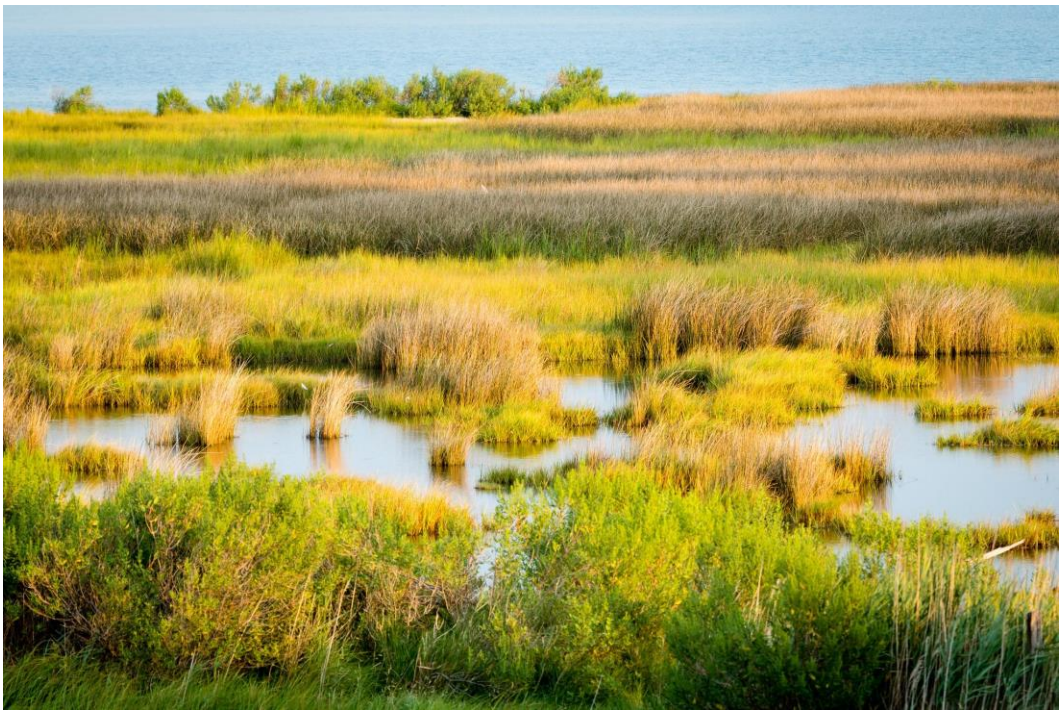
Climate Resiliency Outcomes

Management Strategy

2015–2025, v.3



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I. Introduction

All aspects of life in the Chesapeake Bay watershed—from living resources to public health, from habitat to infrastructure—are at risk from the effects of a changing climate. As one of the most vulnerable regions in the nation to the effects of climate change, the Chesapeake Bay is expected to experience major shifts in environmental conditions. Warming temperatures, rising sea levels and more extreme weather events have already been observed in the region, along with coastal flooding, eroding shorelines and changes in the abundance and migration patterns of wildlife. The stakeholders of the Chesapeake Bay watershed are large and diverse and are a critical component of any work to evaluate current and possible future conditions of the watershed. It is important that the work of the Climate Resiliency Workgroup (CRWG) embrace the diversity of these stakeholders, which includes decision makers, and utilizes the best available science while being responsive to their needs as they deliberate and make choices about implementation of the management strategy.

Changing environmental conditions will affect not only the health of our ecosystem, but also the success of restoration and protection work across the watershed. Documenting changes in temperature, sea level and weather events allows us to plan our efforts to anticipate and withstand the threats facing our communities in order to recover and adapt to the impacts from forecasted climate change. Effective programs and policies rely on good stakeholder engagement as we facilitate the continual assessment of and adaptation to the influence climate change has on our work. Adjusting to a changing environment helps us build the resiliency[1] of the region's living resources, habitats, and communities.

II. Goal, Outcomes and Baseline

This management strategy identifies approaches for achieving the following goal and outcomes:

Climate Resiliency Goal

Increase the resiliency of the Chesapeake Bay watershed, including its living resources, habitats, public infrastructure and communities, to withstand adverse impacts from changing environmental and climate conditions.

Monitoring and Assessment Outcome

Continually monitor and assess the trends and likely impacts of changing climatic and sea level conditions on the Chesapeake Bay ecosystem, including the effectiveness of restoration and protection policies, programs and projects.

Adaptation Outcome

Continually pursue, design and construct restoration and protection projects to enhance the resiliency of Bay and aquatic ecosystems from the impacts of coastal erosion, coastal flooding, more intense and more frequent storms and sea level rise.

Baseline and Current Condition

The Chesapeake Bay watershed has experienced changes in climate over the last century. Overall, the watershed is experiencing stronger and more frequent storms, an increase in heavy precipitation events, increasing Bay water temperatures and a documented rise in sea level, trends that are expected to continue over the next century. These trends, which vary both spatially and temporally throughout the watershed, are altering the ecosystems, the watershed, and the human communities of the Chesapeake Bay. Changes in policies, programs and projects will be necessary to successfully achieve restoration, sustainability, conservation, and protection goals for the Chesapeake Bay watershed.

The Climate Resiliency Goal and Outcomes were added in 2014 to the most recent *Watershed Agreement*. While no formal ecological condition or programmatic baseline for climate resiliency had

[1] *There are numerous definitions of "resiliency" in current academic and gray literature. The partnership will review the term ongoing, but the essence of the term is to ensure that the region's living resources, habitats and communities are prepared for changing conditions, are capable of withstanding impacts, where appropriate, and are able to recover and adapt to climate change impacts over time.*

been established when the climate resiliency goal was added, the Chesapeake Bay Program (CBP) partners have been engaged in climate change-related activities for some time. For example:

- The 2008 Scientific and Technical Advisory Committee (STAC) report "Climate Change and the Chesapeake Bay: State-of-the-Science-Review and Recommendations" synthesized the current understanding of climate change impacts on the Chesapeake Bay, identified knowledge gaps and outlined research priorities to address those gaps.
- The 2010 "Strategy for Protecting and Restoring the Chesapeake Bay Watershed" (Federal Leadership Committee for the Chesapeake Bay) noted that changing climate conditions are a significant challenge to successful restoration and protection of the Chesapeake Bay and its watershed. The report recommended a suite of actions to reduce vulnerability over time.

In addition to these two reports, CBP partners have published a number of additional documents and research related to climate science, monitoring, assessment and adaptation actions for the Chesapeake Bay and its watershed, as well as recommendations to drive future efforts. A compilation of some of these efforts, including key documents, peer-reviewed papers, and agency reports, are summarized in the Appendix A and B. This information could be useful in informing the establishment of baseline conditions for both climate Outcomes. The development of initial baselines for the two associate outcomes will be critical to long-term monitoring and assessment of progress toward goal attainment. Both the CBP's climate change indicator and climate modeling efforts also contribute to the improved understanding of baseline conditions.

III. Participating Partners

The following partners have participated in the development of this strategy. A Logic & Action Plan accompanies this management strategy. It illustrates the link between the factors that could impact the partnership's ability to achieve an outcome and the actions it is taking to manage them. It also identifies collaborative partner commitments for implementation of the strategy.

Chesapeake Bay Watershed Agreement Signatories

Outcome	Participating Jurisdictions/CBC	Participating Agencies
Climate Resiliency Goal		
Monitoring and Assessment	MD, DC, DE, PA, VA, WV, CBC	DOI (USGS/USFWS), NOAA, EPA, NPS, USACE
Adaptation	MD, DC, DE, PA, VA, NY, WV, CBC	USACE, NOAA, FWS, EPA, DOT, DOI (USFWS/NPS/USGS)

Other Key Participants

In addition to the signatory jurisdictions and participating agencies, a broad set of stakeholders is engaged in the development of the Climate Resiliency Outcomes Management Strategy. Organizations include:

Academic Institutions:

- Virginia Institute of Marine Science
- Old Dominion University
- University of Maryland
- Penn State University
- Virginia Tech
- Christopher Newport University
- Bucknell University
- William & Mary
- University of Delaware Cooperative Extension

Non-Governmental Organizations:

- National Wildlife Federation
- Maryland Sea Grant
- The Conservation Fund
- Made Clear
- Sierra Club
- Wetlands Watch
- Alliance for the Chesapeake
- South River Federation
- Virginia Conservation Network
- Chesapeake Research Consortium
- RAND Corporation/Mid-Atlantic Integrated Sciences and Assessments (MARISA) Program
- The Nature Conservancy

Federal Government

- U.S. Department of Defense (DoD)
- U.S. Department of Agriculture (USDA), U.S. Forest Service (USFS)

Local Government

- Metropolitan Washington Council of Governments
- Hampton Roads Planning District Commission

Other

- Bay Journal
- Chesapeake Bay Commission
- Arcadis

Local Engagement

There is an important role for local governments, planners, watershed associations, non-profits, academic institutions, and the private sector in achieving the Climate Resiliency Outcomes. Roles include, but are not limited to, the following:

- *Local Governments and Planners*. Local governments and planners should be prepared for a range of possible future conditions with respect to climate change impacts to better anticipate, prepare, recover and adapt to them over time. Local governments and planners can serve as partners with state and federal regulators and funders in identifying and undertaking implementation opportunities. Local communities, school districts and other public institutions can provide locations for pilot projects that support the monitoring and assessment objectives and can serve as a venue for showcasing successful projects throughout the watershed.
- *Watershed Associations*. Local stream and watershed associations can provide leadership through member-implemented projects to restore riparian areas, which can hold, slow and cool water in streams and rivers for the benefit of adjacent and downstream communities as well as wildlife. Watershed associations are key partners as they can serve a major role in identifying opportunities, as well as implementing on-the-ground best management practices that address both climate impacts and stormwater runoff.
- *Non-Profits*. Non-profit conservation organizations can help apply downscaled climate impact information to improve the resilience of specific sites to sea level rise, storm impacts and other climate-related impacts. They can provide leadership on programs that mitigate climate effects, such as reforestation, urban tree planting, and wetlands and floodplain restoration. As sources of information and public outreach, they can help educate and engage the public in supporting Chesapeake Bay Program climate resiliency objectives.
- *Academic Institutions*. Universities provide essential research needed to better understand climate change impacts on communities. Their findings can support guidance development on the best adaptation strategies to use in reducing risks to local communities. They can assist in translating their research for local decision-making through collaborative partnerships and developing tools to track climate change impacts and resilience progress.
- *Private Sector*. Through voluntary leadership in adapting corporate-owned lands to the impacts of climate change (through use of nature-based features for stormwater management, reforestation, and living shoreline or wetland restoration projects, for example), businesses can provide cost-effective, resilient models of addressing climate effects that will motivate employees and other stakeholders. Business improvement districts can lead the way in providing more resilient infrastructure in public spaces, which can create a more attractive environment for customers and employees as well as increasing protection against climate-related business interruptions.

IV. Factors Influencing Success

The following are natural and human factors that influence the partnership's ability to attain the Climate Resiliency Outcomes:

1. Monitoring & Assessment Factors

- **Scientific Capabilities.** The scientific capabilities to estimate, project, model and monitor ecosystem changes and impacts as a result of climate change are complex and resource intensive. Additionally, impacts are exacerbated by non-climate stressors (e.g., land-subsidence, land use change, growth and development). Appropriate science and modeling of climate and non-climate related stressors are necessary for CBP partners to properly address climate impacts during policy planning and adaptation efforts.

- **Geographic Extent/Variability of Watershed.** The impacts of climate change will be varied across the Watershed. It is important to not limit the focus of the management strategy to coastal issues alone but to recognize the wide range of monitoring, assessment and adaptation needs throughout the region. However, the variability of the ecosystem within the Chesapeake Bay proper and the larger watershed presents challenges in data consistency and comparability among regions and sectors.

- **Complexity of the Monitoring Program.** A monitoring program to detect ecosystem change and inform program and project response is a complex undertaking. Developing an acceptable monitoring approach for the watershed will be complex, and there are clear budgetary challenges associated with such long-term monitoring.

2. Adaptation Factors:

- **Stakeholder Engagement.** Although there is acknowledgement that climate change and adaptation need to be addressed, there is a lack of understanding or agreement from stakeholders on what it means to be resilient or what constitutes resiliency, including what kind of actions support an adaptive management approach. Lack of appropriate stakeholder engagement jeopardizes acceptance of choices made about action plans and implementation strategies, introducing additional levels of social discord in an already complex environmental-economic-social landscape. There are also different types of stakeholders, and in many cases, they have different goals making it challenging to have adequate resources to facilitate meaningful connections across all stakeholder groups.

- **Capacity.** There is a general lack of capacity to fill research gaps and translate the science and incorporate meaningful change into plans, programs, processes or projects across the entire CBP partnership. Although building that capacity is paramount, it can be time consuming and costly, considering the resource constraints faced by governments and organizations and the variability in adaptation approaches.

- **Authority**. Governments and institutions' ability to respond to climate change is limited by legislative, policy, regulatory and other authorities.

- **Guidance.** There is a need to translate existing science into guidance for the CBP, as well as stakeholders, to use to develop adaptation plans and to measure efficacy of response to climate change impacts. The nature of on-the-ground implementation often requires a level of certainty or methods to address uncertainty related to climate change effects on key

factors (e.g., hydrology, water quality, temperature, precipitation, sea level rise, coastal erosion rates). Additionally, there is variability in institutional responses on how to address climate change impacts making it challenging to develop guidance that can be applied consistently across all watershed jurisdictions.

- **Collaboration.** The many and diverse stakeholders and organizations that make up the CBP are a strength, but this also causes collaboration challenges that must be addressed in order to maximize limited resources and provide strategic adaptation approaches across the watershed.

V. Current Efforts and Gaps

The findings of past assessments, such as the 2008 State-of-the-Science Scientific Technical Advisory Committee (STAC) report, provide a foundation on which to continue monitoring and assessment of changing climate conditions, while providing a knowledge base from which to pursue the design and implementation of specific adaptation action strategies for the partnership.

The 2008 STAC Report and a literature review conducted in that report (Najjar et al. 2010) represent a fairly comprehensive review of the effects of climate change on the tidal Chesapeake Bay. There are also numerous published peer-reviewed papers and agency reports related to climate change monitoring and assessment. Additionally, numerous research institutions, such as Old Dominion University, Virginia Institute of Marine Science, University of Maryland, Pennsylvania State University, and Cornell University, have active and ongoing research on climate science, including projections for the Chesapeake Bay region and the associated potential impacts on the ecology of the Bay. There is also a growing toolbox of Climate Change Vulnerability Assessments (CCVA) being used by natural resource agencies, non-profits and other organizations to assess vulnerability of natural resources, including individual species, habitats, and places (e.g., protected areas, watersheds, and landscapes), to the effects of climate change.

Appendix A includes a summary of some relevant studies released during 2000-2015. Appendix B includes information on adaptation and mitigation efforts by academia, government and non-governmental organizations in the Chesapeake Bay region last updated in 2021. More current efforts are highlighted in the workplan developed to address the climate change priorities outlined in the 2021 Chesapeake Executive Council Climate Change Directive. The appendices in this strategy and the directive's workplan are not comprehensive lists as climate change research and efforts are vast in quantity. There are various climate change science and adaptation information databases, including the Georgetown Climate Center's Adaptation Clearinghouse and the U.S. Climate Resilience Toolkit, that have a building collection of climate change resources that are user-friendly to search for relevant information. Moving forward, information databases such as these should be evaluated for use in tracking the CBP partnership's climate resiliency efforts.

A summary of current relevant CBP partnership efforts and associated gaps with respect to both climate outcomes are provided below.

Current Efforts: Monitoring and Assessment

Environmental monitoring is an essential component of the CBP. The Chesapeake Bay Monitoring Program, which began in 1984, is a Bay-wide cooperative effort involving the states of Maryland, Pennsylvania, Virginia, and the District of Columbia, several federal agencies, 10 institutions and over 30 scientists. Current efforts include monitoring and modeling programs to assess ecosystem responses, with focus on the Chesapeake Bay TMDL and water quality. Through the integrated monitoring networks, CBP partners currently monitor various physical, chemical and biological characteristics around 16 times per year in the Chesapeake Bay's mainstem and many tributaries. Measured variables include: 1) freshwater inputs; 2) nutrients and sediments; 3) chemical contaminants; 4) phytoplankton; 5) soft-bottom benthos; 6) finfish and shellfish; 7) underwater Bay grasses, or submerged aquatic vegetation (SAV); and 8) water temperature, salinity, and dissolved oxygen. Many agencies have monitoring plans in place or under development, such as, but not limited to, the annual Bay-wide aerial SAV monitoring program, Chesapeake Bay Sentinel Site program for SAV, the NOAA Chesapeake Bay Sentinel Site Cooperative (CBSSC), the NOAA Chesapeake Bay Interpretative Buoy System (CBIBS), the NOAA Satellites and Information program, and the USGS National Water Information System, where observations related to key climate change parameters could be integrated to simultaneously assess climate and non-climate stressors.

The CRWG utilizes the monitoring data from other agencies to develop and update climate change indicators on Chesapeake Progress. The CRWG collaborated with the U.S. EPA climate indicator team and successfully developed seven climate change indicators that are now on Chesapeake Progress. The development of these indicators followed recommendations from the GIT-funded project report, "Climate Change Indicators for the Chesapeake Bay Program: An Implementation Strategy." These indicators monitor changes in average air temperature, high temperature extremes, stream temperature, total annual precipitation, river flood frequency and magnitude, and relative sea level rise. They provide information on long-term trends based on a 50 to 100-year period of record. Overall, these indicators of physical change provide general information whether the parameter is trending upwards or downwards. In 2021, the Management Board reviewed the climate change indicators and assisted in prioritizing ones that would have management utility related to the living resources and habitat goals (summarized in briefing document). Work continues to update these indicators and initiatives are in place to refine some of the current indicators to connect them more to natural resources management applications along with efforts to develop new climate change indicators. The trend analysis approach by the CBP Integrated Trends Analysis Team could potentially support the development or refinement of climate change indicators.

The CBP's Principal Staff Committee (PSC) recognized that the 2025 climate change projections indicated the need for additional reductions to the nutrient and sediment pollutant loads by the CBP in their 2-year milestones to counteract the impacts of changing climate conditions (e.g., warming, increases in precipitation) on achieving water quality goals. They agreed that jurisdictions are expected to account for additional nutrient and sediment pollutant loads due to 2025 climate change conditions in a Phase III Watershed Implementation Plan (WIP) addendum and/or 2-year milestones beginning in 2022 based on the CBP's modeled results. The partnership further committed to narratively describing the current understanding of 2035 climate change conditions. The CRWG contributed to oversight of the climate

change assessment development process specifically with directing the CBP modeling team on technical direction for input data for climate change analysis. The CRWG supported the STAC Climate Change Modeling 2.0 workshop that brought together experts in climate change, estuarine and watershed sciences to undertake a focused examination of the current results of the CBP Midpoint Assessment climate change modeling efforts, assess lessons-learned and recommend next steps. One of the outcomes of the workshop was the successful modification of bottom dissolved oxygen dynamics and how they are affected by sea-level rise and temperature in the TMDL climate model scenarios. These discussions and analyses demonstrated the importance of evaluating multiple climate change factors that can influence water quality outcomes, which could lead to improved management decisions.

In addition to the importance of considering climate change impacts related to nutrient and sediment loads in the Chesapeake Bay, the CRWG, along with other CBP workgroups and Goal Implementation Teams, supported a series of workshops on rising water temperatures through STAC. These workshops assessed the state of the science of rising water temperatures and resulting impacts to habitats and living resources for both the tidal and non-tidal waters of the Chesapeake Bay. They resulted in the development of recommendations for considering rising water temperatures in management decisions and the identification of research needs presented in the workshop report. These workshops addressed the critical question: what might the CBP partnership do now–within the scope of its current goals, policies and programs–to actively prevent, mitigate or adapt to adverse consequences of warming waters from climate change. Recommendations included expanding monitoring and improving models to improve tracking water temperature change and consequent impacts to living resources; pairing water and air temperature measurements to better understand the forces driving rising water temperature; supporting nearshore research to improve understanding on how and to what extent watershed Best Management Practices (BMPs) used to reduce nutrients and suspended sediment can reduce warming and provide cooling benefits; supporting work to increase understanding of water temperature thresholds and co-occurring stressors on tolerance limits for key species; and increased communication with relevant stakeholders and decision makers on the implications of rising water temperatures.

