The Economic Cost of Sea Level Rise to Three Chesapeake Bay Communities

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Summary and Analysis

Of the Report

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Sea Level Rise in Maryland

The Chesapeake Bay was formed and continues to be shaped by the rising sea. Tide gauge records indicate that sea level in the Chesapeake Bay has risen approximately 3–4 mm/year or 1 foot in the last century. This rate, nearly twice that of the worldwide average, is due to a combination of naturally occurring regional land subsidence and global sea level rise. Since the 1930's, the rate of sea level rise in the Bay has accelerated. Although there is debate surrounding the cause of the acceleration, as well as future projections, if current trends continue Maryland will experience another foot of rise in the next 100 years and, in a worst-case scenario, 2 – 3 feet of rise.

The primary impacts of sea level rise include coastal flooding, coastal erosion, inundation of low-lying lands, and saltwater intrusion. Maryland's coastline, made up of the varied landscapes of the Chesapeake Bay, the Coastal Bays, and the Atlantic Coast, is highly susceptible to such impacts. Sea level rise exacerbates on-going coastal processes, thereby increasing the vulnerability of coastal areas. Low-lying coastal plains and barrier islands, such as those located along Maryland's outer coast, its coastal bays, and the low-lying eastern shore, are particularly susceptible to erosion, flooding and inundation. The Bay's island communities and extensive marsh systems are perhaps most at risk, as the forces of sea level rise intensify the slow but steady erosion and inundation of low-lying lands. Since the colonial era, at least 13 islands in the Chesapeake, some of more than a thousand acres and with established communities, have been completely erased from the map of the Bay due to a combination of sea level rise induced erosion and inundation.

Over the past several years, the Maryland Department of Natural Resources (DNR) has directed substantial efforts towards analyzing and addressing the impact of rising sea levels along the State's coastline. Activities have largely centered on the incorporation of sea level rise issues into coastal planning and policy initiatives, technology, data and research support, and public outreach. DNR published a Sea Level Rise Response Strategy for the State of Maryland in

October 2000, that set forth both short and long-term objectives, along with key activities, to address the primary impacts of sea level rise. DNR also staffed the legislatively chartered Shore Erosion Task Force (2000), which issued a broad suite of recommendations to improve the management of shore erosion. Included among those recommendations was the need to address sea level rise. DNR has also made great strides to obtain up-to-date sea level rise data and information. Recent data gathering efforts include the acquisition of high-resolution topographic data (LIDAR) for a large portion of Maryland's Eastern Shore, the completion of historic shoreline position maps, and the statewide calculation of historic erosion rates.

Study of Potential Impacts at the Community Scale

In 2001, as a continuation of DNR's larger sea level rise research efforts, DNR contracted with Towson University to conduct a study of the potential impacts of sea level rise at the community scale.[1] Using high-resolution elevation data derived from LIDAR, one, two and three-foot elevation contours were developed to determine the potential reaches of sea level rise over a 100-year time frame within three "broadly representative" non-urbanized communities along the Chesapeake Bay. The contour maps of areas potentially subject to sea level rise impacts were subsequently supplemented with the economic analysis, conducted by Towson State University, to assess the potential economic impacts associated with increased flooding and inundation.[2]

Key findings and lessons learned from the overall Study include:

- The projected damages among the sample of communities varied by type and degree due to differences in relief and density of development.
- The greatest impacts would be seen in low-lying areas of the Eastern Shore.
- Below a two-foot rise in sea level, the risk of inundation affected relatively few structures in the three communities.
- While the Study finds that the risk of permanent inundation would affect relatively few properties with the exception of low-lying areas on the Eastern Shore, the risks of increased flood damages are great.
- Even small increases in sea level rise could substantially increase damages particularly in densely populated vulnerable areas on the western shore by raising base flood elevations and expanding the 100-year floodplain.

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[1] Funding for the Study was provided by the Maryland Coastal Zone Management Program using grant funds from National Oceanic and Atmospheric Administration (NOAA) (NOAA Award No. NA07OZ0118). The Study does not necessarily reflect the views of NOAA, any of its sub-agencies, or the DNR.

[2] Michael, J., D. Sides, T. Sullivan. 2003. *The Economic Cost of Sea Level Rise to Three Chesapeake Bay Communities*. Towson University, Maryland.

- As a planning exercise, the Study provided a valuable cautionary lesson on the difficulty in assigning economic costs in long range planning scenarios.

Study Areas

Study sites included portions of the Shady Side in Anne Arundel County, Piney Point in St. Mary's County and a portion of the chain of the Hooper Islands in Dorchester County. All are located on the Chesapeake Bay. Each has only a single road as access into and out of the community. While all of the communities are relatively small, they differ markedly from each other. Relief and density are the primary factors in differences in impacts among the communities (See Table 1.).

Table 1. Community Characteristics

Community	**Shady Side**	**Piney Point**	**Hooper Island**
Development Characteristics	Relatively dense, high percentage of existing shore protection	High expected population growth, significant industrial infrastructure	Lightly developed low bank, marshy shoreline
Area	3.75 sq. miles/1,800 acres	5.7 sq. miles/2,450 acres	6.1 sq. miles/2,150 acres
Elevation below 3 ft. (%)	1%	9%	69%
# of properties	2,120	1,041	521
Properties in FEMA 100-year flood zone (%)	42%	26%	100%
Total road mileage	26 miles	29 miles	12 miles
Wetland acres (%)	7 %	14%	68%
Projected population growth (%) (by 2030)	16%	48%	3%

Study Methodology

The assessment of economic impacts due to flooding and inundation within the selected coastal communities involved a four-step process.[3] First, DNR acquired high-resolution digital elevation data for the three study sites. Second, using the MdProperty View database maintained

[3] Inundation refers to the total loss of property from permanent flooding when sea level rises above its current elevation. Flooding refers to increased storm damage to non-inundated properties from episodic storm events.

by the Department of Planning, existing infrastructure within the Study sites was identified and categorized (i.e., residential, commercial) and assessed property values were assigned. The elevation data was then intersected with the property information to identify properties "at risk" from flooding and inundation. The final step in the process involved the economic analysis, based on a set of assumptions, conducted by a team of economists from Towson University.

Properties at Risk

Merging the high-tech elevation imagery and the assessed property information provided a means to identify properties below two and three feet of elevation, as well as gain a picture of assessed value (see Table 2).

Table 2. Summary of Vulnerable Properties under a 3-foot Sea Level Rise Scenario

Community	**Shady Side**	**Piney Point**	**Hooper Island**
Elevation below 3 ft (%)	1%	9%	69%
Properties in FEMA 100-year flood zone (%)	42%	26%	100%
Miles of roads below 3 ft.	1 mile	5 miles	10 miles
Acres of wetlands threatened	118 acres	333 acres	1,466 acres

An Economic Analysis

The economic analysis of "at risk" properties was framed by the following set of assumptions: sea level rise was assumed to be non-accelerating, meaning that a 2 or 3-foot rise will occur uniformly from the present until the year 2100; no further protection of the shoreline (i.e., bulkheads) in response to sea level rise will occur; there would be no upland migration of wetlands; there will be no increase in storm severity or frequency; and, there will be no new development within identified flood zones. The team of economists at Towson University calculated economic losses for the following set of damage categories: residential inundation loss, residential flood loss, non-residential inundation loss, infrastructure costs, and lost wetland services. Economic losses that occur in the future were calculated using constant value dollars (Year 2000) and discounted to present values using a 2% discount rate. The figures reported in the Study results below have been applied the discounted rate, except where noted. The authors of the Study note that discount rates can be somewhat controversial and that by applying the discount rate of 2%, they made an intentional decision to err on the side of making conservative estimates.

The economic analysis reported in the Study is a complex combination of economic models, theories and assumptions projecting values and losses over a one-hundred year period. The cost estimates should not be taken at face value without closely evaluating the assumptions and intended to be used as a planning model of the potential community impacts of sea level rise under different rise scenarios. It should not be viewed as a predictive model due to known uncertainties associated with the projected rates of sea level rise in the Chesapeake Bay region over the next 100-year time frame.

Study Results

The economic analysis projected impacts under the worst-case sea level rise acceleration scenario of two to three feet over the one-hundred year period from 2000-2100. It was assumed that sea level would rise 2 feet by the year 2050 and 3 feet by the year 2100. An impact model was not developed for the continuation of the trend of a one foot increase over the last 100 hundred years. Study results are presented for each damage category, below.

Inundation of Improved Residential Properties: For Shady Side and Piney Point, relatively few properties would be inundated from a doubling of the rate of sea level rise. A two-foot rise in sea level over the next century would inundate only one improved residential property in Shady Side and two in Piney Point. The projected loss for Hooper Island is 19 residences. If the extreme forecast of three feet of sea level rise were to occur, there would be a dramatic increase in the number of inundated properties in all three communities with the number increasing to 11 in Shady Side, 63 in Piney Point, and 153 on Hooper Island.

Under a two-foot sea level rise scenario, the economic losses projected for improved residential properties in Shady Side and Piney Point are insignificant when considered at the community scale over a 100-year timeframe. Only three properties in total would be lost to inundation in the communities. The loss in Shady Side would be $38,000 and $37,000 in Piney Point. On Hooper Island, where 19 improved residential properties would be lost to a two-foot rise in sea level, the projected loss figure is $267,000.

Under a three-foot sea level rise scenario, projected economic losses of improved residential property would be nearly ten times greater in Shady Side and on Hooper Island, and over 40 times greater in Piney Point. The number of lost improved residential properties would increase to 11 in Shady Side, 63 in Piney Point, and 153 on Hooper Island. The projected damage losses would be $350,000, $1.6 million, and $1.8 million respectively. Given the number of affected properties, these figures appear to understate the significance of the projected losses.

Roads and Bridges: Neither a two-foot nor three-foot rise in sea level would have much impact in Shady Side. A two-foot rise in sea level would inundate less than two-tenths of a mile of road. A three-foot rise would inundate just over a half-mile. Piney Point would see one mile of road inundated under a two-foot rise scenario, and 4½ miles under a three-foot rise scenario. The three-foot rise scenario could require the lengthening of the bridge between St. Georges Island and Piney Point by three to four times its present length. It is projected that there would be over five miles of roads inundated on Hooper Island under the two-foot sea level rise scenario. Under a three-foot scenario, the road inundation on Hooper Island would be substantial with over 10 of the 12 miles of road on the island inundated.

