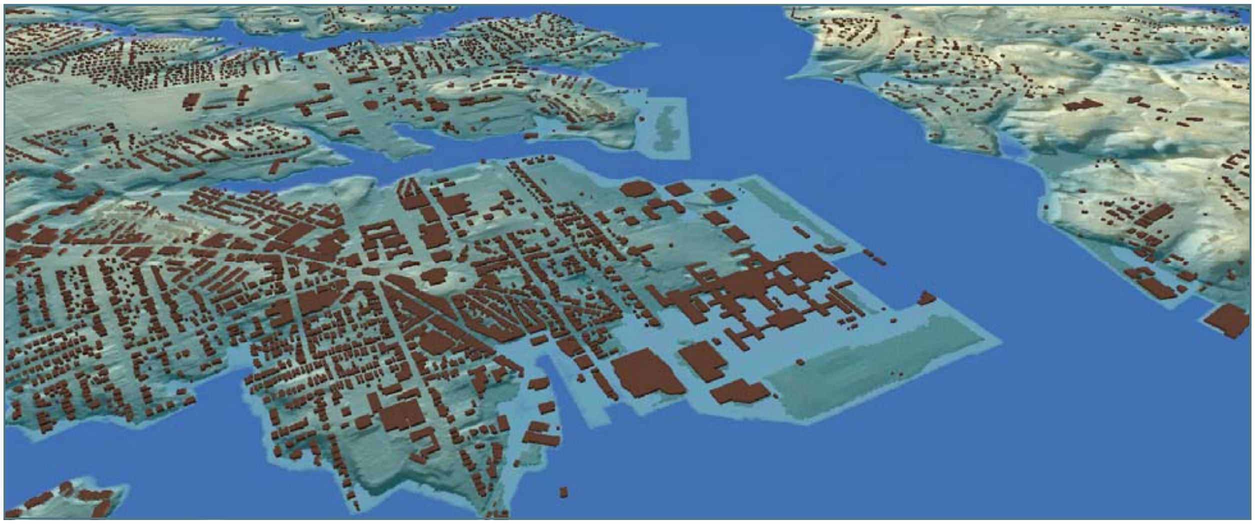
FUTURE COAST



Anne Arundel

What Should Communities Do—or Not Do—about Coastal Flooding and Sea-Level Rise?

A Citizens' Discussion Issue Book

This issue book for the Future Coast Citizens' Discussion in Anne Arundel County, Maryland in Spring 2012 was developed under a grant from Mid-Atlantic Sea Grant by a research team led by George Mason University, Fairfax, VA.

The Future Coast project is not funded — and has no ties to planning efforts — by Anne Arundel County, the City of Annapolis or the State of Maryland.

This project has benefitted from the expertise and insight of many individuals, who were generous in offering their assistance. We particularly wish to thank Zoe Johnson, Jessica Grannis, Lynn Miller, Brian Batten, Jeff Allenby, Mike Rowan, Barbara Husson and Edward Maibach.

All errors within this document are solely those of the authors.

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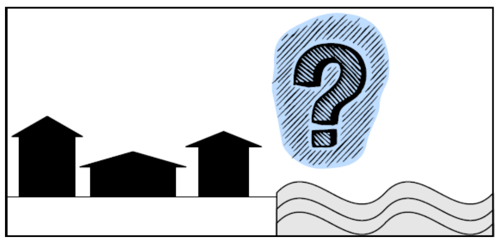
Cover image of Annapolis flood projections courtesy of Dewberry, Fairfax, VA.



What Should Communities Do—or Not Do—About Coastal Flooding & Sea-Level Rise?

A Citizens' Discussion Issue Book

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1. INTRODUCTION

Welcome to Future Coast, Anne Arundel County. We hope you will join us in thinking about a set of problems that is not unique to this place – coastal counties across the United States are thinking about similar sets of issues – but which have solutions that of necessity will be specific to your community, its needs, and its values.

1.1 BACKGROUND

Where the land and sea meet have always been dynamic places of change, with implications for the people who live along these shores. Currently, the mid-Atlantic coast of the United States is particularly vulnerable to change, located in a region of the United States where a combination of factors is creating high rates of rising sea levels relative to the land. As communities contend with flooding and consider the consequences of some areas becoming permanently under water, they are weighing how, and when, to respond.

The Mid-Atlantic is experiencing high rates of sea-level rise relative to the land.

Deciding how to manage the intrusion of the sea presents complex questions. Technical information from specialists in a diversity of fields is important to make informed decisions, and you can hear from some of these experts answering Anne Arundel County residents questions about sea-level rise in short video excerpts on the project website, www.FutureCoast.info.

Bay Ridge, Anne Arundel County, 2003. J. Stein, photographer, Anne Arundel County Soil Conservation District.

The best policies are ones that are also

The best policies are ones that are also guided by community values and priorities. That is where you – and this initiative – come in.

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Future Coast is a project funded by Mid-Atlantic Sea Grant[1] to engage citizens in discussing local policies that address coastal flooding and sea-level rise. During a day-long Citizens' Discussion on April 28, 2012, county residents accessed online visualizations of local sea-level rise impacts, heard from technical experts, and discussed potential community responses to sea-level rise in small groups with trained facilitators. The sea-level rise maps, videos of expert Q&A, and guidance on conducting citizens' discussions are available for public use on the project website, www.FutureCoast.info. We encourage individuals and organizations to use the tools to start their own conversations on this issue.

Future Coast is a collaboration between researchers from George Mason University, the U.S. Naval Academy, Anne Arundel Community College, and Dewberry, an engineering and architectural firm with expertise in flood mapping. An advisory panel of experts and representatives of local stakeholder organizations participated in the project, providing feedback for incorporation into project materials.

The Future Coast project is not funded — and has no ties to planning efforts — by Anne Arundel County, the City of Annapolis or the State of Maryland.

Preserving Maryland's archeological history along its shores. Maryland Historical Trust.

[1]Sea Grant is a nationwide network of university-based programs that work with coastal communities. It is administered through the National Oceanic and Atmospheric Administration (NOAA) under the U.S. Department of Commerce. See http://www.seagrant.noaa.gov/aboutsg/index.html

2. Science and Impacts

In this section we will be discussing what we know about sea-level rise and coastal flooding, and what the impacts may be in specific locations within Anne Arundel County. The Participant Guide — also found on the project website under "Reports" — provides a list of key points and suggested questions for each of the sections in the Issue Book. You may wish to consider these, or use them as a starting point for group discussions.

Over the past 100 years, waters in the Chesapeake Bay have risen more than a foot compared to land elevations.

2.1 Science of Sea-Level Rise

Over the past 100 years, the waters of the Chesapeake Bay have risen more than a foot compared to the land. There are many reasons for this, which we will explore.

Twenty-thousand years ago, the extensive glaciers of the last Ice Age began to melt and retreat toward the poles. Sea levels began to increase across the globe. They continue to rise today, and probably have not yet reached the same levels of the last glacial retreat 125,000 years ago.

The Chesapeake Bay was formed as these water levels crept upwards (Figure 1). Today, tidal gauges in the Chesapeake are still recording steady upticks in sea levels. Some of the longest historical records come from the Bay. For example, between 1928 and 2006, sea levels in Annapolis rose approximately 3.4 mm a year, or a tenth of an inch a year. This is one of the highest sea level rates of change along the East Coast of the United States.