The CRWG has supported a number of cross-workgroup, collaborative efforts to build in climate change considerations to inform natural resource decisions. The collaborative, GIT-funded Marsh Migration Data Synthesis project led by the Wetland Workgroup and the Virginia Institute of Marine Science (VIMS) resulted in a recommended methodology to address variability in marsh migration model outputs for targeting marsh restoration projects. Another collaborative effort included the GIT-funded project, "Envisioning the future for Chesapeake Bay SAV ecosystems under climate change: shifting stressors and shifting foundation species," led by the SAV Workgroup. This project is providing information on how climate change and other stressors will affect SAV communities and likely future shifts in prevalent species occupying the Chesapeake Bay. The CRWG also collaborated with the Water Quality GIT and Virginia Tech in supporting the development of the 2022 report, "A Systematic Review of Chesapeake Bay Climate Change Impacts and Uncertainty: Watershed Processes, Pollutant Delivery, and BMP Performance." This report includes a systematic review of the existing literature to provide insights on how climate change will affect BMP performance and identifies knowledge gaps.

Gaps: Monitoring and Assessment

Climate Resilience Tracking. The Climate Resiliency outcomes do not have quantifiable metrics, making it difficult to evaluate whether the partnership is making progress at the desired rate. While the work to develop the seven indicators on Chesapeake Progress was a critical first step, these indicators only represent physical stressors, and they are not currently structured for local partners to use as a tool to inform climate resilience decisions for restoration projects in their area. These physical change indicators need to connect with ecological and community impacts and ultimately correspond to resilience actions related to habitat and living resource impacts to help evaluate progress toward the outcomes. Progress in monitoring and assessment are needed to help inform which adaptation actions to take and where.

Climate Science. While the efforts at the CBP have focused on assessing the current condition of the watershed, addressing climate change will require continued assessment and analysis, data consistency, as well as new approaches to fill critical science gaps. Moving forward, we will need continued efforts to develop a comprehensive understanding of the current science and management actions across the variable watershed relevant to the goals and outcomes of the *Watershed Agreement*.

Increased understanding of downscaled climate data for the Chesapeake Bay watershed, as well as the availability of future climate projections is needed. Although some modeling efforts have occurred, standardized assessment approaches to utilize projections to identify key vulnerabilities and tradeoffs and account for uncertainty (e.g. BMP effectiveness) have not been developed for the watershed. Such projections could be used as inputs to a variety of hydrological and ecological models to assess potential future climate impacts on natural and human systems. There is a need for more consistent and accurate modeling to enable the consideration of climate impacts.

Assessing the effectiveness of restoration and protection policies, programs and projects, such as the Chesapeake Bay TMDL, BMP implementation, and efforts associated with building resilience for aquatic resources in the watershed and Chesapeake Bay, will require improving scientific capabilities to monitor, model and assess ecosystem impacts and response. Currently, both technical barriers (data availability, accessibility, formatting and model programming, particularly across appropriate spatial scales) and gaps in science knowledge on how climate change will affect BMP efficiencies and restoration strategies, present challenges to completing such assessments.

Monitoring and Modeling Coordination. Ensuring that monitoring systems can reliably detect signs of climate change and differentiate these signals from restoration or degradation is a complex undertaking. Virtually all the parameters measured by the CBP are informative with regard to how climate change is impacting ecological and hydrological systems of the watershed. Better alignment and application of monitoring data is needed to inform CBP watershed and estuary modeling efforts. Integrated environmental modeling consists of utilizing a variety of water quality, flow, sediment, ecological, air quality and other models that more holistically represent an environmental system where all components influence one another. There is also a need to better understand the

interaction of climate (temperature, water flow) and non-climate-related (nutrients, dissolved oxygen, salinity) stressors on the vulnerability of habitats and living resources. A coordinated effort towards improving integrated monitoring and modeling that includes climate and non-climate parameters and the inclusion of future climate change projections is needed to improve our understanding of climate change effects on restoration goals. Ultimately, the process of assessing future climate risk to the Chesapeake Bay watershed and tidal waters will be an iterative process of reassessment reflecting changes in the science, analysis tools, and climate.

Current Efforts: Adaptation

The CBP partners are engaged in a wide array of climate change activities across the region, designed to strengthen the watershed's resilience to climate change. Appendix B includes additional adaptation efforts by governmental and nongovernmental organizations updated in 2021.

Looking towards the future, the CRWG has taken time to evaluate how they can capitalize on recent funding opportunities including the 2021 Bipartisan Infrastructure Law and the 2022 Inflation Reduction Act. Both pieces of legislation allocate funding for natural infrastructure projects. Since then, several federal agencies (e.g., NOAA, EPA, USGS) have released Requests for Proposals for various grant programs supported by this influx of funding. The CRWG has held discussions on how best to maximize resources and capacity as a means of capitalizing on these various funding opportunities. The workgroup has an opportunity to help position partners in a way that makes them more competitive for this federal funding; support could mean assisting with project conceptualization, grant writing, partner alignment, and finding funding sources for projects. The CRWG's current GIT-funded Marsh Adaptation Project is a focused effort to assist with partnership-building and identification of marsh restoration projects that build in resilience considerations. The goals of this project include, 1) synthesize and promote use of common resilience and social vulnerability metrics for selecting marsh restoration locations and measuring success and 2) build partnerships to pursue marsh restoration and research projects under the influx of resiliency funding through alignment of priorities.

To improve stakeholder engagement and inclusion of under-represented groups in restoration and resilience discussions, the CRWG supported the Habitat GIT's project, "Targeted Outreach for Green Infrastructure in Vulnerable Areas," which released their final report in 2022. This project included outreach and conceptual designs for four under-represented community areas, including two areas within tribal lands. The CRWG also assisted the CBP Strategic Engagement Team by providing information on resilience tools and studies to support the following efforts:

- Educational modules with climate change call out boxes: A Local Government Guide to the Chesapeake Bay
- Climate webinars: 1) Plan Integration for Resilience AND Equity and 2) Leveraging Hazard Mitigation for Water Quality Benefits.
- Local Leadership meeting on resilience information to climate related flooding (Aug 2021).
- Maryland Municipal League Panel on Equity in Climate Resilience (June 2021) and Magazine Article 'Seeking Solutions for Addressing Stormwater-related Flooding Challenges' (Dec 2021).

Federal Efforts. The federal partners in the CBP are among the most prominent and active federal agencies addressing climate change. They are acting to build capacity in climate science, develop tools to assist in planning and implement informed decisions on the ground. The National Oceanic and

Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Fish and Wildlife Service (USFWS), the U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA) and the Department of Defense (DOD) are among the numerous agencies actively involved in programs, planning and conducting research on climate change. For instance, NOAA developed the Sea Level Rise Viewer to visualize community-level impacts from coastal flooding and the USGS is supporting research on climate change vulnerability and risks to coastal habitats and lands to inform ecosystem management decisions as part of their 2015-2025 Chesapeake Science Strategy. Furthermore, the USGS developed a Coastal Change Hazards Portal, which provides interactive access to coastal change science and data and focuses on three main coastal change hazard themes: 1) extreme storms, 2) shoreline change, and 3) sea-level rise.

State Efforts. States and communities around the Chesapeake Bay are taking steps to prepare for climate change. The District of Columbia and most Bay states, including Delaware, Virginia, Maryland, Pennsylvania, and New York, have developed either standalone climate change adaptation plans or a sustainability plan that incorporates climate change and adaptation. Several states and the District have established advisory bodies, such as Virginia and Maryland's Climate Commissions, to guide efforts and to oversee plans, projects and future actions that can help create more resilient communities (Source: http://www.georgetownclimate.org/adaptation/state-and-local-plans). Jurisdictions also adjusted their Phase III Watershed Implementation Plans through the two-year milestones to provide a narrative on their programmatic commitments to address anticipated increases in nitrogen, phosphorus, or sediment due to climate change. In 2022, the Chesapeake Bay Program drafted a workplan highlighting actions that would support the priorities listed in the Chesapeake Executive Council Climate Change Directive. To account for the current and planned climate resiliency work, the workplan includes a list of ongoing and planned climate resiliency efforts by the state jurisdictions and federal agencies.

Local Government and Community-Based Planning. Local governments, planners, and communities are employing new and creative strategies to further adaptation opportunities to the impacts of climate change. For instance, the city of Norfolk, Virginia, was selected in 2013 to participate in the Rockefeller Foundation's 100 Resilient Cities Challenge for the purpose of building urban resilience in the face of climate change. The city of Norfolk has also implemented innovative practices to build urban resilience to flooding in their new zoning ordinance, including the use of a resilience quotient system where developers earn points for adopting resilience measures. Additionally, the Virginia Coastal Policy Center at William & Mary Law School, in partnership with local communities, supports implementation of the Resilience Adaptation Feasibility Tool (RAFT), a collaborative, community-driven process and full-service tool developed to help coastal localities improve resilience to flooding and other coastal storm hazards while remaining economically and socially viable. The Middle Peninsula Planning District Commission in Virginia launched their Fight the Flood program, which assists in connecting property owners facing rising flood waters with funding mechanisms to contract with specialized businesses who can help evaluate, design, and build solutions. Inventive legislation includes the Maryland Senate Bill 457 authorizing local governments to establish and fund a Resilience Authority, which offers flexibility to organize funding structures for large-scale infrastructure projects that address climate change effects, such as sea level rise, flooding, increased precipitation, erosion, and heatwaves. Maryland also has created the MD Climate Resiliency Portfolio project, which is a suite of restoration and conservation

projects that work together synergistically to avoid one-off projects, optimizes resiliency benefits and leverages important habitat, water quality, and GHG mitigation gains, allows for longer budgeting timeframes, generates new funding and financing opportunities, and provides an opportunity to better integrate gray/green infrastructure approaches. Through the first seven months of the project, meetings were held with MD Department of Natural Resources, MD Environmental Service, and representatives from the two Targeted Resiliency Areas (TRA). An initial site visit was conducted by staff for both TRA regions to inform discussions around potential projects and familiarize staff with the TRA regions. Substantial time was spent refining the goals and approach for modeling the two different TRAs and initial collection of data from these TRAs was undertaken. Pennsylvania's Department of Environmental Protection is helping local governments develop local greenhouse gas inventories and climate action plans. As of January 2023, 63 local governments and 96 college students have been engaged in the program. Ten local governments who successfully completed the Local Climate Action Program also participated in a Shared Energy Manager program, which assisted the local governments in implementing their plans.

Building resilience against climate change requires improving the understanding and communication of changing climate conditions and the factors impacted by them. The CBP enacted a Local Engagement Team, now known as the Strategic Engagement Team, and Strategy to support actions related to communication, outreach, and/or engagement. The CRWG works with this team by providing climate science and resiliency data for local engagement efforts in support of the adaptation outcome. Additionally, the CRWG partnered with the CBP Local Government Advisory Committee in hosting a forum in 2020 that brought together local elected officials and subject matter experts to collaboratively identify recommendations on what they can do to act more deliberately in addressing climate-related flooding from more intense storms, increasing precipitation, high tides and sea level rise. In 2022, the Local Government Advisory Committee hosted a forum focused on integrating resilience into local planning. Currently, local governments face increasing pressure to ensure the safety and health of residents, businesses, infrastructure, and the natural environment in the face of a changing climate. This forum addressed the need to incorporate resilience into local planning, identified the barriers to integrating resilience into local processes, and developed next steps and recommendations. These next steps include developing communication of clear, localized language to provide to local governments, guidance on integrating resilience into existing processes, expanding funding opportunities to increase flexibility and eligibility criteria, generating greater buy-in from stakeholders through outreach, and building capacity in each state to provide technical assistance and support local governments.

Non-governmental organizations: Non-profit organizations and academic institutions also play an important role in adaptation efforts. Examples include the *Blackwater 2100: A Strategy for Salt Marsh Persistence in an Era of Climate Change* report, where The Conservation Fund and Audubon MD-DC partnered with the USFWS, Maryland Department of Natural Resources, the Chesapeake Conservancy and other organizations to produce a salt marsh adaptation strategy for Blackwater National Wildlife Refuge. The Chesapeake Bay Sentinel Site Cooperative hosted a Marsh Resilience Summit that brought together scientists and practitioners to discuss marsh vulnerability, the different approaches to most effectively respond to the changing marsh conditions and landscapes, and research needs to improve future planning and decision making. Lastly, in October 2022, Maryland Sea Grant hosted a workshop

focused on discussing large-scale marsh persistence and restoration in the Chesapeake Bay. This workshop brought together practitioners, researchers, and local community experts to discuss ways in which to plan for and collaborate on large-scale marsh conservation/restoration projects in the Chesapeake Bay.

Non-governmental organizations are also leading the way to implement blue carbon crediting strategies for marshes and seagrasses. The Virginia Institute of Marine Science (VIMS) received USDA funding to develop a model for mapping estuarine landscapes and quantify blue carbon stocks (organic matter stored in coastal ecosystems). Nonprofit organizations, like the Environmental Policy Innovation Center, Tierra Resources, and Verra, are advancing the application of blue carbon crediting through policy, establishing voluntary carbon markets, consulting, and implementing pilot projects. These organizations have also coached the CRWG on the basics of blue carbon markets to help the workgroup with efforts to begin identifying science needs for applying existing blue carbon crediting protocols for wetland and Submerged Aquatic Vegetation (SAV) restoration efforts in Chesapeake Bay. In 2022, the Chesapeake Bay Program published its report on enhancing monitoring networks within the Bay. Included in this report are identified science needs around assessing carbon sequestration related to tidal wetlands and SAV and potential application of conservation and restoration efforts of these resources in the carbon market.

Gaps: Adaptation

Institutional capacity. Climate change is an emerging issue that has not been fully integrated into existing Chesapeake Bay restoration and management efforts within the CBP. This issue is illustrated by the limited extent to which climate change has been considered in the broader *Watershed Agreement*. To address this gap, capacity must be built among the CBP partnership to: 1) more holistically understand and address the consequences of changing climate conditions, which includes both ecosystem and societal responses; 2) support informal and strategic collaboration across organizational, jurisdictional and disciplinary boundaries to maximize resources; 3) coordinate science needs, environmental monitoring/data collection, tool development and communication products; 4) construct inclusive, transparent processes to inform stakeholders about policy, program and project alternatives; and 5) plan for and implement restoration and protection efforts that build community and ecosystem resilience within the Chesapeake Bay watershed.

Cross-cutting programmatic gaps. The *Watershed Agreement* includes 29 individual Management Strategies to be implemented by six GITs and several workgroups. Most, if not all, of these strategies will likely include a suite of actions intended to address climate change impacts. As a result, the partnership needs to achieve strategic collaboration across the other goals that maximizes resources, encourages a coordinated effort to include climate change resilience in their work, and connects climate science to inform decision making. The identification of climate change cross-linkages with the *Watershed Agreement* goals and outcomes is occurring, but not at the level that is needed to make timely progress in adapting to policies and programs to changing climate conditions.

Linking science to implementation. Resources are needed to connect climate science to implementation, including a cohesive framework and guidance that includes science components

(monitoring, modeling, and assessment) as well as stakeholder deliberation, prioritization and goal-setting components. Starting with the current integrated modeling expertise at USEPA, it is possible to improve the Chesapeake Bay watershed assessments of current and future conditions as well as indicator development and data synthesis analyses to inform targeting and resilient design for on-the-ground projects and other adaptation implementation strategies for both coastal and watershed projects.

Facilitated Stakeholder Engagement. While the Chesapeake Bay stakeholders have a long history of meeting and discussing goals and outcomes, what is missing from current efforts are facilitated discussions guided by a broad assessment framework, which links scientific and social-scientific activities needed for a cohesive Chesapeake Bay management strategy. Rather than seeking to educate and perform outreach at the end of the analytical process and the beginning of the implementation process, cross-disciplinary, collaborative stakeholder discussions should be initiated at the start of adaptation and management efforts. These collaborative learning approaches must include discussions of audience-appropriate climate change education and information materials during the process.

VI. Management Approach

The partnership will work together to carry out the following actions and strategies to achieve the Climate Resiliency Goal. The Management Approach seeks to address the factors affecting the ability to meet the gaps identified above.

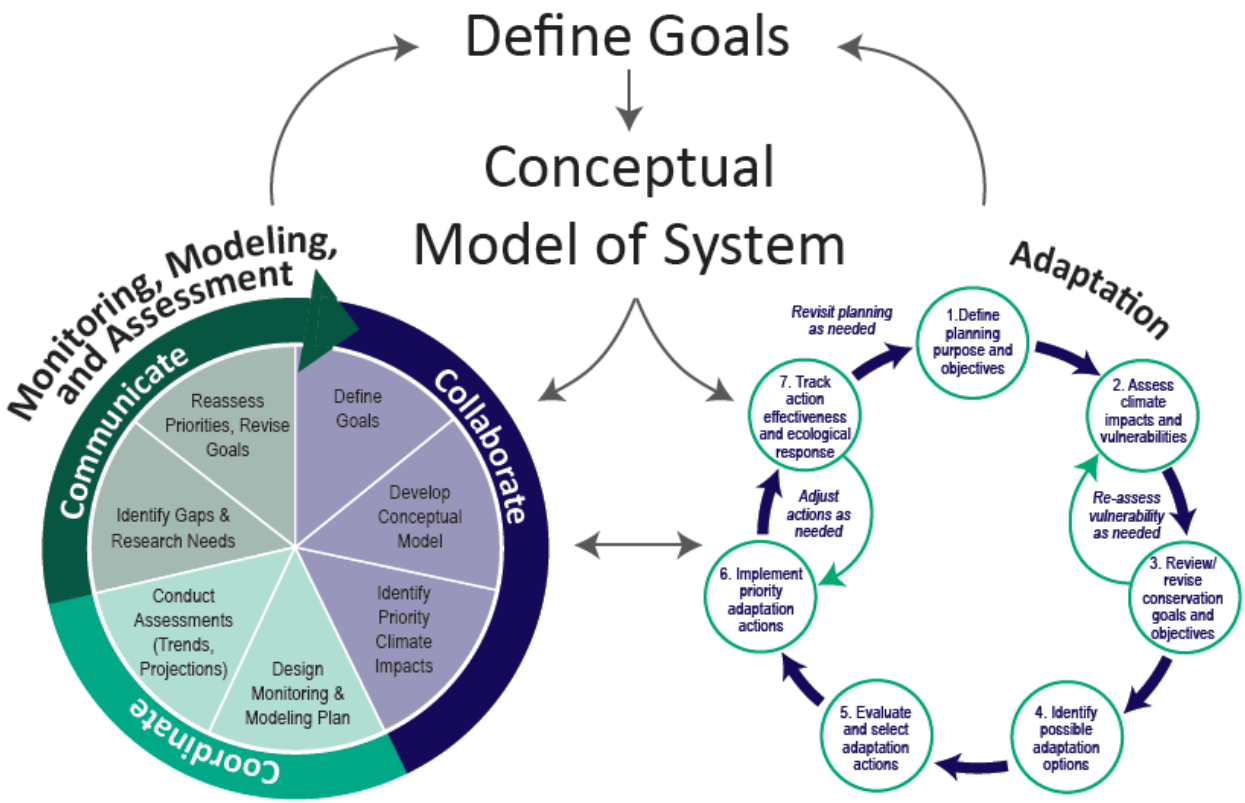
The *Watershed Agreement* includes 29 individual strategies to be developed and implemented by six GITs and various workgroups. In many cases, the effect of climate on individual outcomes is not well understood, and in other cases, it is established and moving forward. The adopted management approach will require coordination across the GITs and with the CRWG providing advisory support to ensure that efforts to incorporate climate change in their strategies are consistent and complementary. The workgroup will consult with the GITs to help prioritize which aspects of climate change have the most impact on achieving outcomes, identify science needs and coordinate a research agenda for those outcomes where the effect of climate is not well understood, and coordinate with the Integrated Monitoring Network Workgroup to establish whether suitable monitoring exists within the Chesapeake Bay to establish baselines and assess progress related to climate change.