It is important to note that while the Study identifies road segments that could be inundated under two and three-foot sea level rise scenarios, the Study does not identify the depth of inundation or whether the roads may remain passable. Nonetheless, it can reasonably be assumed that an inundated road would need to be raised and retrofitted. Describing the findings of the costs of road replacement is one of the more difficult challenges in portraying the results of the economic analysis. This difficulty arises from there being three different estimates of the cost of road construction — $385,000 per lane per mile, $750,000, and $1.5 million. The range of cost estimates was used to allow for known variations in the topography, building materials, and load capacity of typical road networks. The projected total costs resulting from road inundation for all three communities under a two-foot rise scenario are $1.3 million to $5.1 million. For the three-foot rise scenario, the total costs for all three communities range from $3.4 million to $13.3 million.

Wetland losses: The economic analysis of wetland losses was based on an estimation of the loss of public benefits from the functions of those wetlands rather than their market value as real estate. The functional benefits of wetlands include improving water quality and providing essential habitat for commercial fisheries. Based on a literature review, the economic analysis assigned an annual benefit of $350 to each acre. Economic losses were determined by calculating a projected year of inundation, and then multiplying $350 times acres lost times the number of years remaining in the century. The Study reports that quantifying the non-market value of such things as wetlands is a subject of much controversy in environmental economics. Therefore, the value assigned to lost wetlands services should be carefully interpreted.

Substantial losses of wetlands on Hooper Island are projected if there were to be an accelerated rate of sea level rise. Unlike other loss categories, most losses would occur under the two-foot rise scenario with 1,144 acres projected to be lost. A three-foot rise would only increase the wetland loss on Hooper Island by 322 acres to 1,466 acres. Wetland losses in Shady Side and Piney Point would be 61 and 152 acres, respectively, under a two-foot rise scenario. A three-foot rise in sea level would increase wetland losses to 118 and 333 acres, respectively. The projected losses of wetland services are as follows. For a two-foot rise, Hooper Island would lose $4.2 million in wetland services, and $7.1 million under the three-foot rise scenario. Piney Point would lose $598,000 and $1.1 million in services, respectively. Shady Side would have an estimated loss of $142,000 under the two-foot scenario and $362,000, with three feet of rise.

Increase in Episodic Flood Damages: Increased damages were calculated based on an estimation of increased flood insurance premiums for existing structures in the 100-year flood plain as designated by the National Flood Insurance Program (NFIP). This methodology assumed that flood insurance premiums would rise as a result of an increase in base flood elevation under the two and three-foot rise scenarios and that all residential structures were insured under the National Flood Insurance Program. In reality, this is not the case, and as demonstrated by Hurricane Isabel, damages resulting from a single storm event can greatly outweigh those predicted over the 100-year time span examined as part of the Study.

Increased episodic flood damages were projected to affect a much greater number of structures than inundation and much sooner. Whereas only one structure would be inundated by a two-foot rise in sea level in Shady Side, and two in Piney Point, 903 properties were projected to be impacted by increased flood losses in Shady Side and 314 in Piney Point. On Hooper Island, the projected increased episodic flood damages from a two-foot rise in sea level would affect 456 properties. An increase of $2 million in flood damages would be seen on Hooper Island under a two-foot rise scenario. Piney Point would see over $3.5 million in increased damages, and Shady Side $12.6 million. The projected damages under the three-foot sea level rise scenario are $2.6 million for Hooper Island, $5 million for Piney Point, and $17 million for Shady Side. These figures should be carefully evaluated as they represent the additional damage that may be seen due to sea level rise from any given flood event impacting the 100-year floodplain.

Total Economic Damage from Sea Level Rise: The Study projected a total economic damage of sea level rise within the three Study areas over the next century using combined figures from well accepted market-based methodologies with figures derived from more approximate resource-based valuations. The estimated damages for both lost wetlands services and road replacement costs relied on the transference of dollar figures from other academic studies that may not apply directly to local conditions. This greatly increases the degree of approximation, which should be given to the total damage assessment outlined below. Under the two-foot sea level rise scenario; the total damage of sea level rise would be $12.9 million for Shady Side; $9 million for Hooper Island; and $5.3 million for Piney Point. Under the three-foot rise scenario, the total economic damages in each community over then next 100 years are projected to be $19 million for Shady Side; $17.8 million for Hooper Island, and $10.4 million for Piney Point.

In addition to the economic losses discussed above, the economic analysis also developed loss estimates for unimproved residential property and non-residential property. These were among the less significant findings of the analysis but are included in the assessment of total economic loss along with residential, commercial and wetland loss.

Data Limitations

Due to data limitations, the damages outlined in the Study may not fully estimate the economic cost of sea level rise. The analysis only assessed a portion of the economic impacts of sea level rise induced flooding and inundation. Increased flood losses were only calculated for those damages covered by flood insurance, and then only for those structures that are already within the designated 100-year flood plain. No expansion of the floodplain was considered although it certainly would occur if base flood elevations were raised by sea level rise. The analysis did not estimate damage to future development; nor damage to infrastructure other than roads. The economic impacts of sea level rise induced erosion were not examined as part of the analysis. The analysis did not examine other non-market economic losses such as the loss of recreational beaches or invaluable historic properties or structures. Finally, the analysis did not anticipate mitigation measures that might be undertaken to reduce damages.

Use of the Study

Overall, the Study provides a good portrayal of the potentially large economic impacts of sea level rise by examining impacts that may be experienced at the community scale. The findings show that while sea level rise may significantly impact Maryland, the degree of sea level rise impact is dependent on a number of factors. First, the physical characteristics of the shoreline may exacerbate or ameliorate sea level rise impacts. Lower-lying lands with a gradual inland rise in slope (e.g., much of Maryland's lower Eastern Shore) will experience greater levels of inundation. Areas, which may not experience inundation, may still be subject to a great deal of impact due to episodic flooding. Timing is also a major component; sea level rise induced flooding will cause increased damages to residential properties much sooner than anticipated impacts due to inundation. Additionally, population growth and development patterns play a large role. It goes without saying that, greater densities of people located in areas threatened by sea level rise will result in greater impact.

The Study's assumptions and the detailed economic analysis are extremely complex. The cost estimates should not be taken at face value without closely evaluating the assumptions upon which they were based. Given the complexity of the Study and its findings, DNR is not planning to utilize the Study for widespread public outreach efforts or to use the Study as a guide for future funding allocations. The Study will be used, however, as an independent assessment of the potentially extensive impacts of sea level rise in the State of Maryland. Lessons learned from the Study with regard to the type, degree, and timing of potential sea level rise impacts for differing geographic coastal regions will be valuable to the State as it continues its sea level rise and coastal hazard response efforts.

INTRODUCTION

Tide gauge measurements in the Chesapeake Bay and the Mid-Atlantic indicate that sea level is rising along Maryland's coastline at a rate nearly twice the global average (Douglas, 1991). Historically, sea levels in Maryland have risen an average of three to four millimeters per year, or about one foot per century. However, these rates are expected to accelerate in response to global climate change, resulting in a rise of two to three feet by the end of this century (Leatherman, et al., 1995). In addition to inundating coastal margins, this increase is expected to influence and accelerate the erosion process and increase coastal vulnerability to episodic storm events. Responding to citizen concerns over erosion control, Maryland Governor Parris N. Glendening appointed a Shore Erosion Control Task Force in 1999 to examine the state's policies and methods for addressing shore erosion. The Task Force found that a lack of coordinated and comprehensive erosion control efforts produced inefficiencies, duplication of effort, and conflicting control strategies. The Task Force therefore called for the development of a Comprehensive Shore Erosion Control Plan to combine the best available data and resources in the development of regional erosion control plans and strategies. As a first step, the Maryland Department of Natural Resources (DNR) has developed a process combining regional erosion control planning, impact pilot studies, and public outreach to be used as a template for all of coastal Maryland.

This report is an economic analysis of a pilot impact assessment performed in three low-lying Maryland communities: Shadyside in Anne Arundel County; Piney Point and St. George's Island in St. Mary's County; and Upper and Middle Hooper Islands in Dorchester County. This analysis, which is based on a geographic information system developed to examine these communities' vulnerability to an increase in sea level, presents alternate scenarios of 2- versus 3-foot increases over the next 100 years. Whenever possible, we closely follow existing methodologies in the economics literature for damage assessment from sea level rise.

Coastal inundation will result in economic damage, but the form and magnitude of these impacts are uncertain. We conclude that there will be economic damage in all three communities. However, the study areas vary in the types of damage expected. Throughout the report, we differentiate between damage from inundation and flooding. Inundation refers to the total loss of property from permanent flooding when sea level rises above its current elevation.

Flooding refers to increased flood damage to non-inundated properties from episodic storm events. As sea levels rise, storm-related floodwaters and tidal surges will not have to rise as far before causing damage.[1] Because some coastal flooding would occur even in the absence of sea level rise, our estimates of flood losses only include the additional damage expected from lower elevations, not the total amount of damage expected from such an event.

Our results show that inundation is the largest source of damage on Hooper Islands, while increased flooding of non-inundated property is the primary cause of economic damage in Shadyside. Hooper Islands are subject to the greatest overall impact because their topography is exceptionally low-lying. We also find large differences between the alternate scenarios. Inundation losses from a 2-foot rise are generally low, while inundation losses from a 3-foot rise are about seven times higher. Flooding to non-inundated property causes significant damage in both the 2- and 3-foot scenarios.

The report begins with a discussion of previous studies and the characteristics of the study areas. This is followed by a review of the scenario assumptions and description of the data used to assess damages. Finally, we describe the cost estimation methods and results from the following perspectives:

1) The inundation of residential, non-residential, and unimproved property;
2) Increased flood damage caused by sea level rise to non-inundated, improved property;
3) Infrastructure damage focusing on roads;
4) Wetland losses.