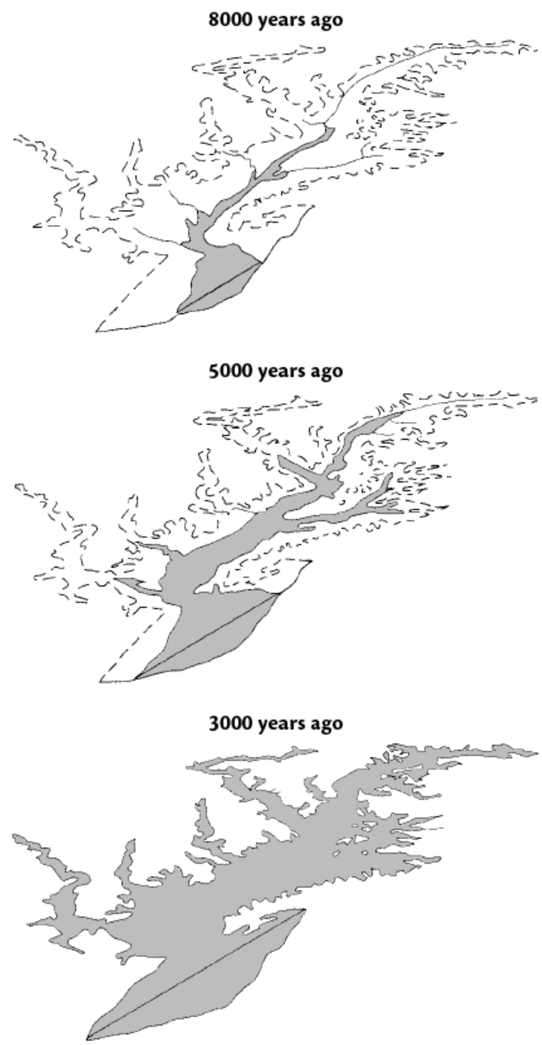


Figure 1. The flooding of the Susquehanna River Valley from sea-level rise over thousands of years formed the Chesapeake Bay. Maryland Commission on Climate Change.

More water combined with sinking land. There are other reasons for rising seas in the Bay aside from glacial melt (Figure 2). Surprisingly, the land is sinking at the same time that seas are swelling from more water and higher temperatures. When glaciers started to disappear from the continental United States, the earth began to sink in the mid-Atlantic region. Sinking of the land accounts for approximately half of the rate of change that we observe in Chesapeake Bay when we compare sea levels against the elevation of the land. Scientists term the change in sea level relative to the land, **relative sea-level rise**, as illustrated in Figure 2.

Future sea-level rise. The challenge for coastal communities is not only dealing with the current effects of sea-level rise, but knowing what to expect in the future. The most conservative estimates are that rates of sea-level rise will remain the same over time in the Chesapeake Bay region. That rate is an increase of approximately a foot each century.

When projected warming from climate change is considered, the rate of change increases, along with the uncertainty. The most recent United Nations report on climate change predicted that sea level will rise between 7 inches to 2 feet by 2100, depending on the amounts of greenhouse gases emitted from sources like cars and power plants.

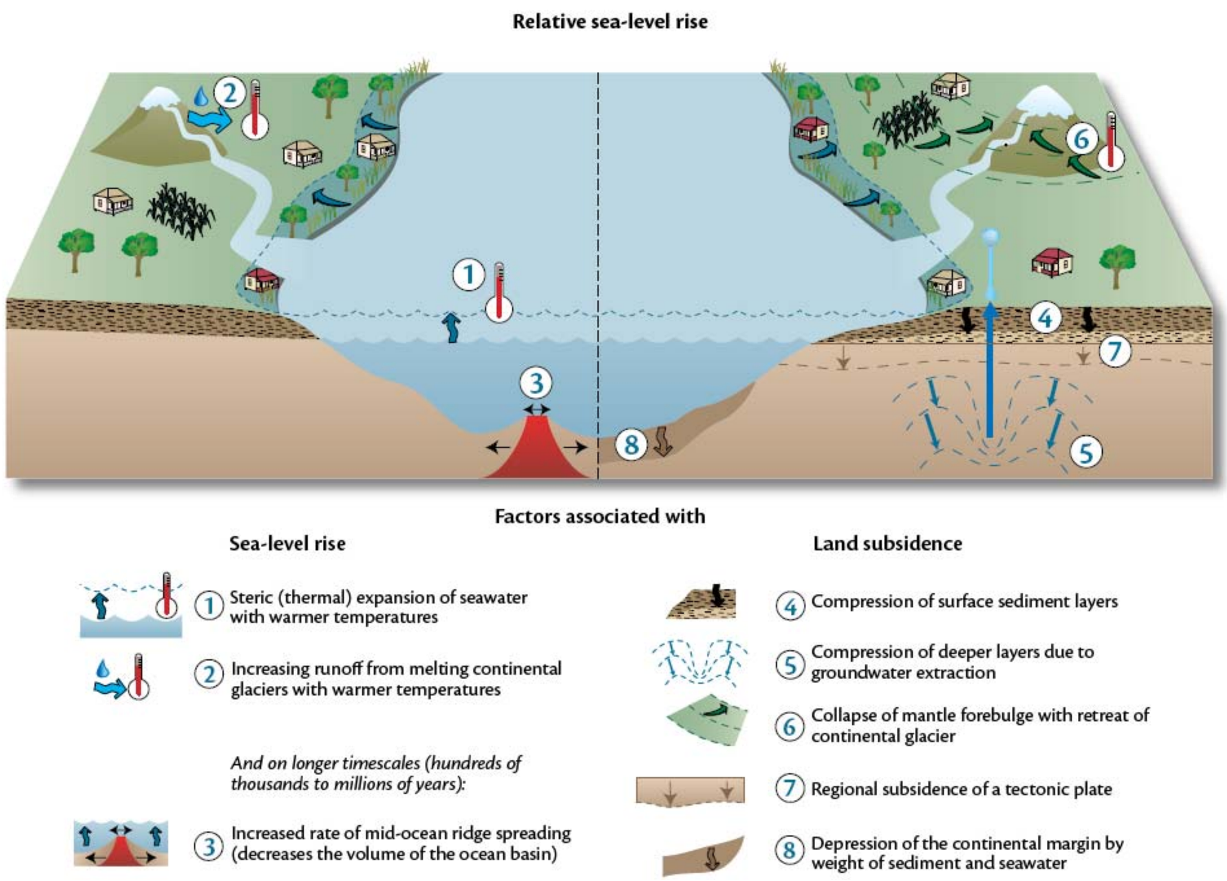


Figure 2. Contributing factors to "relative" sea-level rise. Maryland Commission on Climate Change.

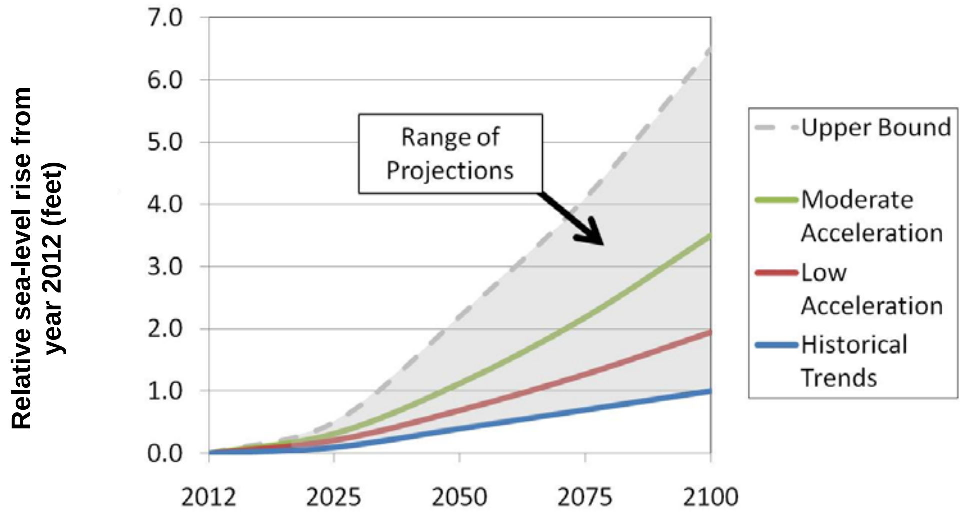


Figure 3. The Future Coast sea-level rise scenarios represent the historical rate, a 1.9-foot rise as recommended by the state for planning purposes (low acceleration), and a 3.4-feet rise in line with the state's higher range by 2100 (moderate acceleration). Scientific analyses of rates of global sea-level rise suggest they possibly will be higher than 3.4 feet by 2100. For comparison purposes, 6.6 feet is given as an estimated upper bound in this figure.