The CBP has had much success in developing a variety of pollutant control measures as well as implementation of restoration and protection projects and commitments. To ensure that these efforts continue and are based on the best science available as well as improving stakeholder engagement, it is important to continue to develop and maintain capabilities to evaluate, assess and forecast the effectiveness of these measures in light of simultaneous impacts from multiple pollutants and climate change. This will require consolidated efforts among scientists, practitioners and stakeholders to understand societal responses as well as limitations of the science.

To address climate resilience, it will be important to assess the relative effectiveness of proposed measures, best management practices, restoration/preservation projects and regulations. Because the

ecosystem response will be holistic, it is important to develop an analytical capability to best capture both science and society. Building cross-science disciplinary knowledge and better understanding societal responses will create greater opportunities to think about the Chesapeake Bay watershed and ecosystem on a broader scale.

Figure 1 graphically represents the Management Approach that will be utilized to achieve the Climate Resiliency Outcomes. This approach includes a biennial reassessment of baselines, goals and priorities.



Climate-Smart Conservation Cycle[2]

Figure 1. Climate Resiliency Outcomes Management Approach – Process Framework

The approach recognizes that multiple spatial and temporal scales are at play with regard to ecosystem impacts, responses and local vs. regional priorities. Without imposing a one-size-fits-all strategy, evaluation of ecosystem responses and stakeholder perspectives requires sensitivity to spatial and

[2] *Stein, B.A et al. 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, D.C.*

temporal scales when proposing or approving projects, control measures, best management practices or other adaptation strategies.

Monitoring and Assessment Outcome

Monitoring and assessment in conjunction with modeling, statistics and other scientific tools will be required to improve our understanding of ecosystem responses to climate change. The strategic development and maintenance of modeling, monitoring and assessment programs will allow the partnership to evaluate and compare current and alternative future scenarios constructed for different policies, programs and projects in response to the potential impacts of climate change together with anthropogenic activities.

Using the framework as illustrated in Figure 1, the following actions and steps to be undertaken in an ongoing process are proposed to achieve the Monitoring and Assessment Outcome:

Management Approach 1: Assess past and future trends of climate change in the Chesapeake Bay and watershed in connection with the goals in the Chesapeake Bay Watershed Agreement

1. ***Define Goals and Establish Baselines*.** This action will require establishing baselines for the monitoring, modeling and assessment of different aspects of climate change as part of a core network. An evaluation of existing data, research, studies and tools, as they relate to climate and the needs for each of the management strategies, should be conducted and thoroughly documented. Available data and gaps in the monitoring network for each management outcome will need to be identified. This action will require coordination between the CRWG and the Integrated Monitoring Network Workgroup and the GITs for each outcome and should utilize existing studies on past conditions by USGS, NOAA, EPA, the academic community and others for the range of climate indicators identified as critical to each outcome. To be successful, the incorporation of key climate change factors in long-term monitoring programs is needed.
2. ***Assess Trends and Conduct Assessments*.** Assessing changing climatic and sea level conditions and trends is a vital and essential component of the Resiliency Goal in the Chesapeake Bay Watershed Agreement. The CRWG will collaborate with partners to analyze trends and document observed changes in sea level, precipitation patterns, Bay temperature, and the ecosystem responses. Using the trend analysis in combination with modeling programs and interrelated socioeconomic assessments, the CRWG will coordinate with STAC and identify prospective cross-workgroup pathways to support climate vulnerability assessments related to the CBP partnership's water quality, habitat, and living resources goals. Additionally the CRWG will support efforts to assess the effectiveness of existing restoration and protection policy and regulatory programs and projects. The results of these assessments will be used to inform the development and prioritization of both on-the-ground projects and programmatic management strategies.

Management Approach 2: Fill critical data and research gaps and improve understanding of climate change impacts and implications for selected outcomes in the Chesapeake Bay Watershed Agreement

1. ***Prioritize Research Gaps*.** Using information from assessment efforts, a consultative prioritization will be performed to determine which of the gaps are most critical to outcome

attainment. The highest priorities for the *Chesapeake Bay Watershed Agreement* should include the identification of gaps that impact multiple outcomes. The CRWG has identified efforts to increase our understanding of sea level rise effects to coastal wetland/marsh habitats and their ecosystem services and how increased precipitation and warming temperatures affect submerged aquatic vegetation as initial cross-GIT outcome priorities. The CRWG will facilitate discussions with subject matter experts to relay emerging research with workgroup members and the scientific community and provide possible connections and application of the science to inform climate resilience decision-making.

2. ***Support Application of Climate Change TMDL Projections****.* Standardized approaches are needed with regard to forecast projections utilized within the CBP for assessing the impact of climate on independent goals and outcomes. There is a wide range of projections within the scientific literature related to forecasted precipitation, storm intensity, air temperature, sea-level rise, etc. It is important that the CBP be consistent in how these projections are utilized as assessments are made. The CBP will re-evaluate the effects of 2035 climate on the reduction of nitrogen, phosphorous, and sediment in 2025. The CRWG will provide directional support again to the CBP modeling team in preparation for the 2035 climate change analysis with the TMDL model.

3. ***Support BMP Research Agenda****.* Better understanding of the BMP responses, including new BMPs, to climate change conditions, such as increased precipitation and warming temperatures, is a pressing and ongoing research need of the CBP. The science understanding BMP vulnerabilities is emerging, and this information can be used to inform a research agenda to better understand how BMP efficiencies are changing as a result of climate change. CBP partners are conducting multiple studies to start answering these science needs, including the Chesapeake Stormwater Network's report on stormwater BMP vulnerabilities and resilient design considerations, Virginia Tech's STAC and NOAA-funded ongoing science synthesis on BMPs and climate change uncertainty, and the Urban Stormwater Workgroup's GIT-funded project with the RAND Corp. to establish new intensity duration frequency (IDF) curves under increased precipitation scenarios for improved stormwater engineering guidance. Even with these efforts, given the vast amount of BMPs used to meet water quality goals and the complexity of incorporating climate change considerations, dedicated funding and research is likely needed to fully answer all the science gaps. The CRWG will support these ongoing efforts through cross-working meetings to discuss findings and next steps and work with CBP partners to identify options for BMP climate change research.

4. ***Support Efforts to Promote use of Climate Science Data***. The CRWG will support STAR's effort to explore collaborative opportunities with existing tools, such as EnviroAtlas and Environmental Justice Screening Tool, to understand their applicability to incorporate climate resilience information related to the CBP goals. These efforts could help maximize limited resources and offer platforms to share climate change science for the CBP, as well as stakeholders, to use to develop plans or to measure efficacy of response.

Approaches Targeted at Local Participation

- ***Undertake Public, Stakeholder and Local Engagement.*** Traditionally led by scientists, partners will need to build the capability to better understand and address societal responses to policies affecting pollution, climate and control measures. The 2008 STAC report concluded that climate change will change the socioeconomic and cultural environment of Bay stakeholders, particularly fishermen and those whose livelihoods are directly connected to the water. As such, it is important that the best physical science information and forecasting are utilized and interpreted in a way that is meaningful to the public and policy makers. The data collected during the monitoring and assessment component must be accessible and able to support stakeholder discussions on the socioeconomic impacts of climate change on the Chesapeake Bay. This can best be achieved by collaborating with stakeholders in the development of data synthesis products for their use.

Adaptation Outcome

The essence of this outcome is to facilitate, demonstrate and implement "climate smart"[3] protection and restoration planning to enhance the resilience of the Chesapeake Bay watershed's habitats, public infrastructure (e.g., water and waste water systems, critical transportation assets) and human communities from the impacts of coastal erosion, coastal flooding, more intense and more frequent storms and sea level rise. Adaptation strategies will need to consider a range of future conditions to appropriately address uncertainty associated with climate change and its corresponding impacts.

On-the-ground restoration efforts will be addressed largely through the 29 individual outcomes comprising the *Chesapeake Bay Watershed Agreement*. It is critical that these restoration efforts be made climate smart by considering and integrating changing climatic conditions (e.g. precipitation patterns), sea-level rise and storm surge factors in the pursuit, design, implementation and long-term maintenance of restoration components of each outcome. Climate change considerations must be designed into current agricultural, forestry, urban and wastewater Best Management Practices (BMPs) associated with the Chesapeake Bay TMDL/WIP goals. Additionally, the CBP partnership may need to use specific BMPs to address specific restoration or protection needs, such as restoring or protecting areas that may serve to facilitate inland wetland/SAV migration, or siting and designing wetland restoration efforts to optimize for accretion.

To ensure that adaptation efforts are forward-thinking and not actually maladaptive, a systematic approach to planning should be undertaken. Several systematic approaches to climate change adaptation planning exist, most of which are modifications of an adaptive management planning rubric such as the *Open Standards for the Practice of Conservation*. Two of the more frequently mentioned approaches to adaptation planning are the *Adaptation for Conservation Targets* (ACT) *Framework* (Cross

[3] *Defined by Stein et al. (2014) as: "The intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities."*

et al. 2012)[4], and the *Climate-Smart Conservation Cycle* developed by an expert group empaneled by the National Wildlife Federation (Stein et al. 2014) (see Figure 1). The Climate-Smart Cycle features seven steps in an iterative process, to be informed by monitoring and assessment, at each step of the cycle.

Guided by a systematic approach to adaptation efforts, the following actions and steps are proposed for an ongoing process to achieve the Adaptation Outcome:

Management Approach 1: Improve knowledge and capacity to implement and track priority adaptation actions in connection with the goals in the Chesapeake Bay Watershed Agreement

1. ***Track Adaptation Action Effectiveness and Ecological Response.*** The establishment of performance metrics will aid in the assessment of progress to achieve the Adaptation Outcome. Based on these metrics, the workgroup will work to: 1) produce or evaluate guidance on implementation of climate change science within adaptation decision making processes; 2) identify significant gaps in terms of adaptive capacity (i.e., maladaptive management strategies or legal, policy or regulatory barriers); and 3) ensure that monitoring and assessment align with adaptive management needs. A feedback loop, to be developed, will ensure that adaptation approaches are utilizing the best available science and techniques.

2. ***Identify and Support Implementation of Priority Adaptation Actions.*** The Adaptation Outcome calls for the continual pursuit, design and construction of restoration and protection projects to enhance the resilience of the Bay and aquatic ecosystems from the impacts of coastal erosion, coastal flooding, more intense and more frequent storms and sea level rise. The pursuit of specific adaptation projects will be a major undertaking on the part of the partnership and an effort that will be carried out, most likely by participating partners, agencies, local government and stakeholders. Implementation will require consideration of long-term planning horizons and a range of possible future conditions to account for the uncertainty associated with climate change impacts, including sea level change. This effort will involve the following components:
    a. Several gaps must be addressed, including increasing the capacity of the CBP to: 1) build community and ecosystem resilience within the Chesapeake Bay watershed through collaborative partnerships; and 2) remove some of the institutional barriers that currently exist. In the near-term, the CRWG will focus efforts on: 1) identifying priority adaptation actions and convening discussions to assess lessons learned from past and ongoing adaptation planning and programmatic efforts within the Chesapeake Bay watershed; 2) providing guidance for climate-related siting and design for on-the-ground protection and restoration projects; 3) identifying science needs and sources for technical and financial assistance (e.g., evaluate science gaps preventing use existing blue carbon crediting protocols); and 4) coordinating with the local leadership and engagement teams to identify specific policy, programmatic and regulatory enhancements that will increase support for such efforts (e.g., the protection of wetland migration corridors).

[4] *Cross et al. (2012). The Adaptation for Conservation Targets (ACT) Framework: A tool for incorporating climate change into natural resource management.* Environmental Management *50: 341-351.*

b. It is recognized that underrepresented communities are often geographically based in high-risk areas that may be vulnerable to the effects of climate change. When targeting and implementing specific adaptation projects and community outreach, the CRWG will use DEIJ principles as a priority targeting mechanism in the decision-making process to ensure fair distribution of CBP partnership resources and restoration activities across all communities in the Chesapeake Bay watershed.

Management Approach 2: Undertake public and stakeholder engagement in increase understanding of climate change impacts to inform and support adaptation.

1. ***Establish Adaptation Outcome Priorities with Stakeholders.*** The CRWG will seek to engage stakeholders (including decision makers) by considering stakeholder-driven approaches that facilitate their articulation of desired outcomes and prioritization of those outcomes. Further, once stakeholders describe and articulate those outcomes, scientists connect the best available appropriate science to those outcomes, which includes the evaluation of climate scenarios for achieving the Chesapeake Bay goals and resilience in light of climate change. Critical to any approach is the capability to facilitate stakeholder inclusiveness, foster coordination and collaboration with affected communities, and ensuring that the best available science is used to evaluate adaptation alternatives that they want to consider. One strategy to increase local engagement is to incorporate climate connections into the Management Strategy and Logic & Action Plan for the Local Leadership Outcome, as appropriate. Current efforts include incorporating information on climate change impacts to local priorities into local government educational modules and workshops.

Management Approach 3: Address the institutional capacity of the Chesapeake Bay Program to prepare for and respond to climate change.

1. ***Capacity Building.*** Working with the Goal Implementation Teams (GIT) and other appropriate CBP partners, the CRWG will help to build the capacity among the CBP partnership to understand and address the consequences of climate change. While this is likely to involve significant investments of time, the CRWG recognizes that without such capacity building, efforts to achieve the other CBP outcomes will likely be in even worse condition in the future.
    a. For the CBP outcomes where the linkages to climate are not well understood, it will be necessary to conduct research to improve that understanding. The CRWG will consult with the GITs on cross- GIT climate change projects and serve as a liaison between the research community and GITs in order to provide the most up to date climate science. In some cases, other Management Strategies of other CBP outcomes may need to be revised or reconsidered to accommodate anticipated climate-related changes or impacts. GITs will need to coordinate with each other, and the CRWG, as well as decision makers to ensure that climate-related impacts have been considered in a manner responsive to these stakeholders' needs.

2. ***Reassess Priorities and Revise Goals.*** Progress will be reviewed on a biennial basis, with emphasis on evaluating progress toward the closing of gaps in baseline monitoring and assessment tools, scientific research, and building collaboration within the CBP and with outside organizations to build institutional capacity. The CRWG will organize and facilitate meetings to work towards these goals and seek to have workgroup activities benefit member organizations around building climate resilience.

3. ***Prepare for Climate Initiatives and Emerging Issues.*** The Federal and state administrations are taking a strong climate stance and forming new climate policy and direction with emerging issues constantly arising. The workgroup will develop a process to document emerging climate issues and efforts are focused on increasing opportunities for formal and informal communication and the exchange of ideas and formation of strategic partnerships among the Chesapeake Bay watershed's existing network as well with other key regional partners. This strategy would maximize the partnership's capacity to implement intentional and effective adaptation across organizational, jurisdictional, regulatory, and disciplinary boundaries.

Approaches Targeted to Local Participation

- ***Undertake Public and Stakeholder Engagement.*** The CRWG will coordinate with the CBP Local Engagement team in support of targeted conversations, focus groups and other appropriate mechanisms with stakeholders that may help to establish and implement the Adaptation Outcome priorities, including recommended changes in policy at the local, state, and regional levels. Local governments and natural resource groups should be engaged alongside the broader community. The workgroup will also strive to engage stakeholders through existing community development, economic development, floodplain management, shoreline protection, hazard and flood mitigation, emergency management and coastal zone management programs. Since climate resilience is an interdisciplinary issue, it will have interdisciplinary solutions.
- ***Foster a Larger Discussion on the Linkage Between Climate Impacts and Diversity.*** In an effort to create resiliency across the Chesapeake Bay watershed, expanding the diversity of the workforce and participants in climate resiliency restoration and conservation activities is a high priority. For this effort to be successful, the CBP partners need to honor the culture, history and social concerns of local populations and communities and include a wide range of people of all races, income levels, faiths, gender, age, sexual orientation, and disabilities, along with other diverse groups, in our decision-making processes. The CRWG will coordinate with the Diversity Workgroup to ensure that a diverse group of local stakeholders are engaged in discussion related to climate change and the Chesapeake Bay. There are many underrepresented and underserved communities at risk from the impacts of climate change, and such communities need to be fully engaged in the design of Adaptation Outcome priorities in their communities.
- ***Increase Regional Collaboration.*** The partnership should explore strategies to increase participation of regional collaborations of local governments and other stakeholders, such as the Greater Baltimore Wilderness Coalition in central Maryland and Metropolitan Washington Council of Governments. Efforts such as these will provide a mechanism for implementing and

creating a broad constituency for Bay-wide goals on adaptation and resilience at the community and neighborhood level to provide effective regional solutions.

- ***Support Targeted Education and Outreach*.** Both practitioners and the general public should feel empowered to have a voice in the decisions being made in their communities. Having the opportunity to learn about adaptation science, approaches and demonstration projects could help facilitate community conversations around building resilience to changing climate conditions. Potential steps that could help make this happen include:
  a. A periodic "special issue" newsletter that disseminates adaptation-related information;
  b. Support climate outreach and education efforts by the Stewardship GIT;
  c. Collaborate with trusted sources, such as the state chapters of the American Planning Association, to provide support for decision-makers, community leaders, and local government planners to engage on climate change adaptation planning efforts at multiple levels (county, city, state, federal);
  d. Support the CBP Communications Team in developing broad CBP climate messaging, including information on how it integrates climate science into restoration efforts and impacts of climate on restoration work in progress;
  e. Identify mechanisms that can increase community engagement and provide communities and diverse stakeholders with a voice and opportunity to engage in climate adaptation planning and policy decision-making processes for their communities;
  f. Explore effective formal and informal education tools to increase climate resilience literacy among multiple audiences in the Chesapeake Bay region. These should be closely linked with management strategies to achieve the Diversity and Environmental Literacy Outcomes;
  g. Engage the academic community to develop effective collaborative learning approaches for informing and empowering communities across the watershed and test and develop new communication tools that are audience specific so that climate information is accessible and understandable across multiple audiences and communities.

The CRWG can support the CBP Local Engagement Team and the Stewardship GIT in these activities by providing climate change content and expertise.

VII. Monitoring Progress

This management strategy is designed to address a current gap regarding the institutional capability to conduct integrated environmental modeling across the entire Chesapeake Bay watershed. Monitoring progress will require a cohesive and collaborative strategy that includes strategic and analytical use of monitoring and modeling information. Evaluating baseline and alternative scenarios (whether current or forecast) rely on selecting appropriate indicators. Ensuring that selected indicators adequately represent desired outcomes is critical to assessing whether those outcomes have been achieved.

One way to accomplish this is to follow a process that allows for the inclusive and transparent construction of an analysis of Chesapeake Bay conditions using indicators chosen by the partners, as well as stakeholders. Some of the indicators will be those already identified, but the partnership should revisit those as well as consider additional indicators that will better describe the watershed's condition

and assess progress. The indicators could be estimated using monitoring data, modeling data or a combination of both. However, to have effective climate change indicators, long-term monitoring of key climate change parameters is needed. Collaboration with the CBP Integrated Monitoring Network Workgroup to identify climate change monitoring needs and strategies to build in key climate change parameters in existing and planned long-term monitoring networks will be important for the longevity of any climate change indicators.

The CRWG supports updates and the development of climate change indicators with partners used to track and analyze trends, impacts, and progress toward advancing the climate resiliency goal and outcomes. There are three categories of climate change indicators: physical climate change trends based on measurements of physical or chemical attributes of the environment; indicators of ecological and societal impact that measure a) attributes of ecological systems, particularly attributes that may be influenced by physical climate trends, or b) impacts on society, such as health or economic outcomes; or indicators of programmatic progress toward resiliency that quantify resilience or show evidence of learning or adaptation over time.