Due to the predictive nature of this study, these estimates are subject to uncertainty and must be interpreted with care. There is scientific uncertainty about the magnitude and effects of sea level rise, economic uncertainty regarding the forecasts of future property values and construction costs, assumptions about human behavior, estimation of non-market values, and choice of discount rates. Throughout the report, we discuss the sources of uncertainty as they arise, and we provide damage estimates for a variety of scenarios for comparison.

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[1] We do not assume any change to storm frequency or intensity due to climate change, because it is the subject of much scientific uncertainty and ongoing research. We only examine the effect of decreasing elevation as sea level rises.

METHODS AND RESULTS

Previous Studies

This study is based on methodologies established in the economics literature and data from previous research conducted by the Towson University Center for Geographic Information Sciences. This section briefly reviews some of the relevant economics literature and leaves the details until later sections that describe the application of the methods to the current study. This is followed by a description of the previous GIS work in the study areas that also serves as a thorough description of the data used in this study.

Economic Studies of Sea Level Rise Damage

The earliest economic studies of the cost of sea level comprised rough estimates for the entire United States and were conducted as part of larger studies on climate change (Nordhaus 1991; Cline 1992). These studies used a 1989 EPA report on climate change that estimated nationwide acreage losses of dryland and wetland and about $100 billion spent on protective measures for a 1-meter sea level rise by the year 2100. Multiplying the acreage losses by average land values, the studies estimate *annual* losses from sea level rise for the entire U.S. at $7 billion. Subsequent studies using more sophisticated methods yielded smaller damage estimates (Yohe, Neumann, and Ameden 1995; Yohe, Neumann, Marshall, and Ameden 1996; Yohe, Neumann, and Marshall 1999; Neumann, Yohe, Nichols and Manion 2000, Parsons and Powell 2001) and established a methodology for detailed estimates at a community level that serve as the basis for this study. This study will most resemble the Parsons and Powell study of the cost of beach erosion in Delaware. Parsons and Powell estimate $291 million (in year 2000 dollar value) in property losses in the area between Rehoboth and Fenwick Island, Delaware, if no defensive measures are taken to protect the beach. To estimate the value of wetland services, we rely on a recent meta-analysis of 39 previous wetland valuation studies (Woodward and Wui 2001). The literature does not provide a good model for increased flooding in non-inundated property, so we developed our own methodology using data from the National Flood Insurance Program. More details on the literature cited and methods employed are found in the later sections describing our calculations for each category of damage estimates.

Previous GIS Study

The Maryland Department of Natural Resources, Coastal Zone Management Division (DNR/CZM) contracted with the Towson University Center for Geographic Information Sciences (CGIS) in spring of 2001 to develop a GIS to be used for modeling potential property loss associated with sea level rise in three selected study areas. The resulting GIS includes detailed parcel information, infrastructure features identified in the field, and road centerlines created from high-resolution orthophotography. These feature sets are intersected with 1-foot interval contours derived from data collected with a LIDAR (Light Detection and Ranging) sensor, and are attributed with an elevation to allow for modeling of loss assessment at 1-foot increments of sea level rise.

Parcel information in this GIS is derived from the MdProperty View dataset. Developed by the Maryland Department of Planning, MdProperty View links point features possessing x,y coordinates to detailed parcel-level property information, including ownership, zoning, parcel size, structural details, assessment valuation, and the date and price of transactions. However, points representing parcels in the MdProperty View database are located based on parcel centroids. To ensure that the database points accurately represent the location (and elevation) of structures, field surveys were performed to positively match all addresses in each study area to structures visible in large-scale (1:1,200) orthophotographs. Then, displayed on-screen over the same orthophotography, points in MdProperty View representing developed parcels were relocated to a position directly overtop the primary structure on the property. An inventory of infrastructure features was also performed during these field surveys. Locations of bridges, water, sewage, telephone, and electric facilities were noted and are represented in the GIS for each study area. Road centerlines were developed for each study area from 1:1,200 scale orthophotography and attributed with surface material, width, and condition information collected in the field surveys.

Earth Data of Maryland collected elevation data with a LIDAR sensor, and also performed post-processing of the data to yield 2-foot interval contours, interpolated to 1-foot intervals. Contour lines extending out of the study areas were closed to produce polygons possessing a 1-foot elevation range (e.g. 2-3 feet). The appropriate1-foot elevation range is attached to all parcel and infrastructure feature points and centerline segments in the database. For the purposes of the present analysis, the wetlands coverage developed by MD Department of

Natural Resources was also intersected with the 1-foot contours to predict area of wetland loss associated with incremental sea level rise.

The Study Areas

The study sites were selected by DNR/CZM and are illustrated in Figure 1. Study site land and property value characteristics and county-level economic data are presented in Table 1. An elevation profile of each area, detailed in Table 2, provides an overview of each area's vulnerability to sea level rise. The development and natural characteristics of the three communities are very different, as they were chosen to broadly represent the range of non-urbanized coastal communities on the Chesapeake Bay.

Shadyside is located in southern Anne Arundel County. It is the only site in this study situated entirely on the mainland, and of the three sites has the smallest percentage of wetlands (6.5%). Shadyside is surrounded on three sides by water: the Chesapeake Bay on the east, the West River to the north and west. Shadyside has the highest income level of the sites, and is the closest to Washington, DC and Baltimore. At 1,811 acres, it is the smallest of the three study areas; however, with 2,120 parcels (1,609 of them with improvements), Shadyside is the most heavily settled. While a wide range of housing exists, small homes on lots less than a quarter acre in size predominate. Aside from limited retail services, the primary commercial development is a few small marinas. Shadyside has less than $1 million in structures at risk of inundation. Although the potential loss from inundation is very low in Shadyside, structures worth over $100 million that are between 3 and 9 feet in elevation face an increased chance of flood damage as sea levels rise. Despite the lack of wetland and low elevation property that could be lost to sea level rise, Shadyside has more than double the amount of properties in FEMA designated 100-year flood zones than the St. Mary's study area.

The St. Mary's County study site stretches along the lower Potomac River from Potomac Shores to St. George's Island and is bounded on the east by St. George's Creek. It includes the communities of McKay's Beach, Tall Timbers, and Piney Point. The St. George's Island Bridge (120 meters in length) links the island to Piney Point. The study area covers 2,452 acres, of which 13.6% is wetlands. There are 1,349 parcels in this site, 935 of them with improvements. Piney Point is home to Steuart Petroleum, a large industrial complex dominated by oil storage tanks and an aboveground 1,500-meter petroleum pipeline. The Harry Lundenberg School of

Seamanship also maintains a large facility in Piney Point. The study area includes public and private recreational beaches and the Piney Point Lighthouse and Museum. The St. George's/Piney Point area has the fastest growing income and population of the three study areas. Compared to Shadyside, Piney Point has more property at risk of inundation but less property at risk of being affected by increased flooding.

Upper and Middle Hooper Islands comprise the third study site. Lower Hooper Island is uninhabited and is therefore not included in the study area. Hooper Islands lie in the Chesapeake Bay in southwestern Dorchester County, separated from the mainland by the Honga River. The study area covers 2,157 acres, of which 68% is wetlands. Upper and Middle Hooper Islands are connected by the Narrows Ferry Bridge. This structure replaced an older, smaller bridge compromised by erosion. While the actual span of the bridge is about 450 meters in length, it is approached on both sides by an elevated roadbed across nearly 2 kilometers of open, shallow water.

The Hooper Islands site is typical of many Eastern Shore watermen's communities: physically dominated by wetlands, its development consisting of mostly modest residences, a limited service sector, and several commercial seafood processing facilities. Despite similarities in size, the $35 million assessed value of property on Hooper Islands is dwarfed by the other two areas, where total assessed property values are well over $200 million. Hooper Islands exhibit low incomes and stagnant population growth due in part to their lower Eastern Shore location that isolates it from major metropolitan areas. With over $8 million in structures under 3 feet in elevation, Hooper Islands are at greatest risk of loss from sea level rise.

Scenario Assumptions

Our objective is to predict the effect of events that have not yet occurred; therefore, we must inevitably make various assumptions about the future. These assumptions include the extent of sea level rise, the human response to this change, and the discount rate utilized to calculate the present value of future costs. We produce damage estimates for a variety of scenarios with varying assumptions about the amount of sea level rise and the discount rate.

We examine two scenarios of mean sea level increase in order to model the upper and lower estimates of expected sea level rise in the Chesapeake Bay region: 2- and 3-foot rises over the 100-year period from 2000 to 2100. In both scenarios, these increases are evenly distributed temporally, occurring at a constant (non-accelerating) rate. Inundation of features at a given elevation is assumed to occur when the scenario calls for the contour interval to be 50% (six inches) encroached upon. For example, the 2-foot/century scenario assumes that mean sea level will be at today's 1-foot contour in 50 years. Our analysis assumes that once the 1-foot contour is 50% inundated (25 years), all features at an elevation of 0 to1 foot are effectively lost. Thus, the 2-foot/century scenario assumes the 0- to 1-foot contour is lost in 2025, and the 1- to 2-foot contour is lost in 2075. Under the 3-foot/century scenario, we assume the 0- to 1-foot contour is lost in 2020, the 1- to 2-foot contour is lost in 2050, and the 2- to 3-foot contour is lost in 2080.

Secondly, we assume there will be no human adaptations to protect against sea level rise such as shoreline hardening or beach re-nourishment. Our estimates of cost are known in the literature as "economic vulnerability," or economic costs under a "no-foresight assumption." Many economic studies also consider a "perfect foresight" scenario where sea walls and other measures are used to protect property from inundation when the value of the property exceeds the cost of protection. The perfect-foresight studies (e.g. Yohe, Neumann and Ameden 1995) employ a narrow estimate of economic costs that looks only at inundated property. In contrast, our study also estimates damage from non-inundated flooding and wetland loss, categories that are less protected and potentially damaged by shoreline hardening. Taking this broader view, it is less certain when hardening the shoreline is cost-effective, and more difficult to implement the perfect-foresight model.[2] Our scenarios do not include the perfect-foresight model with optimal adaptation, but local planners could use our results to inform their own decisions about defensive strategies.

