Coastal Land Conservation in Maryland: Targeting Tools and Techniques for Sea Level Rise Adaptation and Response

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for

Maryland Department of Natural Resources
Chesapeake and Coastal Service
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In partnership with:

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Introduction

The iconic Chesapeake Bay, one of the largest and historically productive estuaries in the world, recognized by Native Americans as *Tschiswapeki* – great shellfish bay – is approaching potentially unprecedented landscape changes due to compounded effects of increased coastal erosion, storm intensity and frequency, and sea level rise associated with climate change. Maryland has over 4,000 miles of coastline with the majority of the coastal zone[1] experiencing naturally occurring land subsidence. Current estimates suggest that relative sea level rise is impacting coastal lands at twice the global average rate. Over the last century relative sea level in the Bay has risen one-foot due primarily to land subsidence and global sea level rise. Rising waters have contributed to the disappearance of 13 Bay islands. The low lying, sinking coastal areas make Maryland uniquely vulnerable to the effects of sea level rise. The sea level rise exhibited in the Chesapeake Bay over the past century is not purely eustatic rise but rather a result of land subsidence. Land subsidence is caused by a variety of factors including: compression of surface sediment layers, isostatic rebound from the last glaciation, tectonic plate movement, groundwater extraction causing subsurface compaction, and depression of continental margin by weight of sediment and seawater (Maryland Commission on Climate Change 2008a, Figure 1).

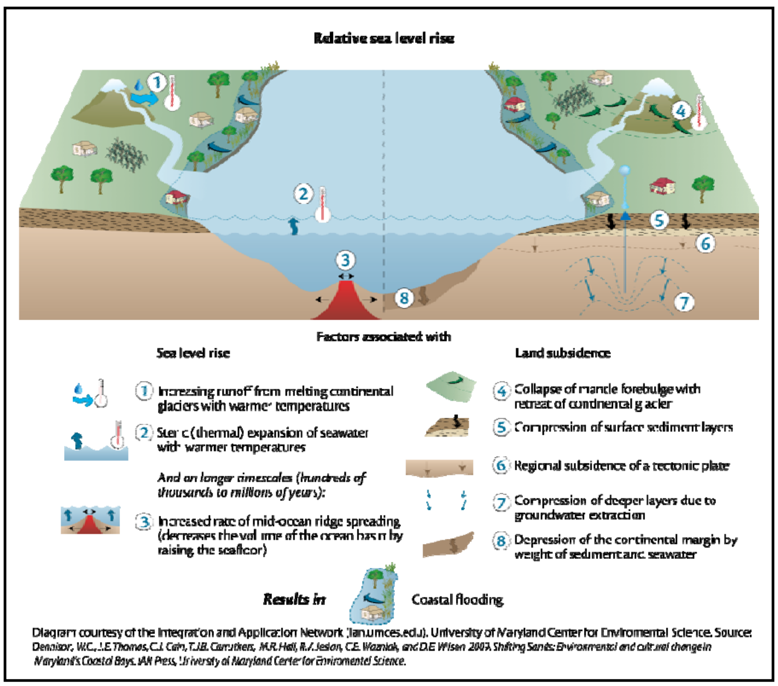

Figure 1: Relative sea-level rise is a result of a combination of factors. Sea-level rise is the combination of the increase in volume of water as a result of global warming and decrease in size of the ocean basins due to mid-ocean ridge spreading. Land subsidence is a consequence of various factors which result in the land surface sinking, reducing elevation. Sea-level rise and land subsidence combine to result in relative sea-level rise.

[1] Maryland's Coastal Zone includes all counties and municipalities that border the Chesapeake and Coastal Bays and the Atlantic Ocean. There are 16 coastal counties (Baltimore, Anne Arundel, Prince George's, Calvert, St. Mary's, Charles, Howard, Cecil, Queen Anne's Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worcester) and Baltimore City covered under Maryland's Coastal Zone Management Program.

Many of the islands lost played a role in Maryland's maritime culture as year-round residences for Chesapeake Bay watermen communities. Like island communities, many coastal communities in today's landscape are being threatened by encroaching waters. Today there is only one inhabited island left in Maryland's portion of the Bay– Smith Island. The effects of sea level rise have not only contributed to the loss of bay islands but also pose a threat to Maryland's coastal systems.

Research by the University of Maryland indicates that sea level rise may cause the loss or degradation of up to 70% of the state's tidal emergent marsh systems within the century (Kearney et. al., 2002). Noticeable losses may even become evident within 10 years. Currently the State of Maryland is losing 580 acres a year due to shoreline erosion, which will only continue to exacerbate with projected sea level rise and extreme storms. Over the past century, coastal erosion contributed to a loss total of 18,000 hectares of coastal lands in the Chesapeake Bay (Wray et al., 1995).

The effects of sea level rise on the landscape will likely vary throughout the Chesapeake Bay depending on wetland habitat, elevation, sediment capture and accretion rates. The most vulnerable areas are on the eastern shore of Maryland where land has limited elevation relief and current wetland degradation is already being witnessed. An example of this is the vast marshes of Blackwater National Wildlife Refuge (Figure 2).

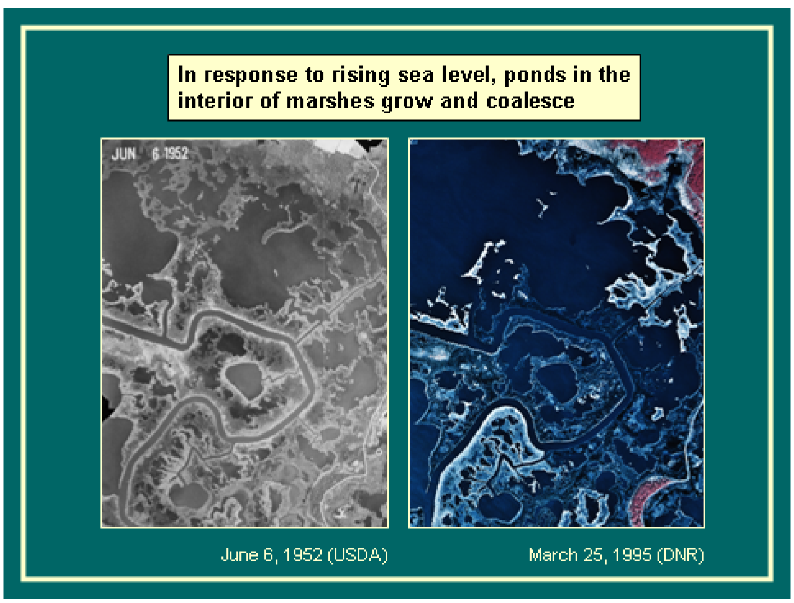

Figure 2: Marsh breakup at Blackwater National Wildlife Refuge as relative sea level rise pushes marshes to keep pace above sea level (Hennessee et al. 2004).

Recognizing this problem, the Maryland Department of Natural Resources (DNR) released the report *A Sea Level Rise Response Strategy for the State of Maryland* (Johnson, 2000). This preliminary report reviewed the sea level rise literature and associated research, identified Maryland's vulnerability, and assessed Maryland's existing response capabilities.

In 2008, Maryland released another strategy to address the impacts of sea level rise and coastal storms. The Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change was a key component of Maryland's Climate Action Plan (2008). Among other many other recommendations, the Strategy lays out key policy recommendations to proactively identify and protect coastal habitat that will help mitigate interim impacts and provide long-term adaptation potential. In response to these key policy recommendations the Maryland DNR completed a targeting project that assessed the future location wetlands under predictive sea level rise modeling. From this modeling key conservation targeting criteria were developed that focused on size, location and diversity of future wetland classes within Maryland's coastal zone. Through this effort Maryland may be better able to protect coastal land and preserve distinct habitat, facilitate shoreline habitat retreat, mitigate coastal hazards, and reduce storm surge impacts.

Developing these new criteria to target land acquisitions and conservation easements is a critical adaptation strategy for Maryland. In order to address these impacts, the Maryland DNR has been developing new land conservation strategies to help preserve the long-term survival of coastal wetlands that provide storm surge buffering to communities as well as critical habitat for aquatic and terrestrial species.

Background

In April, 2007 the Governor of Maryland signed the Executive Order 01.01.2007.07 that established the Maryland Commission on Climate Change. The Commission was tasked to develop a climate change action plan that assessed the regional drivers of climate change, likely impacts in Maryland, and adaptation options and goals. In August 2008, the Commission released the "Climate Action Plan". The Commission's Adaptation and Response Working Group was charged with developing strategies and policy recommendations to reduce the vulnerability and increase the state's resilience to climate change. The Adaptation & Response Working Group produced Chapter Five of the Climate Action Plan, titled *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, Phase I: Sea Level Rise and Coastal Storms*.

The chapter details Maryland's acute vulnerability to rising sea-levels and proposed 19 policies that would enhance the state's resilience to climate change. In the natural resource section of this chapter, guidance was given to "protect and restore the State's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay islands, that inherently shield MD's shoreline and interior". A suite of priority policy recommendations were set forth to address this goal, two of which were used to directly guide this project:

- Identify high priority protection areas and strategically and cost-effectively direct protection and restoration activities; and
- Develop and implement a package of appropriate regulations, financial incentives, and educational, outreach, and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival.

Recommendations from Maryland's Climate Action Plan were the key drivers of this project and were further supported by a previous wetland assessment report on Chesapeake and Delaware Bays by the National Wildlife Federation. This report was based on the outcomes of SLAMM version 5 modeling. The report outlined responses by government and non-government decision makers to:

- Prioritize project sites based one ecological importance as well as vulnerability to sea-level rise;
- Expand restoration areas and coastal protection strategies to accommodate for habitat migration; and

- Restore and protect a diverse array of habitat types to better support ecosystem functions and improve resiliency of fish and wildlife species.

In the Climate Action Plan, the Scientific and Technical Working Group reviewed the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) along with additional global sea-level rise models, such as Rahmstorf (2007) and set forth sea level rise scenarios for the Chesapeake Bay. The projections for Maryland are as follows: under a lower emissions scenario Maryland may experience up to 1.3 foot of rise by the year 2050 and 2.7 feet by 2100 and under a higher emission scenario it was estimated that 1.7 feet by 2050 and 3.4 feet by 2100 (Figures 3 & 4).

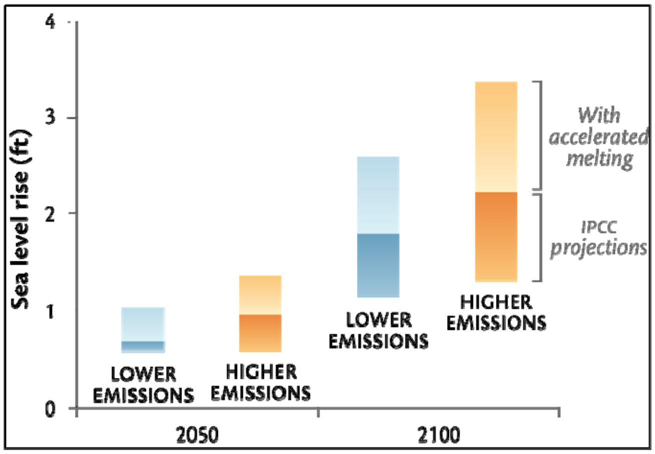

Figure 3: Sea level rise projections for the Chesapeake Bay based on greenhouse gas emission scenarios. By mid-century Maryland may experience up to 1.3 ft and, by the end of the century under accelerated melting relative sea-level may rise 2.7 ft under lower emission scenario to 3.4 ft under the higher emission scenario (MCCC, 2008).

Figure 4: Rates of sea-level rise in Chesapeake and Delaware Bays region. Data are from tide gauges and the period of time they cover is in parentheses (MCCC, 2008).

With these guiding policy recommendations and sea-level rise projections, Maryland DNR undertook a 2-year project to develop geospatial-based evaluation criteria to help identify and target coastal lands that could help the State of Maryland adapt to climate change. As Maryland endeavors to adapt to climate change, the Climate Action Plan recommended that new data on climate change vulnerability and adaptation opportunities, be added to the GreenPrint targeting tool. In December of 2008, Maryland launched a mapping tool called "GreenPrint" to prioritize lands for conservation across the state based on ecological data. GreenPrint uses geospatial software to create color-coded maps of information layers and aerial photographs to help land managers implement conservation strategies and identify land acquisition priorities.

The GreenPrint tool has allowed the DNR to select ecologically valuable lands through the designation of Targeted Ecological Areas (TEAs) for conservation priority. By updating the designation of TEAs with climate change priority areas, GreenPrint will help Maryland make long-term conservation plans with future coastal conditions in mind. As a component of the project, the climate change priority areas were added to the parcel-level scorecard that systematically quantifies the adaptive benefits of a parcel of land relative to others.

Implementation Overview

Maryland has been a leader in planning for the effects of climate change as evident by the 2000 report on climate change response strategies (Johnson). When the Governor signed the Executive Order creating the Commission on Climate Change, many agencies within Maryland were already incorporating climate change into their work, easing the transition into the Climate Action Plan.

In May of 2009, the Department of Natural Resources Chesapeake and Coastal Service (CCS) was awarded a NOAA Coastal Management Fellow. The NOAA Coastal Management fellow joined Maryland DNR CCS in August 2009. Much of the work on identifying and creating a new geospatial-based targeting model for climate change adaptation was completed by the Coastal Fellow (2009-2011). The project was supported and funded by the Department of Natural Resources, Chesapeake and Coastal Service through the NOAA Coastal Zone Management Act of 1972, and NOAA Coastal Services Center as part of the NOAA Coastal Management Program.

In early 2010, during the planning stages of the targeting model, Maryland's Board of Public Works, including the Governor, Comptroller and Treasurer requested that all parcels being pursued for state conservation funding through Program Open Space be reviewed for climate change vulnerability before the Board's approval. To meet this request, a parcel-level evaluation form was developed to aid in the review of all pending state conservation easements and acquisitions within the coastal zone. The evaluation form was developed to enable the DNR Chesapeake and Coastal Service (CCS) to review all State conservation easements and acquisitions by evaluating site-level attributes that support climate change adaptation, including storm surge abatement and resiliency; mitigation and restoration opportunities that would increase the viability of coastal ecosystems and/or the carbon sequestration of the site; and future human ecology[2] attributes. Reviews were completed on a project-by-project basis using spatial data and geospatial mapping tools, including ArcGIS 9.2 and Maryland's Coastal Atlas.

The original evaluation form was updated after the completion of the climate change adaptation model to incorporate key components of the identified wetland adaptation areas and wetland migration corridors. The evaluation form continues to be used for stewardship review– an inter-agency review process required for any parcel of land being considered for state conservation funds. A working version of the Climate Change evaluation form and supporting data guide can be downloaded from DNR's Chesapeake and Coastal Service's project webpage.[3]

In addition, Maryland DNR Coastal Program developed training materials to help other agencies and non-governmental organizations incorporate climate change into their land conservation

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[2] Human Ecology describes connections between people and the world around them. The right land conservation projects can build bridges between human well-being and natural areas giving people the opportunity to understand the value of land, experience its beauty, empower their communities, heal its wounds and become healthier in the process.

[3] Maryland's Evaluation Criteria For Coastal Land Conservation: In Response to Climate Change Impacts of Sea Level Rise
http://www.dnr.state.md.us/CCS/pdfs/MDCCSEForm_July2011.pdf
Maryland's Companion Data Guide For Conservation: Climate Change Data Layers for Parcel Level Evaluation
http://www.dnr.state.md.us/CCS/pdfs/MDCCDataGuide_July2011.pdf

and restoration targeting and review processes. A pilot training was held with Maryland Environmental Trust (MET) regional planners on January 13, 2011. Following the initial screening and feedback from MET, DNR CP co-hosted a training with MET and Defenders of Wildlife on June 30, 2011 which focused on the application of DNR's new climate change data and use of *Coastal Atlas* as a tool for land trusts working in Maryland's coastal zone.

Developing the Targeting Model

Prior to developing the targeting model, a literature review was carried out to select a suite of existing recommendations on climate change adaptation strategies for coastal areas. Specific adaptation strategies were identified to help address climate change responses for the following resource sectors: Aquatic & Terrestrial Ecosystems, Transportation & Land Use, Human Habitat & Health, Resource Based Industries, and Agriculture. These strategies were presented during a December 2009 workshop entitled, "Coastal Land Conservation and Climate Change" organized and co-hosted by NOAA Fisheries Office of Habitat Conservation, NOAA Coastal Services Center and Maryland DNR. The goals of the workshop were to: identify and prioritize climate change adaptation strategies in the context of coastal land conservation; develop criteria for evaluating and targeting on-the-ground implementation of climate change adaptation strategies through coastal land conservation practices; and, identify data sources supportive of the identified criteria. The recommended adaptation strategies and criteria from the workshop were further developed and added to the project as new evaluation criteria for land acquisitions. All of the workshop materials, including the recommended criteria are available for download on Maryland's Chesapeake and Coastal Service website.[4]

One of the most important criteria identified at the December workshop was to identify a means in which to help *facilitate landward movement of coastal wetlands subject to dislocation by sea level rise*. This was identified as cross-cutting criteria that would benefit all sectors having application for adaptation responses to sea level rise. The potential loss of ecological functions coastal wetlands provide would affect all sectors through the loss of storm surge abatement, wildlife habitat, flood management and control, water quality, to name a few.

[4] Maryland Department of Natural Resources, Chesapeake and Coastal Service http://www.dnr.state.md.us/CCS/habitats_slr.asp

en Fertig, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

Jug Bay Wetlands Sanctuary, Chesapeake Bay National Estuarine Research Reserve in Maryland

Why Wetlands?

Wetlands provide critical ecosystem benefits around the world and play a significant role in Maryland's coastal ecosystem. Maryland's rich maritime culture is dependent on the nursery and rearing habitat wetlands provide, not to mention, wetlands help create the aesthetic beauty that makes the Chesapeake Bay unique. Wetlands provide valuable benefits that, if given the opportunity may continue to be provided into the future under sea level rise conditions.

In order to maintain coastal wetlands under sea level rise conditions, wetlands must accrete at a faster or equal rate of sea level rise, have a positive elevation gradient inland, and have limited barriers such as hardened shorelines or other impervious surfaces inland from their current existence. Wetland migration corridors make up some of the most important areas for coastal adaptation in response to sea level rise. These areas are designated by forecasting where wetlands may establish inland as sea levels rise, often in areas currently designated as non-wetland hydric soils. Maintaining areas for wetland migration may provide opportunity for inland retreat of Maryland's coastal and nearshore wetlands that provide a variety of ecosystem services such as, wildlife habitat, water quality improvement, storm surge abatement, flood mitigation, aquifer recharge, carbon sequestration, erosion control, recreation and potentially groundwater recharge.

Maryland has roughly 600,000 acres of vegetated wetlands (9.5% of state's land surface) of which palustrine or freshwater wetlands make up 342,626 acres (88.7% are non-tidal) and 251,542 acres of estuarine wetlands or salt and brackish wetlands (Clearwater, et al. 2000). Maryland's coastal wetlands provide important habitat, shoreline stabilization, carbon storage, storm surge buffers, and nutrient filtration, among many other benefits.

"…tidal freshwater marshes are critical buffers protecting estuarine and coastal waters from sediments, nutrients, and toxics derived from deleterious upland human activities and land use"

(Pasternack & Brush, 1998)

As sea levels rise, coastal marshes may be able to migrate inland through the trapping of sediment and the buildup of organic matter. Coastal wetlands form in areas of sedimentation, and in Maryland many of the vast wetland networks have developed along tidal rivers and estuarine embayments, such as the Choptank, Chester, Patuxent, Potomac, and Nanticoke Rivers (Tiner, R.W. and D.G. Burke, 1995). As mentioned, wetland migration is dependent on multiple factors including a positive elevation gradient or slope inland, sediment supply, limited impervious barriers and intact habitat corridors to name a few. Preserving intact coastal corridors for marsh migration is an adaptive approach to address the environmental impacts of sea level rise associated with climate change. It has been estimated that almost 60% of the low-lying land along the U.S. Atlantic coastline is expected to be developed and thus unavailable for the inland migration of coastal wetlands (Titus et al., 2009).

Historic and Projected Wetland Response

During the end of the last glacial period, the Pleistocene epoch that occurred more then 15,000 years ago, there was a period of rapid eustatic sea level rise that lasted around 4,000-5,000 years as the Pleistocene glaciers melted. The northern ice sheet called the Laurentide came down to 37 degrees latitude, around Pennsylvania border and reached thickness in some areas as much as 8-10,000 feet or more. The weight and mass of the glacier was "sufficient to deform the earth's crust. The mantle material beneath that part of the crust was forced to move outwards forming a bulge around the periphery of the ice sheet" (NOAA CSC, 2000).