Currently the CRWG maintains two physical indicators (i.e., Average Air Temperature and Total Annual Precipitation). The workgroup is in the process of updating these indicators for the first time since 2017. They provide insights into air temperature and precipitation trends throughout the Chesapeake Bay Watershed and assist in providing evidential support for climate resilience efforts, policies, and management actions as well as assisting in targeting general regions where climate adaptation efforts are likely needed. Additional climate change indicators were prioritized by the Management Board that have management utility related to the natural resource and community resilience goals: Bay water temperature change, stream temperature change, relative sea level rise, high temperature extremes, and flood-related indicators. Current efforts include development of a Bay water temperature change indicator linked to fish habitat and refinement of the stream temperature indicator to better relate to brook trout habitat.

Lessons Learned

While the Climate Resiliency management strategy outcomes lack a quantitative endpoint, we continue to make considerable progress. The workgroup focuses on better connecting climate change indicators with natural resource outcomes and climate science with stakeholder needs to inform restoration decisions and adaptation strategies.

Consistent incorporation of climate change considerations into jurisdiction efforts, development of climate change indicators to inform decision-making, and efforts aimed to increase understanding on the impacts of climate change on BMPs and restoration strategies can help explain the existing gaps between actual progress and anticipated trajectory of the climate resiliency outcomes. After going through the SRS, the Climate Resiliency Workgroup noted that the following developments would influence our ability to achieve both outcomes: fiscal challenges associated with long-term monitoring recommendations, ability to address uncertainty of climate science for application in programs, capacity to fill research gaps and develop proposals for new grant opportunities, and lack of a quantitative endpoint.

While the workgroup has made progress towards both the Adaptation and the Monitoring and Assessment Outcomes, tracking progress through indicators presents a few challenges. The Climate Resiliency outcomes are qualitative and do not have numeric metrics, making it difficult to evaluate progress in a quantitative sense. With climate change, there will always be the challenge of keeping up pace since we will never be truly done with achieving the outcomes. Therefore, the workgroup

interprets any progress on assessing climate change trends, identifying climate and adaptation scientific needs, and connecting climate science to inform restoration that better prepares policies, programs, and projects to minimize vulnerabilities to climate change impacts as making progress on the outcomes. However, it will be important to establish metrics for measuring resilience success to inform adaptive management.

Monitoring that is designed for climate change adaptation must include an element of flexibility and adaptability to account for: 1) uncertainty regarding how the climate system will change over time and how those changes will impact resources; 2) changing priorities resulting from an increased understanding of the impacts of climate change on resources; 3) developing new and innovative adaptation approaches that act on systems or resources in ways not accounted for; and 4) other factors such as threshold events and abrupt changes that are revealed to be specific to particular areas or affect certain species.

The CRWG will explore options to track planned or ongoing adaptation activities supported by CBP partners to monitor progress toward achieving the adaptation outcome. This could include collaborative efforts with existing climate resilience databases, such as the Georgetown Climate Center's Adaptation Clearinghouse and the U.S. Climate Resilience Toolkit. Adaptive management, which emphasizes management based on observation and continuous learning, provides a means to effectively address uncertainty in our knowledge of climate change impacts and system responses to adaptation actions. It is necessary to use this approach to reassess and update approaches to restoration, and possible reengineering of existing restoration projects as the understanding of changing climate conditions and impacts to communities and ecosystems increases.

VIII. Assessing Progress

Progress will be assessed every two years. Based on improved institutional modeling, monitoring and assessment capabilities, updated science information (including inventories, monitoring and modeling assessments) and improved information about social and cultural responses to climate change, the basis for the iterative stakeholder discussions could result in reassessing baselines, goals and priorities. Part of the process will be improving the current indicators used to track progress, which could result in identifying and constructing new metrics that better reflect stakeholders' goals and priorities while also better informing management applications. Facilitated stakeholder discussions with decision makers will be important in identifying and constructing better indicators.

IX. Adaptively Manage

The CBP's commitment to adaptive management means that periodic reassessments of the science, stakeholder interests and policy alternatives are necessary. Adaptive management requires information, analysis and stakeholder engagement at multiple spatial (local, state, federal) and temporal (understanding historical trends, current conditions and forecasts into a variety of future time periods) scales. The management strategy describes the relationship among the various science and social science components that will be needed to successfully and adaptively manage the Chesapeake Bay

watershed to meet its climate resiliency and other goals. As described here, monitoring, modeling, assessment and stakeholder engagement (at all levels) are not independent activities but are part of a broad assessment and adaptation framework.

Climate adaptation is not a "one-size-fits-all" effort. It will involve the utilization of multiple approaches to achieve the Adaptation Outcome. To that end, based on an improved understanding of the entire Chesapeake Bay watershed, targeted demonstration projects should be selected, monitored and assessed to inform adaptive management to ensure that on-the-ground projects are not maladaptive (providing benefits in one area but resulting in degradation in another). Understanding tradeoffs when evaluating on-the-ground projects allows stakeholders to use the best information generated by physical and social scientists in light of other stakeholder goals related to current agricultural practices, forestry, urban, wastewater, BMPs and the Chesapeake Bay TMDL. It must also be noted that the adaptive management convention of implementation and subsequent monitoring is problematic for long-lived infrastructure (natural or built) because of the large capital, operation and maintenance costs, and the timeframes that are involved, and therefore must be approached differently.

The CBP will continue to examine the following questions to address implementation challenges and opportunities, incorporate new climate related data and scientific understandings, and refine decision support tools and management strategies toward the achievement of the Climate Resiliency Outcomes in the *Watershed Agreement*:

- What progress has been made in implementing the Climate Resiliency Goal?
- How is climate change affecting the effectiveness and feasibility of achieving overall Chesapeake Bay restoration goals?
- What improvements are needed in modeling, monitoring, or science?
- Are specific changes to water quality standards or BMP efficiencies needed to address climate change and its water quality implications (i.e., modifications and/or changes to the Chesapeake Bay TMDL) and permit requirements? What are we learning about implementing better practices and adaptation strategies to build climate resiliency?

X. Biennial Logic & Action Plan

The Climate Resiliency Workplan includes the following information:

- Key actions
- Expected outcome
- Partners responsible for each action
- Estimated resource

Appendix A.
Summary of Past Research on Effects of Climate Change on the Chesapeake Bay

A1. Introduction

Najjar et al. (2010) summarized research on historical and projected impacts of climate projections for the Chesapeake Bay region and the associated potential impacts on the circulation, biogeochemistry, and ecology of the Chesapeake Bay. The study concluded that climate change has the potential to dramatically alter the Bay with likely changes being: "(1) an increase in coastal flooding and submergence of estuarine wetlands; (2) an increase in salinity variability on many time scales; (3) an increase in harmful algae; (4) an increase in hypoxia; (5) a reduction of eelgrass, the dominant submerged aquatic vegetation in the Bay; and (6) altered interactions among trophic levels, with subtropical fish and shellfish species ultimately being favored in the Bay." The main purpose of this appendix is to review research published over the past five years on the historical and projected effects of climate change on the Chesapeake Bay.

A2. Climate and hydrological processes affecting the Bay

A2.1. Atmospheric composition

Najjar et al. (2010) utilized climate projections based on the Special Report on Emissions Scenarios (SRES), which were produced by the Intergovernmental Panel on Climate Change (IPCC) 15 years ago (Nakićenović and Swart, 2000). For the most recent IPCC climate assessment, a new family of greenhouse gas emissions scenarios, known as Representative Concentration Pathways (RCPs), was prepared (Moss et al., 2010; van Vuuren et al., 2011). Four RCPs have been developed—RCP8.5, RCP6.0, RCP4.5, and RCP2.6—where the numbers refer to the anthropogenic radiative forcing at 2100 in watts per square meter (Figure A1). Compared to the A2 and B1 SRES scenarios, which were in most common use, the RCP family captures a wider range in the forcing and the resulting simulated climate (Figure A2). The projected amount of total (natural plus anthropogenic) radiative forcing in terms of CO_2 equivalents is about 400 to 1200 ppm, which can be compared to the preindustrial CO_2 level of 280 ppm. Surface open-ocean average pH declines from the late 20th century to the late 21st century are between 0.06 and 0.32 pH units (Ciais et al., 2013).

A2.2. Water temperature

A new historical air and stream temperature analysis was conducted for the Chesapeake Bay watershed by Rice and Jastram (2014). Statistically significant trends over the 1960-2010 period of 0.23 and 0.28 °C per decade were found for air and stream temperature, respectively. Land use changes were found to explain differences in air and stream temperature trends.

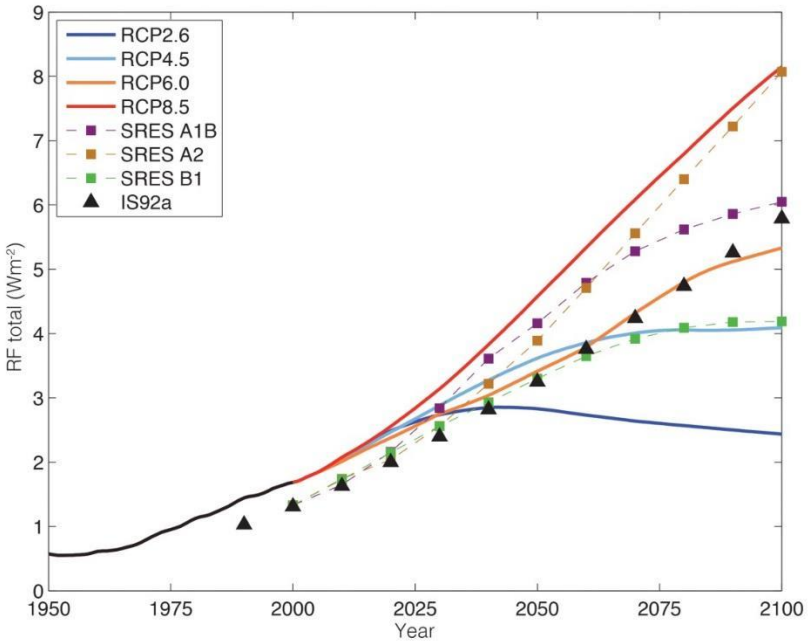


Figure A1. Anthropogenic radiative forcing from the Representative Concentration Pathways (RCPs) and the Special Report on Emissions Scenarios (SRES). Reproduced from Cubasch et al. (2013).

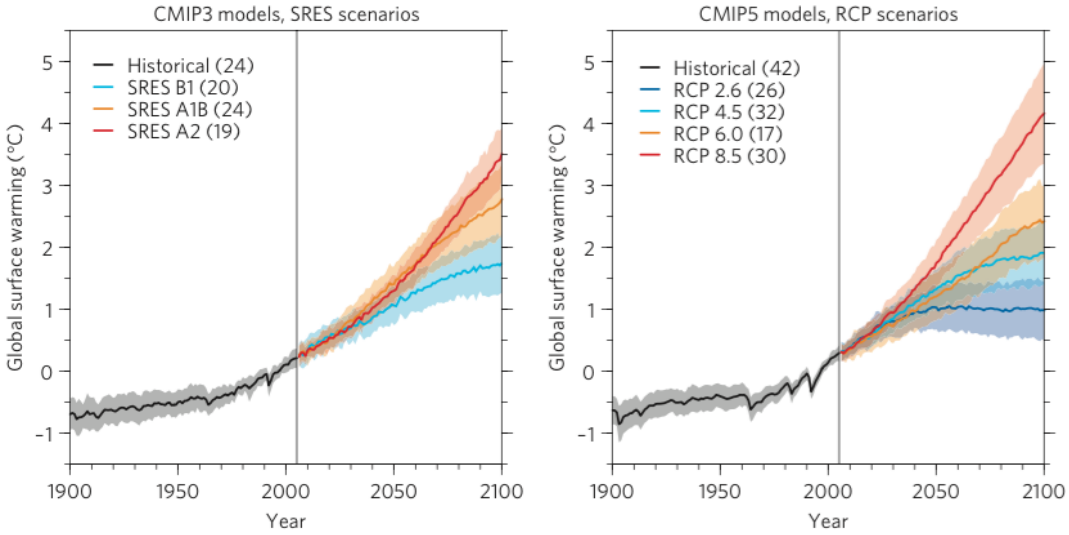


Figure A2. Historical and future simulations of global-mean surface temperature anomaly from the Coupled Model Intercomparison Project (CMIP). Left panel shows CMIP3 global climate models under the SRES emissions scenarios and right panel shows CMIP5 global climate models under the RCP emissions scenarios. Reproduced from Knutti & Sedláček (2013).

Projected changes in water temperature are expected to follow projected changes in air temperature (Najjar et al. 2010). Many new climate model simulations have been conducted over the past five years, which provide new estimates of air temperature change. Compared with previous work, these models

may: (1) have higher spatial resolution, (2) utilize different emissions scenarios (Section A2.1), and (3) have been processed using statistical and dynamical downscaling techniques that provide projections on a finer spatial scale. One set of climate model simulations, known as the North American Regional Climate Change Assessment Program (NARRCAP; Mearns et al., 2012; Mearns et al., 2009), uses regional climate models of relatively high spatial resolution (50 km) embedded in Global Climate Models (GCMs) of coarser resolution. One study of Pennsylvania (PA), which is representative of the northern part of the Chesapeake Bay watershed, showed that NARCCAP simulations were quite similar to global climate model simulations in terms of temperature (Shortle et al., 2013); More recent climate projections for Pennsylvania are available in PA's 2015 Climate Impacts Assessment and 2021 Climate Impacts Assessment. PA's 2020 Climate Impacts Assessment, Chapter 2, specifically looks at climate change impacts to PA's watershed management strategies, including BMPs, and water quality goals (meeting TMDLs). Kunkel et al. (2013) came to a similar conclusion for the Northeast U.S. in an analysis conducted for the National Climate Assessment.

Climate model projections for the Chesapeake Bay watershed have more confidence than they did five years ago because climate models can now successfully simulate the observed warming of the Northeast U.S. over the 20th century (Kunkel et al., 2013).

There has been great interest in winter climate over the past five years, with numerous studies suggesting a linkage between reductions in Arctic sea ice and increases severe winters over land in mid-latitudes (e.g., Francis and Vavrus, 2012; 2015; Liu et al., 2012). Winter temperature trends over the past 50 years were positive everywhere over land in the Northern Hemisphere, but for the past 20 years were actually negative over much of North America and Asia. In a recent review article, Cohen et al. (2014) conclude that "it is possible, in principle, for sea ice and snow cover to jointly influence mid-latitude weather" but "because of incomplete knowledge of how high-latitude climate change influences these phenomena, combined with sparse and short data records, and imperfect models, large uncertainties regarding the magnitude of such an influence remain." To emphasize this uncertainty, one recent study shows that Arctic amplification (greater warming in the Arctic than elsewhere) has actually led to a decline in sub-seasonal cold-season temperature variability (Screen, 2014). Despite these uncertainties, GCMs show a reduction in cold-air outbreaks over North America under enhanced levels of greenhouse gases (Gao et al., 2015). However, the reduction is about 20% smaller in a band that extends from Alaska to the Northeastern U.S. Thus, while winters are expected to become less severe in the future over the Chesapeake Region, the reduction in severity may be less than projections of mean temperature would suggest.

A2.3. Precipitation

Unlike mean temperature, there have been significant changes in projected mean precipitation for the Northeast U.S. Though models still project, on average, increases in annual precipitation, the higher-resolution models from NARCCAP show two important differences (Kunkel et al., 2013): (1) there is increasing consensus that summer precipitation will decline and (2) winter projections of increased precipitation are larger. Therefore, compared with earlier research, there is now a greater seasonality in the projected precipitation change. Increases in precipitation intensity, which are projected by GCMs, are also supported by the NARCCAP models (Kunkel et al., 2013).

A2.4. Streamflow

Whereas historical analysis of annual streamflow in the Chesapeake Bay watershed clearly indicates increasing trends, the question as to whether streamflow is becoming more extreme remains unresolved. An analysis in the Chesapeake Bay watershed for the 1930-2010 period by Rice and Hirsch (2012) used the annual seven-day low flow and one-day high flow as metrics of extreme flow. Low flows were found to have increased whereas high flows generally remained the same, meaning that flows have become less extreme with time. This is in contrast to previous work that suggested that high flows had increased in the Northeast U.S. (Groisman et al., 2001; 2004). Most recently, however, Armstrong and Collins (2014) found that annual maximum instantaneous discharge generally showed increasing trends throughout the Northeast U.S., including the Chesapeake Bay watershed. Similar results were found for another high-flow metric: the number of flow peaks exceeding a USGS-designated, station-specific threshold. The different conclusions among the studies may reflect the different metrics used for extreme flow and the choice of stations analyzed. For example, Armstrong et al. (2014) argue that the use of gauges in regulated watersheds compromised previous results.

Najjar et al. (2010) concluded that future changes in streamflow to the Chesapeake Bay, particularly the annual average, were highly uncertain because of the opposing effects of increases in temperature and precipitation. Major new work in this area was done by Johnson et al. (2012) and U.S. EPA (2013), who simulated changes in the hydrology of the Susquehanna River Basin using two watershed models and multiple sources of climate change projections, including GCMs, statistical downscaling, and dynamical downscaling (NARCCAP). Results in Table A1 are shown for one of the watershed models and six of the NARCCAP models for the middle of the 21st century under the A2 emissions scenario. In general, flow increases, as do peak flows, with median increases of 7% and 18%, respectively. The change in the magnitude of the lowest flows is equivocal. Global model results from Schewe et al. (2013), who used five watershed models in combination with 11 GCMs, indicate that warming will have very modest effects on mean streamflow in the Chesapeake region, with the projected change between -10 and +10% for a 2 °C warming. Modeling results from HiraBayashi et al. (2013) show an increased frequency of the 100-year flood in the lower Chesapeake watershed but a decreased frequency in the upper watershed.

Table A1. Results of Hydrological Model Simulations under Future Climate Change (US EPA, 2013).

	CRCM _ cgcm3	HRM3 _ hadcm3	RCM3_ gfdl	GFDL_ slice	RCM3 _ cgcm3	WRF _ ccsm	Median
Total streamflow	109	106	106	108	111	90	107
7-day low flow	91	120	104	89	107	86	98
100-year peak flow	107	130	106	128	172	100	118
Flashiness index	107	111	107	110	112	103	109
Sediment load	117	108	108	115	118	84	112
Phosphorus load	128	106	111	127	115	109	113
Nitrogen load	162	147	147	156	150	132	149

Results are reported for the time period 2041-2070 as a percent of the time period 1971-2000. Values greater than 100% represent an increase in the quantity being simulated. Results are shown for six

different climate model configurations run under the A2 emissions scenario. The watershed model is SWAT (Soil Water Assessment Tool).

A2.5. Sea level

Numerous studies of sea-level rise at the global scale have been published over the past five years. There is strong consensus now that global-mean sea level is accelerating. Church and White (2011) found an acceleration of global-mean sea level consistent with numerous earlier studies. Problems closing the sea level budget before 1990 have been resolved by a reanalysis that indicates a mean sea-level rise of 1.2 ± 0.2 mm yr^{-1} for the 1901-1990 period, a rate substantially lower than previous estimates (Hay et al., 2015). For the 1993-2010 period, the same reanalysis estimated a global mean sea-level rise of 3.0 ± 0.7 mm yr^{-1}, similar to previous estimates, which indicates that sea level is accelerating more than previously thought.

Significant contributions have been made to our understanding of sea-level rise in the Chesapeake Bay region over the past five years. Despite initial indications of no acceleration of sea-level in the Chesapeake Bay (Boon et al., 2010), further study indicated acceleration larger than the global average and much of the U.S. east coast, which is possibly a result of changing ocean circulation (Boon, 2012; Ezer et al., 2013; Kopp, 2013; Sallenger et al., 2012). Global climate model simulations suggest that the Gulf Stream will weaken in the future, which will weaken the downward slope of the sea surface towards the east coast of the U.S., potentially adding another 0.2 m of sea-level rise to the Chesapeake Bay region by the end of the 21st century (Yin et al., 2009). Global sea-level rise projections that attempt to account for changes in global ice volume have not dramatically changed over the past five years, with typical projections by the end of the century between 0.3 and 1.3 m (Walsh et al., 2014). Boesch et al. (2013) suggest sea-level rise by 2100 of 0.5-1.4 m (best estimate 0.8 m) for the global mean and 0.7-1.7 m (best estimate 1.1 m) for Maryland.