Finally, we must make adjustments for the fact that most of the costs of sea level rise are incurred in the distant future. First, we account for inflation by making all of our calculations in year 2000 dollars. Secondly, we discount future damages to reflect their present value. Although it is sometimes controversial (Brennan 1999), discounting is standard procedure in

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[2] However, hardening the shoreline may not be the most cost-effective response to sea level rise. Coastal ecosystems, including wetlands and beaches, are naturally equipped to buffer sea level rise. For example, wetlands migrate landward as sea level rises by rolling back over themselves and establishing new marsh upland. Hardened shorelines eliminate this natural response mechanism. A variety of land management techniques such as set-backs, relocation of threatened structures, and restrictions on development in hazardous areas can reduce vulnerability to sea level rise without compromising the integrity of natural shoreline habitat (see Johnson, 2000, for a discussion of responses to sea level rise). Advance adaptive planning for sea level rise is most effective when detailed information on sea level rise impacts is available to planners.

cost-benefit analysis. Technically, discounting is the opposite of compound interest. Compounding measures how much a current investment will be worth in the future, whereas discounting calculates the present value of a future benefit or cost. The present value is greatly influenced by the choice of discount rate. Higher discount rates reduce the present value of future benefits and costs. Since 1992, the U.S. government has instructed its agencies to use a discount rate of 7 % for benefit-cost analysis. To most economists, this rate is too high. A standard rule of thumb is to use the real rate of return on risk-free assets such as government bonds. This leads to the discount rates of 3-4% typically used in the environmental economics literature. Recent economic research argues that lower discount rates are appropriate when evaluating costs and benefits over very long time horizons, as in the case of global warming (Weitzman 2001, Newell and Pizer 2002). They find that 2% is an appropriate discount rate for the time horizon of this type of study. For this study, we provide undiscounted estimates of cost and present value estimates of cost using a 2% discount rate. In our discussion, we generally refer to the discounted costs.

Cost Estimation Methods and Results

Residential Property Inundation

Our study follows the general methodology developed by Yohe (1989) and refined in subsequent studies discussed in the literature review. Unlike previous research, we have detailed data on individual properties that allow the use of market transactions to estimate losses on a property-by-property basis. Thus, Yohe (1989) is the basis of the general framework and reasoning (1989), but the details of the calculations more closely resemble the Parsons and Powell study (2001) of the cost of beach erosion in Delaware. The analysis follows several steps.

First, a hedonic price regression is estimated for each of the three study areas. The hedonic model uses regression analysis of recent property sales to estimate implicit prices on a variety of property characteristics. A purchaser of real property is buying a bundle of characteristics ranging from physical characteristics like a fireplace, location characteristics such as crime risk, and environmental characteristics such as air quality. By examining sales over a range of properties where these attributes vary, researchers are able to estimate the implicit prices (values) people place on these characteristics by determining the extent to which they are capitalized into property values. The hedonic method has several advantages over tax-assessed property values, because the issue of sea level rise requires us to consider how a property's attributes change over time. For example, the hedonic regression gives a market estimate of depreciation by examining how the age of a house affects its sale price. More importantly, the hedonic regression estimates a value for waterfront location and proximity to the shore. Sea level rise does not destroy these waterfront values, but does transfer them to more interior properties. Thus, land lost to sea level rise should be valued as interior land rather than waterfront property. Palmquist (1991) and Freeman (1993) are good sources for more details on the theory and methods of using hedonic price analysis to estimate the value of environmental benefits or damage.

Next, we develop a list of inundated properties for each scenario using the elevation data, and we use the results of the hedonic regression to estimate the monetary loss from the inundation of each property on the list. The variables in the estimated regression line are set to the property's characteristics. To purge the property value of coastal amenities that are transferred to other properties, the waterfront variable is set to zero, and the distance to shore variable is set to the mean value of non-waterfront properties in the study area. Because 2000 is the base year for all value and cost calculations in this study, the year of sale is set to 2000, and the age of the house is set to its age in the year 2000.

The first two steps estimate the loss should the property be inundated immediately, and the final step adjusts the value to its future date of loss. There are four sub-steps to this final step:

1) Determining the date of inundation as described in the scenario assumptions;

2) Adjusting the value for the expected appreciation in real property values;

3) Depreciating the structure;

4) Applying the discount rate to calculate the present value of the future loss.

Following the methodology of previous sea level rise studies, we use Abraham and Hendershott's (1993) model of real housing price appreciation as a function of population and income growth. They find

$$d[\ln(p(t))] = -0.006 + 0.313g_{pop} + 0.565g_{inc} + 0.402[\ln(p(t-1))]$$

where p(t) is the real (inflation-adjusted) price of housing in year t, g_{pop} is the rate of population growth, and g_{inc} is the rate of income growth. As shown in Table 3, we apply the Maryland Department of Planning county-level projections of income and population to this equation to estimate appreciation over the period of 2000-2030. Based on widespread expectations of slow population growth following 2030 and the fact that the Department of Planning did not provide estimates beyond 2030, we assume there is no real appreciation from 2030-2100. As explained in previous sections, depreciation rates were drawn from the regression coefficient on structure age, and we use a discount rate of 2%.

Table 4 defines the variables used in the hedonic price regressions. Table 5 shows the regression results for each of the three study areas. For each study area, the sample is all arms-length sales of improved residential real estate from 1995 through early 2001.[3] The dependent variable is the natural log of the sales price, giving the equation a semi-log form that is very common in hedonic property value studies. We also estimated the models with a linear specification, but we found the semi-log specification was a better fit for all three areas. In the semi-log specification, the regression coefficients can be interpreted as the percent change in the house price resulting from a one-unit change in the independent variable.

The hedonic price regressions performed well in Shadyside and Piney Point but were somewhat limited by a lack of data on Hooper Islands, because there were only 42 property sales over the 6-year period. With the exception of AGE, all of the variables performed as expected and were statistically significant for most cases. The coefficient on AGE shows that properties in this area have not depreciated much with age, because it is statistically insignificant in two of the three areas. AGE is only significant in Shadyside, and even here, the results show depreciation of only 0.16% per year of the structure's age. Waterfront location has the largest affect on property values, increasing sales price by 40% in Shadyside, 46% in Piney Point, and 63% on Hooper Islands. ACRES, SQFTSTRC, and STRUGRAD all show that larger lots, larger structures, and higher construction quality significantly increase property values. The coefficient on SALEYEAR estimates the nominal appreciation in property values in the three study areas between 1995 and 2001. There was no statistically significant appreciation on Hooper Islands,

[3] Arms-length sale refers to a private transaction between two unrelated private parties. It does not include gifts, auctions, foreclosures, tax sales, and other types of transactions where property is more likely to be traded at less than its full market value.

but Piney Point and Shadyside property appreciated approximately 5% and 3.5% per year.[4] Finally, the coefficient on DISTANCE indicates that property values decline as structures are farther from shore. Each 100 meters of distance from shore decreases property value by about 3-4% in Shady side and Piney Point, and 18% on Hooper Islands.

Following the steps described above, the regression results are used to calculate the total loss of improved residential property for each study area. Table 6 illustrates these results for each sea level rise scenario with no discounting and with a 2% discount rate. Following Parsons and Powell (2001), we calculate $25,000 in removal costs for each structure at the time of loss. Table 6 shows removal costs separately from the property loss in the last two columns. Although property values are lowest on Hooper Islands, inundation losses there are the highest because there are so many low-elevation structures. The most striking finding is the large difference in damage between the 2- and 3-foot sea level rise scenarios. There are almost no residential structures below the 2-foot elevation in Shadyside and Piney Point. The value of property loss under the 3-foot rise scenario is 6 times higher on Hooper Islands, approximately 10 times higher in Shadyside, and 50 times higher at Piney Point.

Undeveloped Property Inundation

The value of lost undeveloped property is calculated using the same methods used for improved property. Hedonic price regressions are estimated for each study area using all arms-length sales of unimproved property from 1995 to early 1991. Because there are no structures on these properties, the variables in the hedonic regressions are somewhat different from improved properties. As shown in Table 7, the dependent variable is the log of price per acre rather than the log of the total sales price. Also, explanatory variables defining structural characteristics and a variable showing a properties wetland status has been added. Variables for different zoning categories were tried for all areas, but the Open Space zone in Shadyside is the only one that has a statistically significant effect on land prices. The Open Space zone severely restricts the ability to develop land and has a large negative effect on property values.

The regression results are listed in Table 8. Waterfront status has the largest positive effect on sales price, whereas wetland status has a large negative impact on price in all three areas. The negative coefficient on ACRES means that larger parcels sell for a lower price per

[4] These values may slightly underestimate appreciation because the data represent only the first three months of 2001.

acre than small lots. Similar to improved properties, price decreases as distance from the shore increases. Because there were only 12 sales of unimproved property in the Hooper Islands area over this period, the number of explanatory variables was reduced to improve the performance of the regression models in this area.

Table 9 shows the total economic loss to unimproved property. A 3-foot rise creates 5 times the value of losses of a 2-foot rise. Losses are similar in Piney Point and Hooper Islands, and losses are smaller in Shadyside because there is less low-lying property. Hooper Islands have the largest number of inundated properties, but because property values are higher in Piney Point, the total value of damages is similar in the two counties. Table 10 adds damages for improved and unimproved property together to show the total economic loss to all residential properties. Under the 2-foot rise scenario, the present value of losses are $531,000 at Hooper Islands, $154,000 at Piney Point, and only $75,000 in Shadyside. Under the 3-foot scenario, the present value of damages increases significantly: over $3 million at Hooper Islands, about $2.5 million at Piney Point, and nearly $600,000 at Shadyside.

Non-Residential Property Inundation

There is little commercial, industrial or tax-exempt (government, religious, etc.) property below the 3-foot elevation in the three study areas. Looking at commercial and industrial property, Shadyside has only a single small marina in the 2-to 3-foot elevation band, and Piney Point has a larger marina and a small warehouse. Hooper Islands have eight seafood processing facilities at risk for inundation. With respect to tax-exempt properties, the most significant loss will be the Piney Point Lighthouse Museum and Park. A boat launch is also threatened in the Piney Point area, whereas tax-exempt losses in Shadyside are limited to a single ¼ acre community park. Tax-exempt losses on Hooper Islands include Union Holiness Church, Hooper Island Memorial Church, Hosier Church cemetery, the volunteer fire department, and Hoopersville Wharf.

