CCS HABITAT RESTORATION AND CONSERVATION DIVISION:
BUILDING RESILIENCE THROUGH HABITAT RESTORATION

Bay marsh meets Nor'easter. Photo courtesy of Chris Bason, Center for the Inland Bays.

Maryland Department of Natural Resources
Chesapeake and Coastal Service

March 2015

DISCLAIMER: This white paper is a guidance document for restoration planning, implementation, and project management within Maryland Department of Natural Resources' Chesapeake and Coastal Service. As such, it is a living document which will grow and change with advancing science and restoration techniques.

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I. SUMMARY

The Maryland Department of Natural Resources' (DNR) Chesapeake and Coastal Service (CCS) works strategically to meet the state's water quality and restoration goals. CCS's Habitat Restoration and Conservation Division (HRC) implements innovative best management practices related to shoreline, riparian, stream, floodplain, wetland, and aquatic enhancement and restoration. These practices provide many benefits including run-off reduction, enhanced coastal resiliency, and wildlife habitat preservation and expansion. To ensure long-term benefits, climate change must be considered throughout the project planning, implementation, and monitoring process.

Maryland has a suite of climate-related data that are available to inform project targeting, prioritization, site analysis, design, and environmental review. Sea level rise data, for example, are often referenced for tidally-influenced projects. Other factors such as elevation, marsh migration potential or species selection, are vital to the design of resilient projects able to cope with or recover from climate change impacts. In addition to climate data or assessment factors, an adaptive management framework is essential to ensure future project success under changing conditions.

While HRC considers climate change within State restoration and enhancement projects, additional opportunities exist to integrate climate change into the decision-making process. This report highlights step-by-step recommended climate considerations. Some of these recommendations call out data and modeling needs, while others highlight more explicit checklists or processes for considering available climate data or assessment factors. Refined precipitation and hydrology predictions represent examples of predictive models that are necessary to fully evaluate climate impacts to non-tidal or inland areas less susceptible to sea level rise. Hydrology models can also identify tidal and non-tidal sites at risk of increased run-off. While these data and model recommendations are not all-encompassing, they represent necessary planning steps for building resilience through habitat restoration. Many financial and technical tools and resources are available to aid restoration professionals in planning, design, implementation, and decision-making under a climate change lens.

To obtain a more robust understanding of climate impacts to past, present and future restoration sites, project monitoring is necessary. Monitoring remains an essential component of resilience and adaptive management because it allows practitioners to learn from past experiences, better predict future climate impacts, and design more robust and resilient projects. Although monitoring represents a key component of adaptive management, few projects are specifically monitored for climate change impacts due to the long term commitment required – both monetarily and in terms of personnel. Many monitoring protocols already exist to track water quality, biological, and habitat conditions, but a dedicated funding source is necessary for long-term monitoring commitments.

Maryland's 2010 *Building Resilience to Climate Change* policy and the subsequent actions outlined in this paper demonstrate DNR's lead role in climate resiliency planning and

restoration. As regional climate science advances, this paper will be updated to incorporate the latest restoration guidance and climate change resources. By considering climate change throughout the restoration process, CCS will advance more robust, resilient restoration projects while assembling valuable monitoring data to support adaptive management. These efforts will enhance coastal resiliency and protect the multifaceted benefits of habitat restoration, enhancement, and conservation within the Chesapeake Bay watershed.

II. MISSION

The Chesapeake and Coastal Service (CCS) provides the science, financing, and technical services that State and local partners need in order to meet their water quality and habitat restoration goals. CCS's Habitat Restoration and Conservation Division works with federal, state and local governments, conservation groups and private citizens to apply innovative best management practices that reduce harmful run-off from entering the State's waters, increase coastal resiliency, and provide wildlife habitat through the restoration, creation and enhancement of wetlands, streams, and riparian buffers.

III. OBJECTIVES

CCS's Habitat Restoration and Conservation Division undertakes this mission by working to:

- Improve tidal shoreline habitat and protect shorelines using innovative restoration techniques;
- Restore degraded wetlands while protecting healthy wetlands;
- Restore and enhance riparian buffers along the State's waterways;
- Enhance and restore stream corridors;
- Identify and implement stormwater practices on state lands; and
- Engage communities in on-the-ground restoration.

