal wetlands and forested areas along Neshaminy) and Silver Lake Nature Center (or portions thereof) should be included here.
- General Comment. Reading your report gave me some potential leads for habitat restoration areas I had previously not considered.
- General Comment. I guess all of our tidal wetland mitigation sites will become shallow water habitat.

CREDITS AND ACKNOWLEDGEMENTS

The author wishes to thank the individuals and organizations who participated in the creation of this report. James (Jim) G. Titus of the U.S. Environmental Protection Agency provided detailed guidance in the development of all sections of this document. Jim served as a close partner in the cultivation of several unique approaches used to evaluate likely sea level rise responses along Pennsylvania's coast. Jim's detailed reviews and revisions of multiple drafts made it infinitely easier to create a comprehensive, accurate, and readable report. James E. Neumann and Daniel Hudgens of Industrial Economics, Inc. also reviewed the report, provided technical support in creating the maps, furnished wetlands data, and gave strategic advice on the presentation of results. Jim Titus and Jim Neumann provided valuable perspectives on the unique conditions in Pennsylvania's largely developed industrial coast. Their input was used to create a methodology for the designation of protection categories that is uniquely tailored to current and expected future land use conditions in Pennsylvania's coastal zone.

The diagram on tides, wetlands, and reference elevations was produced by collaboration between EPA and NOAA. Titus drafted the summary and several generic sections that appear in all the chapters of this report.

Many thanks are also due to the state and county stakeholders who provided their valuable time to assist in this effort, most of whom are listed in Table 4-4. The county stakeholders provided firsthand knowledge of local conditions and gave detailed comments on the final draft. They were enthusiastic and responsive throughout the study. Developing an understanding of the ways in which state policies and regulations may inform responses to rising seas would not have been possible without the input of knowledgeable officials from the Pennsylvania Department of Environmental Protection. Special thanks are due to Kevin Hess of Pennsylvania's Coastal Zone Management Program, whose intimate knowledge of coastal resources was instrumental in refining the final document. Additionally, David Aubrey (Woods Hole Group) and Amie Howell (US EPA Region III) provided helpful comments during the peer review of this report. Finally, the author wishes to thank Patty Elkis of DVRPC for her editorial support during the creation of the study's initial draft.

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