We are unable to use the hedonic model on non-residential properties because there are too few sales for the regression models. Non-residential properties are also more difficult to assess with conventional techniques because of their specialized nature, lack of comparable sales, and tendency to depreciate more quickly than residential property. Because none of the non-residential properties would be lost before 2050 under either of our scenarios, the best approach is to depreciate all of the structures to zero and simply value the loss in land values.

The current assessed value of these structures is already low in Shadyside and Piney Point, totaling $40,000 and $300,000 respectively, so losses would be very low even if the commercial structures turn out to be more durable than we assume. Full depreciation may result in some underestimation of non-residential losses on Hooper Islands, where the current assessed value of commercial structures below the 3-foot elevation is nearly $1.6 million. In addition, some of the properties lost may have significant social or historical values even if the market values of the property were low. In particular, the Piney Point lighthouse and a pair of churches and cemeteries on Hooper Islands are properties of special significance that are likely to be lost to sea level rise.

We use the same regression models and techniques employed above for unimproved property to value the losses to commercial, industrial, and tax-exempt land. Table 11 shows these estimates. Under the 3-foot scenario, total commercial losses are below $150,000 in all three areas, making commercial, industrial, and tax-exempt losses the least important of all damage categories.

Flood Losses to Non-inundated Property

In addition to inundated property losses, we also estimate the loss to non-inundated property facing a higher risk of flood damage as sea level rises. Our estimates of flood damage are based solely on the effect expected from rising sea levels and not on the possibility of more frequent or stronger storms that many expect to result from climate change. To make these calculations, we rely on the flood insurance rates charged by the Federal Emergency Management Agency (FEMA) in the National Flood Insurance Program (NFIP).

At one time, NFIP insurance was subsidized, but in the mid-1980s, FEMA began developing Flood Insurance Rate Maps (FIRM) and charging actuarially fair rates that differ by elevation for homes constructed after a FIRM has been completed in a designated area. Each flood zone on a FIRM is assigned a base flood elevation for the 100-year flood, and insurance rates are calculated by comparing the elevation of the structure to the base flood elevation. Most flood zones in these three study areas have a base flood elevation of 6 feet. As the elevation of properties decreases due to sea level rise, the increase in their flood insurance rates can be thought of as the increase in expected flood damage due to sea level rise. Table 12 illustrates how flood insurance rates differ by elevation. The sample insurance rates in Table 12 are for $100,000 coverage on the structure and $40,000 coverage for contents. The rates are calculated using the rate tables in the Flood Insurance Manual (FEMA 2002). As seen in Table 12, rates rise dramatically for properties below the base flood elevation.

We calculate an annual flood insurance premium for each property in the study areas that is currently inside the 100-year flood zone. Properties built before the creation of FIRMs are grandfathered into the old NFIP rate structure that does not charge differential rates based on elevation. We calculate premiums for pre-FIRM structures using the actuarially fair post-FIRM rates because our purpose is to estimate expected damages rather than increased insurance costs for homeowners. The subsidized flood insurance for pre-FIRM structures reduces the cost of sea level rise for the property owners, but these costs are just shifted to taxpayers. We also calculate hypothetical premiums for each property if its elevation drops by 1, 2, and 3 feet. The difference between current insurance rates and the hypothetical rates are the expected annual flood damage due to sea level rise for each property. We assume insurance coverage equal to the tax-assessed value of the structure and contents coverage for 40% of the structure's value.

The property-specific premiums are summed for each county, and the difference in the summed premiums at each elevation are used to estimate expected flood damage in the area. For example, the summed difference in premiums at Piney Point is $126,182 for a 1-foot decrease and $231,603 for a 2-foot decrease. Therefore, in the 2-foot rise scenario, we calculate expected sea level rise induced flood damages of $126,182 for 2025 and each subsequent year until 2075, when the increase in expected flood damage goes up to $231,603 per year. Table 13 shows the total expected increase in flood damage to non-inundated property under the various scenarios.

The most striking result is the magnitude of increased flood damage in the Shadyside area. Although Shadyside had few properties at risk of inundation from sea level rise, it does have a large amount of high-value property inside FEMA flood zones at current elevations between 3 and 9 feet. There are two important ways that damage calculations in this category differ from others. First, damages occur much sooner, because every property sees an increase in its expected flood damage from a 1-foot rise in sea levels. Secondly, the difference between the 2- and 3-foot sea level rise scenarios is much lower for estimated flood damage. In fact, expected flood damage to non-inundated property dominates all the other damage categories for the 2-foot rise scenario.

The damage numbers may seem large, but the calculations are actually quite conservative, because we assume no change in flood zone boundaries. Realistically, the boundaries of the 100-year flood zones will change as sea level rises, resulting in a greater number of properties requiring flood insurance and experiencing flood damage. FEMA predicts just such an expansion of flood zones (FEMA 1991) and credits the addition of new properties with relatively low flood risk for balancing rising claims on existing policies as sea level rises in the future.

Infrastructure Damage

Infrastructure is an expansive and indistinct term that has come to include, collectively, all types of substructures and underlying systems that a community relies on for its daily operations. In the context of this study, threatened infrastructure could include such things as roads, bridges, culverts, sidewalks, storm drains, water mains and connections, sewer mains and connections, streetlights, traffic lights, and other devices and materials used in the provision of communication and utility services. On a broader characterization, the concept of public infrastructure could also include an array of buildings and spaces designated for use as schools, churches, burial plots, parks, post offices, hospitals, prisons, and other facilities used by police, fire, and transportation departments.

Given the time frame of this study and the market value of aging and depreciated buildings, and also given the context of anticipated technological change, this study will focus on the costs of replacing, upgrading, and repositioning public roads, bridges, and culverts due to inundation and the resulting lack of accessibility from rising sea levels. The expense of paved roads includes a variety of costs, including construction, rehabilitation, and maintenance expenditures. Costs estimated for this study are restricted to construction and rehabilitation costs, since maintenance costs would exist in the absence of any rise in sea level. Paved roads, like buildings, have a finite life expectancy, and they depreciate in value and usefulness over time and with heavy use (the rate of depreciation likely varies considerably with usage and over time). Recent studies indicate that a properly designed and constructed road can last as long as 50 years or more with proper rehabilitation and resurfacing, but even a good road with moderate use will be in poor condition within 10 to 15 years without adequate care.

Precise, detailed estimates of construction costs are problematic, since construction costs vary with specific site conditions, and many of the affected roads in these test areas are segments of paved roads that will likely require relocation or elevation. The estimates of from $ 385,000 to $ 750,000 to $ 1.5 million per lane mile are approximated from estimates made by a number of public and private agents. These include the U.S. Department of Transportation, State and County Highway Administrations, and private asphalt and concrete-paving firms. A range of cost estimates is provided to allow for the variation such things as topography and building materials. Roads that carry a heavier load, in terms of weight and traffic volume, will be more expensive to construct than roads that carry lighter loads. Elevated roads will be significantly more expensive than surface roads. In several of the threatened study areas, bridges and culverts will have to be constructed to control the flow of water, to deal with storm surges, and to link useable land areas. The cost of constructing new roads, whether the roads are located in urban areas or developed areas, can be significantly higher due to the costs of planning, grading, materials, and construction standards specific to the site. Some communities have estimated the cost of new road construction to be in the range of $1 million per lane per mile in rural areas, and as high as $1.5 to $2.5 million per lane per mile in urban areas (Braeutigam 1999, Gomez-Ibanez 1999, Small 1992).

Table 14 outlines the total cost of replacing all the existing roads that are currently threatened. These costs are undiscounted and are based merely on total mileage and under three alternative cost estimates of contemporary construction costs per lane per mile. These estimated costs are likely to be conservative estimates of the actual cost of construction: many roads may have to be elevated, and bridges may need to be extended, adding significantly to the total cost. Moreover, costs are certain to be higher, since many of these threatened roads are distributed in segments throughout the study areas rather than in a continuous ribbon of roadway that would be cheaper to relocate, resurface, or reconstruct. Total expenditures on inundated infrastructure can be significantly mitigated with appropriate long-term, comprehensive planning.

Tables 15 and 16 outline the estimated discounted costs of this lost infrastructure for the two sea level rise scenarios using a 2% discount rate and varying estimates of $385,000, $750,000 and $1.5 million per lane per mile for road construction. We assume that construction occurs at the time of inundation. This assumption may be inaccurate, since many adjacent sections are inundated at different dates due to 1-foot elevation ranges. In these cases, an entire stretch of road would probably be upgraded at the time the first section is inundated. As a result, actual construction would probably occur earlier than we assume, so our discounted values will underestimate the true costs of sea level rise. The present value of losses from inundated infrastructure in the 2-foot rise scenario range from just over $1 million to $4.3 million on

Hooper Islands; from $186,578 to $726,928 in Piney Point; and from $26,156 to $101,906 in Shadyside. Under the 3-foot rise scenario, the present value of losses range from $2.4 million to $9.5 million on Hooper Islands; from $862,031 to $3.4 million in Piney Point; and from $121,878 to $474,852 in Shadyside. In addition to damage estimates, Tables 15 and 16 show the miles of roadway in each of the elevation bands for each study area. For summary and comparison with other categories, we use the $750,000 per lane mile estimates in the center of the estimated loss ranges.

Of the three study areas, Hooper Islands in Dorchester County with significant segments of paved roads from 1- to 2- and 2- to 3-foot elevations has the most threatened infrastructure and will suffer the greatest loss of paved roads. But, several paved roads in Shadyside and Piney Point will also suffer impact; consequently, all three study areas will incur some measurable loss of infrastructure. Competent long-term planning can significantly, but not completely, offset the total cost of the lost infrastructure. Unfortunately, estimating the cost for severed links in the transportation network is more complicated than merely summing the number of affected segments along a stretch of paved roads. In some cases a road can be elevated by the construction of a bridge or causeway; however, the cost of constructing an elevated roadway is higher than the cost of surface road. In other cases the loss of land coupled with the loss of paved roads may make the cost of construction prohibitively expensive. Decisions to elevate or relocate newly constructed paved roads in alternative positions are long-term decisions for county planners.