After the retreat of the glaciers, the land started a post glacial rebound adding to the rate of relative sea level rise in Maryland and around the Chesapeake Bay. This gradual sinking or land subsidence, in addition to global sea level rise is called relative sea level rise. After the last glacial period and "sea level rise slowed to near zero, but has continued gradually throughout, creating conditions favorable for marsh development and long-term accretion at rates equaling or exceeding sea level rise" (Titus, 1987 cited Emery and Uchupi 1972; Redfield 1972; Davis 1985). Around 3,000 to 4,000 years ago, coastal wetlands stabilized with sea level (Tiner, R.W. and D.G. Burke, 1995).

As sea levels rise in response to global climate change, coastal wetlands will likely be threatened by submergence in the coastal zone. Non-tidal wetlands may become tidally influenced and freshwater systems may convert in to a more saline environment. Forest vegetation will slowly be replaced by salt-tolerant marsh plants. Though the timeframe for this soil conversion is estimated at 180 ± 35 years, and with the current rate of sea level rise this timeframe is reduced by 63% (Hussein, 2009) there may still be a chance for wetlands to respond if conditions are right. Coastal marsh soils may be maintained as low-lying forest soils (ultisols) become inundated by rising water, they may convert to marsh soils over time (histosols) (Hussein, 2009). The inland wetlands established during the Pleistocene epoch will be critical areas for the retreat and establishment of coastal wetlands (Titus, 1987). Rising water tables associated with sea level rise will likely expand existing freshwater systems, further establishing a migration corridor and suitable soils for the inland migration of coastal wetlands.

In response, long-term planning for coastal adaptation should include the protection of wetland corridors to help facilitate the movement of important coastal wetlands inland as they attempt to keep pace with rising waters. In order to proactively respond, wetland modeling with sea level rise was a major component of this project. Predictive results were used to identify areas with the most potential for wetland migration corridors and new wetland areas that can be used to target wetland restoration and conservation activities.

Review of Wetland Models

In order to address the adaptation responses identified by the December workshop and develop a new targeting model for wetland corridors, wetland models were examined for the development of data that could help indicate where wetland migration, loss, and transition may occur in the future under sea level rise conditions.

For decades researchers have studied and modeled wetland response to sea level rise to assess long-term and short-term vulnerability of our dynamic coastal systems. To be able to assess the likelihood of future wetland migration corridors, DNR explored the marsh models available for landscape scale projections. There are additional hydrodynamic models that can be used at the site scale with site specific data, but the extensive data needed for this, and the time intensity of completing a site specific study around the Chesapeake Bay were limiting factors for a two-year study.

As a result the fellow researched reviewed two landscape scale wetland models for addressing the project criterion – *to help facilitate landward movement of coastal wetlands subject to dislocation by sea level rise*. One model was developed by the NOAA Coastal Services Center (CSC) called Marsh Migration Model and the other model was originally developed with Environmental Protection Agency (EPA) funding in the mid-1980’s and is currently being updated and maintained by Warren Pinnacle Consulting, Inc. called Sea Level Affecting Marshes Model (SLAMM). Both models are driven by the same elevation rule-set but differences were found in how the freshwater and upland areas broke out. The charts below provide a quick comparison of the two model parameters (Figure 5).

NOAA Coastal Services Center Wetland Migration Model

- One accretion average for all wetland types
- Elevation data: Digital elevation model built using National Elevation Data (NED) or high resolution elevation data (LiDAR)
- No model inputs for: subsidence, erosion, backwash, overwash, diked areas
- Same elevation rule-set used by SLAMM
- Sea Level Rise Scenarios of the Intergovernmental Panel on Climate Change (IPCC)

SLAMM version 5

- Accretion average rate for 3 wetland types (tidal marsh, brackish marsh and freshwater tidal marsh)
- Elevation data: Digital elevation model (DEM) built using National Elevation Data (NED) or high resolution elevation data (LiDAR)
- Historic sea level rise trends
- Model inputs for: tidal data, salinity, overwash, backwash, diked wetlands, impervious/developed areas, and beach sedimentation rates
- Sea Level Rise Scenarios of the Intergovernmental Panel on Climate Change (IPCC)

Figure 5: Comparison of wetland model parameters from NOAA Coastal Services Center Wetland Migration Model and SLAMM version 5 used by National Wildlife Federation in their 2008 study of the Chesapeake and Delaware Bays. The most notable differentiation between the models was the ability to modify additional parameters with SLAMM, including accretion, erosion, salinity, backwash, barrier island overwash, sedimentation rates and diked wetlands.

The NOAA Coastal Services Center's model estimated wetland conversion and movement inland as sea-level rises using the same elevation and wetland principles as SLAMM. However, there are a number of differences between the models. One of which is the number of model parameters offered by the CSC model. Fewer parameters may lead to less error as figures are extrapolated to the landscape scale, requiring less technical data, and cutting down the run-time for regional or state scale projects. The model can use either Light Detecting and Ranging (LiDAR) or lower resolution elevation data and wetland data from either the Coastal Change Analysis Program (CCAP) or National Wetland Inventory (NWI).

However, there were limitations to the CSC model in that it did not break up accretion rates for wetland types. A single wetland accretion rate was input for the model. In addition, the model did not factor in the following parameters: subsidence, erosion, backwash, overwash, and diked wetlands.

These parameters were found as part of SLAMM v5. The SLAMM v5 primary process was to simulate wetland conversions and shoreline modifications during long-term sea level rise. There were five primary processes used by the model that affect the wetland change under the sea-level rise scenario. They are listed in the following:

Inundation: The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level (MTL) constant at zero. Spatially variable effects of land subsidence or isostatic rebound are included in these elevation calculations. The effects on each cell are calculated based on the minimum elevation and slope of that cell.

Erosion: Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open-ocean. When these conditions are met, horizontal erosion occurs at a rate based on site- specific data.

Overwash: Barrier islands of under 500 meters width are assumed to undergo overwash at a user-specified interval. Beach migration and transport of sediments are calculated.

Saturation: Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.

Accretion: Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain.[5]

Along with model parameters, DNR reviewed the best available vegetation cover data to use for model application. For county wide coverage, Maryland is limited to lower resolution data, since site-level vegetation exists only in select areas. The options reviewed and available for all of Maryland's coastal counties and municipalities were National Wetland Inventory (NWI) and Coastal Change Analysis Program (C-CAP) datasets. A comparison of wetland classes from the NWI SLAMM and C-CAP breakouts was conducted with results compared in Figure 6. The NWI wetland class breakout was more specific with discrete habitat types then the C-CAP wetland data and could be compared to the previous SLAMM study by NWF, thus it was chosen for this mapping project. It was important to ensure the best breakdown of wetland classes so that key groupings could be selected as priority under future wetland conditions, since some wetlands are more vulnerable then others and are relied on by threatened species for habitat (e.g. high marsh habitat is extremely important to black rail).

National Wetland Inventory (NWI) Data

SLAMM 5 classification breakouts

- Scrub Shrub
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Regularly Flooded Marsh
- Irregularly Flooded Marsh
- Estuarine Beach
- Estuarine Water
- Tidal Fresh Marsh
- Tidal Flat
- Tidal Swamp
- Riverine Tidal
- Inland Shore
- Inland Open Water
- Tidal Creek
- Rocky Intertidal

NOAA Coastal Change Analysis Program (C-CAP) Regional Land Cover Data

NOAA CSC's Wetland Migration Model

- Palustrine Forested Wetland
- Palustrine Scrub/Shrub Wetland
- Palustrine Emergent Wetland
- Estuarine Forested Wetland
- Estuarine Scrub/Shrub Wetland
- Estuarine Emergent Wetland
- Palustrine Aquatic Bed
- Estuarine Aquatic Bed
- Unconsolidated Shore
- Bare Land
- Water

Figure 6: Comparison of vegetation cover datasets indicate that the NWI breakout used by NWF (2008) study provides more diversity of wetland classes with the additional distinction within Estuarine and Palustrine classes.

[5] Warren Pinnacle Consulting, Inc. SLAMM Model Overview http://warrenpinnacle.com/prof/SLAMM/index.html

After comparing the two models, DNR took a further look at an updated beta version of SLAMM. The National Wildlife Federation (NWF) completed a SLAMM version 5 study in 2008 that included areas in Chesapeake and Coastal Bays and Delaware Bay. The NWF study focused on large-scale extents both in Maryland, Delaware and Virginia using National Elevation Data (NED). During the model review process, Warren Pinnacle Consulting, Inc. released a beta version for SLAMM 6 that allowed the user to plug in additional parameters; including high resolution elevation data (see Figure 7). Maryland had recently acquired statewide high resolution elevation data or LiDAR and there was interest in re-running SLAMM catered specifically to available county level data for all of Maryland's coastal counties and Baltimore City. Since SLAMM v5 had been run by NWF, DNR was able to do a quick comparison of version v5 model outputs with the latest beta version v6 using the higher resolution elevation data. A case study was run in Dorchester County Maryland to assess the difference between model projections for wetland migration at the county extent.

Breakdown of SLAMM v6 Updated Parameters

- Newer more robust accretion formula
- Site-specific high resolution elevation data compatible
- New salinity model
- Site-specific data can be specified
- OpenGL 3D Rendering of SLAMM landscapes
- Backwards compatibility to SLAMM v5 files

Figure 7: SLAMM version 6 updates included additional parameters for site specific data and the capacity for higher resolution elevation data.

SLAMM v6 was run in Dorchester County to compare the newly updated parameters, including high resolution elevation data with the results from SLAMM v5. As a result, the SLAMM v6 model run using high resolution elevation data (LiDAR) and the IPCC A1B climate scenario for year 2100 produced increased nearshore resolution, most notably producing tide flats by year 2100 that were not indicated using the courser NED dataset. See Figures 8 & 9, on the following page, as they visually compare the A1B scenario results using National Elevation Data (NED) for SLAMM v5 and LiDAR for SLAMM v6. As a result, DNR decided to use SLAMM v6 due to the improved wetland accretion formula; ability to input 3 wetland accretion rates based on wetland type; ability to run the model with LiDAR; use of NWF's wetland classification from their study; and the potential of comparing the results with the previous SLAMM v5 study.

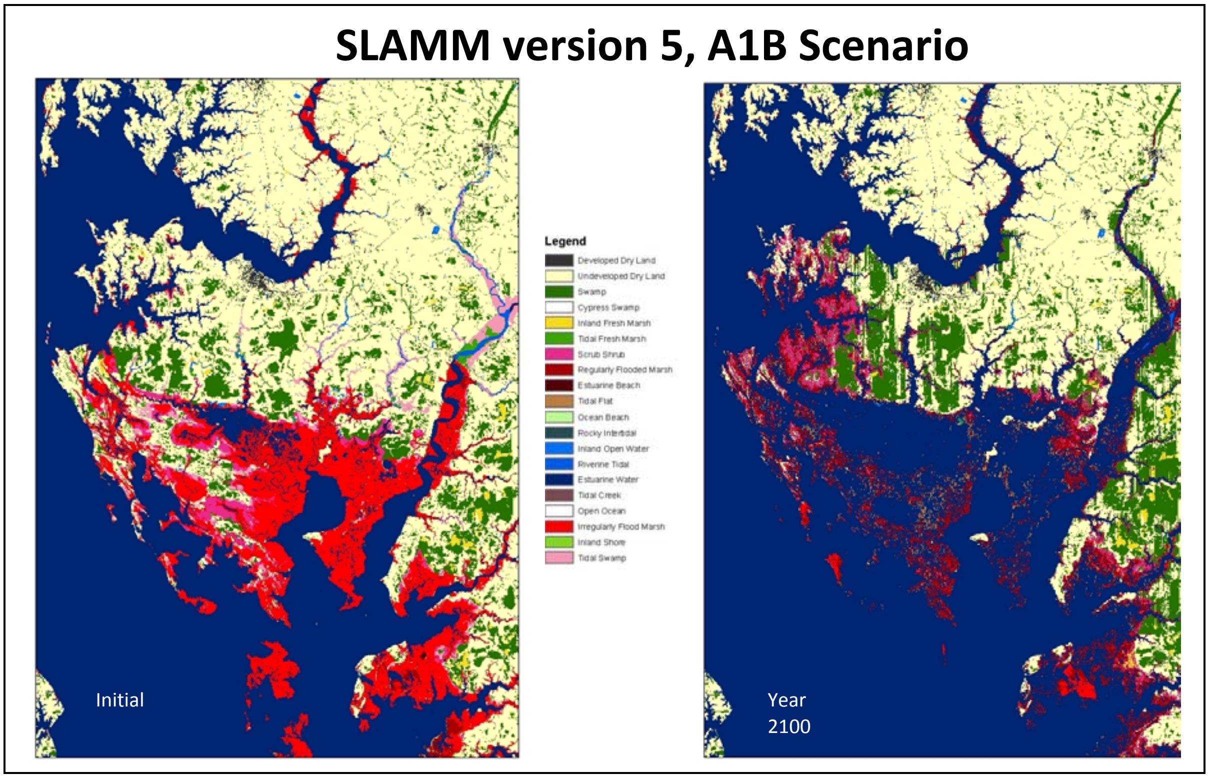

Figure 8: SLAMM v5 was run using A1B climate scenario produced by the Intergovernmental Panel of Climate Change with National Elevation Data (NED). The results show that by year 2100 the majority of the irregularly flooded marsh (bright red) would be lost to open water (blue) or converted to regularly flooded marsh (dark red).

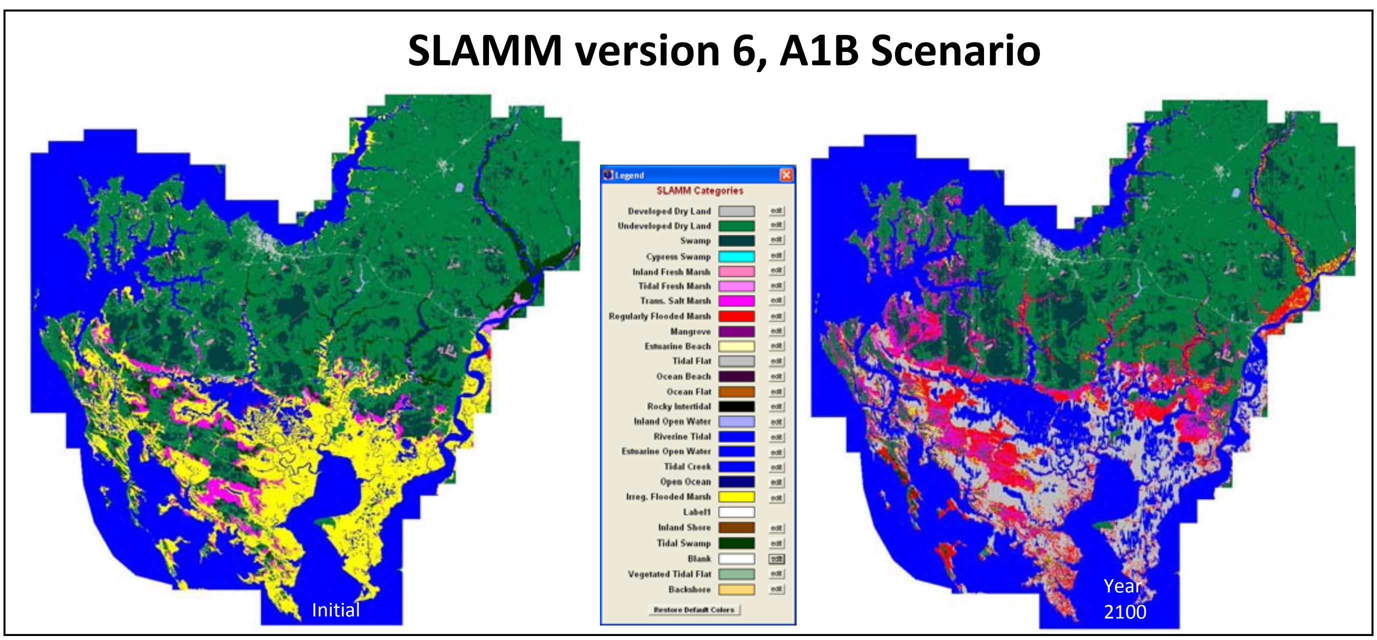

Figure 9: SLAMM version 6 was run using the same parameters and datasets as SLAMM v5 with the exception of higher resolution elevation data (LiDAR). From this model run the yellow colored irregularly flooded marsh converted to open water (blue), regularly flooded marsh (red) and tidal flats (grey).

SLAMM 6 Methods and Parameter Setting

SLAMM v6 was run for all of 16 coastal counties and Baltimore City in Maryland, otherwise known as Maryland's coastal zone defined by the Coastal Zone Management Act of 1972. This included the following project extents: Saint Mary's County, Charles County, Calvert County, Price George's County, Anne Arundel County, Baltimore City, Baltimore County, Harford County, Cecil County, Kent County, Queen Anne's County, Talbot County, Caroline County, Dorchester County, Wicomico County, Somerset County and Worcester County.

SLAMM requires several different data inputs and thus data was collected for each county extent. The datasets included digital elevation models created from county LiDAR, wetland accretion rates, sedimentation rates, erosion, land use and land cover, diked wetlands, historic sea level rise trends, and tidal data. Sedimentation, accretion, and erosion rates were gathered by county based on a literature review and available research sites. Historic SLR trends were gathered from NOAA buoys in the Chesapeake Bay. The nearest buoy to the county (see Figure 4) as used to calculate the rate for each county extent.

Unidirectional movement of wetlands was set for each county model run based on the counties' orientation to the Bay which affected how the model interpreted tidal movement along the county coastline. This is a generalization made county wide and is a model caveat that is worth mentioning since the model cannot be adjusted to the site level due to the size of chosen model extents (counties) and the uncertainty the model has at the site level.

Model Caveats

Dike data was modified from the National Wetland Inventory classification for this study. The dike wetland feature of the model assumes that all wetlands classified as diked, impounded or impeded have a berm height of 2 meters and are not allowed to accrete under the model's scenario. Since 2 meters is above most sea level rise scenarios, it is assumed the dikes would remain intact and thus wetlands within the dike would not migrate inland. After reviewing the model parameter with a variety of wetland scientists the consensus was that the feature under estimates the impact of erosion and the breakdown of berm walls, not to mention the varying dike height. Under future climate change conditions dikes would likely breakdown with increased storm surges and wave action and thus should not be treated as impenetrable islands.

Another approach was to query the NWI h modifier dataset for diked wetlands to extract only major dams and mill dams (average mill dams in Lancaster and Chester Counties Pennsylvania is 2.4 meters in height (Pazzaglia, Frank J., et al. 2006)) throughout the tributaries of the Chesapeake Bay. These dams range from 6 to 105 feet in height and would likely still act as a barrier to further inland migration of wetlands. However, with further investigation there was no easy way to query out the larger mill and hydrologic dams based on available datasets. The existing datasets were lacking a sufficient amount of dam height data that would have allowed this initial query to happen. As a result we re-evaluated the NWI dike data and decided that running the SLAMM with the diked data would at the very least help identify areas to target restoration projects. The caveat of this is that diked areas will remain intact regardless of sea level rise due to the model parameters, thus there may be some island creation or isolated pockets of fresh wetlands in future brackish areas. These areas are easily identified in each county extent using the diked dataset and/or through the examination of the initial wetland distribution with the projected wetland distribution for year 2100.

LiDAR data was used for 15 of the 16 coastal counties and Baltimore City. Due to the incomplete LiDAR data for Harford County the most recent 2009 National Elevation Data (NED) was used for this county. The resolution for the Harford NED was 10-meters in comparison to the other county extents with LiDAR at 2-foot contours. Due to the resolution and the type of data used for Harford County, there is an additional level of error associated with the courser dataset used to run SLAMM.

SLAMM was run for two time periods, years 2050 and 2100. These timeframes provided data that can be used for short and long-term planning for adaptation and response to changing coastal habitat. Each of the dataset inputs were catered as much as possible to the available data for the county extents. Where data gaps existed for county extents, the closest available data was used to fill those gaps. This included wetland accretion, sedimentation, historic sea level rise, and erosion. The best available data was used for all of the SLAMM inputs. The model inputs for all study extents can be found by region in **Appendix A** of this document.

For technical details on the SLAMM runs for Maryland's coastal zone please refer to the associated technical document entitled, *GIS Methodology for the Sea Level Vulnerable Wetland Areas Project*. Additional details on preparing input data for the SLAMM runs and the development of wetland priority areas can be found in this document.

SLAMM Results

The results of the SLAMM runs were clipped to county boundaries for the initial wetland conditions, years 2050 and 2100. The resulting SLAMM data was modified using custom colors and wetland breakouts adapted from the National Wildlife Federation SLAMM study that used National Wetland Inventory data (NWF, 2008) (See **Appendix C** for wetland definitions).