However that report did not fully account for changes in the melting of the large ice sheets across Greenland and Antarctica, a primary driver of sea-level rise. Estimates of sea-level change are greater when those effects are included. Most projections are for global sea-levels to rise somewhere between 0.5 to 2 meters, or 1.6 to 6.6 feet. The Maryland Commission on Climate Change expects a range of 2.7 to 3.4 feet relative sea-level rise for the state by 2100. They recommended that local government planners generally anticipate a 1-foot rise by 2050, and a 2-foot rise by 2100, but for large, long-term investments in property and infrastructure, a 4-foot rise. Analyses done for the Future Coast project were based on projections for a rise of 1 foot, 1.9 feet and 3.4 feet between 2012 and 2100 (Figure 3).

The acceleration of sea-level rise will cause more severe impacts to communities. Scientists expect this acceleration, but it can be hard to detect at global and regional scales. Both the most recent United Nations report and a Virginia Institute of Marine Science study on sea-level rise in the Chesapeake Bay have not been able to definitively identify an acceleration in the rate of sea-level rise; however a newly released scientific study found evidence to support accelerated sea-level rise along the U.S. Atlantic Coast.

2.2 Erosion, Flooding and Inundation

Almost a third of Maryland's coastline is already experiencing coastal erosion. This is occurring because the force of the Bay's waters wears away the land, and flood

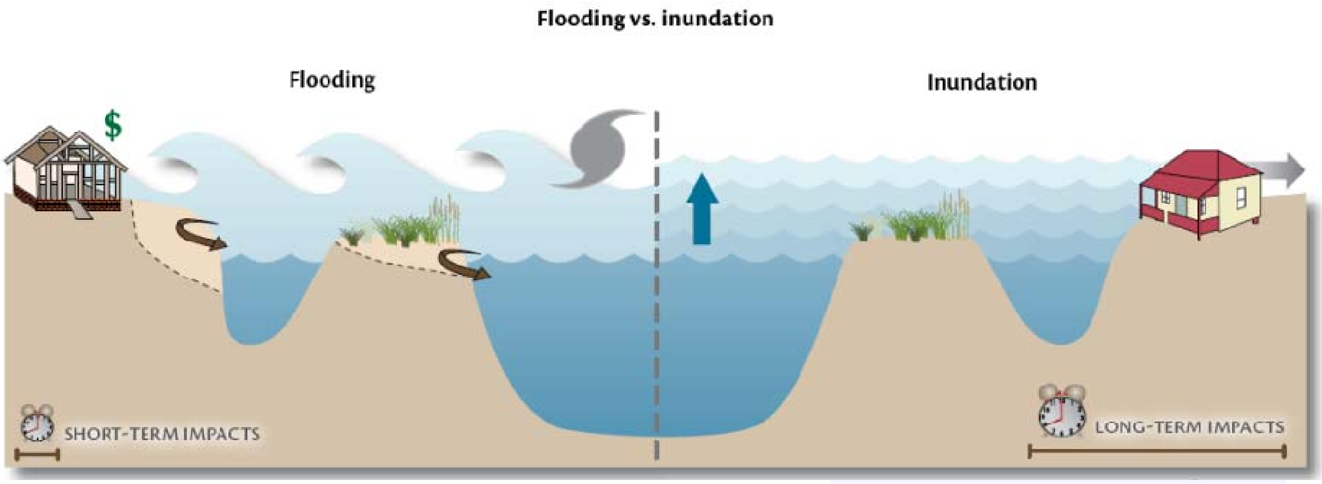


Figure 4. Flooding is a short-term impact of sea-level rise, and causes erosion and property damage. In contrast, permanent flooding — termed inundation — occurs over longer periods of time and results in land and property loss. Maryland Commission on Climate Change.

waters push farther inland. Rising waters increase the severity of flooding, damaging buildings and public infrastructure and natural areas. Over time, some areas could become permanently flooded (Figure 4). This is called **inundation**. Inundation can also occur in wetlands. When these areas become submerged, the defenses the vegetation provided against flooding and erosion are lost, no longer slowing incoming storm waters and anchoring the soil.

2.3 Storms

Flooding and winds from coastal storms — hurricanes, tropical storms, and "northeasters" — are already the two largest natural hazards Anne Arundel County faces. As sea levels increase, the potential for damage to coastal areas goes up during storms. For example, consider the impact of Hurricane Isabel in 2003 compared to the effect of the hurricane of 1933. The 1933 hurricane hit the same area of the mid-Atlantic with a larger storm surge, yet the maximum water level was about the same because sea levels were higher in 2003 than 1933. With higher water lev-

… even without a major tropical storm or hurricane, extratropical storms or 'northeasters' that have not caused significant flooding of homes and property in the past will begin to do so in the future due to rising sea level.

—Boon, Wang and Shen, 2008

els, hurricane-driven storm surges will reach further inland.

Climate change may also cause more intense storms. Over the past few decades, there has been a large increase in intense — category 4 and 5 — hurricanes in the Atlantic. A category 1 hurricane can cause considerable damage. Categories 2, 3, 4, or 5 can cause a lot more. Though the observations cannot be definitively linked to global warming, increased frequency of these more intense storms are projected by the end of the century, even while overall numbers of annual storms may remain the same or even decline.

2.4 What It Means Locally

Maryland is likely to be one of the states most highly impacted by sea-level rise, after Louisiana and Florida. It has also been at the forefront in addressing the issue. Since Governor Martin O'Malley established the Maryland Commission on Climate Change (MCCC) in 2007, the commission has published three reports, all of which address sea-level rise impacts to the state.

Building on the state's assessments, Anne Arundel County performed its own evaluation of the county's vulnerability to sea-level rise in 2010 and developed recommendations for potential response strategies in 2011. The City of Annapolis also released three reports in 2011 on sea-level rise impacts to the City Dock and EastPort areas and potential responses. These reports will be

(Top) Annapolis Roads, Chesapeake Bay, Anne Arundel County, 2003. J. Stein , photographer, Anne Arundel County Soil Conservation District. (Bottom) Annapolis after Hurricane Isabel in 2003. Liz Roll, Photographer.

Anne Arundel County, 2003. J. Stein , Photographer, Anne Arundel County Soil Conservation District.

briefly described in the following sections.

Anne Arundel County. Less than three percent of the county's total land area would be impacted by a sea-level rise of five feet, according to preliminary estimates of the county's September 2010 sea-level rise vulnerability assessment. The majority of the land at risk of permanent flooding is currently woodlands, open land, and wetlands. Most of the communities that may be impacted by a relative rise in sea level are single family residences.

The Deale/Shady Side and Edgewater/Mayo peninsulas have the most residential buildings that would likely be affected by an increase in sea level of 0- to 2- feet. With increases up to 5 feet in sea level, the communities of Annapolis Neck, Lake Shore and Severna Park could also be impacted.