Figures 2-6 are overview maps that illustrate the location of roads threatened by sea level rise. On Upper Hooper Islands there are approximately thirty segments of paved roads that are threatened with inundation over the study period. Even though some of these segments are relatively small in terms of linear feet of roadway, they jeopardize access to portions of the island. The threatened portions of roadway can be found throughout Upper Hooper Island, but roughly two-thirds of these are on the southern half of the island. It is particularly troubling that several of these segments threaten to disrupt access to other portions of the island unless the roads that replace existing surface roads are elevated, and of course the construction of an elevated road will contribute to the cost of maintaining access. The roads leading up to the bridge are threatened, which raises concern not only about the cost of extending the bridge but also strengthening the bridge to cope with the increased flow of water beneath the span of the overpass.

Middle Hooper Island has the most threatened infrastructure of all the study areas. Running nearly the entire length of the island, the surface road as it now exists is at risk of inundation at the 1-to 2- and the 2- to 3-foot elevation levels. Certain segments of the road are not at immediate risk, but given the length and breadth of the at-risk infrastructure, serious discussions must occur about the cost effectiveness of maintaining access to portions of Middle Hooper Island.

In the Piney Point site in St. Mary's County, the threatened infrastructure is concentrated in the southern reaches of the test site. The northern portion of the St. Mary's County study site, comprising the area around McKay's Beach, is relatively safe from inundation over the time period. There is a single section of road approximately fifty yards in length that lies at the 2-to3-foot elevation and thus would have to be elevated or shifted, but generally the existing infrastructure in the northern-most portion of the Piney Point site is not currently at risk.

The central portion of the Piney Point site, comprising the area around Tall Timbers, has ten segments of roadway that lie within the 2- to 3-foot elevation and thus are at risk of inundation sometime later in the study period. Five of these segments lie along the road that leads to the lighthouse on the southern tip of the central area of this portion of the study site. The total length of threatened roadway along this road appears to be approximately a quarter of a mile, but since the segment breaks occur in five locations, the costs will be increased overall in order to maintain access to the entire length of land toward the lighthouse. The remaining five segments of threatened roadway lie scattered on the eastern portion of the central region. The segments are not particularly long: some are less than fifty yards in length, but as is the case in other situations, the cost of elevating or repositioning portions of the road in segments will be higher than elevating or repositioning a single stretch of paved roadway.

The southernmost region of the Piney Point study area is the most problematic region, since access to St. George's Island is directly at risk. Overall, there are about eighteen segments of paved roads that are at risk of inundation at elevation levels from 2- and 3-foot sea level rise scenarios. As is the case in other portions, access to some areas is threatened, since there are sections of the island leading to the bridge that must be elevated if the bridge is to remain functional. The approach to the bridge is threatened on both sides of the bridge such that a new span could easily be three or four times the length of the existing bridge. Consequently, the cost of engineering and maintaining a longer bridge with a significantly increased flow of water beneath it would have to be considered.

The Shadyside study site would suffer the least direct impact of the three test sites. There are eleven segments of paved roads that lie within or below the 2- to 3-foot elevation levels and thus would be subject to inundation. While the total length of these segments is just over half a mile, the fact that these segments are scattered will likely increase the expense of construction. It appears that several of these threatened roads could be relocated and kept as surface roads, and only a few would likely require an elevated surface to remain functional and provide continued access.

Wetland Losses

Wetlands provide many valuable services that are not reflected in the market value losses calculated in the previous sections. In fact, when valuing the market loss of unimproved land described above, wetland status greatly diminishes property values. On Hooper Islands, for example, the current market value of wetlands is estimated at $205 per acre, whereas the market value of dryland is $17,473 per acre. While wetlands do not represent much commercial or economic value to their owners, it has long been recognized that they provide many economically valuable services to the public, such as improved water quality, wildlife habitat, commercial fishing and recreational opportunities. Quantifying these non-market values is a subject of much controversy in environmental economics, but many previous studies have calculated non-market benefits from wetlands in a variety of categories. Original research on the non-market wetland benefits of our specific study areas is well beyond the capabilities of this current project. We rely on Woodward and Wui's (2001) meta-analysis of 43 previous studies to generate benefit values that can be transferred to Chesapeake Bay wetlands. Meta-analysis uses regression analysis to control for different study area characteristics such as salt- or fresh-water location and the presence or absence of commercial fisheries or migrating waterfowl. Inputting the characteristics of a typical Chesapeake Bay wetland into Woodland and Wui's regression results creates an estimated value of wetland services of $350 per acre per year.[5]

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[5] Woodward and Wiu's complete data set and description of their study is available on the internet at http://ageco.tamu.edu/faculty/woodward/.

Table 17 shows the capitalized values of the $350 per acre annual benefits over the period from 2000 to 2100. Using the 2% discount rate, the present value of wetland services is about $15,000 per acre. This corresponds well to some national studies of sea level rise that valued wetlands at $10,000 per acre in 1990 dollars, because one would expect higher values for the Chesapeake Bay estuary and 2000 dollars. In our scenarios, the wetlands would be lost at future dates, so Table 19 also shows the capitalized value of an acre of wetlands from the date of loss until 2100. By intersecting the wetland maps with the elevation contours using GIS, we estimated the total acres of wetlands lost in each study area and scenario. Table 18 shows these acreage losses multiplied by the wetland values in Table 17 to provide the total value of wetland losses in each study area. As seen on Table 18, the large number of wetlands on Hooper Islands leads to enormous losses of $7 million, more than double the market value of property lost to inundation. Wetland losses in Shadyside and Piney Point are considerably less, and the economic damages from wetland loss are less than the loss to inundated property.

Because these non-market valuations are controversial, it is important to make a few notes about their interpretation. First, we have been careful to avoid double counting damages throughout the report, and tallying both market and non-market losses to wetlands is not double counting because they are different value categories accruing to different groups. Second, sea level rise may create new wetlands, but our damage estimates only estimate damages to existing wetlands rather than the net loss in wetlands. We feel this is the best approach, both because of the difficulty of estimating wetland creation, and because the conversion of dryland to wetland creates its own damage to market values. Therefore, calculating a net loss to wetlands would reduce the non-market value of wetlands damage, but would increase the market damage to unimproved properties.

DISCUSSION AND CONCLUSION

Tables 19 and 20 summarize the results for the 2- and 3-foot sea level rise scenarios using a 2% discount rate. Shadyside has the highest estimated damages at $13 million for a 2-foot increase in sea level, and $19 million for the 3-foot increase in sea level. Damage at Hooper Islands is almost as much as Shadyside, ranging from nearly $9 million to $18 million. Piney

Point's total economic damage ranged from $5.3 million to $10.4 million. Although Hooper Islands have the second highest calculated losses it will be the most dramatically affected of the three study areas, because the number of structures and total property values on Hooper Islands is much lower than the other two areas (see Table 1).

It is important to compare the composition of damages across study areas. Shadyside is dominated by flood damage to non-inundated property (over 90% of total economic losses), but total economic damages are more evenly distributed between loss categories in the other study areas. Looking only at losses to inundated properties (the subject of most previous sea level rise studies), sea level rise has virtually no effect on Shadyside but generates significant property losses at Piney Point. The difference between the 2- and 3-foot scenarios is also very dramatic for inundated properties, with estimated damages 5 to 10 times larger for the 3-foot rise scenario.

The differences between the scenarios are much smaller for flooding to non-inundated properties for two reasons. First, all properties within a flood zone see an increase in expected losses from a one foot rise in sea level, whereas very little real property lies within the 0 to 1-foot elevation band that will be inundated from a 1-foot rise. Second, expected losses from floods occur much sooner than the full property losses from inundation, so the present value of these losses is greater after discounting.

Finally, we should stress that these estimates are only midpoints from highly uncertain estimates. All of the tables in the report should be consulted to illustrate the range of possible damages. In particular, the wetland and infrastructure estimates are especially rough because they rely on transferring costs from studies in other areas that may not apply to local conditions. The wetland values are further qualified by noting that the scientific validity of non-market valuation is still a subject of heated academic dispute. The results for these three pilot study areas should not be directly extrapolated to other areas, because, as our three study areas illustrate, local differences in geography and market conditions can have large impacts on the estimated damages. Nevertheless, the report can still provide valuable information to local planners who need to understand the potential impacts of sea level rise on their communities.

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Figure 1 Locations of Three Study Areas.

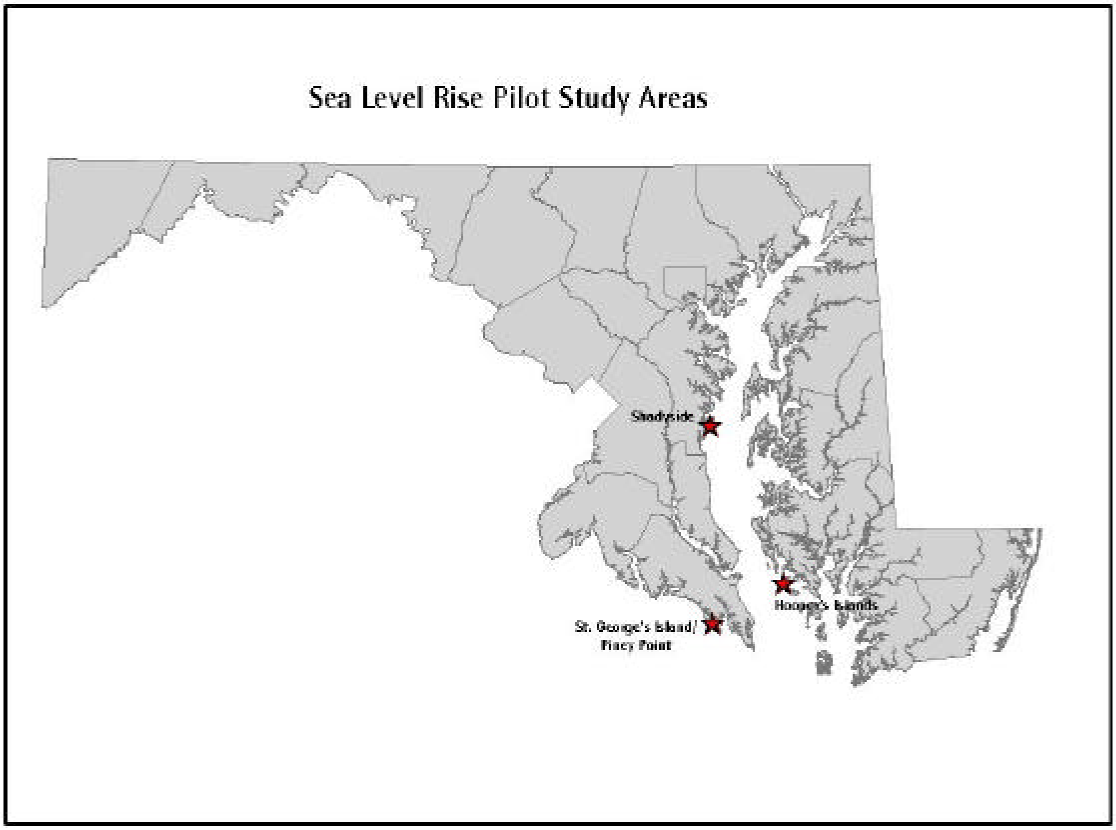

Table 1 Study Area Characteristics. (*Source*: Maryland Department of Planning)