As part of the SLAMM run, the soil saturation feature of the model was turned on to add a water table component to the predictive out comes for the study. As a result, the upland swamps were expanded as a response to increased soil moisture levels. These areas are visible streaked due to this feature. After debating the usefulness of the feature, it was decided it was better to keep the soil saturation turned on and note the caveat of the unnatural appearance of elongated and streaking wetlands (see Figure 10).

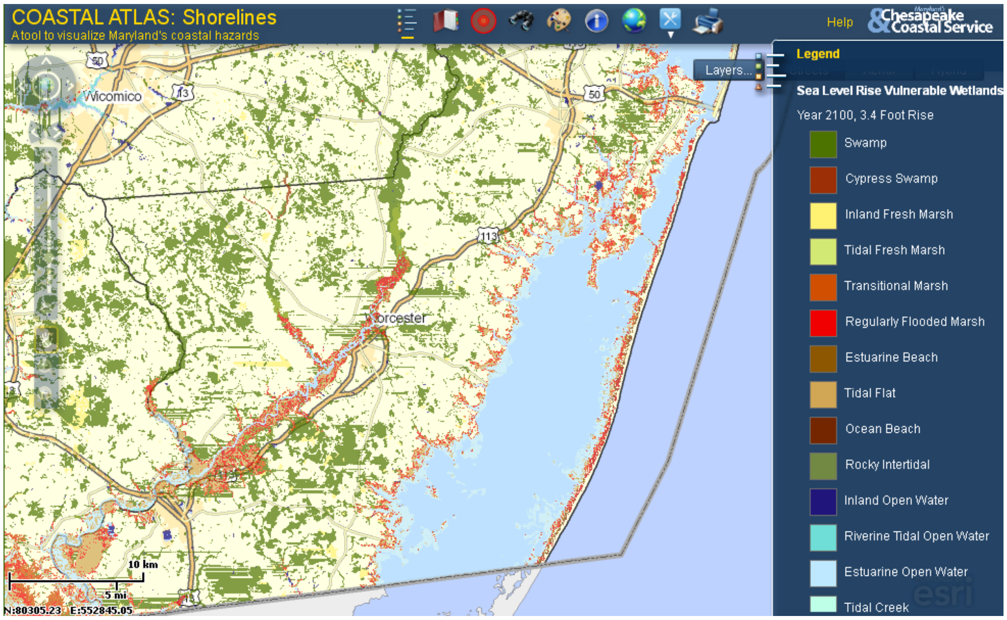

Figure 10: SLAMM year 2100 results for Worcester County Maryland displayed on the Coastal Atlas. The upland swamps (dark green) depict the streaky nature of the soil saturation feature of the model.

All of the SLAMM results can be visualized on Maryland's Coastal Atlas Shorelines mapper (Figure 11). The data layer for statewide SLAMM results for the initial, 2050 and 2100 timeframes is entitled Sea Level Rise Vulnerable Wetlands on the Coastal Atlas (http://dnr.maryland.gov/ccp/coastalatlas/shorelines.asp). For ArcGIS users, individual county extents can be downloaded from Maryland Department of Natural Resources data download site (http://dnrweb.dnr.state.md.us/gis/data/) or pulled into ArcGIS applications as a service via the state iMAP portal (http://www.imap.maryland.gov/portal/services.asp).

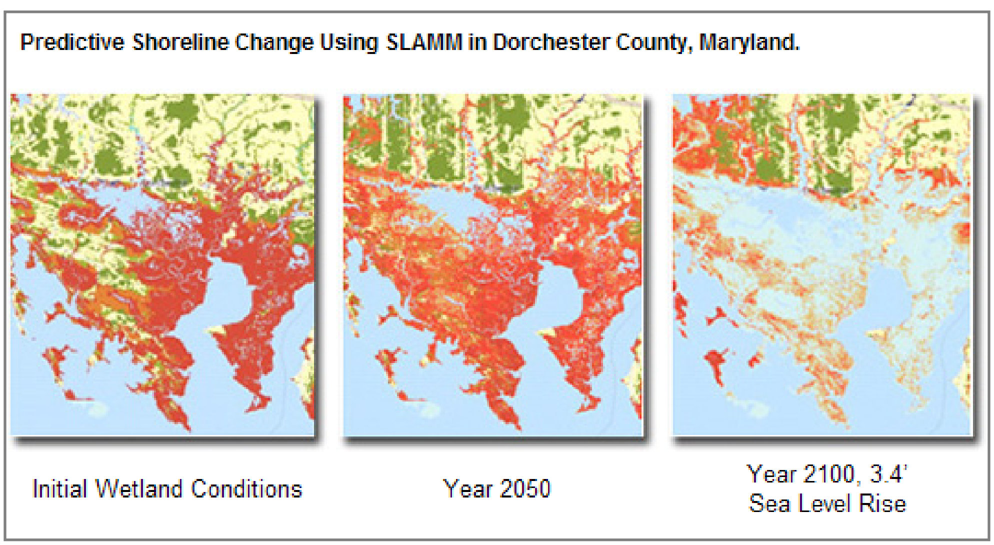

Figure 11: Dorchester County Maryland SLAMM results indicate over time mush of the low-lying marshland may become open water as sea levels rise. For more visualization please visit the Coastal Atlas (http://www.dnr.state.md.us/CCS/coastalatlas/shorelines.asp).

The resulting predictive wetland change is also broken down by county extent and statewide wetland gains and losses, which can be found in **Appendix B**. All pie charts are also available on the Coastal Atlas geoprocessing tools entitled Sea Level Rise Wetland Change. Please note that these figures are given in hectares and are predictive of future climate change conditions affecting the nearshore environment, including a rise in water tables associated with sea level rise.

Developing Conservation Priorities Using SLAMM

Using the outcome of the SLAMM data, additional geospatial analysis was conducted following a model matrix developed with the desired conservation priorities to help *facilitate landward movement of coastal wetlands subject to dislocation by sea level rise*. The datasets and analysis steps of the model matrix can be found in **Appendix C**. The following is a summary of the thought process that went into each step of the model matrix.

There were nine separate objectives within the model matrix that the DNR advisory team helped brainstorm and link to existing spatial data for analysis. All of the objectives were in line with the goal of preserving the opportunity for coastal habitats, primarily wetlands, to move inland as sea levels rise. By doing so, a corridor network and inland targeting was necessary to help pin point areas most suitable for this adaptive response to rising waters.

Objective #1: Using the SLAMM products for all coastal counties, the first objective was to give value to any wetland class that was projected by the year 2100.[6] All wetland classes for year 2100 projections were selected for all of the coastal counties. These wetland classes included: swamp, cypress swamp, inland freshwater marsh, tidal freshwater marsh, transitional marsh, regularly flooded marsh, irregularly flooded marsh, and tidal swamp, though not all wetland classes were represented in each county. As part of the model matrix methods, points were added to each data layer relative to their importance in the overall project objective to *identify high priority coastal wetlands that provide adaptation opportunities under sea level rise projection of 1.04 meters by year 2100*. A value of five points was awarded to all wetlands present by year 2100 SLAMM.

Objective #2: The second objective was to identify areas that were previously identified as non-wetland uplands that converted to a wetland class by year 2100 based on the SLAMM initial wetland status and the projected future wetland areas[7]. All of these projected future wetland areas were extracted from the year 2100 projections and a separate spatial data layer was created. These wetlands were deemed high priority areas that may be considered wetland corridors and thus given 20 points (See Figure 12).

[6] All of the analysis using the model matrix objectives were completed at the county scale defined by county boundaries and in the case of Baltimore City, by the municipality boundary.

[7] These previously non-wetland areas are also called 'New Wetland Areas by year 2100'. These areas can be visualized on the Coastal Atlas for by years 2050 and 2100, though only year 2100 was used in the model matrix targeting.

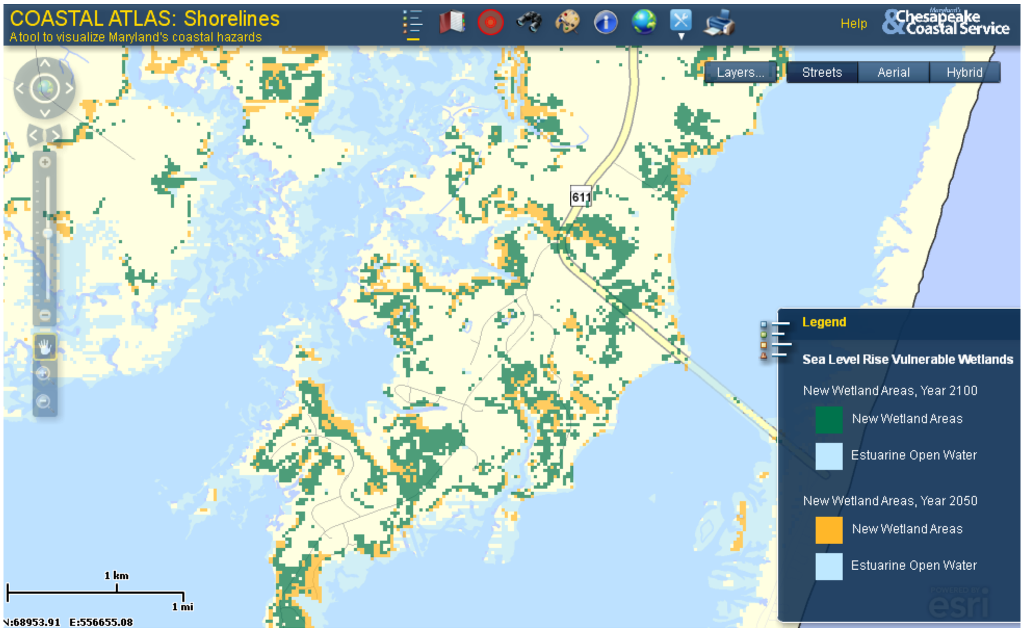

Figure 12: New wetland areas were identified using SLAMM results for years 2050 (orange) and 2100 (green). These areas were identified using spatial analysis of areas that converted from non-wetland uplands to a wetland class during the two time steps. The screen capture is of Worcester County, Maryland that can be visualized on the Coastal Atlas.

Objective #3: To incorporate the common conservation protocol of protecting and preserving species biodiversity, a third objective was created to ensure that a diversity of wetland types were preserved under future climate change conditions. The third objective was created to maintain a diversity of wetland types and was calculated based on percent loss of wetland class cover from the initial wetland to projected year 2100. A quartile approach was used to assign point values based on the range of loss. Below is a quick summary of the ranges and associated point value:

Quartile Breakout % Loss:	
<25%	(+5pts)
25.1-50%	(+10pts)
50.1-75%	(+15pts)
75.1-100%	(+20pts)

For a full summary of points award to each wetland type within the county study areas please see **Appendix D**.

Objective #4: The fourth objective was developed to protect the largest intact and continuous wetland areas. This objective was created to allow for species shifts and movements within large designated areas that may provide more adaptive responses verses smaller unconnected areas. A size threshold of 1 acre or more was established for all study areas. Jenks Natural Breaks was used within each study extent (county) to classify five point categories for each size range (see **Figure 13**). Since wetland sized varied greatly from one region (i.e. eastern shore to western shore) to another, size breakouts were established for each study extent.

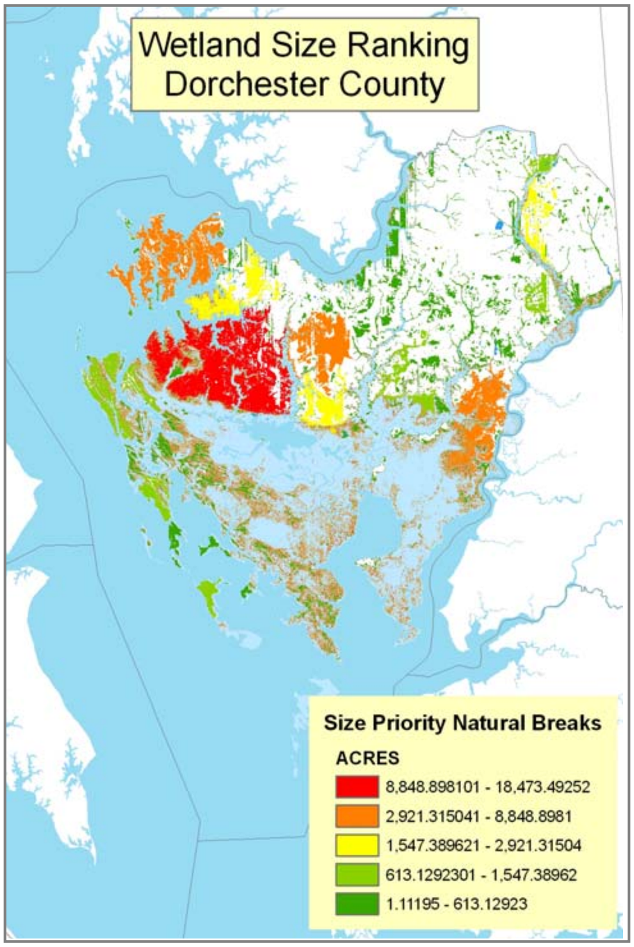

Figure 13: Size priority ranking using Jenks Natural Breaks to determine point values based on breakout class. Points range from +5 to +25, the largest continuous wetland areas receiving the highest point value. The map depicts the outcome for Dorchester County, which had some of the largest continuous wetland areas by year 2100.

Objective #5: The fifth objective was created to identify those wetlands that may be inhibited from migrating inland with sea level rise and to reduce their ranking value. This included wetland areas that fell within a sea level rise of 0-2 feet based on statewide high resolution LiDAR data, areas that were either no longer wetlands due to development or would be prohibited from moving into uplands due to impervious surface, and wetlands that were highly modified by dikes and impoundments that SLAMM predicted would not move due to the dike parameter used to run the model. Each of these layers was given a value of negative 40 and overlaid in the prioritizing process to lower priority of those wetlands that will be less likely to adaptively respond to climate change (see **Appendix C** for more details on the data used).

Objective #6: Objective six was developed in order to incorporate habitat constraints into the model prioritization. Several species of breeding birds are dependent on high marsh for their nesting habitat, particularly the black rail and salt marsh sharp-tailed sparrow. Additional nesting species include American black duck, least bittern, northern harrier, king rail, common moorhen, seaside sparrow, and the coastal subspecies of swamp sparrow which are all supported by Maryland's salt marsh habitat according to Maryland Audubon Society. Keeping these species in mind, two priorities were developed in attempt to identify areas suitable for breeding bird activity. One priority selection was made specific to high marsh areas that are extremely vulnerable to sea level rise. A priority data layer was created for each coastal county based on two wetland classes, irregularly flooded and transitional marsh at year 2100. A total of 15+ points was given to all high marsh areas for overall prioritization to help ensure future habitat would be available for the high marsh-dependent birds.

In addition to these size priorities for high marsh classes, the second priority was for all the emergent wetland classes, critical habitat size for emergent wetland-dependent breeding birds. Based on the size of emergent wetland areas using year 2100 projections, values were assigned to 150 acres or more (10+ points) and for areas 650 acres or more (10+points). The habitat size thresholds were based on what most breeding birds require (150 acres or more) and on the requirements of the larger falcon species of the northern harriers (650 acres or more).

Objective #7: In addition to the new wetland data created from SLAMM projections, priorities were also set using existing priorities areas. Objective seven included Maryland's high priority Blue Infrastructure (BI) watersheds. These are nearshore habitat priorities based on fish spawning and rearing, terrapin nesting, high priority wetlands, submerged aquatic vegetation and a variety of other important habitat components (For more details visit http://dnr.maryland.gov/ccp/bi.asp). The thought process behind this priority objective was that where existing high priority nearshore habitat currently exists, it may also exist in the future if conditions are such that the habitat is able to establish, maintain and move inland. Watershed priorities were used for this purpose. Nearshore BI priority areas were extrapolated to 12-digit watershed priorities for the overlay prioritization of future wetland areas.

Objective #8: Objective eight was developed to identify high priority inland wetlands based on their alignment with existing high quality forest tracts identified through Maryland's Green Infrastructure (GI) Assessment and Forest Interior Dwellers (FIDs) assessment (For more information see http://www.dnr.state.md.us/greenways/gi/gi.html). Presence of future SLAMM year 2100 wetlands within the GI Network were given 10+ points and those that fell into the FIDs network outside of the GI network were given an additional 10+ points. The FIDs dataset includes smaller tracts of forest that were not included in the GI Assessment, but were felt appropriate and necessary to add into this prioritization for more habitat coverage that may help facilitate the establishment of forested wetlands.

Objective #9: The last priority, objective nine, included increased value for SLAMM wetlands that fell within suitable non-wetland hydric soils. Hydric soils have been defined as "a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part" (Tiner, R.W. and D.G. Burke, 1995). These are water saturated soils that are one of the main components that make a wetland, a wetland. Areas that were drained by agricultural or other land-based practices, but still contain hydric soils suitable for future wetland establishment were targeted and prioritized.

The breakout for this priority was taken from the Watershed Resource Registry (WRR) priority hydric soils. Soils that were 'somewhat poorly drained' (SPD) were given 5+ points, soils that were 'poorly drained' (PD) were given 10+ points and those soils that were classed as 'very poorly drained' (VPD) were awarded 15+ points. This objective help to identify suitable areas where wetlands may establish based on appropriate water retention of the soil. The water table or soil saturation function was turned on during the SLAMM runs but this objective helps to further indicate present hydric soils that may be suitable for the inland establishment of wetland areas.

Each objective represents criteria that were given priority for land conservation targeting in light of climate change affects of sea level rise in Maryland's coastal counties. The data layers were summed together to find the highest priority areas that would allow for future wetland establishment, wildlife habitat, and wetland diversity. The totals were calculated by county extent, or in the case of Baltimore City by city extent, to come up with a range (low, medium and high) of priority; Maryland's Wetland Adaptation Areas. The top two tiers (medium and high priority areas) were then selected as the best-of-the-best for Maryland's Greenprint Targeted Ecological Areas (TEAs). These were incorporated into the TEAs that make up Maryland's GreenPrint application for the targeting of the state's land conservation dollars.

This update process occurred from January 2011 to spring of 2012, during which a team of experts from DNR's Wildlife and Heritage, Fisheries, Chesapeake and Coastal Service, Forestry, Office for a Sustainable Future, and Land Acquisition and Planning put forth new priority areas to update Maryland's GreenPrint TEAs. The final outcome will be described on the GreenPrint website. A sample of the full (low, medium and high) priority Wetland Adaptation Areas can be visualized on Maryland's Coastal Atlas (**Figure 14**). For additional information on the GIS analysis of the model matrix please see the technical documentation.

Model outcome: Wetland Adaptation Areas

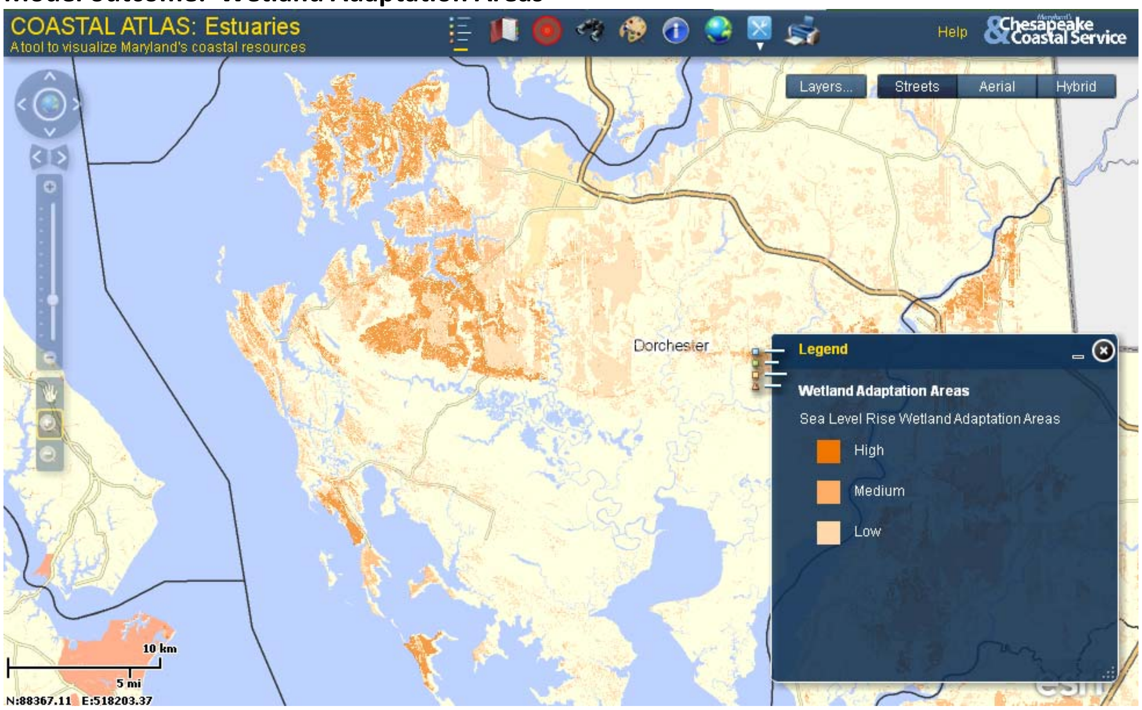

Figure 14: Final outcome of the model matrix prioritization are the Wetland Adaptation Areas. As seen in the screen capture from the Coastal Atlas. Dorchester County high priority areas, like many of the coastal extents, exclude extremely low-lying vulnerable areas that were projected to be open water or tidal flats by the SLAMM at year 2100. The high priority Wetland Adaptation Areas include a range from high to low based on the values given to each of the targeting criteria.