Local roads in coastal communities may also be damaged by rising waters. Although road flooding is not predicted to be widespread, some properties could be left inaccessible, and even small portions of roads that require rebuilding or relocation can be exceedingly costly for governments.

In communities that rely on individual water supply wells and on-site septic systems, these facilities may become damaged or no longer function as a result of sea level rise. Although connection to public utilities may be an option in some locations, in many cases these properties may not be within a feasible distance for connection to public utilities. Other alternatives such as community systems or relocation of individual on-site facilities may become necessary.

Nearly one-third of archaeological sites in the county are located in coastal areas that may be threatened by a sea rise of up to 5 feet. This may require the county to investigate and protect archaeological sites before valuable resources are damaged or lost.

Based on the vulnerability assessment report from 2010, the county developed a series of policy recommendations in November 2011 to address its stated goals. These goals — and the highest priority level of the recommendations — included:

1. Incorporate sea-level rise planning into all related county functions. *(High priority)*
2. Protect coastal ecosystems to reduce the impacts of sea-level rise, coastal flooding and shoreline erosion. *(Medium priority)*
3. Reduce sea-level rise impacts to existing and future development. *(High priority)*
4. Reduce potential impacts to public infrastructure serving existing communities and future development. *(Medium priority)*
5. Ensure safe and adequate water supply and wastewater management for communities vulnerable to sea-level rise impacts. *(Medium priority)*
6. Protect significant cultural resources from loss or damage due to sea-level rise impacts. *(High priority)*
7. Ensure that citizens in the county are educated and informed about sea-level rise and have access to current information and resources. *(High priority)*

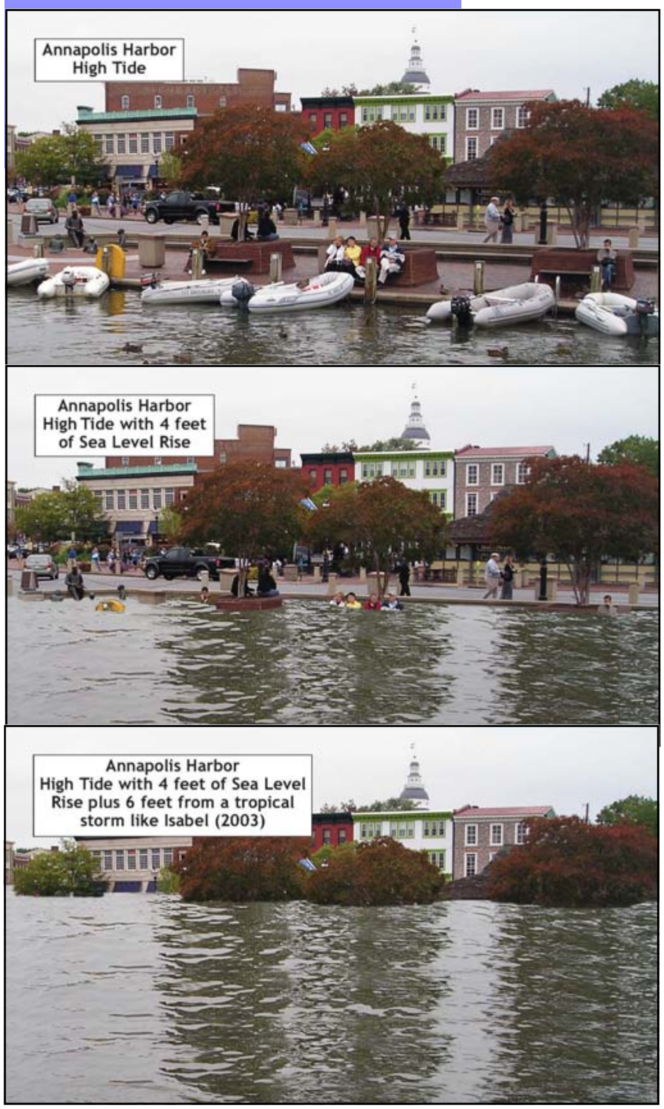
Historic Annapolis after Hurricane Isabel in 2003.

City of Annapolis. The City of Annapolis is a unique historical area, with the largest collection of 18th century buildings in the United States. Protecting this area is thus of high interest to many in the capital city of Maryland. Annapolis regularly experiences flooding from tides above 1.9 feet. Flooding events are expected to more than double by 2050 due to sea-level rise. One of the areas most at risk is the City Dock, located at the heart of the historic district. The city has begun to explore how to protect the public areas in collaboration with private owners and the U.S. Naval Academy.

Coastal flooding is the city's primary concern from sea-level rise. Annapolis already has built shorelines, so will not be subject to much erosion from sea-level rise, and the City Dock is the only area at risk of permanent inundation. Residents rely on water from deep wells (300-1,000 feet) which should not be affected by saltwater intrusion.

The Army Corps of Engineers evaluated ways of protecting the City Dock area for the U.S. Naval Academy in 2006, and presented an array of options using both structural and non-structural options. These options are again being assessed by the City of Annapolis, and include elevation and relocation, flood-proofing, a pumping station, and sea walls and levees.

The city is also considering revisions to its city code, primarily to its floodplain ordinances and zoning codes. Annapolis's 2009 Comprehensive Plan already addresses sea-level rise in two policies: evaluating land-use changes, and developing a climate change adaptation planning strategy.



Visualizations of Annapolis Harbor under differing sea-level rise scenarios. Maryland Sea Grant and Michael Kearney, Department of Geography, University of Maryland.

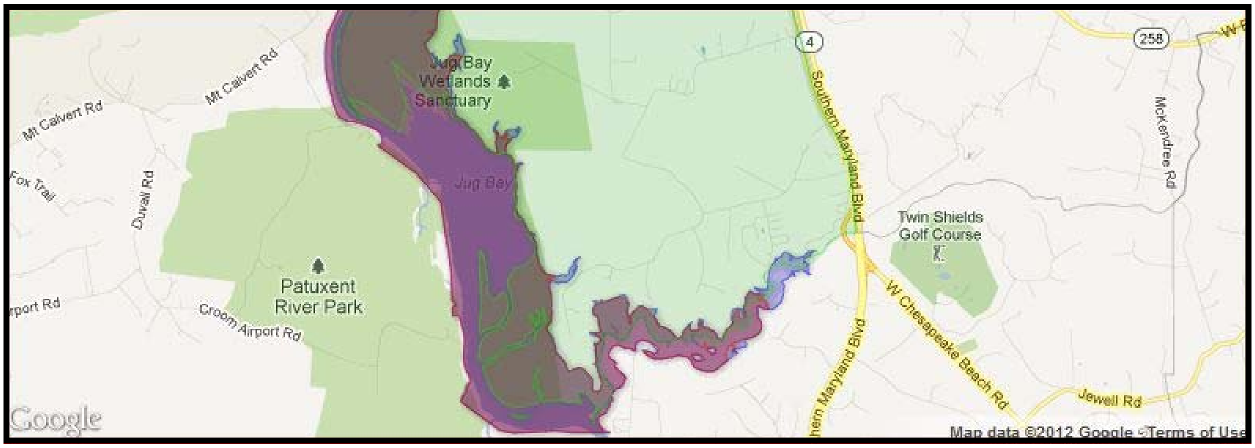
(Left) Jug Bay Wetlands Sanctuary on the Patuxent River is a county park as well as a site in the Chesapeake Bay National Estuarine Research Reserve System. (Center) City of Annapolis. (Right) Gibson Island in winter.