Study Area	***Shadyside***	***Piney Point***	***Hooper Islands***
Area (acres)	1, 811	2,452	2,157
Wetlands (%)	6.5%	13.6%	68.0%
Elevation under 3 ft. (%)	1.0%	8.7%	68.6%
Properties in FEMA 100-year flood zone	42.4%	25.8%	100%
Total Assessed Value of Property	$274,680,840	$219,823,500	$35,105,100
County Economic Data	***Anne Arundel***	***St. Mary's***	***Dorchester***
Median Household Income (2000)	$65,200	$57,400	$33,700
Population Growth (1970-2000)	64.6%	81.9%	4.3%
Income Growth (1970-2000)	38.4%	46.4%	29.1%
Projected Population Growth (2000-2030)	15.5%	48%	3.2%
Projected Income Growth (2000-2030)	22%	30%	19.2%

Table 2 Elevation Profile.

	Acres	Assessed Value of Structures	Total Assessed Value
Shadyside			
0-3 feet	17.9	$677,910	$3,058,380
3-6 feet	476.9	$48,706,940	$106,268,530
6-9 feet	972.8	$68,036,130	$141,151,760
Over 9 feet	196.9	$9,684,300	$24,202,150
Piney Point			
0-3 feet	214.9	$4,278,860	$13,700,590
3-6 feet	1,174.1	$76,648,470	$117,701,240
6-9 feet	658.9	$17,976,539	$58,138,080
Over 9 feet	403.8	$31,043,241	$30,283,590
Hooper Islands			
0-3 feet	1,480.1	$8,332,090	$15,014,810
3-6 feet	648.9	$10,418,840	$19,832,700
6-9 feet	28.1	$156,480	$257,590
Over 9 feet	0	$0	$0

Table 3 Projected Population Growth, Income Growth, and Real Estate Appreciation, 2000 - 2030. (*Source*: Maryland Department of Planning)

Study Area	County	Population Growth	Income Growth	Real Estate Appreciation
Shadyside	Anne Arundel	24%	22%	20%
Piney Point	St. Mary's	48%	30%	32%
Hooper Islands	Dorchester	3%	19%	12%

Table 4 Variable Definitions for Hedonic Price Regressions, Residential Improved.

Dependent Variable	
ln (price)	Natural log of sales price
Explanatory Variables	
WATERFRT	=1 for waterfront properties, =0 for non-waterfront
ACRES	Lot size in acres
SQFTSTRC	Total living space in square feet
SALEYEAR	Year of the sale, ranges from 1995 to 2001
AGE	Age of the home at the time of sale
STRUGRAD	Tax appraisal record of construction quality, ranges from 1 (low cost) to 9 (luxury plus)
DISTANCE	Shortest distance from the structure to the shore in meters

Table 5 Hedonic Price Regressions, Improved Residential.

Dependent Variable: LNPRICE			
	B	Std. Error	t-statistic
Shadyside			
(Constant)	-58.44734	11.25392	-5.19351
WATERFRT	0.40153	0.03630	11.06249
ACRES	0.08452	0.01569	5.38562
SQFTSTRC	0.00026	0.00003	10.45091
SALEYEAR	0.03481	0.00563	6.17803
AGE	-0.00162	0.00046	-3.56060
STRUGRAD	0.12826	0.03261	3.93334
DISTANCE	-0.00033	0.00007	-4.82551
Piney Point			
(Constant)	-88.50179	28.15929	-3.14290
WATERFRT	0.45559	0.06502	7.00739
ACRES	0.04805	0.02545	1.88817
SQFTSTRC	0.00021	0.00004	4.71844
SALEYEAR	0.04965	0.01410	3.52132
AGE	-0.00123	0.00126	-0.97359
STRUGRAD	0.22822	0.04730	4.82494
DISTANCE	-0.00042	0.00035	-1.18086
Hooper Islands			
(Constant)	79.42060	65.95131	1.20423
WATERFRT	0.63647	0.13696	4.64725
ACRES	0.00074	0.03983	0.01855
SQFTSTRC	0.00088	0.00016	5.62300
SALEYEAR	-0.03555	0.03302	-1.07638
AGE	0.00173	0.00181	0.95838
STRUGRAD	0.54410	0.09049	6.01302
DISTANCE	-0.00183	0.00112	-1.63267

Table 6 Inundation Loss of Improved Residential Property.

Shadyside						
2 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2025	0				
	2075	1	$168,932.62	$38,256.40	$25,000.00	$5,661.49
	Total	1	$168,932.62	$38,256.40	$25,000.00	$5,661.49
3 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2020	0				
	2050	1	$175,825.92	$65,323.94	$25,000.00	$5,661.49
	2080	10	$1,386,075.76	$284,299.90	$250,000.00	$51,277.84
	Total	11	$1,561,901.67	$349,623.84	$275,000.00	$56,939.33
Piney Point						
2 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2025	0				
	2075	2	$163,410.33	$37,005.83	$50,000.00	$11,322.98
	Total	2	$163,410.33	$37,005.83	$50,000.00	$11,322.98
3 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2020	0				
	2050	2	$168,365.89	$62,552.34	$50,000.00	$11,322.98
	2080	61	$7,673,220.30	$1,573,864.77	$1,525,000.00	$312,794.85
	Total	63	$7,841,586.19	$1,636,417.11	$1,575,000.00	$324,117.82
Hooper Islands						
2 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2025	2	$189,230.02	$115,341.96	$50,000.00	$30,476.65
	2075	17	$670,105.72	$151,751.83	$425,000.00	$96,245.30
	Total	19	$859,335.74	$267,093.79	$475,000.00	$107,568.28
3 ft Scenario	Year	Properties	Loss	Loss-2%disc	Remove Cost	Remcost-2%
	2020	2	$187,007.80	$125,854.90	$50,000.00	$33,649.64
	2050	17	$670,105.72	$248,961.85	$425,000.00	$96,245.30
	2080	134	$7,664,124.29	$1,571,999.08	$3,350,000.00	$687,123.11
	Total	153	$8,334,230.02	$1,820,960.93	$3,775,000.00	$783,368.41

Table 7 Variable Definitions for Hedonic Price Regressions, Unimproved Property.

Dependent Variable	
ln (price/acre)	Natural log of sales price per acre
Explanatory Variables	
WATERFRT	=1 for waterfront properties, =0 for non-waterfront
ACRES	Lot size in acres
DISTANCE	Shortest distance from the property center to the shore in meters
SALEYEAR	Year of the sale, ranges from 1995 to 2001
WET	=1 if wetland, =0 if not wetland
OPENSPAC	=1 if zoned as open space, = 0 otherwise (Shadyside only)

Table 8 Hedonic Price Regressions, Unimproved Property.

	B	Std. Error	t-statistic
Shadyside			
(Constant)	121.1070	144.8429	0.8361
WATERFRT	0.3880	0.3743	1.0364
ACRES	-0.2654	0.0664	-3.9989
DISTANCE	-0.0023	0.0008	-2.7281
SALEYEAR	-0.0545	0.0725	-0.7517
WET	-0.9447	0.3966	-2.3819
OPENSPAC	-1.9312	0.5927	-3.2584
Piney Point			
(Constant)	130.1682	110.0148	1.1832
WATERFRT	0.7052	0.2082	3.3870
ACRES	-0.2092	0.0361	-5.7892
DISTANCE	-0.0043	0.0013	-3.3817
SALEYEAR	-0.0594	0.0551	-1.0789
WET	-0.5222	0.3144	-1.6609
Hooper Islands			
(Constant)	9.7684	0.3724	26.2313
WATERFRT	1.3167	0.6967	1.8899
WET	-4.4450	0.6081	-7.3094

Table 9 Inundation Loss of Unimproved Property.

Shadyside				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	1	$386.55	$235.61
	2075	6	$137,444.85	$31,125.70
	Total	7	$137,831.40	$31,361.31
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	1	$379.66	$255.51
	2050	6	$137,444.85	$51,064.37
	2080	13	$628,296.32	$128,870.72
	Total	20	$766,120.84	$180,190.60
Piney Point				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	1	$69,960.81	$42,643.43
	2075	6	$280,128.71	$63,437.82
	Total	7	$350,089.53	$106,081.25
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	1	$67,783.05	$45,617.50
	2050	6	$280,128.71	$104,075.16
	2080	49	$1,763,008.08	$361,613.01
	Total	56	$2,110,919.84	$511,305.68
Hooper Islands				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	3	$69,290.16	$42,234.65
	2075	33	$505,796.51	$114,542.44
	Total	36	$575,086.67	$156,777.09
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	3	$68,476.45	$46,084.16
	2050	33	$505,796.51	$187,916.67
	2080	48	$1,351,266.14	$277,160.06
	Total	84	$1,925,539.10	$511,160.89

Table 10 Total Inundation Loss to all Residential Property (Improved + Unimproved).