State Conservation Targeting

As mentioned previously, the final implementation of this product was completed in 2012, when the Wetland Priority Areas were incorporated into Maryland's GreenPrint. The incorporation of the new climate change priorities into GreenPrint occurred during a year-and-half update exercise. The process focused on updating Greenprint Targeted Ecological Areas (TEAs) with new statewide priorities for land conservation. TEAs are used by the Department of Natural Resources Stateside Program Open Space program to target conservation dollars in the most ecologically valuable areas, the best-of-the-best, to ensure these areas continue to provide high quality habitat and ecological services for future generations to enjoy and benefit from.

The wetland adaptation data that was used to identify TEAs represents the highest two priority subsets of wetland adaptation areas that would help to facilitate landward movement of coastal wetlands subject to dislocation by sea level rise. To prioritize for conservation value, only medium and high value areas that would help maintain or avoid certain features were selected as GreenPrint TEAs. These include particular wetland classes, upland areas suitable for future wetlands, a diversity of wetland types, and intact or continuous natural habitats. These areas would generally avoid features (e.g. impervious surface or hardened shorelines) that would constrain landward movement). These decision criteria are outlined above. In addition to updating GreenPrint TEAs with wetland adaptation priorities, coastal lands that occur within a 1-2 foot elevation zone were removed from the map to avoid spending limited funds in areas likely to be submerged by sea level rise within a 50-year timeframe.

The incorporation of this data as a new element in the State's GreenPrint land conservation targeting system will influence how Maryland's Program Open Space, Coastal and Estuarine Land Conservation Program (CELCP), Maryland Environmental Trust and other state and local land conservation programs address climate change considerations in the coastal zone[1]. This approach to climate change adaptation using future wetland projections and vulnerability to sea-level rise is a unique and innovative way to address climate change in land conservation practices. This model approach can be adopted in different regions with existing comparable national, state and local datasets.

Moving Forward

As new models and data are developed to better understand climate change effects on ecological systems, the Maryland DNR will continue to update and refine conservation targeting to incorporate the best available science.

Maryland DNR will continue to review all of Maryland's land conservation easements and acquisitions in light of climate change vulnerability, mitigation and adaptation potentials. Evaluation criteria are currently being used in addition to targeting conservation dollars in the newly updated Targeted Ecological Areas to better inform the state's conservation efforts. DNR reviews every parcel of land that is considered for land conservation for potential climate adaptation benefits before seeking funding approval for land acquisition by the Maryland Board of Public Works. To learn more about this review process see **Appendix E & F** for the full evaluation form and companion data guide.

DNR's climate change evaluation form and companion data guide can be used and adapted by other conservation programs. The evaluation form provides a foundation for how to incorporate climate change project reviews into conservation decision making, highlighting the available statewide climate change data, and resources for acquiring or using the data online or on your desktop ArcGIS program.

Impact

U.S. Fish & Wildlife, Audubon, The Conservation Fund, Maryland Environmental Trust and other coastal land trusts are also incorporating the resulting high-priority areas into land conservation planning, targeting, and parcel-level reviews to aid in climate change adaptation. Conserving these high-priority areas will allow habitats to shift inland naturally, protect developed areas, and allow places for wildlife to seek refuge as conditions change in the future. To further share Maryland's efforts to address climate change in land conservation targeting, this project is also

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[1] For more information on the GreenPrint targeting tool please visit the following website http://www.greenprint.maryland.gov/.

highlighted on the Climate Adaptation Knowledge Exchange (CAKE) and NOAA's Digital Coast *In Action* websites.

Resource Links
Maryland Department of Natural Resources Project:
http://dnr.maryland.gov/ccp/habitats_slr.asp

Maryland Department of Natural Resources GreenPrint: http://www.greenprint.maryland.gov/

Maryland Department of Natural Resources climate change:
http://dnr.maryland.gov/dnrnews/infocus/climatechange.asp

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Appendix A

SLAMM 6.01 Inputs by Study Extents

Western Shore Counties & Baltimore City

Harford County	
NWI Photo Date (YYYY)	1985
DEM Date (YYYY)	2007
Direction Offshore [n,s,e,w]	S
Historic Trend (mm/yr)	3.08
MTL-NAVD88 (m)	-0.013
GT Great Diurnal Tide Range (m)	0.546
Salt Elev. (m above MTL)	0.363
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	TRUE

Baltimore County	
NWI Photo Date (YYYY)	1983
DEM Date (YYYY)	2005
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.08
MTL-NAVD88 (m)	-0.013
GT Great Diurnal Tide Range (m)	0.506
Salt Elev. (m above MTL)	0.234
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Baltimore City	
NWI Photo Date (YYYY)	1983
DEM Date (YYYY)	2008
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.08
MTL-NAVD88 (m)	-0.013
GT Great Diurnal Tide Range (m)	0.506
Salt Elev. (m above MTL)	0.234
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Anne Arundel County	
NWI Photo Date (YYYY)	1983
DEM Date (YYYY)	2004
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.44
MTL-NAVD88 (m)	-0.02
GT Great Diurnal Tide Range (m)	0.459
Salt Elev. (m above MTL)	0.305
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	4
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Prince George County	
NWI Photo Date (YYYY)	1985
DEM Date (YYYY)	2009
Direction Offshore [n,s,e,w]	S
Historic Trend (mm/yr)	3.41
MTL-NAVD88 (m)	-0.033
GT Great Diurnal Tide Range (m)	0.651
Salt Elev. (m above MTL)	0.433
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	4.29
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Calvert County	
NWI Photo Date (YYYY)	1981
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.41
MTL-NAVD88 (m)	-0.033
GT Great Diurnal Tide Range (m)	0.478
Salt Elev. (m above MTL)	0.318
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	4.29
Beach Sed. Rate (mm/yr)	2.2
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Charles County	
NWI Photo Date (YYYY)	1984
DEM Date (YYYY)	2004
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	4.78
MTL-NAVD88 (m)	-0.009
GT Great Diurnal Tide Range (m)	0.591
Salt Elev. (m above MTL)	0.393
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

St. Mary's County	
NWI Photo Date (YYYY)	1983
DEM Date (YYYY)	2004
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.41
MTL-NAVD88 (m)	-0.018
GT Great Diurnal Tide Range (m)	0.525
Salt Elev. (m above MTL)	0.349
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	3
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Eastern Shore Counties

Cecil County	
NWI Photo Date (YYYY)	1984
DEM Date (YYYY)	2005
Direction Offshore [n,s,e,w]	S
Historic Trend (mm/yr)	3.08
MTL-NAVD88 (m)	-0.013
GT Great Diurnal Tide Range (m)	0.737
Salt Elev. (m above MTL)	0.490
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	5
Irreg. Flood Marsh Accr (mm/yr)	6
Tidal Fresh Marsh Accr (mm/yr)	7.5
Beach Sed. Rate (mm/yr)	5.2
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Kent County	
NWI Photo Date (YYYY)	1982
DEM Date (YYYY)	2006
Direction Offshore [n,s,e,w]	West
Historic Trend (mm/yr)	3.08
MTL-NAVD88 (m)	-0.013
GT Great Diurnal Tide Range (m)	0.528
Salt Elev. (m above MTL)	0.351
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2.5
Irreg. Flood Marsh Accr (mm/yr)	5.15
Tidal Fresh Marsh Accr (mm/yr)	3.8
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Queen Anne's County	
NWI Photo Date (YYYY)	1982
DEM Date (YYYY)	2006
Direction Offshore [n,s,e,w]	West
Historic Trend (mm/yr)	3.44
MTL-NAVD88 (m)	-0.053
GT Great Diurnal Tide Range (m)	0.483
Salt Elev. (m above MTL)	0.321
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2.5
Irreg. Flood Marsh Accr (mm/yr)	5.15
Tidal Fresh Marsh Accr (mm/yr)	3.8
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Talbot County	
NWI Photo Date (YYYY)	1984
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	West
Historic Trend (mm/yr)	3.48
MTL-NAVD88 (m)	-0.0265
GT Great Diurnal Tide Range (m)	0.548
Salt Elev. (m above MTL)	0.364
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2.5
Irreg. Flood Marsh Accr (mm/yr)	5.15
Tidal Fresh Marsh Accr (mm/yr)	3.8
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Caroline County	
NWI Photo Date (YYYY)	1982
DEM Date (YYYY)	2006
Direction Offshore [n,s,e,w]	West
Historic Trend (mm/yr)	3.48
MTL-NAVD88 (m)	-0.0265
GT Great Diurnal Tide Range (m)	0.548
Salt Elev. (m above MTL)	0.364
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2.5
Irreg. Flood Marsh Accr (mm/yr)	5.15
Tidal Fresh Marsh Accr (mm/yr)	3.8
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Dorchester County	
NWI Photo Date (YYYY)	1991
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	South
Historic Trend (mm/yr)	3.9
MTL-NAVD88 (m)	-0.136
GT Great Diurnal Tide Range (m)	0.438
Salt Elev. (m above MTL)	0.291
Marsh Erosion (horz. m /yr)	2.2
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2
Irreg. Flood Marsh Accr (mm/yr)	2.65
Tidal Fresh Marsh Accr (mm/yr)	2.1
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Wicomico County	
NWI Photo Date (YYYY)	1983
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	South
Historic Trend (mm/yr)	3.9
MTL-NAVD88 (m)	-0.136
GT Great Diurnal Tide Range (m)	0.438
Salt Elev. (m above MTL)	0.291
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2
Irreg. Flood Marsh Accr (mm/yr)	2.65
Tidal Fresh Marsh Accr (mm/yr)	2.1
Beach Sed. Rate (mm/yr)	2.05
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

Somerset County	
NWI Photo Date (YYYY)	1987
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	W
Historic Trend (mm/yr)	4.97
MTL-NAVD88 (m)	-0.027
GT Great Diurnal Tide Range (m)	0.552
Salt Elev. (m above MTL)	0.367
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	2
Irreg. Flood Marsh Accr (mm/yr)	5.1
Tidal Fresh Marsh Accr (mm/yr)	3.5
Beach Sed. Rate (mm/yr)	1.82
Freq. Overwash (years)	0
Use Elev Pre-processor [True,False]	FALSE

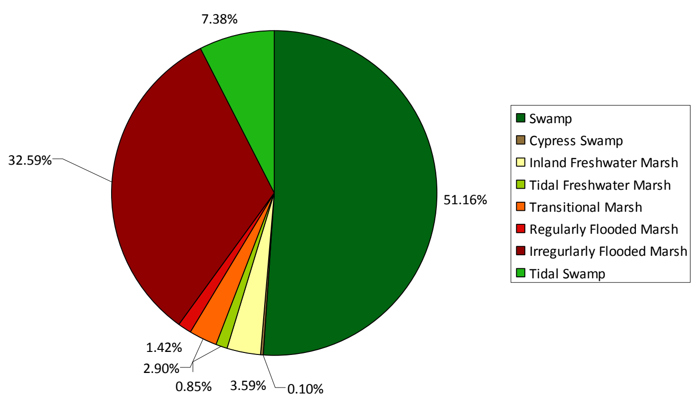
Worcester County	
NWI Photo Date (YYYY)	1996
DEM Date (YYYY)	2002
Direction Offshore [n,s,e,w]	E
Historic Trend (mm/yr)	3.3
MTL-NAVD88 (m)	-0.146
GT Great Diurnal Tide Range (m)	0.698
Salt Elev. (m above MTL)	0.464
Marsh Erosion (horz. m /yr)	1.2
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	6
Reg. Flood Marsh Accr (mm/yr)	4.35
Irreg. Flood Marsh Accr (mm/yr)	4.7
Tidal Fresh Marsh Accr (mm/yr)	5.9
Beach Sed. Rate (mm/yr)	0.95
Freq. Overwash (years)	25
Use Elev Pre-processor [True,False]	FALSE

Appendix B: SLAMM Results by Extent

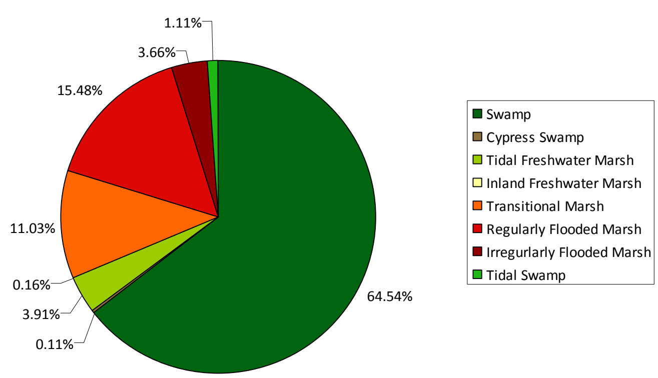
Maryland Coastal Zone

Statewide	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	118774.53	125133.93	6359.40	5.35%
Cypress Swamp	228.42	220.86	-7.56	-3.31%
Inland Freshwater Marsh	8346.42	7587.63	-758.79	-9.09%
Tidal Freshwater Marsh	1974.69	302.94	-1671.75	-84.66%
Transitional Marsh	6742.35	21383.37	14641.02	217.15%
Regularly Flooded Marsh	3302.28	30005.10	26702.82	808.62%
Estuarine Beach	3299.58	324.00	-2975.58	-90.18%
Tidal Flat	2933.73	40198.32	37264.59	1270.21%
Ocean Beach	39.51	167.40	127.89	323.69%
Rocky Intertidal	1.17	0.09	-1.08	-92.31%
Inland Open Water	14765.31	13935.69	-829.62	-5.62%
Riverine Tidal Open Water	11191.68	8414.01	-2777.67	-24.82%
Estuarine Open Water	596608.74	676804.58	80195.85	13.44%
Tidal Creek	10.44	10.44	0.00	0.00%
Open Ocean	12.33	301.95	289.62	2348.91%
Irregularly Flooded Marsh	75664.98	7089.93	-68575.05	-90.63%
Tidal Swamp	17139.15	2148.03	-14991.12	-87.47%
Freshwater Shoreline	494.01	319.41	-174.60	-35.34%

Statewide Initial Wetland Area



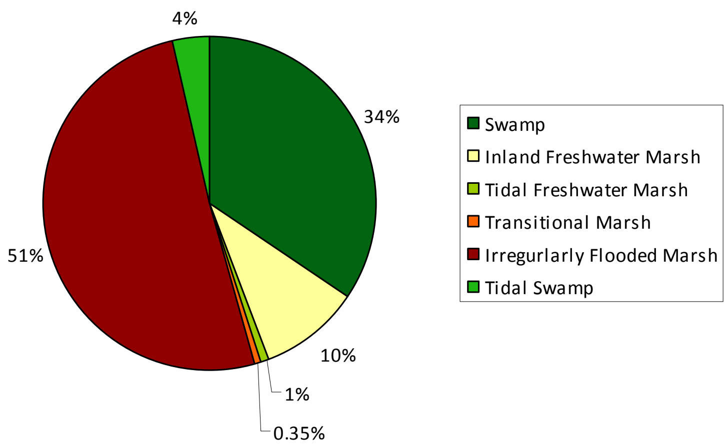
Statewide Year 2100 Wetland Areas



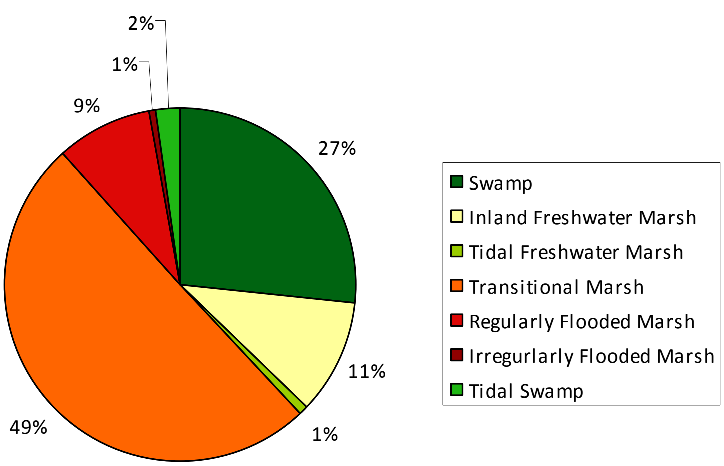
Western Shore Counties & Baltimore City

Harford County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	2095.92	1658.16	-437.76	-20.89%
Inland Freshwater Marsh	603.27	659.79	56.52	9.37%
Tidal Freshwater Marsh	51.75	48.24	-3.51	-6.78%
Transitional Marsh	21.06	3133.44	3112.38	14778.63%
Regularly Flooded Marsh	0.00	560.07	560.07	GAIN
Estuarine Beach	66.42	3.24	-63.18	-95.12%
Tidal Flat	423.54	779.40	355.86	84.02%
Inland Open Water	3527.73	3436.11	-91.62	-2.60%
Riverine Tidal Open Water	1089.36	972.27	-117.09	-10.75%
Estuarine Open Water	40065.48	43424.10	3358.62	8.38%
Irregularly Flooded Marsh	3109.86	45.36	-3064.50	-98.54%
Freshwater Shoreline	50.13	44.82	-5.31	-10.59%
Tidal Swamp	217.08	130.32	-86.76	-39.97%

Harford County Initial Wetland Area

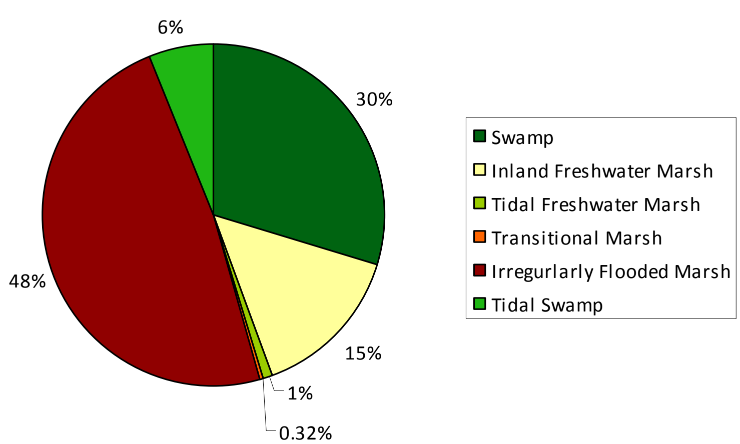


Harford County Year 2100 Wetland Area

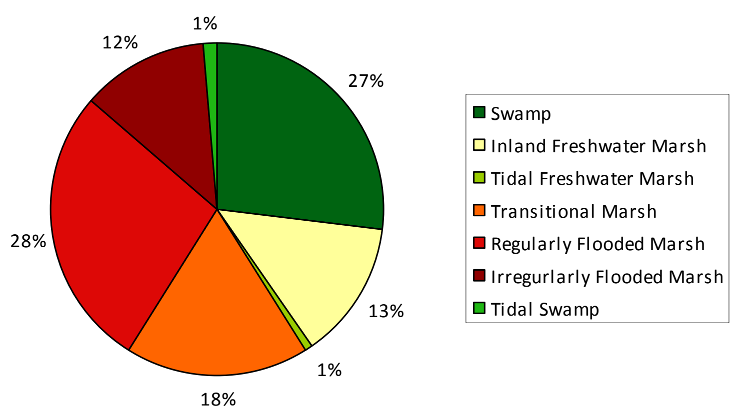


Baltimore County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	545.13	539.46	-5.67	-1.04%
Inland Freshwater Marsh	271.62	269.28	-2.34	-0.86%
Tidal Freshwater Marsh	14.22	13.86	-0.36	-2.53%
Transitional Marsh	5.85	359.10	353.25	6038.46%
Regularly Flooded Marsh	0.00	554.22	554.22	GAIN
Estuarine Beach	11.79	1.98	-9.81	-83.21%
Tidal Flat	105.39	370.71	265.32	251.75%
Inland Open Water	2497.86	2472.12	-25.74	-1.03%
Riverine Tidal Open Water	10.26	2.07	-8.19	-79.82%
Estuarine Open Water	21575.52	22271.13	695.61	3.22%
Irregularly Flooded Marsh	890.91	244.35	-646.56	-72.57%
Freshwater Shoreline	135.36	135.09	-0.27	-0.20%
Tidal Swamp	112.50	26.37	-86.13	-76.56%