The high rates of sea-level rise in the Chesapeake Bay are also due to land subsidence, caused by isostatic adjustment in response to the retreat of ice sheets as well as aquifer-system compaction resulting from groundwater withdrawals. Eggleston and Pope (2013) conclude that, in the southern Chesapeake Bay region, land subsidence currently contributes to approximately half of the relative sea-level rise and aquifer-system compaction contributes to about half of the land subsidence.

Rising sea level has increased the shoreward energy delivered to Chesapeake Bay's shorelines. Along the upper tidal shorelines of the lower Chesapeake Bay, the average shoreward energy flux for 1982-2010 was twice that for 1948-1981 (Varnell, 2014).

Rising sea level has dramatically increased flooding as well, including nuisance flooding, which is defined using a sea-level criterion determined by the local National Weather Service office (Sweet et al., 2014). For example, in Annapolis, Maryland, nuisance flooding occurred during only a few hours per year before 1940 whereas it is not uncommon over the past 10 years for it to occur for more than 200 hours per year.

Often ignored in historical sea-level rise analyses and projections is natural variability. Cronin et al. (2012, 2014) using a temperature-based reconstruction of sea-level for the Chesapeake Bay over the last 2000 years, notes that short-term rates of sea-level change have been frequently as large as they are

now. These authors thus caution that the current acceleration in sea level may not be unusual or representative of a long-term average.

A2.6. Storms

Significant storms that impact the Chesapeake Bay are North Atlantic tropical storms and winter extratropical cyclones (including nor'easters). The most recent National Climate Assessment (Walsh et al., 2014) concluded that there is "high confidence that the intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest (Category 4 and 5) hurricanes, have increased substantially since the early 1980s; low confidence in relative contributions of human and natural causes in the increases; and medium confidence that hurricane intensity and rainfall rates are projected to increase as the climate continues to warm." These conclusions are generally similar to the state of the science five years ago. Continued research on winter extratropical cyclone changes indicates little consensus on changes in the Northern Hemisphere, especially in the North Atlantic basin (Collins et al., 2013).

A3. Fluxes of nutrients and sediments from the watershed

Flow-adjusted concentrations of total nitrogen and total phosphorus at the mouths of the three largest rivers emptying into the Chesapeake Bay (Susquehanna, Potomac, and James Rivers) declined from 1985 to 2013 (Langland et al. 2012; Blomquist et al., 2014), with the exception of total phosphorus in the Susquehanna River, which showed no trend. Suspended sediment concentration trends for 1985-2013 were not significant, except for a decreasing trend in the Potomac. More recent trends (2003-2013) are negative for nitrogen (except for the James, which showed no trend), and not significant for phosphorus and sediment, except for an increasing phosphorus trend in the Susquehanna River.

High-flow events and their effect on the Conowingo Dam appear to play a disproportionate role in the delivery of nutrients and sediments from the Susquehanna River to the Chesapeake Bay. Hirsch (2012) analyzed the 1996-2011 period and found that flow-adjusted concentrations of nitrogen declined by 3% and those of total phosphorus and sediment increased by 55% and 97%, respectively. Upstream of the dam, however, concentrations declined for all constituents. Remarkably, Tropical Storm Lee, which contributed only 2% of the freshwater flow from the Susquehanna River to the Chesapeake Bay during 2002-2011, contributed 5%, 22%, and 39% of the nitrogen, phosphorus, and sediment loads. Zhang et al. (2013) reached similar overall conclusions. Both studies suggest that the Conowingo Dam is close to reaching its capacity to store particulate material and that increases in extreme flow events will pose significant management challenges.

The fraction of net anthropogenic nitrogen inputs (NANI) to a watershed that is exported from that watershed is a function of the watershed's climate, with some studies showing that this fraction increases with streamflow (e.g., Howarth et al., 2006) and others showing a decrease with temperature (Schaefer and Alber, 2007). In a recent analysis of a very large number of watersheds in the U.S. and Europe, it was found that the fraction of NANI exported varied significantly with temperature, precipitation, and streamflow, but the latter had by far the most predictive power (Howarth et al., 2012).

Modeling of future nutrient and sediment loads in the Susquehanna River Basin show increases in all quantities by mid-century under the A2 emissions scenario (Table A1). Median increases in sediment, phosphorus, and nitrogen loads are 12%, 13%, and 49%, respectively (Johnson et al., 2012; U.S. EPA, 2013).

A4. Bay physical response

Two modeling studies have been conducted over the past five years to estimate potential changes in the circulation and salinity of the Chesapeake Bay in response to sea-level rise. Rice et al. (2012) investigated changes in salinity in the James and Chickahominy Rivers resulting from sea-level increases between 0.3 and 1 m. They found that salinity was more sensitive to sea level during dry years, with salinity increases as large as 4 ppt for a 1-m rise in sea level. They also found that a local drinking water supply will be affected by saltwater intrusion resulting from sea-level rise. Hong and Shen (2012) explored similar sea-level scenarios for the whole of the Chesapeake Bay and found salinity and stratification to increase. In addition, they found an increased exchange flow, weaker downstream transport of fresh water, increased residence time, and increased vertical transport time. In addition, tidal currents were found to increase with sea-level rise, but not enough to negate the weakened vertical exchange associated with the stratification increase.

A5. Estuarine biogeochemistry

A5.1. Plankton

Harding et al. (2015) investigated historical changes in plankton composition in the Chesapeake Bay from 1985 to 2007. They found diatoms to be the predominant taxonomic group. Diatom abundance tended to be higher in wet years. Furthermore, flow-adjusted diatom abundance decreased towards the end of the time series, which was suggested to be a result of nutrient reductions; this suggests that future nutrient reductions could result in a more diverse phytoplankton population.

A5.2. Pathogens

We were unable to identify recent research on the impact of future climate change on estuarine biogeochemistry and plankton, with one exception: Urquhart et al. (2014) studied current models of ***Vibrio vulnificus*** and argued that these models are inadequate for predicting the effects of warming on this microbe.

A5.3. Dissolved oxygen

The processes driving interannual variations in summertime hypoxic volume in the Chesapeake Bay have been investigated in numerous studies over the past five years. Scully (2010a) found a correlation between observed wind direction and hypoxic volume, which was supported by numerical modeling results (Scully, 2010b). Murphy et al. (2011) found trends in the timing of summertime hypoxia, which were attributed to changes in stratification and nutrient loads. Testa and Kemp (2014) determined that higher Susquehanna River flows resulted in an earlier onset of hypoxia. Zhou et al. (2014) were able to account for 85% of the interannual variability in hypoxic volume using January-May total nitrogen load, April-August winds, and April-May precipitation as predictors. A numerical modeling study by Li et al. (2015) suggested that vertical mixing, vertical advection, and lateral advection are all important sources of dissolved oxygen to bottom waters. Hypoxic volume was surprisingly insensitive to river flow in this

modeling study; this resulted from compensating changes in the lateral and vertical supply of dissolved oxygen to bottom waters. Li et al. (2015) also found that wind speed affected the timing and magnitude of hypoxic volume.

A6. Vascular plants

A6.1. Submerged aquatic vegetation

Orth et al. (2010) analyzed submerged aquatic vegetation (SAV) distributions in the Chesapeake and found support for the assertion that increases in nitrogen pollution reduce SAV abundance.

Jarvis et al. (2014) developed a model of *Zostera marina* and examined impacts of temperature and light stress. They found high sensitivity of established beds to consecutive years of stress and negative effects of multiple stressors on *Z. marina* resilience and recovery.

A6.2. Estuarine wetlands

Recent research suggests that sea-level rise continues to pose an uncertain but potentially significant threat to estuarine wetlands. Kirwan et al. (2013) used mesocosms to evaluate the hypothesis that sea-level rise would reduce organic matter decay rates, thereby providing a negative feedback loop that would help to reduce submergence. However, they found no effect of sea-level rise on decay rates, and concluded that enhanced organic matter production or mineral sediment supply would be needed in order for marshes to keep pace with accelerated sea level. Furthermore, temperature increases are expected to reduce net ecosystem production (Drake, 2014). However, elevated CO_2 was shown to enhance net ecosystem production of C3- and, to a lesser extent, C4-dominated communities in a Chesapeake Bay tidal wetland (Erickson et al., 2013).

A7. Fish and shellfish

A meta-analysis by Vaquer-Sunyer and Duarte (2011) showed that "ocean warming is expected to increase the vulnerability of benthic macrofauna to reduced oxygen concentrations and expand the area of coastal ecosystems affected by hypoxia."

A study of blue crabs along the east coast of the U.S. (Hines et al., 2010) concluded that warming may have positive and negative effects. The reduced severity of winters associated with global warming will increase winter survival and promote rapid growth and brood production. Warming, however, may increase juvenile mortality and size at maturity.

New research has been conducted on the impact of environmental factors on oysters. Levinton et al. (2011) found in a modeling study that projected increases in precipitation may lower salinities enough to be harmful to oysters. Kimmel et al. (2012) found that long-term variability in Eastern oysters in the Chesapeake Bay was related to salinity.

Waldbusser et al. (2011a), in laboratory studies of juvenile eastern oysters, found that biocalcification declined significantly with a reduction of ~0.5 pH units, but that increases in temperature and salinity reduced the sensitivity to pH. A related study using a flow-through control system found that pH declines increased shell dissolution rates (Waldbusser et al., 2011b).

Through a literature review, Jones (2013) examined the potential impact of climate change on finfish in the Chesapeake Bay through changes in seagrass and concluded that the uncertainty is too large to make reliable projections.

A8. Human systems

Some new research has been conducted on the human response to climate change in the Chesapeake region and in coastal areas in general. Paolisso et al. (2012) studied two African-American communities on the eastern shore of the Chesapeake Bay and found that community members recognize potential impacts and are organized through their churches to address some of those impacts. More generally, Moser et al. (2012) underscore multiple stressors that coastal systems face and the need for transformative changes in the science and management to address what appears to be an overwhelming challenge.

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Appendix B.
Current Adaptation and Mitigation Efforts (Last Updated in 2021; PA and NOAA provided updates in 2023)

B1. State Policy, Plans, and Programs

B1.1. State of Delaware

Delaware has invested more than a decade's worth of work in maximizing resilience and adapting to climate change impacts through statewide planning efforts; policy development and regulations; capacity-building for state and local governments; and the development of research, data and tools. The table below summarizes some of these initiatives.

Delaware Initiatives to Maximize Resilience to Climate Change Impacts

Policy, Planning and Regulations	Starting in 2009, DNREC carried out a 5-year sea level rise planning initiative to assess the impacts of sea level rise on the state. Outputs of this effort included a vulnerability assessment, recommendations for adapting to climate change impacts, an interim implementation plan and, in 2017, updated sea level rise planning scenarios for the state. In 2013, then-Governor Jack Markell signed Executive Order 41: Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing Emissions. As part of the Executive Order, the state developed the 2014 Climate Framework for Delaware, a summary of efforts that state agencies identified as ways they could better help maximize Delaware's resilience to climate change. Other outputs from this effort included a guide for state agencies to avoid and minimize flood risk to state assets and the Flood Risk Adaptation Map, a tool for state flood risk planning that combines current flood modeling with sea level rise projections to depict areas in Delaware vulnerable to flooding, now and in the future. In 2016, DNREC released a Climate Action in Delaware report, outlining progress made on efforts included in the Climate Framework. In 2017, Governor John Carney signed into law amendments to Delaware's Coastal Zone Act. A newly created permit under the amended act requires prospective businesses to develop a Sea Level Rise and Coastal Storms Plan as part of the permitting process. This is the first time such a requirement was codified in Delaware law. A number of state agencies have outlined plans and policies that address how they will account for climate change impacts in their programs and operations. Such documents include: ● Delaware Division of Historical and Cultural Affairs Strategic Plan FY15/FY19 (Department of State, 2013) ● Delaware Wetland Management Plan (DNREC, 2015) ● Delaware Wildlife Action Plan (DNREC, 2015) ● Strategic Implementation Plan for Climate Change, Sustainability & Resilience for Transportation (Department of Transportation, 2017) ● State of Delaware All-Hazard Mitigation Plan (Department of Safety and Homeland Security, Delaware Emergency Management Agency, 2018) ● Delaware Statewide Forest Strategy (Department of Agriculture, Delaware Forest Service, 2020)

Capacity-Building for State and Local Governments	In 2015, DNREC launched its Resilient Community Partnership program to provide technical assistance and potential funding to plan for and reduce the impacts of coastal hazards related to flooding from sea level rise, coastal storms and climate change through the development of planning strategies at the local level. Recipients of assistance through this program include the Town of Slaughter Beach, the City of New Castle and various Atlantic beach communities. In 2016, DNREC led the establishment of the Resilient and Sustainable Communities League, a collaborative network of state, nonprofit and academic partners that provides information, technical assistance and networking opportunities to state, local and county governments, citizen groups, the private sector and nonprofit organizations to advance the goals of resilience and sustainability in Delaware. DNREC continues to provide strategic direction and funding to this effort. In 2016 and 2018, DNREC provided funding through its Strategic Opportunity Fund for Adaptation program to assist state agencies in adapting to climate change, particularly focusing on efforts that agencies outlined in the Climate Framework for Delaware. Some example projects include on-the-ground restoration projects, asset vulnerability assessments, climate change impact modeling and health tracking databases. State agencies that have used program funds include the Delaware State Housing Authority, Department of Agriculture, Department of Health and Social Services, DNREC, Department of Safety and Homeland Security (including the Delaware State Police and the Delaware Emergency Management Agency), Department of State (Division of Historic and Cultural Affairs), Department of Transportation and the Office of Management and Budget. In 2017, DNREC provided funding through its Sustainable Communities Planning Grant program to assist local governments with developing sustainability plans that reduce greenhouse gas emissions and increase readiness for climate change impacts. Recipients of funding through this program include Wilmington, Newark, Frederica, Milton and Fenwick Island. DNREC offers an ongoing Coastal Training Program that provides technical assistance and training for coastal resource planners and managers on critical issues. Past trainings have addressed climate change and community resilience, wetlands restoration, project planning and evaluation and science communication techniques.

Research, Data and Tools	In 2011, the Delaware Geological Survey and the Delaware Environmental Observing System, with support from DNREC, developed the Delaware Coastal Flood Monitoring System, a web-based tool and alert system designed to provide emergency managers, planners and the Delaware public with information on the extent, timing and severity of upcoming coastal flood conditions. In 2014, DNREC released the Delaware Climate Change Impact Assessment, which provided an overview of climate change impacts in Delaware, including projections for heat and precipitation to the year 2100. The assessment looked at what those projections mean for Delaware's public health, water resources, agriculture, infrastructure and ecosystems. In 2016, the University of Delaware's Institute for Public Administration, with support from DNREC, developed the Delaware Database for Funding Resilient Communities, a searchable web database of relevant financial assistance programs that can be used by communities to support climate change resilience projects. In 2017, the Delaware Geological Survey, with support from DNREC, developed a series of coastal inundation maps for the state. These maps, in coordination with the updated sea level rise planning scenarios for the state, were created to inform long-range planning for the state's infrastructure, facilities, land management, land use and capital spending. In 2018, the University of Delaware Center for Environmental Monitoring, with support from DNREC, established the Delaware Climate Information Center, an online clearinghouse of data, reports, tools, funding opportunities and events aimed at providing easy access to relevant and useful information for assessing impacts and preparing for climate change in Delaware. DNREC has helped fund climate-related research for numerous graduate students over the years. Supported research has looked at, among other things, groundwater movement and storage, greenhouse gas exchanges between land and atmosphere, and the landward migration of wetlands. DNREC also leads a variety of multiyear monitoring efforts to better understand short- and long-term climate change impacts; these monitoring activities include examining the timing of plant life cycles, measuring water levels and wetland surface heights, and taking surveys of aquatic animals. Delaware actively participates in the Mid-Atlantic Coastal Acidification Network, which seeks to better coordinate, support and lead coastal and ocean acidification research and monitoring. Staff from DNREC sit on the Network's Steering Committee, Science Workgroup and Outreach Workgroup.

Over the last two decades, Delaware has invested in programs and policies that reduce greenhouse gas emissions. This includes efforts to use energy more efficiently, expand renewable energy, reduce emissions from cars and trucks, and replace industrial refrigerants. The table below summarizes some of these initiatives.

Delaware Initiatives to Minimize Greenhouse Gas Emissions

	Consumer and Business Incentives	Policy and Regulations
Clean and Renewable Energy	DNREC's Green Energy Program provides grants to offset the cost of solar panels, solar water heating, wind and geothermal renewable energy technologies.	The Delaware Renewable Energy Portfolio Standards Act, passed in 2005 and updated in 2021, requires Delaware's utilities to get an increasing percentage of their electricity from renewable sources. By 2035, 40% of the utilities' electricity must be from renewable sources.
Energy Efficiency	Delaware's Weatherization Assistance Program provides no-cost home energy efficiency upgrades to low- and moderate-income Delawareans who rent or own a home. DNREC's Energy Efficiency Investment Fund provides grants and low-interest loans to help commercial and industrial customers replace aging, inefficient equipment and systems with energy-efficient alternatives. DNREC also has an Energy Efficiency Industrial program that helps large-scale energy users make their operations more energy-efficient through innovative upgrades.	DNREC is required to review and update the statewide code for energy conservation every 3 years. In 2020, DNREC amended the Code for Energy Conservation by adopting the 2018 International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 2016 Energy Standard for Buildings Except Low Rise Residential Buildings. In 2017, DNREC issued Evaluation, Measurement and Verification regulations that set forth procedures and standards for defining and measuring electricity and natural gas savings from energy efficiency programs provided by Delaware's utilities.
Transportation	DNREC's Clean Transportation Incentive Program offers rebates to businesses and individuals to offset the up-front cost of purchasing an electric or plug-in hybrid electric vehicle. Rebates for vehicle charging stations are also available. Delaware participates in the National Clean Diesel Campaign through Diesel Emission Reduction Act funding. This U.S. Environmental Protection Agency program funds grants and rebates for technologies that reduce harmful emissions from diesel engines. Delaware received $9.6 million from the Volkswagen Environmental Mitigation Trust. These funds are being used to replace high-emitting diesel engines and install electric vehicle charging stations.	DNREC's Low Emission Vehicle Program regulations hold to the more stringent California tailpipe emissions standard to reduce smog-forming emissions and greenhouse gases, beginning with 2014 model year vehicles. As a result of this program, new cars will emit 75% less smog-forming pollution in 2025 than the average new car sold in 2015. Delaware's Office of Management and Budget Fleet Services section has committed to transitioning 20% of its light-duty vehicle fleet to electric by 2025. This will result in an emissions reduction of 1,300 metric tons of carbon dioxide equivalent by 2025.
High Global Warming Potential Greenhouse Gases	DNREC's newly launched "Cool Switch" Low Impact Refrigerant Program provides financial incentives to commercial and industrial users to replace hydrofluorocarbon refrigerants with refrigerants that have less climate change impacts.	In March 2021, DNREC issued regulations requiring the phase down of specific hydrofluorocarbons used in air conditioning/refrigeration equipment, aerosols and foam. The regulations go into effect in September 2021.

Delaware has also reduced greenhouse gas emissions through interstate collaboration. One such collaboration is the Regional Greenhouse Gas Initiative, a multistate carbon dioxide cap-and-trade program consisting of 11 Northeast and Mid-Atlantic states. This program sets a regional cap on carbon dioxide emissions from the power sector. Since the program's inception in 2008, emissions from electricity generation in the state have decreased by 45%. Electricity generators that emit carbon pollution must purchase credits in an auction platform; proceeds from the auction are returned to states, which invest the funds into programs that further reduce greenhouse gas emissions. Many of the "Consumer and Business Incentives" mentioned in Table 1 are partially or fully funded by proceeds from the Regional Greenhouse Gas Initiative. This program also helps fund the Delaware Sustainable Energy Utility, known as Energize Delaware, a statewide organization that offers incentive and loan programs to residents, nonprofits and commercial entities to enhance energy efficiency and renewable energy opportunities in the state.