2.5 Examples of Impacted County Areas

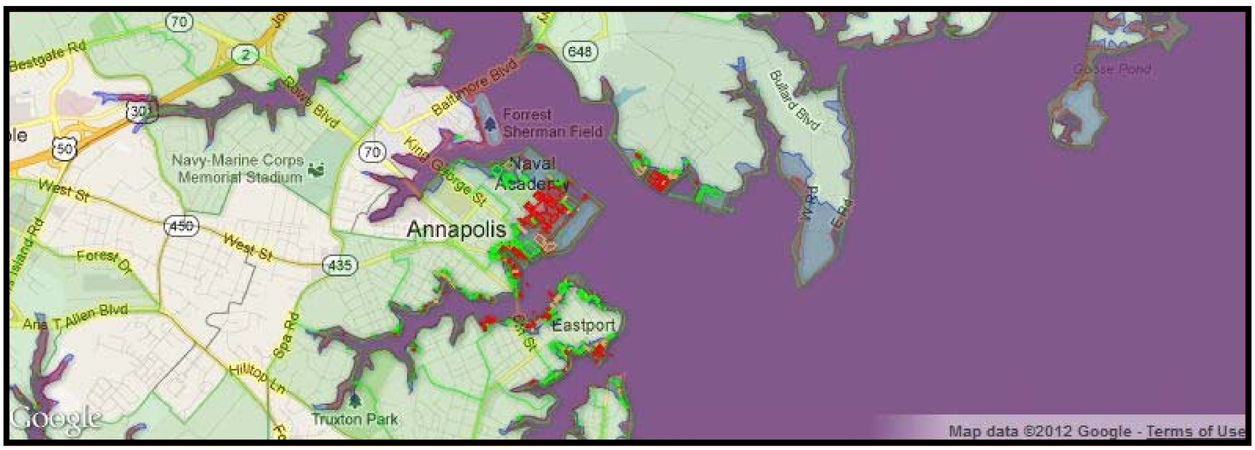
In the next section of this report, we will present different types of strategies to address coastal flooding and sea-level rise depending on the characteristics of the area: publicly owned natural lands vs. high-density commercial and residential areas vs. residential areas with single-family homes. But first, we would like to give you a brief visual overview of some of the impacts from coastal flooding and sea-level rise to specific regions, starting with a publicly owned natural park, Jug Bay Wetlands Sanctuary; then a high-density commercial and residential area, the City of Annapolis; and finally a series of low-density residential coastal areas.

All the maps show the projected floodplain and permanently flooded areas in the year 2100 assuming that there was an increase of 3.4 feet in sea-level rise (a moderate acceleration scenario). These projections of future sea level and impacts are based on best available scientific information, but have large uncertainties due to the nature of the data (see data sources, page 28). The values do not reflect the likelihood of changes in climate and or sea level. We provide the maps — both here and online — solely as a tool to consider potential policy responses to sea-level rise and coastal flooding. For more detailed maps and summary information, see the viewer online at www.FutureCoast.info.

PROJECTED IMPACTS FROM 3.4 FEET OF SEA-LEVEL RISE IN 2100



PUBLICLY OWNED NATURAL AREA: *Jug Bay Wetlands Sanctuary.*



HIGH DENSITY COMMERCIAL AND RESIDENTIAL AREA: *City of Annapolis .*

Permanent Inundation *(loss of land to flooding)*

Floodplain *(1% chance of flooding yearly)*

Building Impacts (all scenarios through 2100):