Baltimore County Initial Wetland Area

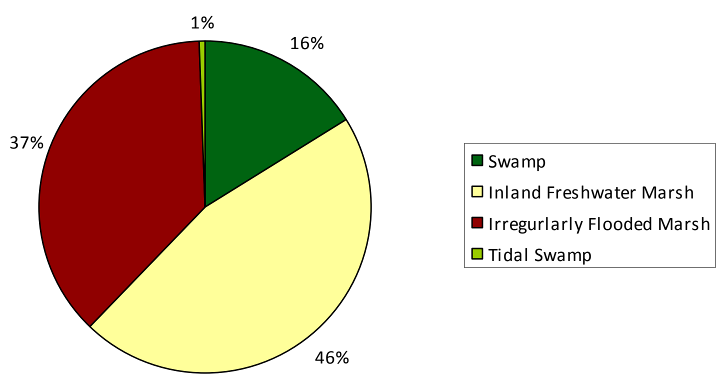


Baltimore County Year 2100 Wetland Area

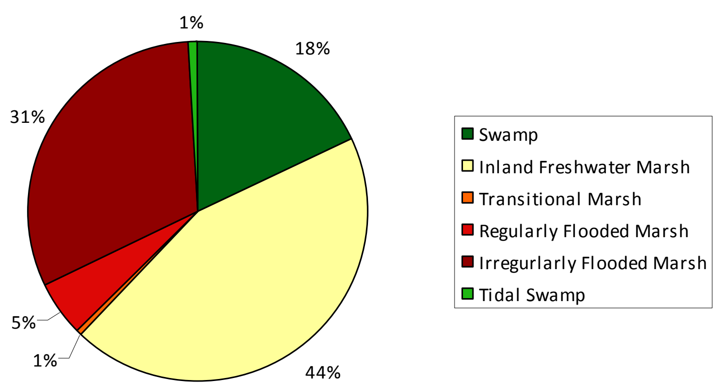


Baltimore City	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	6.30	6.30	0.00	0.00%
Inland Freshwater Marsh	17.91	15.21	-2.70	-15.08%
Transitional Marsh	0.00	0.18	0.18	GAIN
Regularly Flooded Marsh	0.00	1.89	1.89	GAIN
Estuarine Beach	1.53	1.17	-0.36	-23.53%
Tidal Flat	2.52	0.36	-2.16	-85.71%
Inland Open Water	90.99	90.27	-0.72	-0.79%
Riverine Tidal Open Water	3.24	3.24	0.00	0.00%
Estuarine Open Water	2865.78	2873.79	8.01	0.28%
Irregurlarly Flooded Marsh	14.40	10.89	-3.51	-24.38%
Freshwater Shoreline	16.38	16.38	0.00	0.00%
Tidal Swamp	0.27	0.27	0.00	0.00%

Baltimore City Initial Wetland Area

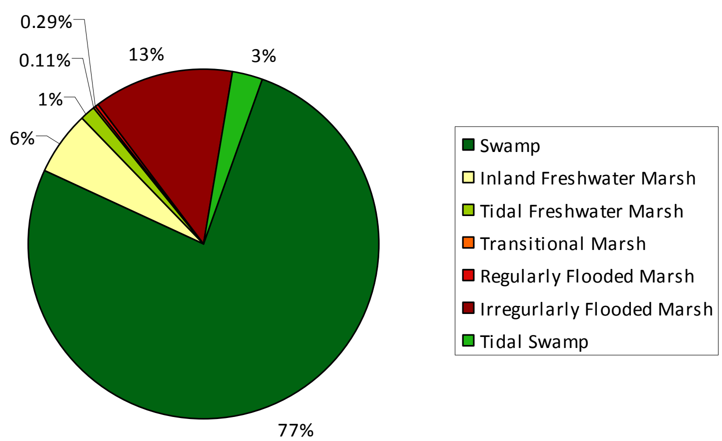


Baltimore City Year 2100 Wetland Area

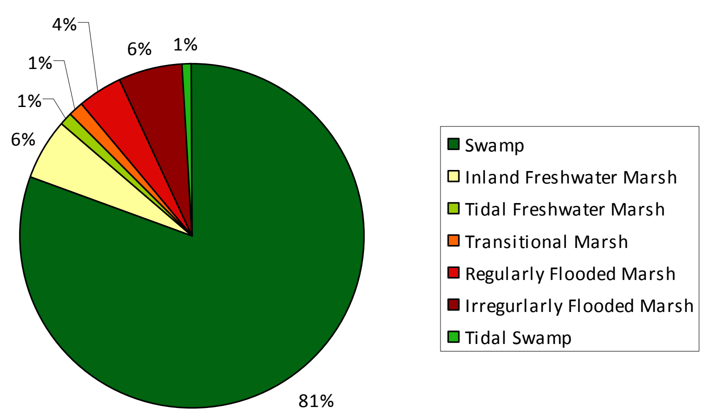


Anne Arundel County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	4919.49	5121.72	202.23	4.11%
Inland Freshwater Marsh	375.48	370.98	-4.50	-1.20%
Tidal Freshwater Marsh	85.86	63.99	-21.87	-25.47%
Transitional Marsh	7.38	83.34	75.96	1029.27%
Regularly Flooded Marsh	18.72	267.30	248.58	1327.88%
Estuarine Beach	57.60	14.04	-43.56	-75.63%
Tidal Flat	55.71	152.01	96.30	172.86%
Inland Open Water	646.83	630.09	-16.74	-2.59%
Riverine Tidal Open Water	32.94	12.78	-20.16	-61.20%
Estuarine Open Water	46362.69	46910.16	547.47	1.18%
Irregularly Flooded Marsh	840.24	387.18	-453.06	-53.92%
Freshwater Shoreline	11.34	11.07	-0.27	-2.38%
Tidal Swamp	183.60	56.07	-127.53	-69.46%

Anne Arundel County Initial Wetland Area

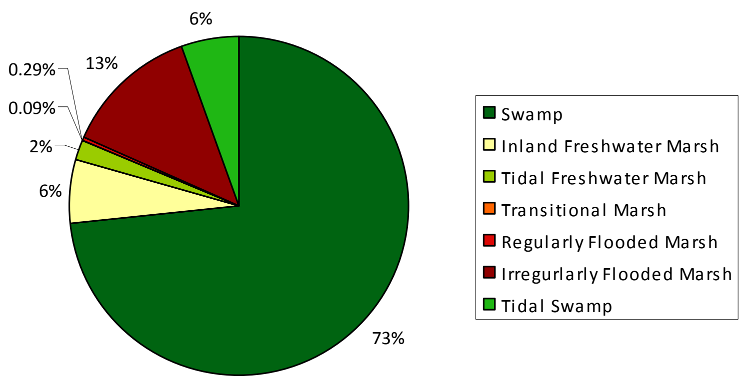


Anne Arundel County Year 2100 Wetland Area

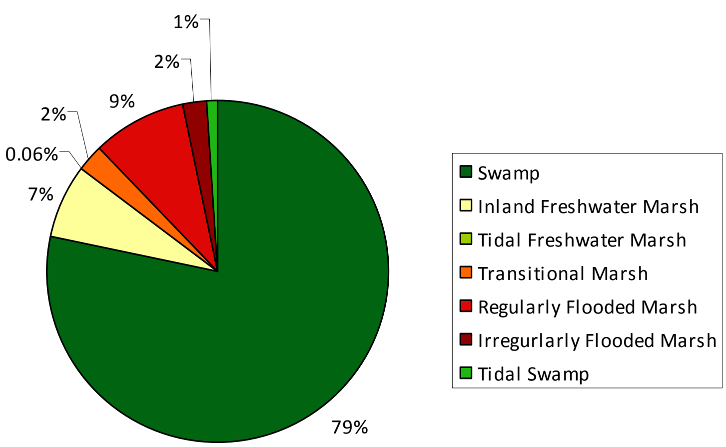


Prince George's County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	4902.48	4765.95	-136.53	-2.78%
Inland Freshwater Marsh	423.00	417.24	-5.76	-1.36%
Tidal Freshwater Marsh	115.65	3.87	-111.78	-96.65%
Transitional Marsh	6.12	137.88	131.76	2152.94%
Regularly Flooded Marsh	19.62	543.51	523.89	2670.18%
Estuarine Beach	11.25	4.86	-6.39	-56.80%
Tidal Flat	0.09	472.77	472.68	525200.00%
Inland Open Water	750.24	728.19	-22.05	-2.94%
Riverine Tidal Open Water	2358.90	2046.69	-312.21	-13.24%
Estuarine Open Water	1039.59	1846.80	807.21	77.65%
Irregurlarly Flooded Marsh	853.56	143.82	-709.74	-83.15%
Freshwater Shoreline	47.52	46.98	-0.54	-1.14%
Tidal Swamp	374.94	63.63	-311.31	-83.03%

Prince George's County Initial Wetland Area

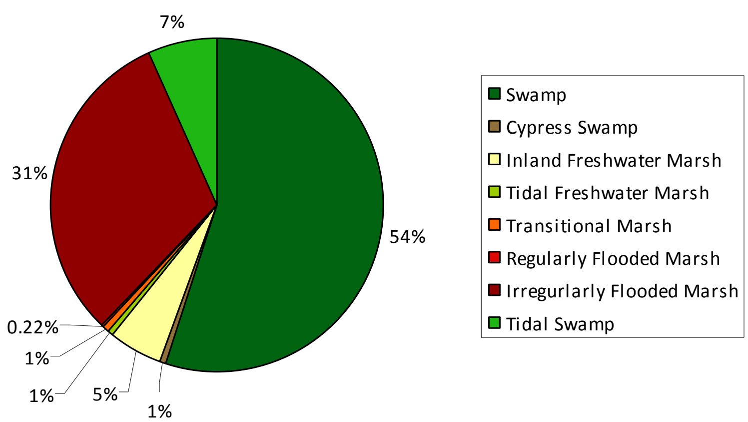


Prince George's County Year 2100 Wetland Area

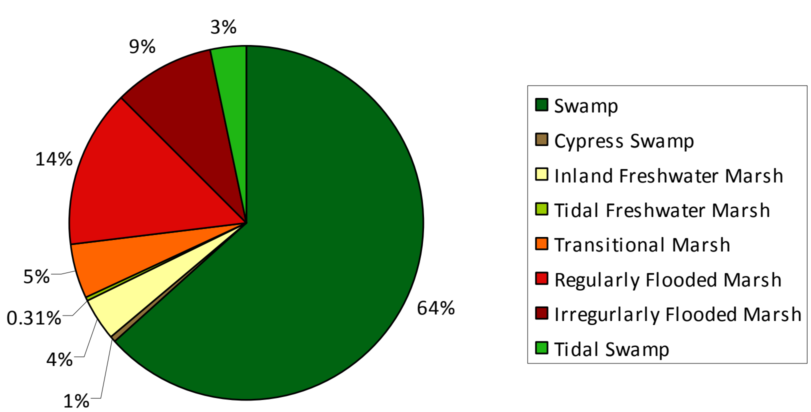


Calvert County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	1954.53	1920.42	-34.11	-1.75%
Cypress Swamp	25.83	18.27	-7.56	-29.27%
Inland Freshwater Marsh	179.64	112.77	-66.87	-37.22%
Tidal Freshwater Marsh	29.34	9.36	-19.98	-68.10%
Transitional Marsh	19.08	154.89	135.81	711.79%
Regularly Flooded Marsh	7.74	434.88	427.14	5518.60%
Estuarine Beach	52.92	6.57	-46.35	-87.59%
Tidal Flat	4.14	334.89	330.75	7989.13%
Inland Open Water	273.69	261.45	-12.24	-4.47%
Riverine Tidal Open Water	1.08	0.00	-1.08	-100.00%
Estuarine Open Water	34441.02	35376.21	935.19	2.72%
Irregurlarly Flooded Marsh	1101.96	282.15	-819.81	-74.40%
Freshwater Shoreline	2.70	2.70	0.00	0.00%
Tidal Swamp	240.48	98.19	-142.29	-59.17%

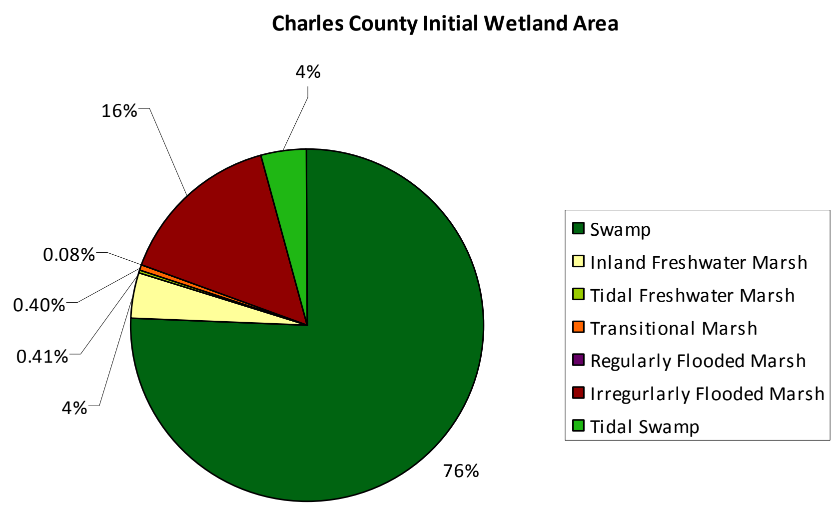
Calvert County Initial Wetland Area

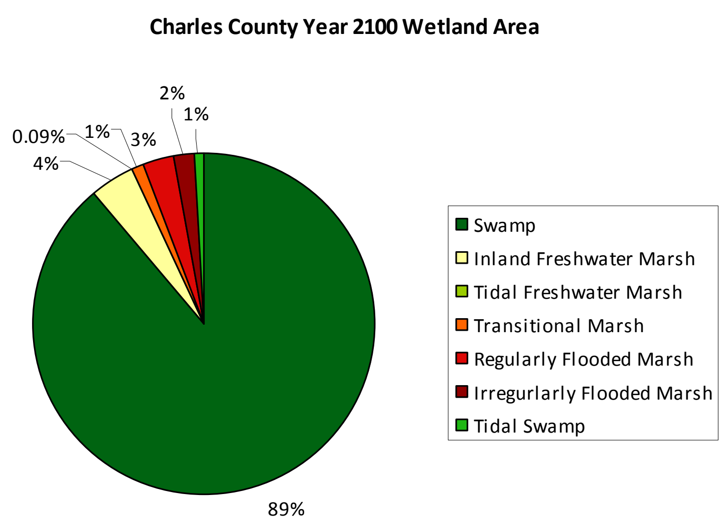


Calvert County Year 2100 Wetland Area



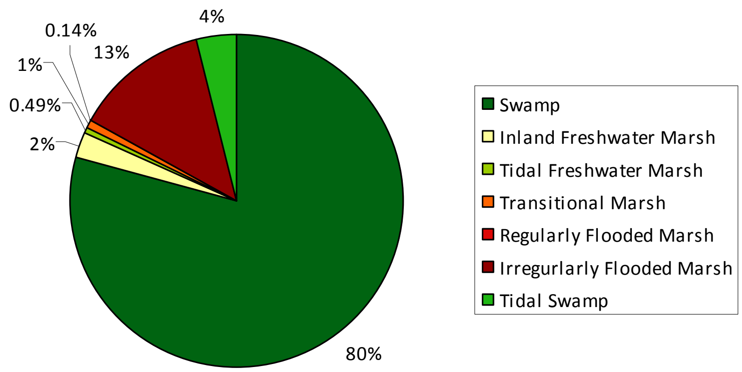
Charles County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	8742.87	9277.29	534.42	6.11%
Inland Freshwater Marsh	497.61	440.19	-57.42	-11.54%
Tidal Freshwater Marsh	48.06	9.72	-38.34	-79.78%
Transitional Marsh	45.90	115.65	69.75	151.96%
Regularly Flooded Marsh	9.36	316.89	307.53	3285.58%
Estuarine Beach	22.95	6.30	-16.65	-72.55%
Tidal Flat	2.52	508.14	505.62	20064.29%
Inland Open Water	564.03	551.07	-12.96	-2.30%
Riverine Tidal Open Water	4549.68	4351.05	-198.63	-4.37%
Estuarine Open Water	43993.62	45699.39	1705.77	3.88%
Irregurlarly Flooded Marsh	1775.70	200.70	-1575.00	-88.70%
Freshwater Shoreline	24.48	24.30	-0.18	-0.74%
Tidal Swamp	471.51	79.83	-391.68	-83.07%



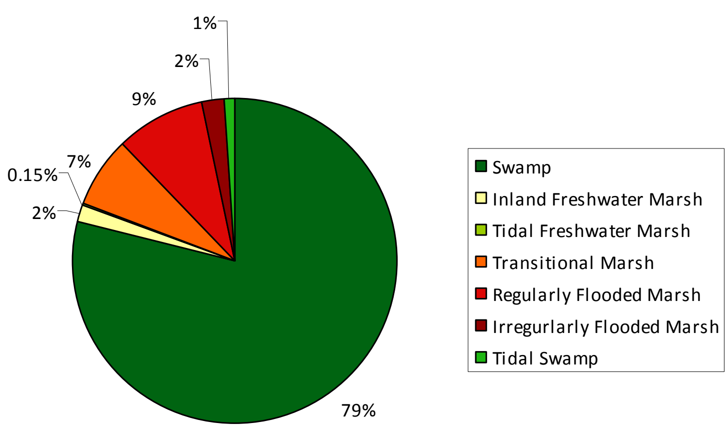


St. Mary's County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	7269.03	9183.15	1914.12	26.33%
Inland Freshwater Marsh	222.12	209.07	-13.05	-5.88%
Tidal Freshwater Marsh	44.73	17.19	-27.54	-61.57%
Transitional Marsh	84.42	813.42	729.00	863.54%
Regularly Flooded Marsh	13.23	1029.42	1016.19	7680.95%
Estuarine Beach	70.29	26.19	-44.10	-62.74%
Tidal Flat	11.52	613.89	602.37	5228.91%
Ocean Beach	0.99	0.18	-0.81	-81.82%
Inland Open Water	529.11	491.49	-37.62	-7.11%
Riverine Tidal Open Water	3.60	0.63	-2.97	-82.50%
Estuarine Open Water	104024.43	105579.90	1555.47	1.50%
Open Ocean	0.00	0.81	0.81	GAIN
Irregularly Flooded Marsh	1198.71	276.12	-922.59	-76.97%
Freshwater Shoreline	30.96	7.02	-23.94	-77.33%
Tidal Swamp	346.59	119.43	-227.16	-65.54%

St. Mary's County Initial Wetland Area



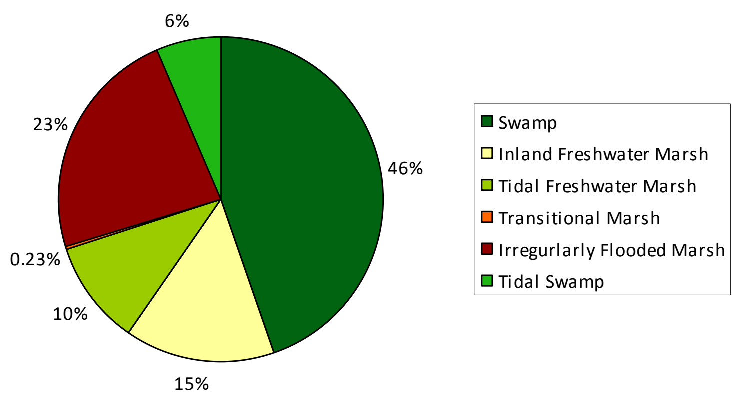
St. Mary's County Year 2100 Wetland Area