Additionally, Delaware participates in the Transportation and Climate Initiative, a multistate collaborative of Northeast and Mid-Atlantic states seeking to reduce emissions in the transportation sector. The states in the Transportation and Climate Initiative have worked to evaluate transportation emissions in the region, develop strategies to encourage zero-emission vehicles and alternative fuels, and enhance freight efficiency. The Transportation and Climate Initiative states are now engaged in a multiyear effort to develop a market-based program that would cap regional emissions from transportation fuel combustion. Emissions allowances would be auctioned, and auction proceeds would be returned to states to invest in programs that further reduce greenhouse gas emissions. Delaware is at the table in the development of this program to evaluate its implications for Delaware.

Finally, Delaware has made strides to track greenhouse gas emissions in the state. Since 2008, DNREC has overseen the state's Greenhouse Gas Inventory, which presents data and analyses on six greenhouse gases. DNREC's Division of Air Quality prepares the annual inventory to characterize the state's historical greenhouse gas emissions, providing information on activities that contribute to greenhouse gas emissions.

B1.2. District of Columbia

Sustainable DC Omnibus Amendment Act of 2014 – The amendment includes provisions that support climate adaptation. These include more public access to energy and water use data and protections for urban forests.
https://does.dc.gov/page/sustainable-dc-omnibus-amendment-act-2014-0-does

Sustainable DC Act of 2012 – The Act is intended to promote various energy-related programs including energy efficiency, renewable energy, and financing. It supports a robust sustainability plan for the District, Sustainable DC.
https://code.dccouncil.us/dc/council/laws/19-262.html

National Capital Region Climate Change Report (2008) – The report reflects the work of representatives from the District, Maryland, Virginia and other regional organizations. It presents a regional climate change strategy to meet the regional greenhouse gas reduction goals.
http://www.mwcog.org/uploads/pub-documents/zldXXg20081203113034.pdf

2013-2016 Climate, Energy, and Environment Policy Committee Action Plan and Resource Guide – The Committee drafted an Action Plan and Resource Guide - The Plan identifies goals and implementation actions for sectors such as greenhouse gas reduction, infrastructure, and transportation. The Guide provides descriptions, best practice examples, and resources needed for implementing the Plan.

ACTION PLAN
https://www.mwcog.org/environment/climate/Documents/2013-4-22%20CEEPC%20Action%20Plan%20Resource%20Guide_Working%20Final.pdf

RESOURCE GUIDE
https://www.mwcog.org/environment/climate/Documents/2013-5-22%20Final%202013-2016%20CEEPC%20Action%20Plan.pdf

Climate Ready DC (2016) – The District's strategy to adapt to a changing climate, Climate Ready DC identifies projected climate impacts, assesses risks to DC's infrastructure, community resources, and residents, and outlines adaptation strategies for key sectors: transportation and utilities, buildings and development, neighborhoods and communities, and governance and implementation. https://doee.dc.gov/climateready

Sustainable DC 2.0 (2019) – The first update to the District's 20-year sustainability plan (2012 – 2032), SDC 2.0 contains 167 across 13 topics including climate adaptation and mitigation, restoring our natural environment, energy, and the built environment. https://sustainable.dc.gov/sdc2

Clean Energy DC (2018) and Clean Energy DC Omnibus Amendment Act of 2018– As the District's energy and climate action plan, Clean Energy DC charts a pathway to meeting the Sustainable DC goal to reduce greenhouse gas emissions 50% by 2032. It contains 57 actions concentrating on buildings, energy, and transportation electrification. To advance the goals of the plan, the District passed legislation codifying key initiatives for renewable energy, building energy performance, and transportation.

Clean Energy DC plan https://doee.dc.gov/cleanenergydc

Clean Energy DC Act: https://lims.dccouncil.us/downloads/LIMS/40667/Signed_Act/B22-0904-SignedAct.pdf

Commission on Climate Change and Resiliency – Created in 2016, the Commission is composed of 16 members with expertise across a range of fields, from public health, to transportation, to emergency preparedness. The Commission is charged with assessing the District's ability to mitigate and adapt to climate change and making recommendations to advance the city's climate goals. https://dccccr.org/

B1.3. State of Maryland

Climate Action Plan (2008) – The plan addresses strategies to reduce the state's vulnerability to climate change by considering impacts, mitigation, and other concerns. The Plan includes a report to the Maryland Commission on Climate Change from the Scientific and Technical Working Group on the impacts and recommended actions to protect Maryland's property and people from the effects of climate change.

https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/2008ClimateActionPlan.pdf

Comprehensive Strategy for the Reducing Maryland's Vulnerability to Climate Change, Phase I: Sea-level Rise and Coastal Storms (2008) – A report by state agencies that lays out policy recommendations and identifies implementation targets with respect to sea level rise and coastal hazards. https://dnr.maryland.gov/climateresilience/Documents/Comprehensive_Strategy.pdf

Comprehensive Strategy for the Reducing Maryland's Vulnerability to Climate Change, Phase II: Building Societal, Economic, and Ecological Resilience (2011) – The strategy lays out policy recommendations and identifies implementation targets including aquatic and terrestrial ecosystems and water resources. https://dnr.maryland.gov/climateresilience/Documents/climatechange_phase2_adaptation_strategy.pdf

Building Resilience to Climate Change, MDNR – Policy applied to MDNR that provides direction and guidance in the management of land, resources, and assets in facing climate change impacts. In addition, MDNR lists as a resource a report published by Restore America's Estuaries provides extensive recommendations on adaptation through the restoration of coastal habitat. https://estuaries.org/wp-content/uploads/2019/02/Restore-Adapt-Mitigate.pdf

Greenhouse Gas Reduction Act Plan (2030) – The Plan advances strategies to: reduce greenhouse gas emissions, transition to new energy sources, and stimulate technological development. The 2030 Greenhouse Gas Emissions Reduction Act (GGRA) Plan was released February 19, 2021. Chapter 7 of the Plan details the strategies underway within State Government to address the impacts of climate change, including sea level rise. https://mde.maryland.gov/programs/Air/ClimateChange/Pages/Greenhouse-Gas-Emissions-Reduction-Act-(GGRA)-Plan.aspx

Coastal Atlas – The Atlas is an online interactive mapping tool, developed by Maryland DNR to access and assess sea level rise, coastal hazard data and imagery. http://www.dnr.state.md.us/ccp/coastalatlas/index.asp

CoastSmart Communities Scorecard – The Scorecard provides planning guidance in five major sectors: Risk and Vulnerability Assessment; People and Property; Infrastructure and Critical Facilities; Natural Resources; and Societal and Economic Impacts, and can be used to develop a custom made strategic planning and response guide. http://dnr.maryland.gov/coastsmart/

Updated Sea Level Rise Projections (2018) – Updated Sea Level Rise Projections - Dr. Donald F. Boesch, UMCES President, convened a panel of highly qualified scientific experts on sea level rise drawn from Maryland and the Mid-Atlantic region (VA, DE, NJ, PA). An updated report detailing best estimates for MD was issued in December 2018. The likely range (66% probability) of the relative rise of mean sea level expected in Maryland between 2000 and 2050 is 0.8 to 1.6 feet, with about a 1-in-20 chance it could exceed 2.0 feet and about a one-in-one hundred chance it could exceed 2.3 feet. Findings support Maryland's "rule of thumb" to plan for 2.1 feet in sea-level rise in that time frame. After 2050, rates of

sea-level rise depend increasingly on the future pathway of global emissions of greenhouse gases during the next sixty years. If emissions continue to grow well into the second half of the 21st century, the likely range of sea-level rise experienced in Maryland is 2.0 to 4.2 feet toward the end of this century with a 1-in-20 chance that it could be over 5.2 feet. On the other hand, if global society were able to bring net greenhouse gas emissions to zero—sufficient to meet the goals of the Paris Climate Agreement to limit the increase in global mean temperature to less than 2°Celsius over pre-industrial levels—the likely range for 2100 is 1.2 to 3.0 feet, with a 5% chance that it would exceed 3.7 feet.
https://www.umces.edu/news/maryland-sea-level-rise-projections-reveal-potential-impact-inaction-warming-climate

Climate Change and Conservation Practices – DNR has developed new conservation criteria and easement provisions to identify coastal habitats that may help Maryland proactively adapt to sea level rise and increased storm events associated with climate change. Climate change targeting criteria was used to develop new conservation areas for "GreenPrint" and a parcel-level scorecard used to review land acquisition projects.
http://dnr.maryland.gov/ccs/habitats_slr.asp

Coast Smart Council (House Bill 0615) – House Bill 615 codifies into law and builds on key provisions of Executive Order 01.01.2012.29 by creating a Coast Smart Council chaired by the head or designee of DNR, with membership comprised of the head or designee of DBM, MDE, DGS, MDP, MDOT, DBED, MEMA, Critical Area Commission, University of Maryland, and 5 members appointed by the Governor to represent local government, environmental, and business interests. Coast Smart Construction Executive Order - EO 01.01.2012.29, issued in December 2012, enacted a number of policy directives, including directing all State agencies to consider the risk of coastal flooding and sea level rise when they design capital budget projects and charging the Department of General Services with updating its architecture and engineering guidelines to require new and rebuilt State structures be elevated two or more feet above the 100-year base flood level.

https://dnr.maryland.gov/climateresilience/Pages/cs_Council.aspx

- House Bill 1350 (2018) – Section 3-101(a) and (f) and 8-101(a) and (i) of the Natural Resource Article - entitled "Sea Level Rise Inundation and Coastal Flooding - Construction, Adaptation, and Mitigation" expands the scope of the Coast Smart Council, the applicability of the Coast Smart siting and design criteria and modifies a requirement that must be included in the criteria. Under the bill, the criteria now apply to state and local projects for which at least 50% of the project costs are funded with state funds. The bill also specifies that the criteria do not apply to a public work contract of less than $500,000. The bill clarified the inclusion of a "highway facility" updated the lowest floor elevation requirement and expanded the participation of the Council.
- House Bill 1427 (2019) – Section 3-1001(a) and (c) of the Natural Resources Article - entitled "Sea Level Rise Inundation and Coastal Flooding - Construction, Adaptation, and Mitigation" clarified the applicability of the siting and design guidelines, extended deadlines for revising the criteria and submission of nuisance flood plans.

Climate Change and Coast Smart Construction – Infrastructure Siting and Design Guidelines (2020*):* The guidelines require specific siting and design criteria for State construction projects to protect against the impacts of climate change (MD Nat Res Code § 3-1009 (2019)). The guidelines are also be applied to non-state buildings and infrastructure projects if partially or fully funded by the State, as well as projects on state lands. Recommended practices include: increasing the elevation requirements for State buildings, and critical and essential facilities, such as 911 centers and fire stations; increasing the setback requirements for State structures to avoid areas likely to be impacted by sea level rise within the next 50 years; and protecting natural storm surge buffers on construction sites.
https://dnr.maryland.gov/climateresilience/Documents/2020-Coast-Smart-Program-Document-FINAL.pdf

Bay Acidification Task Force – House Bill 118 required the State to devise a team, or Task Force, of State leaders, and water quality, fishery and climate experts, to address how changing Bay chemistry negatively impacts Maryland's coast and shellfish industry. The Task Force studied and assessed water quality in Maryland's Chesapeake and coastal Bays, and review ocean acidification studies and findings from other states. The group presented recommendations for monitoring and addressing acidification, and its effects on Maryland's commercial fishery and aquaculture industry in January, 2015. The Task Force included State agency representatives, along with representatives from the State's aquaculture industry, the Maryland Watermen's Association, the National Aquarium in Baltimore, the University of Maryland Center for Environmental Science, and the Chesapeake Bay Foundation.
http://msa.maryland.gov/megafile/msa/speccol/sc5300/sc5339/000113/020000/020856/unrestricted/20150253e.pdf

Maryland Ocean Acidification Action Plan 2020:
https://mde.maryland.gov/programs/Air/ClimateChange/Documents/OA%20Action%20Plan.pdf

Maryland's Plan to Adapt to Saltwater Intrusion and Salinization (2019) – The plan identifies near-term, mid-term and long-term research needs and priority adaptation measures for each resource impacted by saltwater intrusion: aquifers, surface waters, coastal wetlands, coastal forests, agriculture and infrastructure.
https://planning.maryland.gov/Documents/OurWork/envr-planning/2019-1212-Marylands-plan-to-adapt-to-saltwater-intrusion-and-salinization.pdf

Nuisance Flood Plan Guidance (2019): https://dnr.maryland.gov/ccs/Documents/NuisanceFloodPlan.pdf

Coast Smart Climate Ready Action Boundary – Coast Smart Climate Ready Action Boundary (CS-CRAB) shows how 3 additional feet of water beyond the FEMA Floodplain Limit moves across new areas of the landscape based on the land elevation profile or Digital Elevation Model (DEM). The CS-CRAB boundary is used as the threshold in determining applicability for projects under the Coast Smart Construction Program (see above).
https://mdfloodmaps.net/CRAB/

B1.4. State of New York

New York State Climate Action Interim Report (2010) – The interim report focuses on achieving the goal of reducing greenhouse gas emissions by 80 percent below the levels emitted in 1990 by the year 2050.

Adaptation policy options and relevant financial aspects are identified and examined. http://www.dec.ny.gov/energy/80930.html

Responding to Climate Change in New York Synthesis Report (2011) – This state level assessment of climate change impacts is intended to assist with developing adaptation strategies. https://nyclimatescience.org/resources/resource::224/responding-to-climate-change-in-new-york-state-synthesis-report

B1.5. Commonwealth of Pennsylvania

Pennsylvania has been enacting laws, regulations, and policies which serve to reduce the Commonwealth's greenhouse gas emissions and increase adaptive capacity for over two decades.

Current and ongoing legislation:

- Act 213 of 2004, Alternative Energy Portfolio Standards Act: requires that electric distribution companies and electric generation suppliers include a specific percentage of electricity from alternative resources in the generation that they sell to Pennsylvania customers
- Act 129 of 2008, Energy Efficiency and Conservation Program: requires electric distribution companies to develop energy efficiency and conservation plans and other methods of reducing residential and commercial customers' electricity consumption.
- Act 70 of 2008, Pennsylvania Climate Change Act: requires the administrations of a Climate Change Advisory Committee; the development and annual update of a greenhouse gas inventory; and the development and triannual update of a Climate Change Impacts Assessment and Climate Action Plan.
- Act 40 of 2017: Solar Renewable Energy Credits: requires that solar facilities be located within Pennsylvania in order to qualify for AEPS Tier I certification.
- Act 30 of 2018, Commercial Property Assessed Clean Energy Program: authorizes PA counties or municipalities with community or economic development departments to pass a local resolution and adopt guidelines for C-PACE, a financial tool for property owners to finance energy efficiency, renewable energy, and water conservation projects.

Current and ongoing Executive action:

- Executive Order 2019-01, Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance: set greenhouse gas reduction goals of a 26 percent reduction of net greenhouse gas emissions statewide by 2025 from 2005 levels, and an 80 percent reduction of net greenhouse gas emissions by 2050 from 2005 levels; established clean energy and energy efficiency goals for Commonwealth agencies; and reestablished the GreenGov Council to assist Commonwealth agencies in achieving sustainability goals.
- Executive Order 2019-07, Addressing Climate Change through Electric Sector Emissions Reductions (RGGI): charged DEP with developing a rulemaking to abate, control, or limit CO2 emissions from the fossil-fuel-fired electric power generators, consistent with RGGI.

Current and forthcoming regulations and policies:

- Methane regulations: limit emissions of VOCs from oil and natural gas sources.

- ZEV Program: coordinates standards that control smog-causing pollutants and GHG emissions of light-duty vehicles.
- Medium- and heavy-duty ZEV MOU: advances and accelerates the market for electric medium- and heavy-duty vehicles.

Financial incentives:

- Alternative Fuels Incentive Grants (AFIG): provides funds to promote alternative fuels development and deployment in the transportation sector.
- Driving PA Forward: provides grants for transportation projects aimed at reducing emissions from diesel engines.
- PEDA COVID-19 Restart Grant: provided grants to support clean energy projects in Pennsylvania that were interrupted by the COVID-19 pandemic.

Planning efforts:

Pennsylvania has published Climate Impacts Assessments and Climate Action Plans approximately every three years since 2009. DEP's Climate Change Advisory Committee provides sector-specific expertise in the development of these reports. The most recent of these reports include:

- 2021 Pennsylvania Climate Impacts Assessment Update
- 2020 Pennsylvania Climate Impacts Assessment Update
- 2015 Pennsylvania Climate Impacts Assessment Update
- Pennsylvania Climate Action Plan 2018

Pennsylvania's DEP has also been involved in efforts to assist local governments with climate mitigation and adaptation planning through the Local Climate Action Program, which helps local governments develop local greenhouse gas inventories and climate action plans, and a Shared Energy Manager Program, which helps local governments implement their local climate action plans.
Pennsylvania is also establishing the PA Climate Change Mitigation & Resilience Network to educate stakeholders, as well as engage them in peer-to-peer networking, information exchange, partnerships, and collaboration that will further drive climate problem solving and human-centered solutions for the state.

Additional Commonwealth planning efforts and studies include:

- DCNR's Climate Change Adaptation and Mitigation Plan, 2018
- PennDOT Extreme Weather Vulnerability Study, April 2017
- Drive Electric PA Coalition: a stakeholder effort to develop strategies to increase use of EVs by state and local government agencies, businesses, industry, and individual consumers in Pennsylvania.
- Pennsylvania Electric Vehicle Roadmap: reviews the state of the electric vehicle market in Pennsylvania, presents a set of proposed strategies to support the expansion of the EV market, and estimates the potential benefits and impacts to the state from an increased EV market.
- Pennsylvania Electric Vehicle Roadmap, 2021 Update: highlights on progress made, more actions that can be taken, and a summary of the current electric vehicle market in Pennsylvania.

B1.6. Commonwealth of Virginia

Climate Change Final Report: A Climate Change Action Plan (2008) - The report presents recommendations to meet the state greenhouse gas reduction target of 30 percent below the business-as-usual projection by 2025. It includes findings and recommendations for effects on the built environment and insurance, natural systems, human health; general strategies; and greenhouse gas reduction goals.
https://www.adaptationclearinghouse.org/resources/virginia-governor-s-commission-on-climate-change-final-report-a-climate-change-action-plan.html

In 2014, the Governor convened the Climate Change and Resiliency Update Commission to review, update, and prioritize the recommendations of the 2008 Climate Change Action Plan. Moreover, the updated report will work to identify sources of revenue to fund the implementation of these recommendations.