Low Total Risk Exposure

Medium Total Risk Exposure

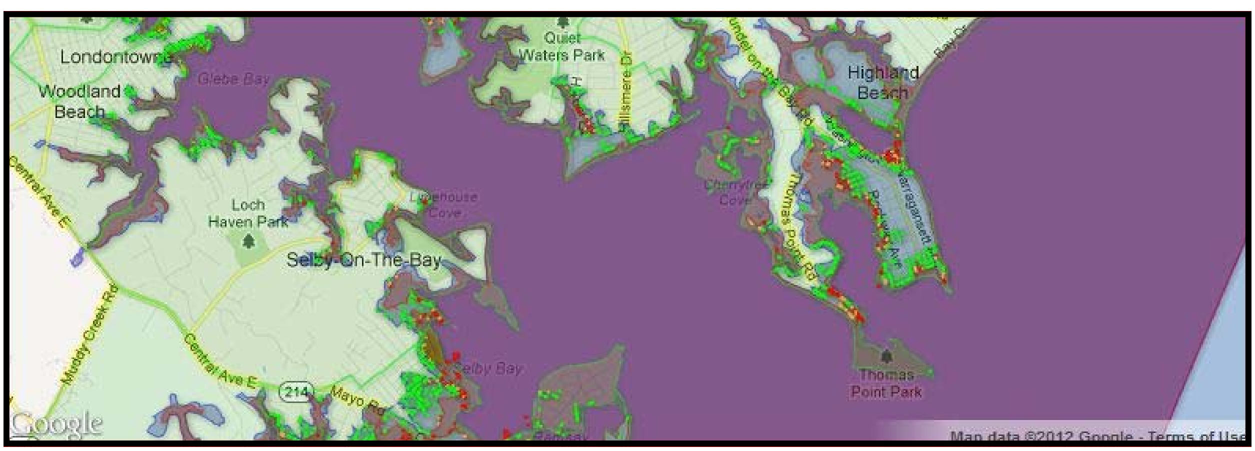
High Total Risk Exposure

**Shaded green areas represent neighborhoods impacted by coastal flooding and sea-level rise.*

PRIMARILY SINGLE-FAMILY, LOW-DENSITY RESIDENTIAL AREAS

Gibson Island

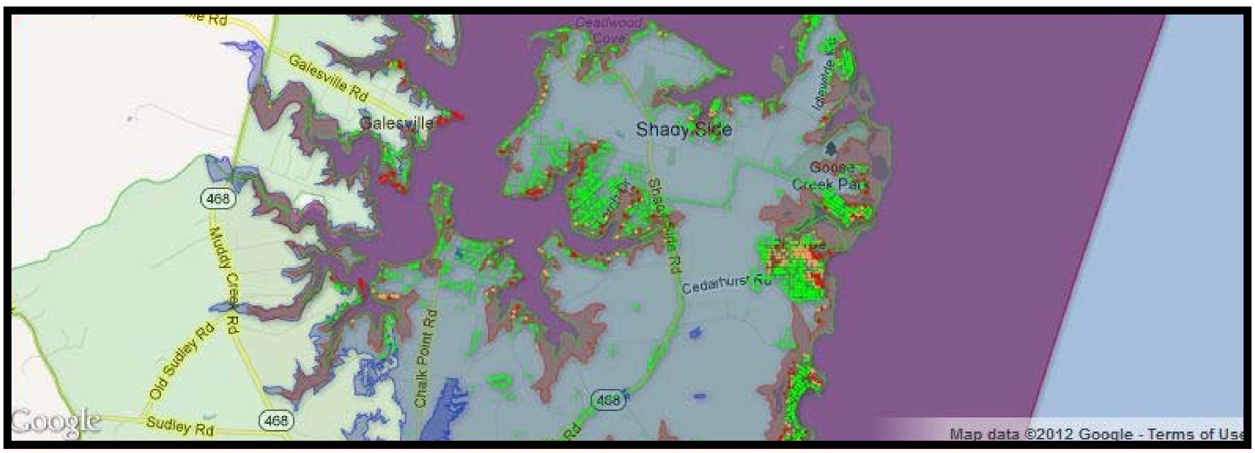
Severna Park



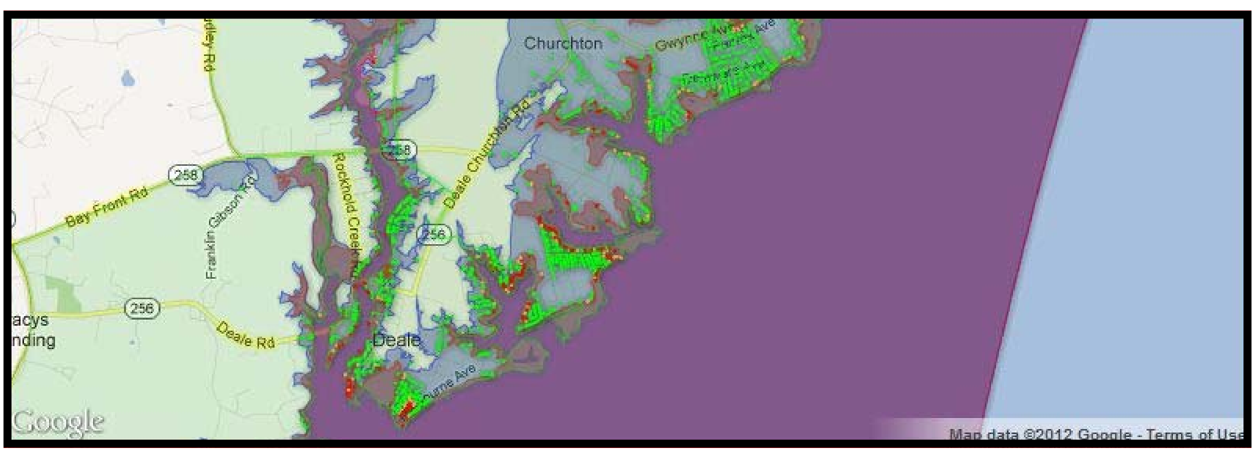
Selby-on-the-Bay and Highland Beach

PRIMARILY SINGLE-FAMILY, LOW-DENSITY RESIDENTIAL AREAS

Mayo



Shady Side



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3. Policy Strategies

In the previous section we described the science of sea-level rise and its impacts, so now the question is, what should communities and local governments do about it? How should communities decide what the priorities should be?

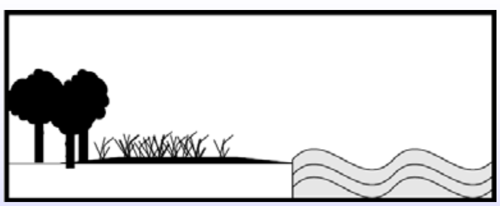
3.1 Long-term Strategies for Projected Coastal Flooding

There are three long-term strategies for responding to projected coastal flooding and sea-level rise:

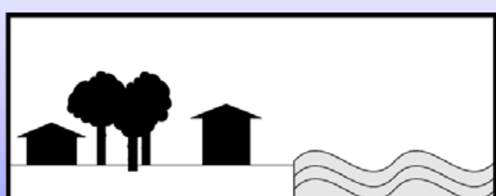
- **move inland over time**;
- **create more resilient communities**;
- **use natural and artificial barriers to protect against rising waters.**

In the following pages, we suggest possible approaches to each of these long-term strategies, and list advantages and disadvantages. We lay out potential strategies for different types of areas within the county, such as a park, residential community, or highly developed commercial and residential area. There is overlap in the types of choices that could be made for each of them, as your preferences may change depending on the context.

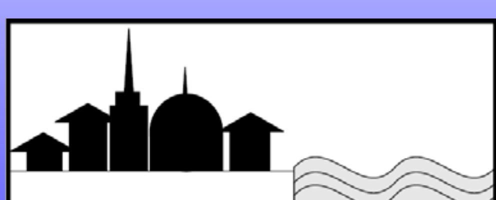
Think about how these approaches might work — or not work. These are complex questions with long-lasting implications.



Publicly Owned Natural Areas

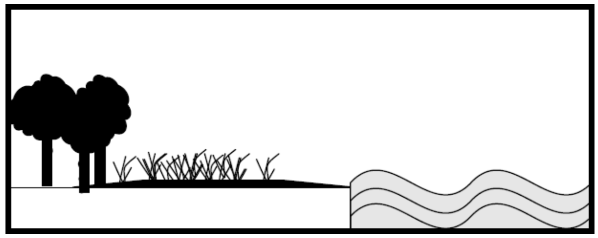


Residential, Low Density



Commercial and Residential, High Density

PUBLICLY OWNED NATURAL AREAS



Strategy #1. Buy adjacent lands to enable natural areas to move inland

How would it work?
Governments, private organizations or non-profits would buy property adjacent to existing public lands to enable habitats to move inland as waters rise. Private organizations or non-profits could donate the lands to the government for public use. The sale would be voluntary for the property owner.

Considerations
Governments and other organizations will need to prioritize which properties to target based on their future value in providing public access, wildlife habitat, and/or buffers to coastal flooding.

Advantages
Lands provide buffers against flooding, preserve wildlife and ecosystems, and ensure continued public access to coastal areas.

Disadvantages
Buying land is expensive. Government or other organizations will need to pay for maintenance, and may need to remove existing structures.

Strategy #2. Maintain beaches and health of wetlands against rising seas

How would it work?
Sand would be replenished in eroded public beach areas. Wetland areas would be restored and potentially elevated with dredged sediment.

Considerations
Depending on the rate of erosion and/or sea-level rise, and the geography, beach and wetland restoration may not be suitable. Dredged sediments may harm the environment.

Advantages
Healthy beaches and wetlands decrease land loss. They provide habitat for wildlife and space for public parks. Wetlands filter pollutants before they reach the Chesapeake Bay. "Living shorelines" are the preferred form of protection in Maryland *(2008 Living Shoreline Protection Act)*.

Disadvantages
Sand replenishment and wetland restoration can be costly and require long-term maintenance. Living shoreline projects may cause changes in local ecosystems, turning shallow-water habitats into marsh habitats.

Strategy #3. Build walls and other structural barriers along the shore to hold back coastal waters

How would it work?
Barriers like rock and sea walls would be placed along shorelines to reduce erosion and flooding. Structures could also be sited offshore to reduce impacts of higher sea levels. For example wetlands could be protected with levee and pump systems, or tidal gates.

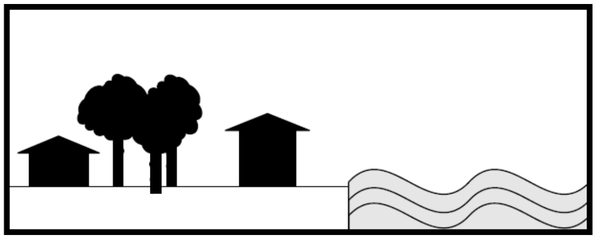
Considerations
Structural defenses are not preferred under Maryland law *(2008 Living Shoreline Protection Act)*. Maryland's Department of the Environment controls permitting for hard shoreline defenses.

Advantages
Shoreline barriers are familiar forms of erosion- and flood-control, and use well-tested engineering methods.

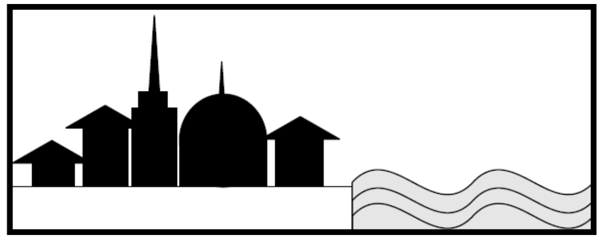
Disadvantages
Barriers and other hard structures are expensive to build, require maintenance, cause erosion of adjacent shorelines, and damage ecosystems. The aesthetics of natural areas may be compromised. Structures may lessen public access to the water.