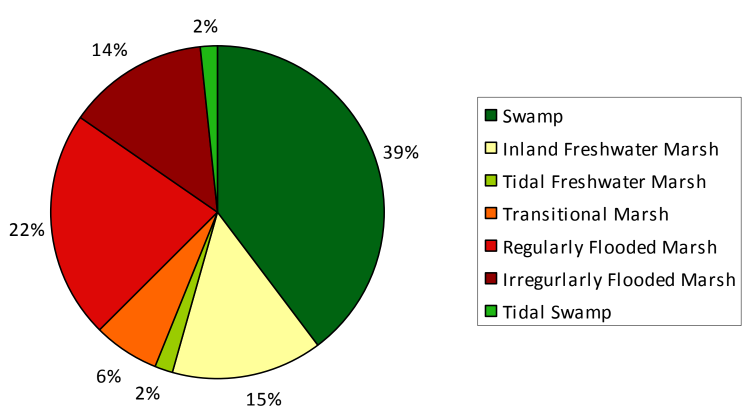
Eastern Shore Counties

Cecil County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	987.48	851.85	-135.63	-13.73%
Inland Freshwater Marsh	332.10	313.83	-18.27	-5.50%
Tidal Freshwater Marsh	229.86	38.52	-191.34	-83.24%
Transitional Marsh	5.04	137.52	132.48	2628.57%
Regularly Flooded Marsh	0.00	476.10	476.10	GAIN
Estuarine Beach	12.51	7.11	-5.40	-43.17%
Tidal Flat	247.86	254.43	6.57	2.65%
Inland Open Water	1686.15	1638.36	-47.79	-2.83%
Riverine Tidal Open Water	534.24	451.44	-82.80	-15.50%
Estuarine Open Water	17183.07	18128.70	945.63	5.50%
Irregurlarly Flooded Marsh	515.25	290.16	-225.09	-43.69%
Freshwater Shoreline	83.97	26.10	-57.87	-68.92%
Tidal Swamp	139.41	37.44	-101.97	-73.14%

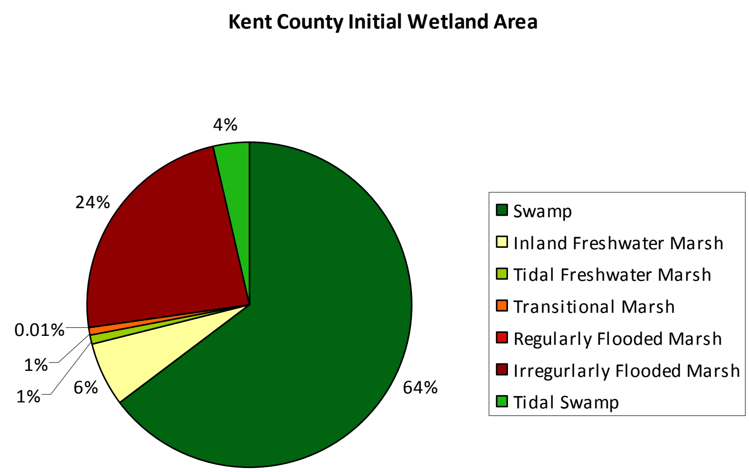
Cecil County Initial Wetland Area

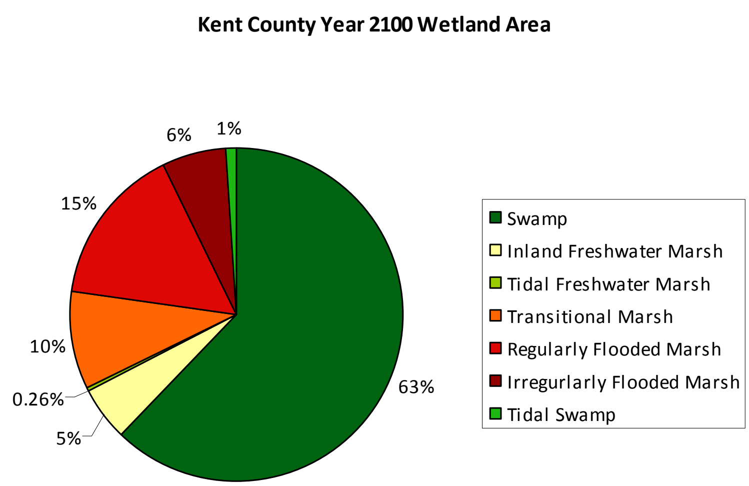


Cecil County Year 2100 Wetland Area



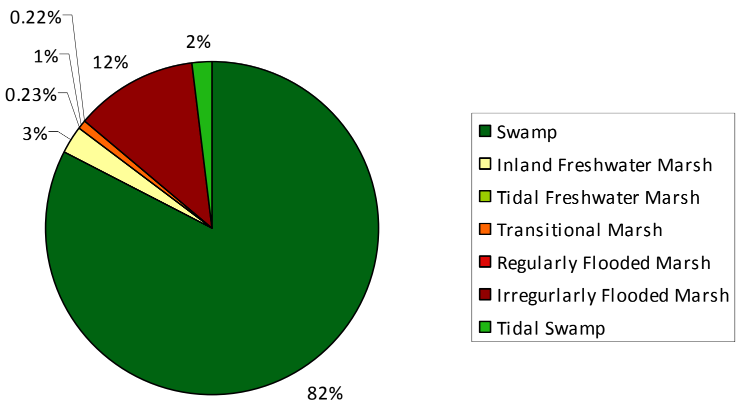
Kent County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	3890.25	3867.84	-22.41	-0.58%
Inland Freshwater Marsh	370.35	326.52	-43.83	-11.83%
Tidal Freshwater Marsh	51.66	16.29	-35.37	-68.47%
Transitional Marsh	47.52	595.17	547.65	1152.46%
Regularly Flooded Marsh	0.54	959.31	958.77	177550.00%
Estuarine Beach	66.06	6.66	-59.40	-89.92%
Tidal Flat	255.78	426.33	170.55	66.68%
Inland Open Water	1042.74	973.26	-69.48	-6.66%
Riverine Tidal Open Water	35.73	5.31	-30.42	-85.14%
Estuarine Open Water	31996.98	33342.21	1345.23	4.20%
Irregularly Flooded Marsh	1421.73	395.64	-1026.09	-72.17%
Freshwater Shoreline	0.72	0.72	0.00	0.00%
Tidal Swamp	217.53	62.19	-155.34	-71.41%



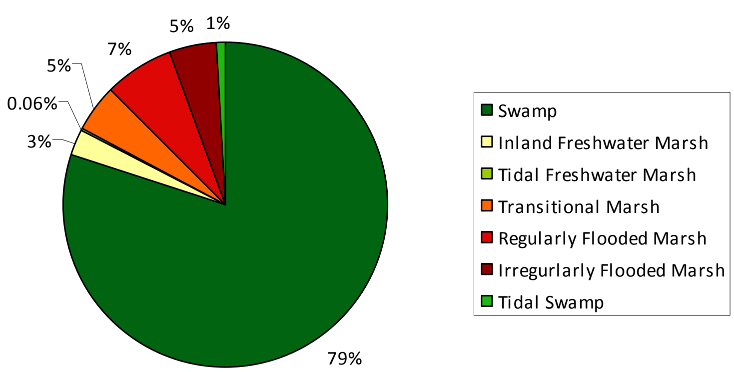


Queen Anne's County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	11021.13	11249.01	227.88	2.07%
Inland Freshwater Marsh	360.00	354.33	-5.67	-1.58%
Tidal Freshwater Marsh	30.51	9.09	-21.42	-70.21%
Transitional Marsh	77.76	670.50	592.74	762.27%
Regularly Flooded Marsh	29.16	973.08	943.92	3237.04%
Estuarine Beach	145.17	30.78	-114.39	-78.80%
Tidal Flat	34.38	353.88	319.50	929.32%
Rocky Intertidal	0.09	0.00	-0.09	-100.00%
Inland Open Water	534.69	520.02	-14.67	-2.74%
Riverine Tidal Open Water	36.27	11.52	-24.75	-68.24%
Estuarine Open Water	35561.34	36370.17	808.83	2.27%
Irregurlarly Flooded Marsh	1571.76	659.34	-912.42	-58.05%
Freshwater Shoreline	0.18	0.18	0.00	0.00%
Tidal Swamp	272.79	126.36	-146.43	-53.68%

Queen Anne's County Initial Wetland Area

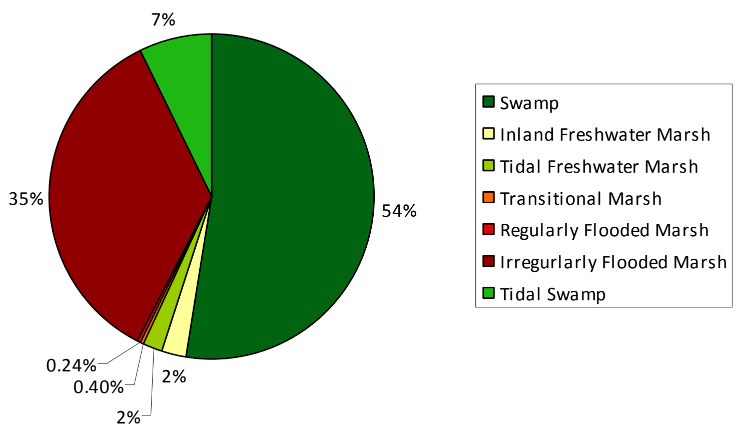


Queen Anne's County Year 2100 Wetland Area

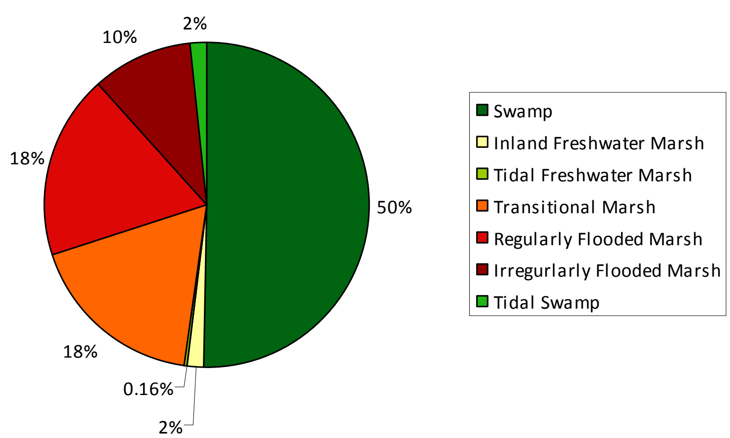


Talbot County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	2841.75	3591.81	750.06	26.39%
Inland Freshwater Marsh	131.40	120.60	-10.80	-8.22%
Tidal Freshwater Marsh	107.82	11.16	-96.66	-89.65%
Transitional Marsh	21.69	1262.52	1240.83	5720.75%
Regularly Flooded Marsh	13.05	1309.95	1296.90	9937.93%
Estuarine Beach	79.20	30.24	-48.96	-61.82%
Tidal Flat	91.26	727.92	636.66	697.63%
Inland Open Water	387.27	375.84	-11.43	-2.95%
Riverine Tidal Open Water	170.28	27.54	-142.74	-83.83%
Estuarine Open Water	53453.43	54682.65	1229.22	2.30%
Irregularly Flooded Marsh	1908.81	719.19	-1189.62	-62.32%
Freshwater Shoreline	1.71	1.71	0.00	0.00%
Tidal Swamp	386.37	120.60	-265.77	-68.79%

Talbot County Initial Wetland Area

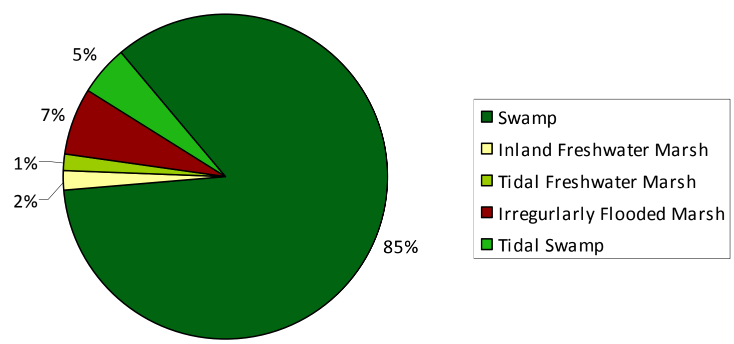


Talbot County Year 2100 Wetland Area

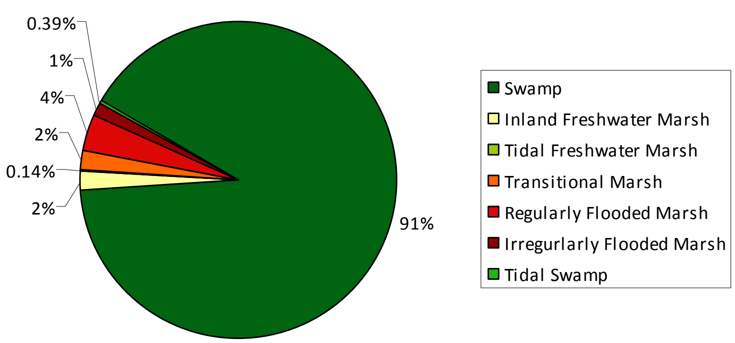


Caroline County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	8071.92	7980.21	-91.71	-1.14%
Inland Freshwater Marsh	191.25	187.65	-3.60	-1.88%
Tidal Freshwater Marsh	142.56	12.15	-130.41	-91.48%
Transitional Marsh	0.00	174.96	174.96	GAIN
Regularly Flooded Marsh	0.00	325.71	325.71	GAIN
Tidal Flat	44.28	453.87	409.59	925.00%
Inland Open Water	327.33	319.95	-7.38	-2.25%
Riverine Tidal Open Water	349.11	117.54	-231.57	-66.33%
Estuarine Open Water	1161.63	2197.44	1035.81	89.17%
Irregurlarly Flooded Marsh	642.60	105.12	-537.48	-83.64%
Freshwater Shoreline	86.22	2.34	-83.88	-97.29%
Tidal Swamp	477.63	34.47	-443.16	-92.78%

Caroline County Initial Wetland Area

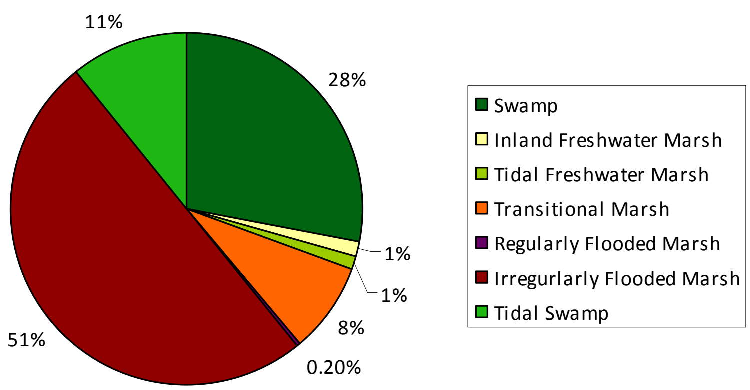


Caroline County Year 2100 Wetland Area

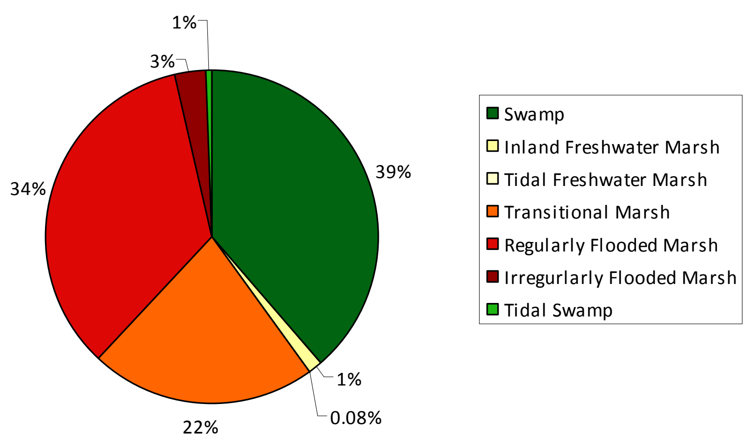


Dorchester County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	16416.45	13876.38	-2540.07	-15.47%
Inland Freshwater Marsh	842.58	458.28	-384.30	-45.61%
Tidal Freshwater Marsh	664.74	29.79	-634.95	-95.52%
Transitional Marsh	4930.47	7805.16	2874.69	58.30%
Regularly Flooded Marsh	115.92	12326.31	12210.39	10533.46%
Estuarine Beach	41.94	5.40	-36.54	-87.12%
Tidal Flat	152.91	15986.07	15833.16	10354.56%
Inland Open Water	750.42	456.39	-294.03	-39.18%
Riverine Tidal Open Water	874.26	142.74	-731.52	-83.67%
Estuarine Open Water	58948.38	93878.10	34929.72	59.25%
Irregularly Flooded Marsh	29438.46	1116.00	-28322.46	-96.21%
Freshwater Shoreline	2.34	0.00	-2.34	-100.00%
Tidal Swamp	6366.87	211.32	-6155.55	-96.68%

Dorchester County Initial Wetland Area

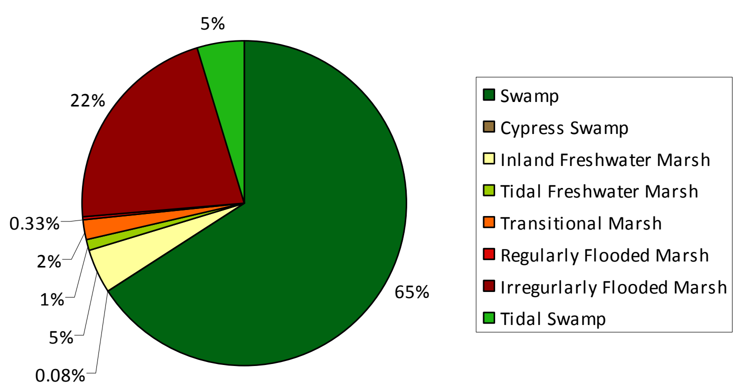


Dorchester County Year 2100 Wetland Area

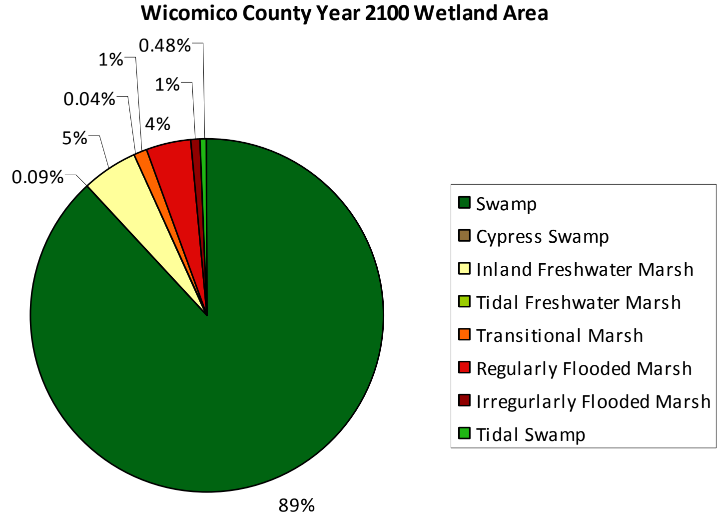


Wicomico County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	14775.30	18948.15	4172.85	28.24%
Cypress Swamp	18.45	18.45	0.00	0.00%
Inland Freshwater Marsh	1035.99	1087.47	51.48	4.97%
Tidal Freshwater Marsh	253.80	9.54	-244.26	-96.24%
Transitional Marsh	386.37	224.28	-162.09	-41.95%
Regularly Flooded Marsh	75.33	948.06	872.73	1158.54%
Estuarine Beach	12.87	1.35	-11.52	-89.51%
Tidal Flat	45.72	2242.53	2196.81	4804.92%
Inland Open Water	484.29	468.90	-15.39	-3.18%
Riverine Tidal Open Water	565.65	225.45	-340.20	-60.14%
Estuarine Open Water	6174.27	10710.18	4535.91	73.46%
Tidal Creek	2.88	2.88	0.00	0.00%
Irregurlarly Flooded Marsh	4851.18	168.75	-4682.43	-96.52%
Tidal Swamp	1092.15	102.24	-989.91	-90.64%