Shadyside				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	1	$386.55	$235.61
	2075	7	$331,377.47	$75,043.59
	Total	8	$331,764.02	$75,279.20
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	1	$379.66	$255.51
	2050	7	$338,270.77	$122,049.80
	2080	23	$2,264,372.08	$464,448.47
	Total	31	$2,603,022.51	$586,753.78
Piney Point				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	1	$69,960.81	$42,643.43
	2075	8	$493,539.04	$111,766.62
	Total	9	$563,499.85	$154,410.85
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	1	$67,783.05	$45,617.50
	2050	8	$498,494.60	$177,950.48
	2080	110	$10,961,228.38	$2,248,272.63
	Total	119	$11,527,506.03	$2,471,840.62
Hooper Islands				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	5	$308,520.18	$188,053.26
	2075	50	$1,600,902.24	$362,539.57
	Total	55	$1,909,422.41	$531,439.15
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	5	$305,484.26	$205,588.70
	2050	50	$1,600,902.24	$533,123.83
	2080	182	$12,365,390.43	$2,536,282.24
	Total	237	$14,034,769.12	$3,115,490.23

Table 11 Total Inundation Loss to Non-residential Property.

Shadyside				
2 ft Scenario	Year	Properties	Loss	Loss- 2% disc
	2025	0	$0	$0
	2075	0	$0	$0
	Total	0	$0	$0
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	0	$0	$0
	2050	0	$0	$0
	2080	2	$100,166	$20,545
	Total	2	$100,166	$20,545
Piney Point				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	0	$0	$0
	2075	2	$221,296	$50,114
	Total	2	$221,296	$50,114
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	0	$0	$0
	2050	2	$221,296	$82,216
	2080	5	$327,997	$67,272
	Total	7	$549,273	$149,488
Hooper Islands				
2 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2025	2	$22,428	$13,670
	2075	8	$199,585	$45,198
	Total	10	$222,013	$58,868
3 ft Scenario	Year	Properties	Loss	Loss-2%disc
	2020	2	$22,164	$14,916
	2050	8	$199,585	$74,151
	2080	19	$93,607	$29,596
	Total	29	$202,047	$118,663

Table 12 Illustrative Annual Flood Insurance Rates by Elevation. Zone AE, base flood elevation is 6 feet above sea level. $100,000 coverage on structure, $40,000 contents. Rates do not include administrative fees that are constant for each policy. (*Source*: FEMA, National Flood Insurance Program: Flood Insurance Manual.)

Elevation	Annual Premium
9 feet	$188
8 feet	$218
7 feet	$363
6 feet	$614
5 feet	$2,134
4 feet	$2,702
3 feet	$3,632

Table 13 Estimated Increase in Flood Damage from Rising Sea Level. (Number of properties in 100-year flood zone in parenthesis)

Study Area	**Total Damage**	**Total Damage – 2% disc**	**Non-inundated Properties in Flood Zone**
2-foot Rise Scenario			
Shadyside	$43,993,081	$12,660,223	(903)
Piney Point	$12,330,781	$3,541,604	(314)
Hooper Islands	$6,879,584	$2,024,922	(456)
3-foot Rise Scenario			
Shadyside	$60,547,488	$17,714,062	(791)
Piney Point	$17,004,970	$4,968,405	(126)
Hooper Islands	$8,575,516	$2,634,739	(255)

Table 14 Total Mileage and Total Estimated Costs (Undiscounted) of Threatened Roads

		Estimated Total Costs		
	Total mileage	At $385,000 per lane per mile	At $750,000 per lane per mile	At $1.5 million per lane per mile
Hooper Islands (Dorchester County)	10.22	$7,869,400	$15,330,000	$30,660,000
Piney Point / St. George's (St. Mary's County)	4.59	$3,534,300	$6,885,000	$13,770,000
Shadyside (Anne Arundel County)	0.65	$500,500	$975,000	$1,950,000
Totals:	15.46	$11,904,200	$23,190,000	$46,380,000

Table 15 Estimated Discounted Costs of Lost Infrastructure Under the 2-foot Scenario and Using a 2% Discount Rate.

		Estimated Costs – 2025		
	Total mileage	At $385,000 per lane per mile	At $750,000 per lane per mile	At $1.5 million per lane per mile
Hooper Islands (Dorchester County)	0.59	$276,910	$539,435	$1,078,870
Piney Point / St. George's (St. Mary's County)	0	0	0	0
Shadyside (Anne Arundel County)	0	0	0	0
		Estimated Costs – 2075		
Hooper Islands (Dorchester County)	4.76	$830,012	$1,616,906	$3,233,813
Piney Point / St. George's (St. Mary's County)	1.07	186,578	363,464	726,928
Shadyside (Anne Arundel County)	0.15	26,156	50,953	101,906
Totals:	5.98	$1,042,746	$2,031,323	$4,062,647
Hooper Islands (Dorchester County)	5.35	$1,069,922	$2,156,341	$4,312,683
Piney Point / St. George's (St. Mary's County)	1.07	$186,578	$363,464	$726,928
Shadyside (Anne Arundel County)	0.15	$26,156	$50,953	$101,906
Totals:	6.57	$1,282,656	$2,570,758	$5,141,517

Table 16 Estimated Discounted Costs of Lost Infrastructure 3-foot Scenario and Using a 2% Discount Rate.

		Estimated Costs – 2020		
	Total mileage	At $385,000 per lane per mile	At $750,000 per lane per mile	At $1.5 million per lane per mile
Hooper Islands (Dorchester County)	0.59	$305,731	$595,579	$1,191,159
Piney Point / St. George's (St. Mary's County)	0	0	0	0
Shadyside (Anne Arundel County)	0	0	0	0
		Estimated Costs – 2050		
Hooper Islands (Dorchester County)	4.76	$1,361,724	$2,652,709	$5,305,418
Piney Point / St. George's (St. Mary's County)	1.07	306,102	596,302	1,192,604
Shadyside (Anne Arundel County)	0.15	42,911	83,593	167,188
Totals:	5.98	$1,710,737	$3,332,604	$6,665,210
		Estimated Costs – 2080		
Hooper Islands (Dorchester County)	4.86	$767,562	$1,495,250	$2,990,500
Piney Point / St. George's (St. Mary's County)	3.52	555,929	1,082,979	2,165,959
Shadyside (Anne Arundel County)	0.50	78,967	153,832	307,664
Totals:	8.88	$1,402,458	$2,732,061	$5,464,123
Hooper Islands (Dorchester County)	10.22	$2,435,017	$4,743,538	$9,487,077
Piney Point / St. George's (St. Mary's County)	4.59	$862,031	$1,679,281	$3,358,563
Shadyside Anne Arundel County)	0.65	$121,878	$237,425	$474,852
Totals:	15.46	$3,418,926	$6,660,244	$13,320,492

Table 17 Estimated per acre value of wetland services.

Discounted value		Undiscounted value is $350*years	
Current	$15,084.42	Current	$35,000.00
Year of loss			
2020	$9,596.96	2020	$28,000.00
2025	$8,464.55	2025	$26,250.00
2050	$4,216.20	2050	$17,500.00
2075	$1,626.69	2075	$8,750.00
2080	$1,245.63	2080	$7,000.00

Table 18 Estimated value of lost wetland services.

Dorchester (Hooper Islands)				
2 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2025	350.428	$9,198,735.00	$2,966,215.02
	2075	793.535	$6,943,431.25	$1,290,838.03
	Total	1143.963	$16,142,166.25	$4,257,053.05
3 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2020	350.428	$9,811,984.00	$3,363,043.98
	2050	793.535	$13,886,862.50	$3,345,698.91
	2080	322.295	$2,256,065.00	$401,460.88
	Total	1466.258	$25,954,911.50	$7,110,203.77
St Mary's (Piney Point)				
2 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2025	51.088	$1,341,060.00	$432,436.89
	2075	101.574	$888,772.50	$165,229.74
	Total	152.662	$2,229,832.50	$597,666.63
3 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2020	51.088	$1,430,464.00	$490,289.56
	2050	101.574	$1,777,545.00	$428,255.87
	2080	180.288	$1,262,016.00	$224,572.45
	Total	332.95	$4,470,025.00	$1,143,117.88
Anne Arundel (Shadyside)				
2 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2025	6.003	$157,578.75	$50,812.69
	2075	55.809	$488,328.75	$90,784.12
	Total	61.812	$645,907.50	$141,596.81
3 ft Scenario	Year	Acres	Loss	Loss-2% disc
	2020	6.003	$168,084.00	$57,610.56
	2050	55.809	$976,657.50	$235,301.67
	2080	55.759	$390,313.00	$69,455.18
	Total	117.571	$1,535,054.50	$362,367.41

Table 19 Total Economic Loss from Sea Level Rise Under the 2-foot Sea Level Rise Scenario and Using the 2% Discount Rate.

Damage Category	*Shadyside*	*Hooper Islands*	*Piney Point*
Residential: Inundation Loss	$75,279	$531,439	$154,410
Residential: Non-Inundated	$12,660,223	$2,024,922	$3,541,604
Non-Residential	$0	$58,868	$50,114
Infrastructure Loss	$50,953	$2,156,341	$363,464
Wetland Values	$141,597	$4,257,053	$1,143,118
Total	$12,928,052	$9,028,623	$5,252,710

Table 20 Total Economic Loss from Sea Level Rise Under the 3-foot Sea Level Rise Scenario and Using a 2% Discount Rate.

Damage Category	*Shadyside*	*Hooper Islands*	*Piney Point*
Residential: Inundation Loss	$586,753	$3,115,490	$2,471,840
Residential: Non-Inundated	$17,714,062	$2,634,739	$4,968,405
Non-Residential	$20,545	$149,488	$118,663
Infrastructure Loss	$237,425	$4,743,538	$1,679,281
Wetland Values	$362,367	$7,110,204	$1,143,118
Total	$18,921,152	$17,753,459	$10,381,307