Recommendations to the Secure the Commonwealth Panel on the Issue of Sea Level Rise and Recurrent Flooding in Coastal Virginia (2014) – In addition to recurrent flooding issues and future flooding challenges, the report evaluates adaptation strategies for reducing the impact of flood events.
http://ccrm.vims.edu/SCPRecommendationsReport_Sept2014.pdf

Virginia's Strategy for Safeguarding Species of Greatest Conservation Need from the Effects of Climate Change (2009) - A climate change strategy for the Virginia's Wildlife Action Plan. This strategy outlines the importance of considering a changing climate in developing and implementing successful wildlife conservation practices, particularly for those species already experiencing stressors that threaten their long-term viability and persistence in Virginia.
https://www.adaptationclearinghouse.org/resources/virginia-strategy-for-safeguarding-species-of-greatest-conservation-need-from-the-effects-of-climate-change.html

B1.7. Metropolitan Washington Council of Governments

In 2008, the Metropolitan Washington Council of Governments (COG) Board adopted the National Capital Region (NCR) Climate Change Report, which established regional greenhouse gas (GHG) reduction goals and identified over 100 actions, including adaptation measures. A key focus of COG's adaptation initiatives has been to build the capacity of regional leaders to understand and address the unavoidable impacts of climate change. In order to help facilitate COG's initiatives, COG applied for and received technical assistance through the U.S. Environmental Protection Agency's Smart Growth Implementation Assistance Program (EPA SGIA). EPA published Using Smart Growth Strategies to Create More Resilient Communities in the Washington, D.C., Region, a guidebook that provides an overview of general climate adaptation approaches that pulls most of its case studies from the NCR. In addition, COG staff has written a report that is a synopsis of lessons learned during the project called Summary of Potential Climate Change Impacts, Vulnerabilities, and Adaptation Strategies in the Metropolitan Washington Region. For more information and additional resources on MWCOG climate resilience and adaptation efforts, visit:
http://www.mwcog.org/environment/climate/resilience.asp

B2. Federal Programs and Policies

2021 Executive Order on Tackling the Climate Crisis at Home and Abroad: https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

B2.1. Environmental Protection Agency (EPA)

EPA National Center for Environmental Assessment (NCEA) Global Impacts and Adaptation Program within the Office of Research and Development (ORD)/National Center for Environmental Assessment (NCEA) - NCEA's Global Change Impacts and Adaptation program, as part of the ORD Air, Climate and Energy Program, assesses the potential vulnerability to climate change (and other global change stressors such as land-use change) of EPA's air, water, ecosystems, and human health protection efforts at the federal, regional, state, municipal, and tribal levels, as well as adaptation options to build resilience in the face of these vulnerabilities. The focus is on interdisciplinary syntheses across newly emerging scientific findings to identify potential impacts, and characterize and communicate the uncertainty in the science, to provide support for decision makers and managers. https://www.epa.gov/climate-change

EPA Office of Research and Development Science Inventory - Catalogue of ORD Research relevant to climate change. http://cfpub.epa.gov/si/si_lab_search_results.cfm?subject=Air%20Research&showCriteria=0&searchAll=Climate%20and%20Adaptation&actType=Product&TIMSType=PUBLISHED+REPORT&sortBy=revisionDate

B2.2. National Oceanic and Atmospheric Administration (NOAA)

The NOAA Chesapeake Bay Office (NCBO) connects climate science, habitat, and fisheries management. NCBO leads the CBP's Sustainable Fisheries Goal Implementation Team (Fisheries GIT) and manages the Climate Resiliency Workgroup (CRWG) with USGS and U.S. EPA. Through these workgroups, NCBO helps connect state and local decision makers with the most up-to-date fisheries and climate science to help them with fisheries management and climate change assessment and adaptation efforts, including the development of indicators, and the consideration of nature-based solutions (e.g., living shorelines, marsh restoration, oyster restoration). NCBO also funds fisheries science research including the recent Notice of Funding Opportunity that included requests for research proposals that would increase understanding of climate change and related ecological shifts to inform fisheries management and natural resource decisions. Additionally, NCBO enables nearshore habitat restoration, including assistance with shoreline restoration and living shoreline projects that builds habitat for fisheries and resilience to climate change impacts. NCBO also operates the Chesapeake Bay Interpretive Buoy System (CBIBS), a network of observing platforms in the Bay that provide real-time data on weather and water conditions and synthesizes data in connection with environmental change and effects on fisheries for the annual State of the Ecosystem Report for the Northeast/Mid-Atlantic. The NCBO also develops seasonal summaries of water quality parameters in the Chesapeake Bay and narratives on how anomalies compared to the average could affect living resources in the Bay. The NCBO also supports and provides climate change education, including hosting climate education and resilience education

workshops through the NOAA Environmental Science Training Center and working with partners to implement the Mid-Atlantic Climate Change Education Conference.

The NCBO supports both the Choptank River, MD/DE and Middle Peninsula, VA Habitat Focus Areas. NOAA provides capacity building, coordination, and resources to improve and sustain the ecological health of these areas by working with partners and communities. Climate change and sea level rise, combined with land subsidence, further threaten losses of nearshore marshes and coastal environments. These areas are ideal locations to target habitat projects that can contribute to enhancing fish habitat and coastal resilience.

List of additional NOAA climate change-related activities:

- A Coastal Community Vulnerability Assessment for the Choptank Habitat Focus Area (2017) – Report from the NOAA National Centers for Coastal Ocean Science (NCCOS) that provides findings from a community vulnerability assessment in the Choptank Habitat Focus Area within the Chesapeake Bay. https://coastalscience.noaa.gov/data_reports/a-coastal-community-vulnerability-assessment-for-the-choptank-habitat-focus-area/
- Identifying priorities for adaptation planning: an integrated vulnerability assessment for the town of Oxford and Talbot County, Maryland (2016) – Report from the NOAA National Centers for Coastal Ocean Science (NCCOS) that aims to provide coastal communities with the information needed to identify and prioritize areas that have the potential to be negatively impacted by climate-related hazards such as storm surge and sea level rise by designing and implementing a framework for an integrated social environmental vulnerability assessment. https://coastalscience.noaa.gov/data_reports/identifying-priorities-for-adaptation-planning-an-integrated-vulnerability-assessment-for-the-town-of-oxford-and-talbot-county-maryland/
- NOAA Sea Level Rise Viewer – A web-mapping tool to visualize community-level impacts from coastal flooding. Also includes a marsh migration tool. https://coast.noaa.gov/digitalcoast/tools/slr.html
- Resilience Metrics – A website resource tool that guides planners, resource managers, resilience officers, and adaptation practitioners to answer critical climate change questions in a local context. https://resiliencemetrics.org/
- Northeast Climate Integrated Modeling (NCLIM) – Sponsored by the NOAA Coastal and Ocean Climate Applications (COCA) program, the Gulf of Main Research Institute is developing scientific knowledge on marine resource decision-making through integrated models, including global climate models, regional oceanographic models, ecosystem and population models, and human dimension models. https://www.gmri.org/projects/northeast-climate-integrated-modeling-nclim/
- NOAA Fisheries Northeast Vulnerability Assessment – Uses expert opinion and existing information on the climate, the state of the ocean, species distributions, and life history to assess species' vulnerability under projected future climate and ocean conditions. https://www.fisheries.noaa.gov/new-england-mid-atlantic/climate/northeast-vulnerability-assessment#:~:text=The%20Northeast%20Fish%20and%20Shellfish,future%20climate%20and%

20ocean%20conditions. https://www.fisheries.noaa.gov/national/climate/climate-vulnerability-assessments

- NOAA Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) team – MARISA focuses on efforts that help mid-Atlantic communities become more resilient to climate change impacts through improved data, place-based decision support, and public engagement. MARISA recently released the Chesapeake Bay Model Inventory and Selection Tool (MIST), which is a searchable collection of relevant models for water management and decision-making in the Chesapeake Bay Watershed and Mid-Atlantic region. The MARISA team is comprised of interdisciplinary researchers from the RAND Corporation, Penn State University, Johns Hopkins University, and Cornell University. https://www.midatlanticrisa.org/
- NOAA Geophysical Fluid Dynamics Laboratory (GFDL) – GFDL focuses efforts on model building relevant for society, for hurricane research, weather and ocean prediction, seasonal forecasting, and understanding regional and global climate change. https://www.gfdl.noaa.gov/
- National Climatic Data Center (NCDC) – The Center provides access to climate and historical weather data and information that scientists need to understand climate change, e.g., paleoclimatology data derived from natural sources such as ice cores. http://www.ncdc.noaa.gov/
- NOAA Technical Report NOS CO-OPS 073: Sea Level Rise and Nuisance Flood Frequency Changes around the United States – This report discusses results of measuring water levels around the United States. It shows exceedances above minor coastal flooding impacts have been increasing in time and frequency, including changes in regional patterns, and their effects on coastal communities. https://tidesandcurrents.noaa.gov/publications/NOAA_Technical_Report_NOS_COOPS_073.pdf
- NOAA National Data Buoy Center – NDBC designs, develops, operates, and maintains a network of data collecting buoys and coastal stations in U.S. waters, including in the Mid-Atlantic region. http://www.ndbc.noaa.gov/
- NOAA National Environmental Satellite Data and Information Service (NESDIS) – Provides secure and timely access to global environmental data and information from satellites and other sources to promote and protect the Nation's security, environment, economy, and quality of life. https://www.nesdis.noaa.gov/
- 2013 Highlights of progress: Responses to Climate Change by the National Water Program – This is a joint EPA-NOAA report on incorporating climate change considerations into stormwater planning efforts. http://water.epa.gov/scitech/climatechange/upload/Final-2013-NWP-Climate-Highlights-Report.pdf
- NOAA Coastal Storms Program – The Coastal Storms Program is a nationwide effort to make communities safer by reducing the loss of life and negative impacts caused by coastal storms. This work is accomplished by bringing together organizations from all sectors. Each funded project lasts three to five years and brings additional capacity, focus, and funding to a specific region. In 2015, the program will be focusing on the Mid-Atlantic/Chesapeake Bay area and will have a coordinator working in the region. The results often include new data and predictive tools, new ways of keeping the public informed and enlightened, and new partnerships that

strengthen existing resilience efforts. https://coast.noaa.gov/digitalcoast/topics/coastal-storms.html

- NOAA Coastal Mapping – NOAA's National Geodetic Survey (NGS) is surveying coastal regions to provide the Nation with accurate, consistent, up-to-date national shoreline. The national shoreline provides the critical baseline data for demarcating America's marine territorial limits, including its Exclusive Economic Zone, and for the geographic reference needed to manage coastal resources and many other uses. http://www.ngs.noaa.gov/RSD/cmp.shtml
- NOAA National Center for Coastal Ocean Science (Cooperative Oxford Lab) – Oxford Lab helps local decision-makers understand the pressures on the Chesapeake Bay watershed, among them: climate change, urbanization, and pollution. Developing a model to forecast striped bass recruitment in the Chesapeake Bay: Unlike other models, this one accounts for weather and climate variability, as well as fishing pressure.
- Chesapeake Bay Climate Sensitivity Assessment: using weather, water, biological, and climate data from a variety of sources and a state of the art biophysical model (the Chesapeake Bay Ecological Prediction System) to address the needs and goals of the Chesapeake Bay NERRS, the Chesapeake Bay Program, and NOAA's Chesapeake Bay Sentinel Site Cooperative. https://coastalscience.noaa.gov/project/chesapeake-bay-climate-sensitivity-assessment/
- NOAA Office of Coastal Management National Estuarine Research Reserve System (NERRS) – NOAA and the Reserve System have identified climate change and its impacts as strategic priorities. As one of three 2011-2016 priority areas for the Reserve System, reserves are supporting both the Climate Adaptation and Mitigation goal as well as the Resilient Coastal Communities and Economies goal in NOAA's Next Generation Strategic Plan. The 2017-2022 priority areas focus on stewardship, recreation, and tourism, preparedness and risk reduction (e.g., hurricanes and flooding), and safe and efficient transportation and commerce. https://coast.noaa.gov/nerrs/. https://coast.noaa.gov/data/docs/nerrs/StrategicPlan.pdf
- Chesapeake Bay NERRS Contribution to Climate Change (Stewardship) – National Estuarine Research Reserves will contribute to scientific understanding of climate change and monitor ecosystem changes. National Estuarine Research Reserves will assess climate change impacts on human and estuarine ecosystem communities, vulnerability of these communities, and their capacity for adaptation and mitigation. The National Estuarine Research Reserve System will provide educational opportunities and training related to effects of climate change on human and estuarine systems to increase public awareness and foster behavior change. https://www.vims.edu/cbnerr/stewardship/index.php
- NOAA's Coastal Zone Management Program – A voluntary partnership between the federal government and U.S. coastal and Great Lakes states and territories authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. NOAA administers the program. The act provides the basis for protecting, restoring, and responsibly developing our nation's diverse coastal communities and resources. To meet the goals of the CZMA, the national program takes a comprehensive approach to coastal resource management-balancing the often competing and occasionally conflicting demands of coastal resource use, economic development, and conservation. A wide range of issues are addressed through the program, including coastal development, water quality, public access, habitat protection, energy facility

siting, ocean governance and planning, coastal hazards, and climate change. http://coast.noaa.gov/czm/about/

- National Oceanic and Atmospheric Administration (NOAA) initiated a Sentinel Site Program (SSP) to encourage federal, state and local partners to cooperatively address impacts of climate change, with an initial emphasis placed on rising sea levels. In 2011, NOAA selected the Chesapeake Bay as one of five initial regional Sentinel Site Cooperatives to demonstrate the value of using a place-based approach to address issues of local, regional and national significance. The Cooperative provides integrated observations across a host of environmental monitoring programs within the Bay area. The goal of the cooperative is to provide information to Chesapeake Bay communities and managers who need to address challenges such as storm flooding, long term, local sea level rise, barrier island movement, degraded water quality, and wetland loss. http://oceanservice.noaa.gov/sentinelsites/
- NOAA Coastal Blue Carbon: NOAA is working to advance awareness of coastal blue carbon, the carbon captured by living coastal and marine organisms and stored in coastal ecosystems. Salt marshes, mangroves, and seagrass beds absorb large quantities of the greenhouse gas carbon dioxide from the atmosphere and store it, thus decreasing the effects of global warming. https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/

B2.3. US Fish and Wildlife Service (FWS)

Fish and Wildlife Service Landscape Conservation Cooperatives (LCC) – Landscape Conservation Cooperatives are partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues, such as climate change in a defined geographic area.

Climate Change Vulnerability Index for Northeast species – Collaborators in the Northeast Regional Vulnerability Assessment have developed a Climate Change Vulnerability Index (CCVI) to provide a rapid, scientifically defensible assessment of species' vulnerability to climate change. http://northatlanticlcc.org/projects/completing-northeast-regional-vulnerability-assessment-incorporating-the-natureserve-climate-change-vulnerability-index/completing-northeast-regional-vulnerability-assessment-incorporating-the-natureserve-climate-change-vulnerability-index

North Atlantic Landscape Conservation Cooperative works with a number of potentially relevant data layers related to climate and resilience. The Chesapeake Conservancy and its partners use these layers to develop conservation projects that will protect the Susquehanna's ecological and cultural resources. A project entitled “Envisioning the Susquehanna: Incorporating Landscape Science into Large Landscape Conservation”, may be related and tied into work done by Mid-Atlantic Regional Ocean Agreement Climate Resiliency Workgroup. https://www.fws.gov/northeast/test/northatlanticlcc/

Support for Understanding Land Use and Climate Change in the Appalachian Landscape – This research will compile climate change vulnerability assessments and other relevant information on vulnerable species and habitats, discern the various methodologies and criteria used in these assessments, and use a team of exert peer reviewers to recommend the most efficient, effective, and appropriate methods for adoption by the Appalachian LCC for conservation and adaptation planning. http://applcc.org/research/climate-change-vulnerability-group

B2.4. U.S. Geological Survey (USGS)

USGS Chesapeake Science Strategy, 2015-2025—Informing Ecosystem Management of America's Largest Estuary – Strategy aimed to support research that improves understanding of fish and wildlife population and health, and factors, including climate change, affecting their condition. The science focuses on documenting critical ecosystem connections in the Chesapeake Bay to help enhance decision-making related to restoration and conservation activities.
https://pubs.usgs.gov/of/2015/1162/ofr20151162.pdf

Disentangling the potential effects of land-use and climate change on stream conditions (2020). USGS study focusing on evaluating future climate scenarios and landscape futures on stream health.
https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14961

USGS/US DOI: Land Subsidence and Relative Sea-Level Rise in the Southern Chesapeake Bay Region (2013) – Land subsidence has been shown to be a good indicator of sea-level rise.
http://pubs.usgs.gov/circ/1392/pdf/circ1392.pdf

Research to examine North Atlantic Oscillation (NAO)-type climate variability, provided supporting evidence of climate variability in the Chesapeake Bay during the Holocene era. The large contrast between early and late Holocene regional climate conditions, multidecadal salinity and temperature variability is similar to those observed during the twentieth century.
https://fds.duke.edu/db/attachment/1774

Cronin, T. M., R. Thunell, G. S. Dwyer, C. Saenger, M. E. Mann, C. Vann, and R. R. Seal II (2005), Multiproxy evidence of Holocene climate variability from estuarine sediments, eastern North America, Paleoceanography, 20, PA4006, doi:10.1029/2005PA001145.

Late Holocene sea level variability and Atlantic Meridional Overturning Circulation: A report examined sea level and Atlantic Meridional Overturning Circulation variability along the eastern United States over the last 2000 years, using a sea level curve constructed from proxy sea surface temperature records from the Chesapeake Bay, and twentieth century sea level-sea surface temperature relations derived from tide gauges and instrumental sea surface temperatures.

Cronin, T. M., J. Farmer, R. E. Marzen, E. Thomas, and J. C. Varekamp (2014), Late Holocene sea level variability and Atlantic Meridional Overturning Circulation, Paleoceanography, 29, 765–777, doi:10.1002/2014PA002632.

Rapid sea level rise and ice sheet response to 8,200-year climate event: Report on the largest abrupt climate reversal of the Holocene which slowed Atlantic meridonal overturning circulation and cooled global climate.

Cronin, T. M., P. R. Vogt, D. A. Willard, R. Thunell, J. Halka, M. Berke, and J. Pohlman (2007), Rapid sea level rise and ice sheet response to 8,200-year climate event, Geophys. Res. Lett., 34, L20603, doi:10.1029/2007GL031318.

Invited Review: Rapid sea-level rise by Thomas M. Cronin. Global processes include changes in ocean mass (glacio-eustasy from ice melt), ocean volume (steric effects), viscoelastic land movements (glacioisostatic adjustment GIA), and changes in terrestrial water storage. The practical difficulties of assessing regional sea-level patterns at submillennial timescales is discussed using an example from the eastern United States.
http://www.sciencedirect.com/science/article/pii/S0277379112003344

B2.5. U.S. Army Corps of Engineers (Corps)

Climate Change Adaptation Plan (2014) – The Corps' Plan mainstreams climate change adaptation and increased preparedness and resiliency into its missions and operations including constructed and natural water-resources infrastructure. Four strategies, e.g., focus on priority areas and external collaboration, are employed to integrate and incorporate considerations of climate change and variability in all phases of project lifecycle.
http://www.usace.army.mil/Portals/2/docs/Sustainability/Performance_Plans/2014_USACE_Climate_Change_Adaptation_Plan.pdf

Engineering Technical Letter NO. 1100-2-1 (2014) Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation – Coastal climate change effects vary depending on project type, planning horizon, and other factors. Guidance is provided to promote understanding direct and indirect physical and ecological effects of projected future sea level change on USACE operations, missions, programs and projects.
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf

North Atlantic Coast Comprehensive Study – Resilient Adaptation to Increasing Risk (2015). USACE recently released the North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk, a two-year study to address coastal storm and flood risk to vulnerable populations, property, ecosystems and infrastructure in the North Atlantic region of the United States affected by Hurricane Sandy in October 2012. The study, authorized by Congress in January 2013 in the Disaster Relief Appropriations Act of 2013 (Public Law 113-2), brought together experts from Federal, state, and local agencies, as well as non-governmental organizations and academia, to assess the flood risks facing coastal communities and ecosystems, and collaboratively develop a coastal storm and flood risk management framework to address increasing risks, which are driven in part by climate and sea level change. The full report and study products are available online at:
http://www.nad.usace.army.mil/CompStudy.aspx.