Wicomico County Initial Wetland Area

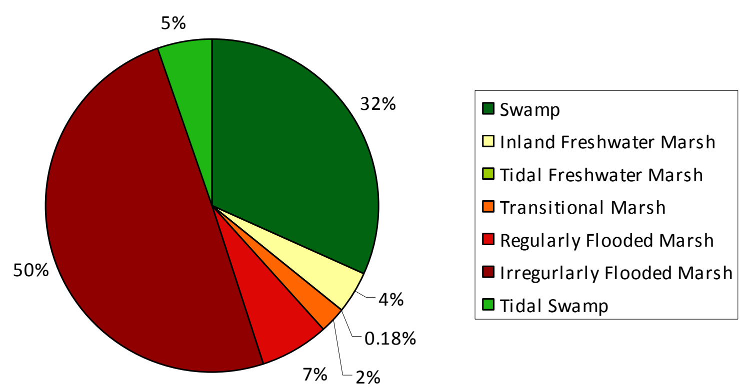


Wicomico County Year 2100 Wetland Area

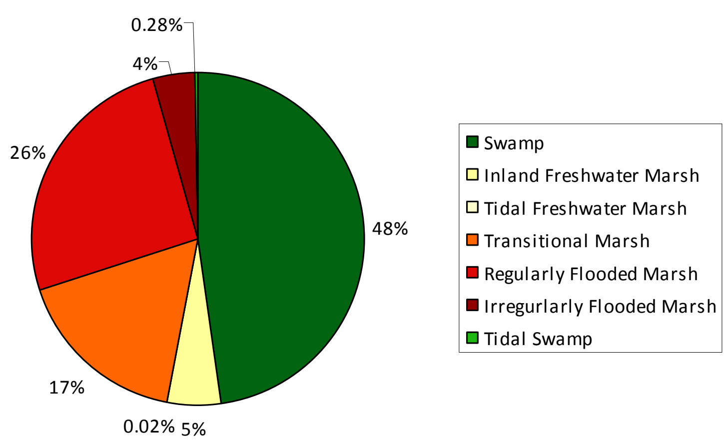


Somerset County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change
Swamp	11986.92	10795.05	-1191.87	-9.94%
Inland Freshwater Marsh	1580.58	1233.99	-346.59	-21.93%
Tidal Freshwater Marsh	69.84	3.42	-66.42	-95.10%
Transitional Marsh	887.40	3788.73	2901.33	326.95%
Regularly Flooded Marsh	2529.72	5842.71	3312.99	130.96%
Estuarine Beach	432.27	29.97	-402.30	-93.07%
Tidal Flat	1269.27	12320.55	11051.28	870.68%
Inland Open Water	189.45	122.85	-66.60	-35.15%
Riverine Tidal Open Water	95.13	8.91	-86.22	-90.63%
Estuarine Open Water	71247.78	87902.46	16654.68	23.38%
Irregularly Flooded Marsh	18945.09	918.00	-18027.09	-95.15%
Tidal Swamp	1983.06	62.28	-1920.78	-96.86%

Somerset County Initial Wetland Area



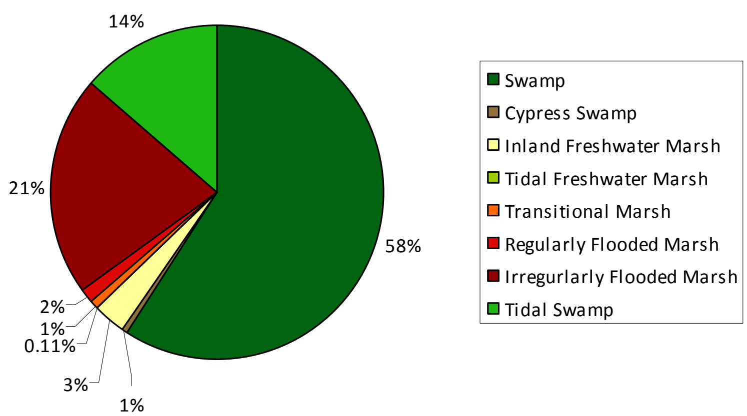
Somerset County Year 2100 Wetland Area



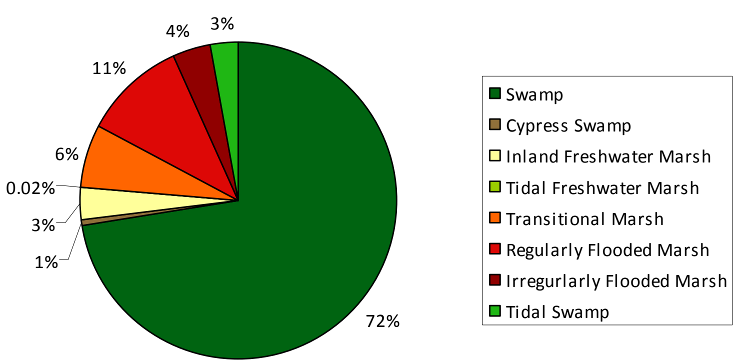
Worcester County	Current Hectares	Year 2100 Hectares	Change (Hectares)	% Change

Swamp	18347.58	21501.18	3153.60	17.19%
Cypress Swamp	184.14	184.14	0.00	0.00%
Inland Freshwater Marsh	911.52	1010.43	98.91	10.85%
Tidal Freshwater Marsh	34.29	6.75	-27.54	-80.31%
Transitional Marsh	196.29	1926.63	1730.34	881.52%
Regularly Flooded Marsh	469.89	3135.69	2665.80	567.32%
Estuarine Beach	2392.56	148.14	-2244.42	-93.81%
Tidal Flat	186.84	4200.57	4013.73	2148.22%
Ocean Beach	38.52	167.22	128.70	334.11%
Rocky Intertidal	1.08	0.09	-0.99	-91.67%
Inland Open Water	482.49	399.33	-83.16	-17.24%
Riverine Tidal Open Water	481.95	34.83	-447.12	-92.77%
Estuarine Open Water	26513.73	35611.20	9097.47	34.31%
Tidal Creek	7.56	7.56	0.00	0.00%
Open Ocean	12.33	301.14	288.81	2342.34%
Irregurlarly Flooded Marsh	6584.76	1127.16	-5457.60	-82.88%
Tidal Swamp	4256.37	817.02	-3439.35	-80.80%

Worcester County Initial Wetland Area



Worcester County Year 2100 Wetland Area



Appendix C: Land Conservation Model Matrix

Geospatial Analysis: Identify high priority coastal wetlands that provide adaptation opportunities under sea level rise projection of 1.04 m by 2100

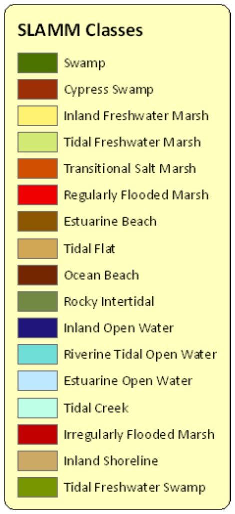
Objective #1	Data	Analysis	Selection Criteria	Score
Identify all future wetlands	SLAMM output for year 2100 under sea level rise scenario of 1.04 meter (3.4')	Extract all wetland classes from the 2100 SLAMM output	Reclassify SLAMM 2100 output for only the **8 wetland classes**: Swamp, Cypress Swamp, Inland Freshwater Marsh, Tidal Freshwater Marsh, Transitional Marsh, Regularly Flooded Marsh, Irregularly Flooded Marsh, and Tidal Swamp Note: not all classes are represented in each county	All Wetland Classes (+5)
Objective #2	**Data**	**Analysis**	**Selection Criteria**	**Score**
Identify non-wetland uplands that may shift to wetlands by 2100	SLAMM output for year 2100 under sea level rise scenario of 1.04 meter (3.4')	Extract undeveloped dry uplands that converted to wetland by year 2100	Undeveloped dry upland (UDL) converted to wetland under SLAMM scenario by year 2100. Use an overlay tool to find the dry lands that changed to wetland by year 2100 to identify upland transitional zones or new wetland areas. Note: All non-wetland classes, such as open water, were removed for this analysis	New Wetlands by 2100 (+20)
Objective #3	**Data**	**Analysis**	**Selection Criteria**	**Score**
Maintain Diversity of Wetland Types	SLAMM output for year 2100 under sea level rise scenario of 1.04 meter (3.4')	Calculate hectares of each wetland class at the initial and 2100 conditions to determine percent loss. This was calculated at the county level.	Diversity prioritization was completed using a quartile breakout of the % wetland loss, giving the highest priority to the classes with the highest loss.	Wetland Diversity Quartiles % loss <25% (+5) 25.1-50% (+10) 50.1-75% (+15) 75.1%-100% (+20)

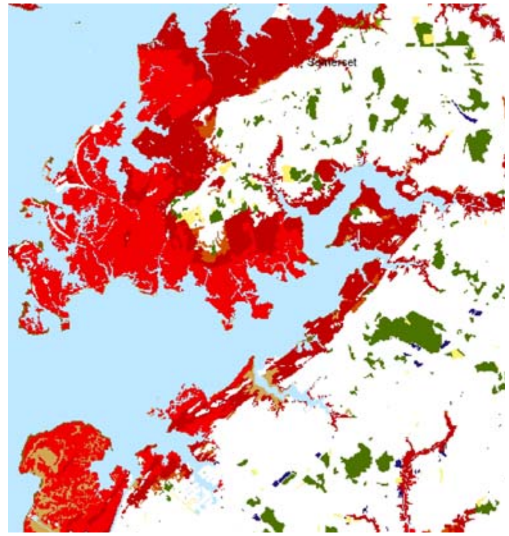
Objective #4	Data	Analysis	Section Criteria	Score
Indentify large intact wetlands to avoid fragmentation of conservation areas and to give size priority	SLAMM output for year 2100 under sea level rise scenario of 1.04 meter (3.4’)	All extracted year 2100 wetland classes analyzed together to find the largest intact continuous wetlands by coastal county	Prioritization for wetlands that meet the size threshold of 1 acre or more. Jenks Natural Breaks were used for each county to set size priority. Note: Size breakouts differed by study area so they were analyzed and prioritized by county extent	Class 1 (+5) Class 2 (+10) Class 3 (+15) Class 4 (+20) Class 5 (+25)
Objective #5	**Data**	**Analysis**	**Section Criteria**	**Score**
Identify all wetlands that may not be able to migrate inland with sea level rise	a. Using Sea Level Rise LiDAR data b. Updated NLCD impervious surface data (2006) c. National Wetland Inventory modifier data	a. Give a negative value to the 0-2 feet SLR layer b. Give a negative value to wetlands within new impervious surface c. Give a negative value to wetlands that are modified by dikes/impoundments	a. Overlay to give negative value to any wetlands that fall within the 0-2 feet inundation zone b. Overlay to give negative value to any wetlands with in the new impervious surface areas c. Overlay to give negative value to any wetlands that are diked/impounded/impeded	2. a. 0-2' SLR Zone (-40) b. Impervious (-40) b. Diked (-40)
Objective #6	**Data**	**Analysis**	**Selection Criteria**	**Score**
Identify high priority habitat based on habitat size and ecological importance	SLAMM 2100 a. Emergent Wetland Classes b. High Marsh Wetland Classes	a. Extract emergent wetland classes at least 150 acres in size for breeding birds. Give priority to those that are 650 acres or more for Northern Harrier hawk. habitat size threshold based on bird nesting requirements (150+ & 650+ Acreage) b. Extract wetland classes of high ecological priority with vulnerable high marsh habitat	a. Select habitat size threshold based on most breeding bird requirements and Northern Harrier to prioritize habitat: 150 acres or more to prioritize habitat for most breeding birds and 650 acres for Northern Harriers. b. Select wetland classes representative of high marsh (Irregularly Flooded and Transitional Marshes) to prioritize areas that are ecologically important to species dependent on high marsh habitat. Note: These priorities were analyzed at county level.	a. 150 acres+ (+10) 650 acres+ (+10) b. Combined high marsh classes (+15)

Objective #7	Data	Analysis	Selection Criteria	Score
Identify high priority nearshore wetlands	High Priority Blue Infrastructure Watersheds and SLAMM output for year 2100	Using the BI watershed identify future wetlands of key aquatic habitat priority	Overlay analysis: Presence/Absence of SLAMM 2100 wetlands that fall within BI High Priority Watersheds to give higher priority to those wetlands	BI Watersheds (+10)
Objective #8	**Data**	**Analysis**	**Selection Criteria**	**Score**
Identify high priority inland wetlands	a. Green Infrastructure v6 Hubs and Corridors and SLAMM output for year 2100 b. Forest Interior Dwellers and SLAMM output for year 2100	a. Using the GI hubs and corridor layer identify future wetlands within key terrestrial habitat priority b. Using FIDs layer identify future wetlands within key terrestrial habitat priority	a. Overlay analysis: Presence/Absence of SLAMM 2100 wetlands that fall within GI Network to give higher priority to those wetlands b. Overlay analysis: Presence/absence of SLAMM 2100 wetlands that fall within FIDs (that are not part of GI Network) to give higher priority to those wetlands	a. GI Network (+10) b. FIDs outside GI Network (+10)
Objective #9	**Data**	**Analysis**	**Selection Criteria**	**Score**
Identify suitable soils for wetland establishment/ transition	Water Resource Registry (WRR) Priority hydric soils and SLAMM output for year 2100	Using the drainage classes from the soil data to identify suitable hydric soils for wetland transition	Overlay analysis: Presence/Absence of SLAMM 2100 wetlands that fall within Hydric Soil Drainage classes to give higher priority to those wetlands SPD – Somewhat Poorly Drained PD – Poorly Drained VPD – Very Poorly Drained	Hydric Soil Drainage SPD (+5) PD (+10) VPD (+15)

Description of Coastal Habitat Classifications

(based on National Wildlife Federation's SLAMM Report adapted from U.S. Fish & Wildlife Service National Wetlands Inventory Classes)





INLAND

Swamp

Freshwater forested and scrub-shrub habitats without tidal influence. Representative forest species include red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), black gum (*Nyssa sylvatica*), willow oak (*Quercus phellos*), pin oak (*Quercus spp.*) and sweetgum (*Liquidambar spp.*). Scrub-shrub species include buttonbush (*Cephalanthus spp.*), swamp rose (*Rosa palustris*), alders (*Alnus spp.*), willows (*Salix spp.*), and holly (*Ilex spp.*). These habitats support numerous wildlife species, including white-tailed deer, raccoon, beaver, turtles, wood ducks, bald eagles and many songbird species.

Inland Freshwater Marsh

Freshwater marshes that occur along lakes, rivers, and isolated low-lying areas. Comprised primarily of grasses and other grass-like plants, including broadleaf cattail (*Typha latifolia*), pickerelweed (*Pontederia cordata*), rice cutgrass (*Leersia* oryzoides) and sedges. Support numerous species of fish and wildlife, including great blue heron, snowy egret, river otter and muskrat, osprey, mallard and American black duck.

ESTUARINE

Tidal Freshwater Swamp

Freshwater forest and scrub-shrub habitats with tidal influence. Comprised of bald cypress (*Taxodium distichum*), swamp tupelo (*Nyssa biflora*), loblolly pine (*Pinus taeda*). These habitats are relatively rare, but they support a rich variety of plants and animals, including the endangered Delmarva fox squirrel.

Cypress Swamp

Freshwater forested wetland dominated by bald cypress (*Taxodium distichum*) – swamp tupelo (*Nyssa biflora*), Pumpkin ash (*Fraxinus profunda*), green ash (*Fraxinus pennsylvanica*) may also add to the canopy structure. Cypress swamp soils are highly saturated, poorly drained, and contain high levels of organic matter. These are freshwater systems that maintain standing water that may be seasonally or tidally influenced. A variety of shrubs may also be present, winterberry (*Ilex verticillata)*, swamp azalea *(Rhododendron viscosum)*, sweet pepperbush (*Clethra alnifolia*), and northern arrow-wood (*Viburnum recognitum).* Like other wetland systems, cypress swamps help buffer uplands, control erosion and filter storm water runoff. They also provide essential habitats for rare, threatened or endangered plant and animal species in Maryland, such as catchfly cutgrass *(Leersia lenticularis),* red bay *(Persea palustris),* southern twayblade *(Listera australis),* and Virginia least trillium (*Trillium pusillum* var. *virginianum)*. These swamps also provide habitat for species of crayfish, many reptiles and amphibians, including the State-listed carpenter frog.

Tidal Freshwater Marsh
Riverine freshwater marshes with tidal influence. Plant varieties include spatterdock (*Nuphar spp.*), arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), wild rice (*Zizania spp.*) and cattails (*Typha* spp.). Provide habitat for numerous fish and wildlife species of animals, including hundreds of species of birds. They also help improve water quality by removing excess nutrients.

Transitional Marsh
Estuarine intertidal scrub-shrub wetlands includes areas dominated by broad-leaved deciduous vegetation less than 6 m (20 feet) tall, provides a transition zone between salt marsh and the upland boarder. Foliage can include true shrubs, young trees, and stunted trees and shrubs due to environmental conditions. May or may not include: marsh elder (*Iva frutescens*), cordgrass (*Spartina spp.*), common reed (*Phragmites australis*) and groundsel tree (*Baccharis halimifolia*). These habitats support numerous songbird species.

Irregularly Flooded Marsh
Irregularly flooded estuarine inter-tidal emergent wetlands have lower salinity than salt marsh and are often brackish. Representative plant species include saltmeadow cordgrass (*Spartina patens*), salt reed grass (*Distichlis spicata*), black needlerush (*Juncus roemerianus*), and short-form smooth cordgrass (*Spartina alterniflora*). These marshes make up the majority of the coastal marsh types in the region and provide food and habitat for many species of mammals, reptiles, amphibians and birds. They also support fish species such as rockfish, white perch, herring and shad. They absorb excess nutrients and pollution, and anchor loose soils.

Regularly Flooded Marsh
Estuarine intertidal emergent wetlands that occur in the zone between low and high tides that have higher salinity than brackish marsh. Comprised largely of long-form smooth cordgrass (*Spartina alterniflora*), which provides a major source of nutrition for the marine food web when it decomposes. Salt marshes also provide critical habitat for juvenile fish, fiddler crabs and other species that are food for rails, terns, gulls, blue crab and diamondback terrapin. In addition, as with brackish marshes, salt marshes absorb excess nutrients and pollution and anchor loose soils.

Estuarine Beach
Estuarine intertidal unconsolidated shore sand or beach-bar including salt pans these areas may include plant species such as saltgrass (*Distichlis spicata*). Estuarine beaches support numerous insects and other invertebrates such as sand diggers, sand fleas and crabs, which play a critical role in the bay's food web. These are especially important for migratory shorebirds such as the threatened piping plover.

Tidal Flat
Estuarine intertidal unconsolidated shore, generally flat areas with sandy or muddy soils and little or no vegetation. Tidal flats support numerous invertebrate species and provide important forage areas for fish, blue crab, waterfowl, and other migrating birds.

Ocean Beach
Marine intertidal unconsolidated shore sand. In addition to supporting the region's thriving recreation and tourism industry, ocean beaches provide critical nesting habitat for birds such as least tern and piping plover as well as for loggerhead sea turtle. In addition, sandy beaches are important spawning habitat for horseshoe crab.

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Appendix D:

Objective #3 - Maintaining Wetland Diversity

* Based on 2100 Results by County Boundaries

% Loss Tidal Swamp	Class 23
Harford County	39.97%
Queen Anne's County	53.68%
Calvert County	59.17%
St. Mary's County	65.54%
Talbot County	68.79%
Anne Arundel County	69.46%
Kent County	71.41%
Cecil County	73.14%
Baltimore County	76.56%
Worcester County	80.80%
Prince George's County	83.03%
Charles County	83.07%
Wicomico County	90.64%
Caroline County	92.78%
Dorchester County	96.68%
Somerset County	96.86%

% Loss Inland Fresh Marsh	Class 5
Baltimore County	0.86%
Anne Arundel County	1.20%
Prince George's County	1.36%
Queen Anne's County	1.58%
Caroline County	1.88%
Cecil County	5.50%
St. Mary's County	5.88%
Talbot County	8.22%
Charles County	11.54%
Kent County	11.83%
Baltimore City	15.08%
Somerset County	21.93%
Calvert County	37.22%
Dorchester County	45.61%

% Loss Swamp	Class 3
Kent County	0.58%
Baltimore County	1.04%
Caroline County	1.14%
Calvert County	1.75%
Prince George's County	2.78%
Somerset County	9.94%
Cecil County	13.73%
Dorchester County	15.47%
Harford County	20.89%

% Loss Tidal Fresh Marsh	Class 6
Baltimore County	2.53%
Harford County	6.78%
Anne Arundel County	25.47%
St. Mary's County	61.57%
Calvert County	68.10%
Kent County	68.47%
Queen Anne's County	70.21%
Charles County	79.78%
Worcester County	80.31%
Cecil County	83.24%
Talbot County	89.65%
Caroline County	91.48%
Somerset County	95.10%
Dorchester County	95.52%
Wicomico County	96.24%
Prince George's County	96.65%

% Loss Irregularly Flooded Marsh	Class 20
Baltimore City	24.38%
Cecil County	43.69%
Anne Arundel County	53.92%
Queen Anne's County	58.05%
Talbot County 2100	62.32%
Kent County	72.17%
Baltimore County	72.57%
Calvert County	74.40%
St. Mary's County	76.97%
Worcester County	82.88%
Prince George's County	83.15%
Caroline County	83.64%
Charles County	88.70%
Somerset County	95.15%
Dorchester County	96.21%
Wicomico County	96.52%
Harford County	98.54%

Quartile Breakout % Loss:	
<25%	(+5pts)
25.1-50%	(+10pts)
50.1-75%	(+15pts)
75.1-100%	(+20pts)

Climate Change Evaluation Criteria

Projected impacts are based on the best available science for the Mid-Atlantic Region. Relative sea-level rise projections for the Maryland range between 1-1.3 feet by 2050 and 2.7-3.4 feet by 2100. Please refer to the companion guide that identifies the supporting data for this evaluation.