Long-term strategies for responding to sea-level rise and coastal flooding in ...

BUILT COMMUNITIES



RESIDENTIAL
LOW DENSITY



COMMERCIAL AND RESIDENTIAL
HIGH DENSITY

Strategy #1. Retreat — or move — inland over time, restricting new building in areas likely to flood, and moving or abandoning existing structures

How would it work?

Community evacuations from coastal areas sometimes occur as the immediate result of severe storm damage. Optimally moving communities inland take place over long periods of time to minimize social and economic disruptions. This strategy would site new development away from coastal flood hazards, and relocate or abandon structures that become repeatedly or permanently flooded. An array of tools could be used:

- local government planning guidelines;
- changes in local zoning to restrict the development of structures in areas determined to be at risk of flooding;
- additional regulations on structures in floodplains;
- requirements to site buildings inland;
- prohibitions on hard shoreline barriers to maintain the area of public tidal lands as waters move inland;
- and tax benefits, compensation, or credits that homeowners would be able to sell, in return for accepting development restrictions.

Considerations

Planned moves inland require long periods of time to change community expectations and investment strategies regarding land use. Feasibility depends on the density of development, available adjacent land, and the challenges of moving existing structures.

Advantages
Moving inland reduces the exposure of the community to repeated damage from storms and flooding, and losses from permanent flooding (**inundation)**. It allows natural coastal processes to occur, and generally has fewer environmental impacts than shoreline protection.

Disadvantages
Changes in permitted land use will affect property values. Use of these types of tools is relatively new and may be difficult for governments to implement. Contaminated lands may need to be addressed before they are flooded.

Strategy #2. Maintain and restore natural areas such as wetlands as buffers against coastal flooding

How would it work?
The restoration and maintenance of natural shorelines would provide a buffer against flooding and storms. Governments would allocate space for wetlands to move inland by moving barriers. The addition of sand and sediment helps natural areas withstand erosion and flooding. Tools to ensure space for restoration include low density zoning; government land purchases; requiring siting of buildings away from the shoreline; "living shorelines" that provide natural protection from plants and other materials; renourishment of beaches with sand; and buying development interests from owners.

Considerations
Planning for movement of natural areas before adjacent lands are developed is most effective and least costly. The more highly developed the area, the less feasible it will be to provide enough space for the restoration and inland movement of natural areas.

Advantages
Maintaining natural front-line protection provides buffers from flooding and storms, habitat for wildlife, and filtration of run-off water. "Living shorelines" are the preferred form of protection in the State of Maryland *(2008 Living Shoreline Protection Act)*.

Disadvantages
Maintaining natural areas, and purchasing additional lands, can be costly. Federal permits may be needed if fill is required for beaches or wetlands. Living shorelines offer less certain protection against flooding than walls, bulkheads and other forms of structural protection.

Strategy #3. Design and retrofit buildings to be more flood resilient

How would it work?
Sometimes called "floodable development," new buildings and other structures are designed to withstand projected future levels of flooding. This is accomplished primarily through revised building codes and planning of community infrastructure projects. Tax incentives can be provided to retrofit buildings to higher standards. Buildings can be elevated above expected flood levels, tapping designs that reduce the effects of storm surge and placing habitable areas on upper levels. Floating structures are a novel — and extreme — example of this strategy.

Considerations
Local governments requiring new buildings to be more flood-resilient can assist residents in obtaining reduced premiums through FEMA's National Flood Insurance Program. Requiring higher standards for new building design is easier than retrofitting older buildings, particularly ones with historical value. Building public infrastructure to accommodate future sea level rise — such as roads, bridges and coastal drainage systems — is less expensive than later rebuilding.

Advantages
These types of actions are low cost and "low regrets" regardless of eventual sea-level rise impacts, and lessen the risk of flood damage.

Disadvantages
Living in areas of periodic flooding may pose risks. Flood events can be dangerous, and storm waters can carry contaminants that pose public health threats. Elevated buildings can make access more difficult for people with limited mobility. This strategy is more difficult to implement with existing structures.

Strategy #4. Build walls and other structural barriers along the shore to hold back coastal waters

How would it work?
Engineered structures — such as sea walls, bulkheads, and tidal gates — are placed along the shoreline or offshore to stabilize coastal lands, prevent erosion and protect against storm surge. They are used on both private and public property.

Considerations

Hard barriers are not preferred protection solutions under Maryland's Living Shoreline Act. Maryland's Department of the Environment controls their permitting. Protective barriers provide immediate short-term benefits. These may be outweighed by consideration of long-term maintenance costs, value of the structure being protected, and environmental and social costs. Hard defenses may be most suitable in areas with critical infrastructure and highly valuable development that cannot be easily moved or protected using other methods.

Advantages

Hard barriers have traditionally been used to withstand flooding. They can be implemented quickly to provide protection from flooding and erosion. Building protective structures takes less time than building up natural buffers or planned moves inland.

Disadvantages

Structures are designed to certain thresholds that may not withstand stresses under high sea levels and increased storm surges. Barriers prevent public access to the shore. They are expensive to build and require continued maintenance. Environmental impacts of shoreline barriers include erosion to adjacent areas, and loss of shoreline ecosystems. They also prevent wetlands from migrating inland as sea levels rise.

4. CONCLUSION

At the end of your deliberation you will have covered a large number of topics and have heard the views of other county residents — either in your group or through the survey report at www.FutureCoast.info — and the perspectives of people with expertise in the science, impacts and policy of coastal flooding and sea-level rise, using the online videos. We hope that you will have enjoyed the experience, and that your discussions will in turn promote a wider community conversation in Anne Arundel County.

The discussion may bring into focus community values regarding issues such as property rights, the role of government and the maintenance of public lands. Differences of opinion will always arise around these types of issues. The goal of the discussion isn't to resolve these differences, but to facilitate a process in which participants gain a greater understanding of the trade-offs of different approaches, and how they are viewed by other community members. As intersections of interest appear between groups, it may allow communities to move forward.

Thank you for your participation in this initiative. Please come back to the project website at www.FutureCoast.info to look for a final project report in late fall of 2012.

APPENDICES

RESOURCES

We have compiled a list of the primary resources that were used in developing the materials for the Future Coast project. Maryland state and local governments have been actively assessing how coastal flooding will impact shorelines in coming years, and what types of policies would lessen long-term damage to built communities and the environment. Their reports, along with a variety of other useful sources, are listed below. Links to these reports are also available on the website at www.FutureCoast.info.