B2.6. US Department of Agriculture

USDA Natural Resources Conservation Service – Agency offers various programs, practices, and tools to assist agriculture producers in addressing climate related issues on working lands.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/climatechange/

USDA Climate Change Program Office – The office coordinates USDA's responses to climate change, focusing on implications of climate change on agriculture, forests, grazing lands, and rural communities. https://www.usda.gov/oce/energy-and-environment/climate

USDA Climate Change Hubs (Forest Service, NRCS, ARS) – The Bay falls into 2 hubs, the Northeastern and Southeastern Hub
http://www.nrs.fs.fed.us/niacs/

USDA Forest Service – The Service has various inter-related programs to help mitigate and adapt to global climate change.
http://www.fs.fed.us/climatechange/

USDA Chesapeake Forest Restoration Strategy (2020) – Includes section on climate change and forest restoration.
https://www.chesapeakebay.net/channel_files/42309/cst91_chesapeake_forest_restoration_strategy.pdf

USDA-ARS Crop Systems and Global Change Laboratory investigate plant response to climate change related environmental variables (temperature, CO2).
http://www.ars.usda.gov/ba/csgcl

B2.7. Department of Defense (DoD)

In 2010 the Vice Chief of naval Operations prepared a Navy Climate Change Roadmap which provides a list of Navy actions to assess, predict, and adapt to global climate change from 2010-2014 and assigns responsibility for implementation.
http://greenfleet.dodlive.mil/files/2010/08/US-Navy-Climate-Change-Roadmap-21-05-10.pdf

Climate Adaptation for DoD Natural Resource Managers: https://www.nwf.org/Educational-Resources/Reports/2019/05-01-19-DoD-Climate-Adaptation

DoD Integrated Natural Resource Management Plans (INRMPs) – Includes information on climate resilience. Many DoD installations are embedded within their surrounding communities. Plans can promote the integration of climate resiliency strategies between local, state, and federal entities.

DoD is conducting a peer-review of a DoD Climate Assessment Tool (DCAT). It is currently in Beta. The DCAT is a high-level screening assessment of exposure to climate hazards using consistent, authoritative, standardized data and methods. It is designed to produce risk assessments of future climate exposure to eight hazards: coastal flooding, riverine flooding, heat, drought, energy demand, land degradation, wildfire, and historical extreme weather events. DCAT identifies relative exposure across DoD, Departments, or commands, allowing them to determine sensitivity and adaptive capacity, identify actionable preparedness and adaptation pathways to reduce vulnerability and develop resilience measures.

B2.8. Chesapeake Bay Program (CBP)

CBP Climate Resiliency Workgroup – The Work Group compiled a list of current climate change research and resiliency efforts, gaps, and resources (2014) and supporting efforts to assess climate change effects

on water quality, habitats, and living resources and identify adaptation strategies.
https://www.chesapeakebay.net/who/group/climate_change_workgroup

Integrated Trends Analysis Team – Conducting trend analyses on climate-related (water temperature, water flow) and non-climate-related (nutrients, dissolved oxygen, salinity) stressors using Generalized Additive Models.
https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

B2.9. National Aeronautics and Space Administration (NASA)
Adapting to a Changing Climate – A report for Federal Agencies in the Washington, DC Metro Area
http://www.mwcog.org/environment/climate/adaptation/building/NASA_DCmetroClimCg%20FINAL%20NOV%202012.pdf

B3. Consortiums

B3.1. Climate Communication Consortium of Maryland (Public Engagement)
The Consortium's mission is to broaden and deepen public engagement in climate change and energy issues across all of Maryland's communities and sectors by encouraging and facilitating collaboration in the communication efforts of government agencies and elected officials, businesses, non-profit organizations, advocates and citizens.
https://www.facebook.com/pg/climatemaryland/about/

B3.2. Creating Green Infrastructure Resiliency in Greater Baltimore and Annapolis Watersheds
(Planning) – 2014-2016 project led by The Conservation Fund and American Planning Association on behalf of the Greater Baltimore Wilderness Coalition (local governments, DNR, regional federal agencies and NGOs) to identify green infrastructure network and key opportunities for increasing regional resiliency to impacts of coastal storms and climate change.
https://www.planning.org/nationalcenters/green/gbwc/

B3.3. The Conservation Fund
Increasing Salt Marsh Acreage and Resiliency for Blackwater National Wildlife Refuge (Maryland) – Funded by the National Fish and Wildlife Foundation, The Conservation Fund in cooperation with USFWS, Audubon MD-DC, USGS and USACE, is leading a set of projects to increase the resiliency of the Atlantic Coast's largest salt marsh ecosystem centered on the Blackwater NWR and Fishing Bay Wildlife Management Area to the effects of sea level rise and other climate factors. Project mechanisms include 1) thin-layer marsh elevation, 2) tidal exchange system modeling, 3) invasive plant mapping and control in marsh migration corridor, and 4) invasive animal eradication in regional watersheds.
http://www.conservationfund.org/projects/blackwater-national-wildlife-refuge

Blackwater 2100: A Strategy for Salt Marsh Persistence in an Era of Climate Change – Working with Audubon MD-DC and US Fish and Wildlife, The Conservation Fund developed a comprehensive set of strategies for ensuring the continued presence of healthy, productive high salt marsh in Dorchester County (MD) world-class Blackwater NWR. Integrated strategies include slowing rates of loss of existing salt marsh, improving in the transition of upland fields and forests into high quality salt marsh, and protecting targeted marsh migration "corridors" from disruptive development and uses. MD DNR and

Chesapeake Conservancy assisted in assessment of sea level rise projections with other land use characteristics in identifying high-promise migration corridors. Summary of strategy and underlying models and research is available at:
http://www.conservationfund.org/images/projects/files/Blackwater-2100-report_email.pdf

B4. Projects

A Framework for Assessing Climate Change Impacts on Water and Watershed Systems – Article presents a framework for assessing climate change impacts on water and watershed systems to support management decision-making. The framework addresses three issues complicating assessments of climate change impacts—linkages across spatial scales, linkages across temporal scales, and linkages across scientific and management disciplines.
https://link.springer.com/article/10.1007/s00267-008-9205-4

Case Study Application of the Basins Climate Assessment Tool, And Development of a Framework for Assessing Climate Change Impacts on Water Quality in the Chesapeake Bay Watershed – The EPA Global Change Research Program (GCRP) recently supported the development of a Climate Assessment Tool (CAT) for the Office of Water's BASINS water quality modeling system. The BASINS CAT provides users with the ability to modify historical climate, generate synthetic weather time series, and conduct systematic sensitivity analyses of specific hydrologic and water quality end-points to changes in climate using the BASINS models (e.g. HSPF). This project will demonstrate the use and capabilities of the BASINS CAT, as well as support on-going efforts to achieve Bay-wide integrated climate and land use change scenarios for 2030 and, ultimately, 2100.
http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=158295&simpleSearch=1&searchAll=climate

Coastal SEES: Chesapeake Bay Sustainability: Implications Of Changing Climate And Shifting Management Objectives – A National Science Foundation funded collaborative project lead by VIMS that aims to develop an advanced modeling framework that integrates the physical, biogeochemical, and human components needed to simulate and select climate change adaptation strategies that will support a sustainable system. The National Science Foundation - Science, Engineering and Education for Sustainability (SEES) Program provides a funding mechanism to advance science, engineering, and education to inform the societal actions needed for environmental and economic sustainability and sustainable human well-being.
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504816

Climate Change Effects on Stream and River Biological Indicators: A Preliminary Analysis – A preliminary assessment that describes how biological indicators are likely to respond to climate change, how well current sampling schemes may detect climate-driven changes, and how likely it is that these sampling schemes will continue to detect impairment.
http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=190304&simpleSearch=1&searchAll=climate

Development of strategies to improve conservation of Virginia headwater wetland ecosystems in the face of climate change – Researchers at the Virginia Institute of Marine Science received a 3-year grant

(2014-2017) from the Environmental Protection Agency to identify the streams and wetlands most vulnerable to sea-level rise, and to develop tools to help local governments and citizens conserve these important ecosystems. The project team will analyze climate-induced changes in downstream marshes, evaluate the connections between these marshes and the headwater wetlands that feed them, refine the protocol used to identify the headwater wetlands at greatest risk, and identify management options for sustaining headwater acreage and function. These outcomes will inform strategies for long-term protection of headwater resources in Virginia.

Hampton Roads Intergovernmental Pilot Project – The Hampton Roads Pilot Project The Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project is a two-year project that seeks to develop adaptive planning for sea level rise by combining the efforts of federal, state and local agencies with private industries and researchers.
http://www.centerforsealevelrise.org/

EPA Climate Change and Urban Stormwater Guide – EPA is developing a climate change design guide for stormwater management practices to inform on how climate change will affect stormwater control performance of gray and green infrastructure. The guide will provide information on factors affecting urban stormwater controls due to climatic changes in order to support adaptation in the stormwater community.

Framework and Inventory of Relative Wetland Vulnerabilities to Inform EPA Office of Water Programs – EPA Office of Research and Development project to develop a framework and inventory of relative wetland vulnerabilities to climate change at multiple scales based on integration of information on vulnerability assessment methods and wetlands classification systems.

Implications of Climate Change for State Bioassessment Programs and Approaches to Account for Effects – The study investigates the potential to identify biological response signals to climate change within existing bioassessment data sets; analyzes how biological responses can be categorized and interpreted; and assesses how they may influence decision-making processes. The analyses suggest that several biological indicators may be used to detect climate change effects and such indicators can be used by state bioassessment programs to document changes at high-quality reference sites.
http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=239585

Maryland's Ecological Effects of Sea Level Rise Project: The Nature Conservancy, George Mason University, and Maryland Department of Natural Resources are working together to understand how nature can help protect coastal communities from storm and flood impacts as sea levels rise. Results will help shape decisions about where the state and its natural resource partners conserve, restore or enhance wetlands, submerged aquatic vegetation and shorelines to enhance community resilience. Funding for this three-year study is provided by the NOAA Ecological Effects of Sea Level Rise Program.
https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/md/Pages/EESLR-Study.aspx

National Wildlife Federation Vulnerability Assessment for the Middle Patuxent Subwatershed – NWF and NOAA partnered to produce a report examining the anticipated climate change impacts as they

relate to conservation and restoration actions that benefit vulnerable species and habitats in the watershed.
https://www.nwf.org/~/media/PDFs/Global-Warming/Climate-Smart-Conservation/Middle%20Patuxent%20Subwatershed%20Vulnerability%20Assessment%20and%20Adaptation%20Report%20August%202013.ashx

Rockefeller 100 Resilient Cities – The city of Norfolk Virginia was selected in 2013 to participate in the Rockefeller Foundation's 100 Resilient Cities (100RC) Challenge for the purpose of building the practice of urban resilience in the face of climate change.
https://www.rockefellerfoundation.org/100-resilient-cities/

SAGE Initiative (Systems Approach to Geomorphic Engineering) – Collaborative effort between the Army Corps of Engineers, the National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, the Nature Conservancy, the Conservation Fund, and the Virginia Institute for Marine Sciences, SAGE is an initiative that brings together technical experts and field practitioners from the government, academic, non-profit and private sectors to advance a comprehensive view of shoreline change that seeks to reduce impacts to coastal communities from the consequences of land cover and climate change through prevention, mitigation and/or adaptation.
http://ccrm.vims.edu/sage/SAGEreport_Summer15.pdf
http://www.iwr.usace.army.mil/Missions/Coasts/ProgramsandInitiatives.aspx

The Potential Impacts of Climate Change on the Mid-Atlantic Coastal Region - Paper assesses the potential impacts of climate change on the Mid-Atlantic Coastal (MAC) region of the United States. In order of increasing uncertainty, it is projected that sea level, temperature and streamflow will increase in the MAC region in response to higher levels of atmospheric CO2
http://www.int-res.com/articles/cr/14/c014p219.pdf

Using Robust Decision Making to Manage Climate and Other Uncertainties in EPA's National Water Program: Framework for Analysis and Water Quality Case Studies - Robust decision making (RDM) is an approach that shifts focus from uncertainty quantification to uncertainty management. This method examines management strategies across a full range of climate changes and other key uncertainties to identify those that are effective across the full range of uncertainties. EPA applied RDM in two pilot case studies—Patuxent River, MD and North Farm Creek, IL.
https://www.rand.org/pubs/research_reports/RR720.html

VA Sea Grant Adaptation Efforts – Wetlands Watch awarded a grant to help a Hampton Roads neighborhood design a sea level rise/flooding adaptation approach. This project also incorporates ecosystem services while protecting against flooding.
https://wetlandswatch.org/adaptation-resources

Virginia's Climate Modeling and Species Vulnerability Assessment: How Climate Data Can Inform Management and Conservation – Recognizing the need to use more regionally explicit, or "downscaled," set of climate models Virginia's vulnerability assessment can provide more detailed and locally relevant climate projections to better inform the species threat assessments. This report includes a summary of the findings from the modeling effort and assessment as well as highlights management concerns and

implications based on the assessment results. The information developed through this project and included in this document will help inform the update of Virginia's Wildlife Action Plan.
http://www.bewildvirginia.org/climate-change/virginias-climate-vulnerability-assessment.pdf

B5. Non-Governmental Organizations

Wetlands Watch – Wetlands Watch is a non-profit environmental group dedicated to protecting and conserving Virginia's wetlands using grass roots education and activism to influence local government land use and regulatory decisions. They are currently collaborating with state and local organizations to develop innovative land-use models that can be used by Virginia tidewater communities in coming years to protect our wetland resources as the sea rises. Wetlands Watch is conducting education and advocacy programs at the local level to educate and motivate citizens to press our state and local governments to take sea level rise into account in wetlands regulation and conservation.
http://www.wetlandswatch.org/WetlandScience/SeaLevelRise.aspx

The Nature Conservancy (TNC) – TNC in Maryland and DC supports large-scale, science-based conservation projects that help people and nature adapt to climate change, including the restoration of floodplains, reversing ditching, controlled burns, and supporting research on marsh resilience and migration.
https://www.nature.org/en-us/about-us/where-we-work/united-states/maryland-dc/stories-in-maryland-dc/mddc-how-we-work-resilient-coasts/

https://www.nature.org/en-us/about-us/where-we-work/united-states/maryland-dc/

Netherlands Water Partnership – Hosted the, "Building a climate-resilient Maryland together," symposium. Brought Maryland and Dutch resilience experts together to share climate adaptation strategies and foster partnerships. Also partnered with the American Flood Coalition and Arcadis to produce the, "Adaptation for all: how to build flood resilience for communities of every size," manual.

B6. Academic

B6.1. Old Dominion University (ODU)

The Mitigation and Adaptation Research Institute (MARI) at Old Dominion University engages in research that produces the practice-relevant knowledge needed to cope with the impacts of climate change and sea level rise on the coastal zone and the urban coast in particular. In doing so, MARI responds to the knowledge needs of a wide range of community stakeholders, including government, military, private sector, and citizens.
http://www.mari-odu.org/

The mission of the Pilot Project is to develop a regional "whole of government" and "whole of community" approach to sea level rise preparedness and resilience planning in Hampton Roads that also can be used as a template for other regions.
http://www.centerforsealevelrise.org/

B6.2. Pennsylvania State University (PSU)

Founded within the College of Earth and Mineral Sciences in 1986, the Earth System Science Center (ESSC) maintains a mission to describe, model, and understand the Earth's climate system. ESSC is one of seven centers supported by the Earth & Environmental Systems Institute.
http://www.essc.psu.edu/

Penn State is establishing a new Center: The Center for Solutions to Weather and Climate Risk (CSWCR). CSWCR's vision is to create the knowledge, training and solutions to enable the optimal outcome for every decision where weather and climate matter. Achieving this vision will extract the maximum value out of every forecast, best serve the public and private sectors, and highlight Penn State's skill and relevance in creating significant additional value to the Weather and Climate Enterprise. CSWCR's Mission is to leverage and integrate the capabilities of the University, in particular those found in Meteorology, Engineering, Statistics, e-Education and Communications, along with external partners, to advance the science of exploiting environmental opportunities and understanding environmental impacts to manage risk.
http://solutions2wxrisk.psu.edu/about-us/

The main goals of the Center for Climate Risk Management (CLIMA) are:

- To develop a new Penn State integrated assessment model of climate change that improves the representation of potential climate threshold responses and the uncertainty about ethical frameworks.
- To use this new integrated assessment model to analyze two questions.
    1. How does the uncertainty about potential climate threshold responses and future ethical value judgments affect the choice of efficient climate risk management strategies?
    2. How can we improve probabilistic climate change projections to better inform decision-making about climate change mitigation and adaptation strategies?
- To promote interaction among faculty, students, and staff in the growing interdisciplinary field of climate risk management (e.g., through seminars series and the support of the integrated assessment model).
  http://www.clima.psu.edu/

B6.3. University of Maryland (UMD)

Maryland Coastal Adaptation Report Card – Development of indicators to track climate adaptation progress at the community-level. https://mdcoastaladaptation.net/what-why-and-who/

There are efforts dedicated to widening the understanding and mitigating the effects of climate change that are being undertaken by UMCES (University of Maryland Center for Environmental Science) and UMERC (University of Maryland Energy Research Center).
http://www.umerc.umd.edu/research/environment

The Joint Global Change Research Institute (JGCRI) houses an interdisciplinary team dedicated to understanding the problems of global climate change and their potential solutions. Joint Institute staff bring decades of experience and expertise to bear in science, technology, economics, and policy. One of

the strengths of the Joint Institute is a network of domestic and international collaborators that encourages the development of global and equitable solutions to the climate change problem.
http://www.globalchange.umd.edu

Climate Information Responding to User Needs (CIRUN) seeks to form a partnership among climate scientists, experts from disciplines such as agriculture, engineering, public health, and risk management, companies which deliver specialized information, and decision makers in the private and public sectors.

CIRUN was created with the vision of developing and piloting effective ways to provide such actionable information: the environmental analogue of the "translational research" or "bench to the bedside" approach in medical research. It will focus on building links among the communities above through the following activities:

- Pilot projects to deliver actionable information.
- A program of workshops.
- A public lecture series: Living with a Changing Planet.
- Support for interdisciplinary proposals to federal agencies relevant to environmental change where connections to decision makers are important.
- An active website.
- Development of a database of potential collaborators in all the components of the information supply chain.
  http://www.climateneeds.umd.edu/

B6.4. VIMS Coastal Climate Change Research (IC^3R)

The Virginia Institute of Marine Science (VIMS) is committed to conducting state-of-the-art scientific research on issues related to climate change, particularly in the world's coastal zones, where half of humanity lives and where climate-change impacts are expected to be felt most acutely. VIMS' Initiative for Coastal Climate Change Research (IC^3R): encourages further collaboration among the many research programs at VIMS that are engaged in issues of climate and global change, serves as a central source of knowledge concerning the effects of climate change on our environment, society, and economy, and provides recommendations concerning the most effective responses to sea-level rise and other climate-change impacts.
https://www.vims.edu/research/units/legacy/icccr/index.php

Virginia Coastal Policy Clinic, W&M Law School/VIMS
http://law.wm.edu/academics/programs/jd/electives/clinics/vacoastal/index.php

B6.5. Virginia Polytechnic Institute and State University (Virginia Tech)

Scientists at Virginia Tech were awarded $2 Million to study climate change effects on Chesapeake Bay.
http://www.vtnews.vt.edu/articles/2014/07/072214-cals-nsfwater.html

B6.6. University of Delaware

Participates in the MADE CLEAR Initiative: http://www.madeclear.org/. Through the University of Delaware Cooperative Extension research on climate variability and change is being conducted with

partners such as: USDA, USGS, and Delaware Environmental Monitoring & Analysis Center which maintains real-time feeds of satellite imagery for the Delaware region.

B6.7. William and Mary Law School Virginia Coastal Policy Center

Resiliency Adaptation Feasibility Tool – a collaborative, community-driven process and full-service tool developed to help coastal localities improve resilience to flooding and other coastal storm hazards while remaining economically and socially viable. The RAFT was conceived and developed by an academic interdisciplinary collaborative led by the University of Virginia Institute for Engagement and Negotiation, the Virginia Coastal Policy Center at William & Mary Law School, and Old Dominion University/ Virginia Sea Grant. The RAFT offers a year-long process in which localities are: 1) provided an independent assessment of their resilience, including attention to social equity, using The RAFT Scorecard; 2) engaged in a community leadership workshop where participants discuss the locality's strengths and opportunities, and develop a Resilience Action Checklist of actions that will make a difference in community resilience and that can be completed and/or initiated within one year; and 3) supported through one year of implementation by The RAFT university collaborative. https://raft.ien.virginia.edu/