Property Name:________________________________**County:**____________________

Scoring: In interpreting the scale it is assumed that the higher the rating, the greater the capacity of the property to provide resiliency to climate change stressors of sea level rise and storm surge through adaptation and/or mitigation.

I. Sea Level Rise Resiliency

Identifying potential sea level rise vulnerability of a site will help establish a long-term management plan to help increase the resiliency of the site.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Sea Level Rise Resiliency Potential

i. Is there potential for inundation on the property by 2050?

Yes ○ No ○

If yes, roughly how much of the property would be inundated?

a. 76-100% ○ slight

b. 51-75% ○

c. 26-50% ○

d. 25% or less ○ high

ii. Is there potential for inundation on the property by 2100?

Yes ○ No ○

If yes, roughly how much of the property would be inundated?

a. 76-100% ○ slight

b. 51-75% ○

c. 26-50% ○

d. 25% or less ○ high

II. Wetland Migration

Identifying the potential for future wetland areas can help prioritize sites to maintain coastal wetlands into the future.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Wetland Migration Potential

i. Percentage of the property wetlands potentially inundated by 2050

a. 76-100% of the property within the 0-2' elevation ○ slight
b. 51-75% of the property within the 0-2' elevation ○
c. 26-50% of the property within the 0-2' elevation ○
d. 25% or less of the property within the 0-2' elevation ○ high

ii. Percentage of the property wetlands potentially inundated by 2100

a. 76-100% of the property within the 2-5' elevation ○ slight
b. 51-75% of the property within the 2-5' elevation ○
c. 26-50% of the property within the 2-5' elevation ○
d. 25% or less of the property within the 2-5' elevation ○ high

iii. Land Use/Land Cover

a. Low to medium residential development ○ slight
b. Forested, orchards and open urban land ○
c. Wetlands, scrub shrub, pastures, and cropland ○ high
d. Not applicable/no score if property is used by heavy transportation, high residential, and/or commercial development

iv. Living Shoreline Suitability (Worcester, Somerset and Calvert Counties)

a. May not be suitable for living shoreline ○ slight
b. May be suitable for hybrid option ○
c. May be suitable for soft stabilization ○ high
d. Not applicable/no score

III. Restoration Potential

Identifying restoration potential may help to build the resiliency of the site if forest canopy and wetland areas were improved and/or expanded.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Restoration Potential

i. Percentage of property currently forested _____%

ii. Current or future reforestation projects on site yes ____ no _____

If yes:

a. Reforestation planned for _____ acres

1. If most acreage is *within* 2-5' elevation ○ slight

2. If most acreage is *above* 2-5' elevation ○ high

If no:

a. There is *no* potential for reforestation *above* 2-5' elevation ○ slight

b. There is potential for reforestation *above* 2-5' elevation ○ high

iii. Percentage of property is wetland _____%

a. Wetlands onsite

1. If *Phragmites* (invasive wetland grass) present ○ high

2. If wetlands are ditched or diked ○ high

3. Not applicable/no score

IV. Natural Storm Surge Protection
Identifying the natural capacity of storm surge protection a property may provide surrounding communities, protected lands, and/or adjacent properties may help prioritize the protection of the property.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Natural Storm Surge Potential

i. Storm Surge Buffers

a. Stabilization Structures present ○ slight
b. Bare bank ○
c. Beach buffer present ○
d. Marsh buffer present ○ high

ii. Shoreline Rates of Change

a. High (less than -8ft) ○ slight
b. Moderate (-4 to -7.99ft) ○
c. Low (-2 to -3.99) ○
d. Slight (less than -2ft) ○ high

iii. Natural storm surge resiliency of the site: select the category that best describes the property

a. Majority of the property is within Category 1 ○ slight
b. Majority of the property is within Category 1 & 2 ○
c. Majority of the property is within Category 2 & or 3 ○
d. Majority of the property is within Category 4 or above ○ high
e. Not applicable/no score

iv. Land Use/Land Cover

a. Open urban lands ○ slight
b. Agriculture, row crops, cropland, pasture ○

c. Brush, beaches, orchards and vineyards ○

d. Wetlands and deciduous/mixed/evergreen forest ○ high

e. Not applicable/no score if property is bare ground/exposed rock or used by heavy transportation, residential/commercial/industrial development and/or feeding/breeding operations

V. Potential Barriers to Habitat Migration

Identifying the potential barriers to wetland migration under accelerated sea-level rise may help inform the long-term restoration potential for the site.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Habitat Migration Potential

i. Stabilization Structures

a. Yes, majority of shoreline is hardened ○ slight

b. Yes, some of the shoreline is hardened ○

c. No hardened structures but not fully vegetated ○

d. Living shoreline or fully vegetated ○ high

*Additional structures present: groins, revetments, and breakwaters
Yes, there is another type of shoreline protection: _____________

ii. Bank Cover

a Bare Bank Cover ○ slight

b. Partial Bank Cover (partial vegetated) ○

c. Total bank Cover (vegetated) ○ high

iii. Bank Height

a. 5 - 30 feet high ○ slight

b. 0 - 5 feet high ○ high

c. Not applicable/no score

iv. Is the Bank undercut?

a. Yes ○ slight

b. No ○ high

c. Not applicable/no score

v. Shoreline Rates of Change

a. High ○ slight

b. Moderate ○

c. Low ○

d. Slight ○ high

VI. Environmental Hazard Mitigation

Identifying the potential hazards that inundation and temporal flooding of septic tanks and drain fields, fuel tanks, and animal feed operations may pose to the property will help inform an effective management plan to increase the long-term resiliency of the property through the removal of these hazards.

Overall Rating: ○ **slight** ○ **low** ○ **moderate** ○ **high**

Mitigation Potential

i. Does the property have a septic system?

a. No ○ slight

b. Yes, but it is not likely to be inundated ○

c. Yes, likely to be inundated by year 2100 ○

d. Yes, likely to be inundated by year 2050 ○ high

ii. Does the property have an existing or decommissioned underground fuel tank?

a. No ○ slight

b. Yes, but not likely to be inundated ○

c. Yes, likely to be inundated by year 2100 ○

d. Yes, likely to be inundated by year 2050 ○ high

iii. Current or past animal feeding operations present?

a. No ○ slight

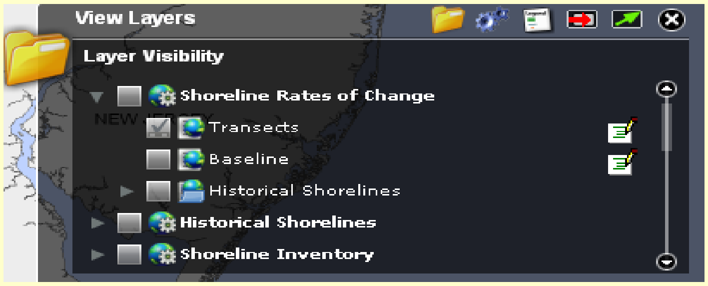
b. Yes and not likely be inundated by sea level rise ○

c. Yes and likely to be inundated by year 2100 ○

d. Yes and likely to be inundated by year 2050 ○ high

COASTAL ATLAS:

SHORELINES ONLINE MAP DATA SELECTION (www.dnr.state.md.us/ccp/coastalatlas/)



** Data is available through the use of Coastal Atlas Shoreline Map (www.dnr.state.md.us/ccp/coastalatlas/) or downloadable in ArcGIS format from the MD iMAP server (www.imap.maryland.gov/portal/services.asp) or DNR GeoSpatial Data Center (http://dnrweb.dnr.state.md.us/gis/data/)*

**Sections I-VI: Use the parcels data layer to determine project evaluation boundary*

I. Sea Level Rise Vulnerability

i. Sea Level Rise Vulnerability layer 0-2 feet

ii. Sea Level Rise Vulnerability layer 2-5 feet

II. Wetland Transition Potential

i. Sea Level Rise Vunerability layer, 0-2 feet and SLR Vulnerable Wetlands (current wetlands layer turned on)

ii. Sea Level Rise Vulnerability layer, 2-5 feet and SLR Vulnerable Wetlands (current wetlands layer turned on)

iii. Land Use/Land Cover layer (view the legend for details)

iv. Living Shoreline Suitability layer (currently available for Worcester, Somerset and Calvert Counties)

III. Restoration Potential

i. Imagery layer (turn off Shoreline and Street Map layers to view) and/or property description

ii. Imagery and Sea Level Rise Vulnerability layers

  a. Sea Level Rise Vulnerability 2-5' inundation over Imagery (turn off Shoreline and Street Map layers to view Imagery)

iii. Sea Level Vulnerable Wetlands layer (only current layer turned on)
  a. Shoreline Inventory layer
    1. Shoreline Inventory – turn on *Phragmites* layer
    2. Imagery and/or property description for visible signs of diked or ditched wetlands

IV. Natural Storm Surge Protection

i. Shoreline Inventory layer
  a. Stabilization Structures (i.e. groin, rip rap, marina, bulkhead, etc.)
  b – d. Bank Cover (i.e. bare bank cover, partial bank cover, total bank cover)

ii. Shoreline Rates of Change (transect data) or Erosion Vulnerability Assessment

iii. Storm Surge Areas layer
  a – d. Turn on and off Hurricane Categories 1-4

iv. Land use/Land cover data (view the legend for details)

V. Barriers to Habitat Transition

i. Shoreline Inventory layer
  a – b. Stabilization Structures (if no data exists for the area refer to the property description)
  c. Stabilization Structures and Imagery/property description of the shoreline for information on vegetation
  d. Imagery and property description or site visit

ii. Shoreline Inventory layer – turn on Bank Cover

iii. – iv. Shoreline Inventory layer – turn on Bank Height and Condition

v. Shoreline Rates of Change
  a. Use transect data or use Erosion Vulnerability Assessment layer

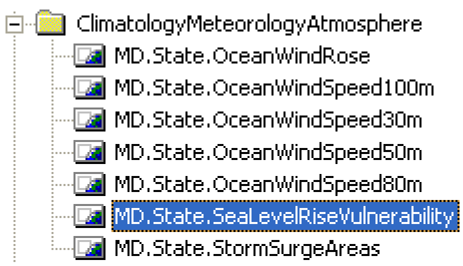
VI. Environmental Hazards

i. – iii. Property description, Sea Level Rise Vulnerability, and aerial Imagery layers
  c. Use Sea Level Rise Vulnerability layer 2-5 feet
  d. Use Sea Level Rise Vulnerability layer 0-2 feet

DESCRIPTIONS OF DATA LAYERS

Sea Level Rise Vulnerability – This is a basic bathtub simulation based on elevation data that displays potential inundation at 0-2', 2-5' and 5-10' of sea level rise. The inundation breakouts roughly correlate to Maryland's projected inundation rates for years 2050 (0-2') and 2100 (2-5'). The dataset is a derivative of high-resolution topographic data LiDAR (Light Detection And Ranging). The resolution of Maryland's LiDAR is in 2-foot contours, which provides us with an estimate of future vulnerable resources. Metadata can be downloaded at the DNR GIS data site: http://dnrweb.dnr.state.md.us/gis/data/

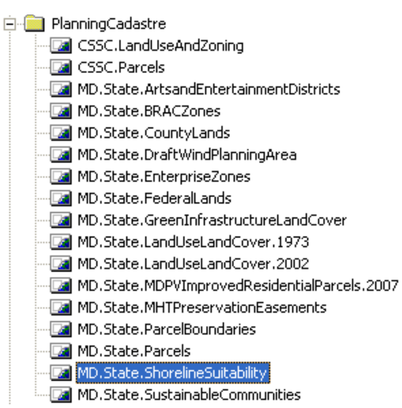
MD iMAP Folder



SLR Wetland Vulnerability – this is based on projections from Sea Level Affecting Marshes Model (SLAMM), which simulates the dominant processes in wetland conversions and shoreline modifications during long-term sea level rise. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summaries in tabular and ArcGIS grid forms. Statewide data can be visualized on the Shorelines Coastal Atlas. County level data can be downloaded from http://dnrweb.dnr.state.md.us/gis/data/.

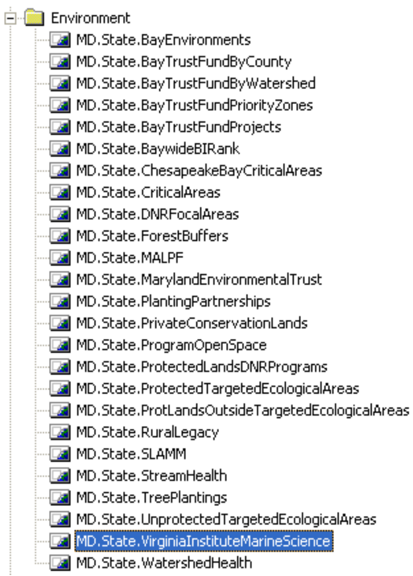
Living Shoreline Suitability – The Virginia Institute of Marine Sciences developed a model to geographically target shoreline areas potentially suitable and potentially unsuitable for the placement of a variety of living shoreline projects to counteract erosion problems. To date, models have been completed for Worcester, Calvert and Somerset Counties. This data can be downloaded from the iMap server in the following folder.

MD iMAP Folder



Shoreline Inventory – A Comprehensive Shoreline Inventory (CSI) was completed for the tidal regions of Maryland's coastal counties in partnership between Maryland DNR and the Virginia Institute of Marine Science (VIMS). The CSI captures baseline shoreline conditions throughout the tidal portions of the Chesapeake and Coastal Bays. Shoreline features and conditions were identified through a three-tiered shoreline assessment approach. Data from the survey was processed to create three GIS coverages, displayed through reports, summary tables, and maps, which are viewable Shorelines iMAP. This data can be downloaded from the iMap server in the following folder.

MD iMAP Folder



NAIP Imagery – National Agriculture Imagery Program (NAIP) collects aerial imagery for the U.S. during the growing season to make the digital ortho photography. NAIP imagery for Maryland can be downloaded from http://dnrweb.dnr.state.md.us/gis/data/

DNR Wetlands – were defined by the U.S. Fish & Wildlife Service's National Wetlands Inventory (NWI) program. The dataset was produced from aerial photography (Digital Orthophoto Quarter Quads) flown from 1988-1995. The metadata and spatial data can be downloaded from http://dnrweb.dnr.state.md.us/gis/data/

Shoreline Rates of Change – In 2003 Maryland Geological Survey (MGS) compiled historical digital shorelines for 1841-1977 time period. MGS contracted with EarthData International, Inc. to extract the shorelines from existing wetland coverage to estimate the shoreline rates of change for the Chesapeake and Coastal Bays. Metadata and spatial data can be downloaded from http://dnrweb.dnr.state.md.us/gis/data/ or pulled in from the iMAP server.

MD iMAP Folder

- Oceans
  - MD.State.HistoricalShorlines
  - MD.State.ShorelineInventory
  - MD.State.ShorelinePhotos
  - MD.State.ShorelineRatesOfChange
  - MD.Worc.ArtificialReefs
  - US.CoastalAreas.MarineMultipurposeCadastre

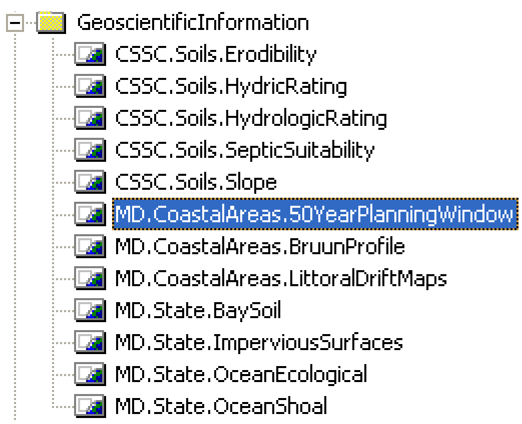
Storm Surge Areas – The US Army Corps of Engineers (USACE) completed two hurricane evacuation studies for the eastern (2007) and western (2010) shores of Maryland. The storm surge zones were generated using the Sea, Level, and Overland Surges from Hurricanes (SLOSH) model. SLOSH is a computerized model run by the National Weather Service to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes. The model provides geographical displays of color-coded storm surge heights for a particular area based on the shoreline, unique bay and river configurations, water depths, bridges, roads, and other physical features. This data can be downloaded from the iMap server in the following folder.

MD iMAP Folder

- ClimatologyMeteorologyAtmosphere
  - MD.State.OceanWindRose
  - MD.State.OceanWindSpeed100m
  - MD.State.OceanWindSpeed30m
  - MD.State.OceanWindSpeed50m
  - MD.State.OceanWindSpeed80m
  - MD.State.SeaLevelRiseVulnerability
  - MD.State.StormSurgeAreas

Erosion Vulnerability Assessment Tool (EVA) – the Baltimore District Army Corps of Engineers and DNR developed EVA to identify areas alongshore that have demonstrated historic patterns of instability, and currently support valued natural, social, or economic resources. As a planning tool, EVA uses a 50-year planning window to project shoreline position in 50 years to inform local planners where community infrastructure, cultural resources, and habitat are potentially at risk in the future. The map outputs identify where resources will be vulnerable, and can enhance or redirect future development options for individual communities, and define areas where opportunities for conservation easements could be directed. This data can be pulled from the iMap server in the following folder.

MD iMAP Folder



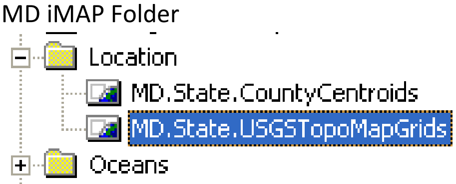
Parcel Boundaries – For each county, parcel polygons were extracted from a comprehensive parcel dataset. Depending on the County, the comprehensive parcel dataset may have contained parcels, rights of way, easements, annotation, subdivision boundaries, parcel centroids, and other property related features. The Maryland Department of Planning (MDP) collected the data from Maryland counties from May to July 2010. The parcel data is maintained and updated by the counties. Most of the coastal counties and municipalities (Baltimore City and Ocean City) were updated in 2010 with the exception of Worcester (2008), Wicomico (2009), Somerset (2007/08), and Caroline (2006) Counties.

Additional Data:

Hydric soil data (sSURGO) from Natural Resources Conservation Service may help identify areas for wetland restoration based on soil drainage; this may include restoring the natural hydrology to the site through the removal of dilapidated and unmanaged ditches and dikes. (http://soils.usda.gov/survey/geography/ssurgo/)

USGS Topographic Map – Digital color composite images of topographic quadrangle maps were produced by scanning a set of the USGS 7.5' topographic quadrangle maps covering the state of Maryland. The hardcopy source maps used for scanning were produced by USGS on loftrite, a white opaque stable base medium. The hardcopy maps were scanned at 250 dpi in 8-bit color by STS Systems of Parker, Colorado. The scanned images include all map collar information. The digital images and hard copy meet National Map Accuracy Standards at 1:24,000. This data can be pulled from the iMap server in the following folder.

MD iMAP Folder



Coastal Atlas
Shorelines Map Data Disclaimer

The historical shorelines and the rates of change, and predictive marsh modeling derived from this application are intended for informational use only. This application reports average rates of shoreline change over about the last 50 years. Please contact Maryland Geological Survey for specific questions about how the shoreline change data were generated. The information is not intended to predict future shoreline position, nor can it determine short-term changes associated with short-term storm events.

The marsh modeling displayed on this application is intended to be viewed at the landscape level and is based on the Sea Level Affecting Marshes Model (SLAMM) version 6.0.1 that was run by DNR in 2011. The model was run at the county level, for all 16 coastal counties and Baltimore City using local erosion, sedimentation, accretion rates and an estimated 3.4 foot rise in sea level by the year 2100 as outlined in Maryland's Climate Action Plan. This project brings together multiple data layers from different sources, and thus is challenged by spatial and temporal scales. In the coastal environment, this is most evident when comparing data originally referenced to different shoreline bases and mapped at different scales. Efforts to correct data to a single baseline can consume resources, and for that reason some data have been corrected; others have not.

While every effort has been made to provide useful coastal planning tools in the Coastal Atlas, the State of Maryland, its agencies, officers, employees, agents, and representatives, and SLAMM contributors can not guarantee the accuracy, reliability or timeliness of any information contained in the Coastal Atlas. Users rely on information contained in the Coastal Atlas at their own risk, and any conclusions or decisions based on the use of these tools are the responsibility of the user. The data, maps, and information provided should be used only as a screening-level tool for management decisions. As with all remotely sensed data, all features should be verified with a site visit. The data and maps in this tool are provided "as is," without warranty to their performance, merchantable state, or fitness for any particular purpose. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference tool and not for navigation, permitting, or other legal purposes.