State of Maryland

Boesch, D.F. (Ed.). (2008). *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland.* Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change. University of Maryland Center for Environmental Science, Cambridge, MD. Available at http://www.umces.edu/sites/default/files/pdfs/global_warming_free_state_report.pdf

Maryland Commission on Climate Change. (2008). *Maryland Climate Action Plan*. Available at http://www.msa.md.gov/megafile/msa/speccol/sc5300/sc5339/000113/010000/010896/unrestricted/20080365e-000.html

Maryland Commission on Climate Change. (2008). *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, Phase I: Sea Level Rise and Coastal Storms*. Report of the Maryland Commission on Climate Change Adaptation and Response Working Group. Maryland Department of Natural Resources, Annapolis, MD; Maryland Department of the Environment, Baltimore, MD; Maryland Department of Planning, Baltimore, MD. Available at http://www.dnr.state.md.us/coastsmart/pdfs/comprehensive_strategy.pdf

Boicourt, K., & Johnson, Z. P. (Eds.). (2011). *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, Phase II: Building Societal, Economic, and Ecological Resilience.* Report of the Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Groups. University of Maryland Center for Environmental Science, Cambridge, MD; Maryland Department of Natural Resources, Annapolis, MD. Available at http://www.dnr.state.md.us/climatechange/climatechange_phase2_adaptation_strategy.pdf

City of Annapolis

Whitney, Bailey, Cox & Magnani, LLC. (2011). *Flood Mitigation Strategies for the City of Annapolis, MD: City Dock and Eastport Area.* City of Annapolis Department of Neighborhood and Environmental Programs, Annapolis, MD. Available at http://www.annapolis.gov/Government/Departments/PlZon/CDAC/Presentation/Copy%20of%20SEA%20RISE%20STUDY%20Report%20City%20Dock%203-31-11.pdf

Whitney, Bailey, Cox & Magnani, LLC. (2011). *Flood and Inundation Mitigation Strategies, City of Annapolis, Maryland: Eastport Area*. City of Annapolis Department of Neighborhood and Environmental Programs, Annapolis, MD. Available at http://dnr.maryland.gov/CoastSmart/pdfs/Annapolis_FIMS_eastport.pdf

Environmental Resources Management, & Whitney, Bailey, Cox & Magnani, LLC. (2011). *Regulatory Response to Sea Level Rise and Storm Surge Inundation, City of Annapolis, MD*. City of Annapolis, Annapolis, MD. Available at http://dnr.maryland.gov/CoastSmart/pdfs/Annapolis_RRSLRnSSI.pdf

Anne Arundel County

Anne Arundel County. (2010). *Sea Level Rise Strategic Plan Anne Arundel County. Phase 1 Report: Vulnerability Assessment*. Anne Arundel County Office of Planning and Zoning, Annapolis, MD. Available at http://www.dnr.state.md.us/CoastSmart/ pdfs/AASLRStrategicPlan.pdf

Anne Arundel County. (2011). *Sea Level Rise Strategic Plan Anne Arundel County*. Anne Arundel County Office of Planning and Zoning, Annapolis, MD. Available at http://dnr.maryland.gov/CoastSmart/pdfs/AASLRStrategicPlan_final.pdf

Regional Sea-Level Rise

Boon, J. D., Brubaker, J. M., & Forrest, D. R. (2010). *Chesapeake Bay Land Subsidence and Sea Level Change: An Evaluation of Past and Present Trends and Future Outlook.* Virginia Institute of Marine Science, Gloucester Point, VA. Available at http://web.vims.edu/GreyLit/VIMS/sramsoe425.pdf

Boon, J. D., Wang, H., & Shen, J. (2008). Planning *for Sea-Level Rise and Coastal Flooding.* Virginia Institute of Marine Science, Gloucester Point, VA. Available at http://www.vims.edu/research/units/programs/icccr/_docs/coastal_sea_level.pdf

U.S. Climate Change Science Program. (2009). *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.* [James G. Titus

(Coordinating Lead Author), K. Eric Anderson, Donald R. Cahoon, Dean B. Gesch, Stephen K. Gill, Benjamin T. Gutierrez, E. Robert Thieler, and S. Jeffress Williams (Lead Authors)] U.S. Environmental Protection Agency, Washington, DC. Available at http://www.globalchange.gov/publications/reports/scientific-assessments/saps/sap4-1

Intergovernmental Panel on Climate Change reports

Bindoff, N.L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S., Hanawa, K., Le Quéré, C., Levitus, S., Nojiri, Y., Shum, C. K., Talley L. D., & Unnikrishnan, A. (2007). Observations: Oceanic Climate Change and Sea Level. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge and New York. Available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter5.pdf

Intergovernmental Panel on Climate Change. (1990). *Strategies for Adaptation to Sea Level Rise.* Report of the Response Strategies Working Group, Coastal Zone Management Subgroup. Available at http://epa.gov/climatechange/effects/downloads/adaption.pdf

Local Government Policy Tools

Grannis, J. (2011). *Adaptation Tool kit: Sea-Level Rise and Coastal Land Us*e. Georgetown Climate Center, Georgetown University, Washington, DC. Available at http://www.georgetownclimate.org/sites/default/files/Adaptation_Tool_Kit_SLR.pdf

Nuckols, W. H., P. Johnston, D. Hudgens, & J. G. Titus. (2010). Maryland. In James G. Titus and Daniel Hudgens (editors). *The Likelihood of Shore Protection along the Atlantic Coast of the United States.* Volume 1: Mid-Atlantic. Report to the U.S. Environmental Protection Agency. Washington, DC. Available at http://risingsea.net/ERL/shore-protection-retreat-sea-level-rise-Maryland.pdf

Titus, J. G. (2010). *Rolling Easements.* Climate Ready Estuaries Program, U.S. Environmental Protection Agency, Washington, DC. Available at http://www.epa.gov/cre/downloads/rollingeasementsprimer.pdf

Coastal Wetlands and Habitats

Glick, P., Clough, J., & Nunley, B. (2008). *Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region: Technical Report.* National Wildlife Foundation, Reston, VA. Available at http://www.nwf.org/~/media/PDFs/Global-Warming/Reports/FullSeaLevelRiseandCoastalHabitats_ChesapeakeRegion.ashx

DATA SOURCES FOR COASTAL FLOODING AND SEA-LEVEL RISE VIEWER

Changes to coastal tidal inundation and episodic coastal flooding were estimated by increasing current day conditions by the projected changes to sea level for each scenario and year. Inundation was defined as land with elevations less than the local mean higher high water tidal datum. Episodic coastal flooding was defined as the FEMA 1% annual chance floodplain, also referred to as the “100-yr floodplain.” The extent of flooding was determined using standard flood modeling practices and high resolution/high accuracy topographic data. Flood depths were determined by subtracting water surface elevations from the topography.

Impacts were evaluated by intersecting the flood extents with building footprint data. First floor elevations were estimated using lowest and highest adjacent grade relationships for each structure, with grade elevations derived from the building footprint and digital elevation model. Flood depth was attributed to each structure, and then potential damages were estimated by application depth damage functions sourced from FEMA Benefit-Cost Analysis Flood Module. All structures were assumed to be slab-on-grade construction. Structures having basements were differentiated in the depth-damage function analysis. Damages were generalized into three categories: minor (>25% damages), moderate (>25%, <50% damages), and severe (>50%) damages.

Floodplain. Floodplain elevations were provided by the Federal Emergency Management Agency (FEMA). Storm surge elevations were sourced from the regional storm surge modeling effort completed in 2011.

Elevation. Elevation data for floodplain and inundation modeling were sourced from Anne Arundel County. These data were collected by the Maryland Department of Natural Resources. The dataset was derived from countywide high-accuracy/high-resolution LiDAR ground elevations measured in 2004. The vertical accuracy of this dataset was tested to have a root mean square error of 14.3 centimeters (5.6 inches). These data were processed from a tile format into a continuous elevation model.

Tidal Inundation. Ground elevations less than the elevation of the mean higher high water (MHHW) tidal datum were labeled “inundated.” MHHW is defined by NOAA as “the average of the higher high water heights of each tidal day observed over the National Tidal Datum Epoch.” The elevation was established using the NOAA Vdatum tool. This software application provides conversions between tidal and geodetic datums in overwater areas. A continuous MHHW surface for Anne Arundel County was developed through a standard application of this tool.

Building Footprints. Building footprints were sourced from Anne Arundel County. These data were originally developed from 2002 orthophotography and later updated against 2007 orthophotogrpahy. Changes in the built environment subsequent to 2007 are not reflected in this dataset.

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