CCS's ability to meet the above objectives is strongly correlated to adaptive management practices, especially as climate change threatens our State's coastal resources. Over the next century, Maryland expects increased winter-spring precipitation and runoff, warmer air and water temperatures, and relative sea level rise of at least 3.7 feet.[1, 2] Storm and hurricane intensity may also increase as ocean temperatures rise. Maryland's people, natural resources, public lands, and public investments are increasingly vulnerable to the effects of climate change due to the State's low lying topography and coastal proximity. Sixteen of Maryland's 23 counties lie within the coastal zone and the majority of these counties are experiencing naturally occurring land subsidence. Furthermore, relative sea level has risen 1 foot in

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[1] Boesch, D.F. and the Scientific and Technical Working Group. 2008. Chapter 2: Comprehensive Assessment of Climate Change .Climate Action Plan. Maryland Commission on Climate Change *In* Impacts in Maryland

[2] Boesch, D.F., L.P. Atkinson, W.C. Boicourt, J.D. Boon, D.R. Cahoon, R.A. Dalrymple, T. Ezer, B.P. Horton, Z.P. Johnson, R.E. Kopp, M. Li, R.H. Moss, A. Parris, C.K. Sommerfield. 2013. Updating Maryland's Sea-level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission, 22 pp. University of Maryland Center for Environmental Science, Cambridge, MD.

Maryland's Chesapeake Bay over the past century due to global sea level rise and regional factors, such as land subsidence. Land subsidence is influenced by sediment compaction and groundwater withdrawal along the Maryland coast.

As this trend continues or intensifies, climate change will affect CCS's ability to meet the aforementioned objectives of the Habitat Restoration and Conservation Division unless staff are proactively addressing and planning for climate impacts. CCS must adjust restoration and conservation efforts to consider climate impacts while ensuring enhanced resiliency of Maryland's coastal habitats and ecosystems.

IV. ADDRESSING RESILIENCY

Ecosystem resiliency is the "ability of (natural or human) systems or communities to withstand or recover from the impacts of change."[3] By identifying, designing, and constructing habitat restoration and enhancement projects, we provide the opportunity for coastal systems to naturally cope with climate change. Coastal resiliency can be enhanced by restoring our coastal environment where appropriate and by augmenting those natural features which help to protect inland areas from damaging storm surges. Examples of ecosystem resiliency include:

- Functioning riparian buffers lower streamside temperature, increase groundwater infiltration, and enhance floodwater storage.[4, 5]
- Wetlands provide storm surge relief and act as sea level rise buffers.
- Living shorelines buffer our coasts from high wave energy and provide stable transition areas to accommodate sea level rise, higher tidal amplitudes, and storm surges.
- Functioning wetlands, riparian buffers and floodplains provide wildlife habitat, enhance carbon sequestration, reduce nutrient run-off, and naturally establish soil conditions that foster denitrification and water quality improvement.
- Stream systems can reduce erosion and nutrient runoff while providing aquatic habitat and refuge. The rehabilitation of degraded stream channels and the reconnection of streams with their floodplains will reduce the impacts of flashy storm events while providing water quality and habitat benefits.

Attention to resiliency will protect Maryland's vulnerable communities, natural resources, and investments as sea levels rise and weather patterns change. To ensure long-term protection, however, CCS must address climate change before, during, and after project implementation.

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[3] Subramanian, B. and K. Smith. Living Shorelines and Coastal Resiliency in Maryland. 2011 National Conference on Ecosystem Restoration. Website http://conference.ifas.ufl.edu/ncer2011/Presentations/Thursday/Waterview%20A-B/am/1100_BSubramanian.pdf

[4] Eubanks, E. U.S. Department of Agriculture Forest Service, Technology & Development Program. Riparian Restoration. Available at http://www.blm.gov/pgdata/etc/medialib/blm/wo/blm_library/tech_refs.Par.75656.File.dat/TR_1737-22.pdf

[5] Klapproth, J.C. and J.E. Johnson. 2009. Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality. Virginia Cooperative Extension. PUBLICATION 420-151. Website http://pubs.ext.vt.edu/420/420-151/420-151.html

V. DNR CLIMATE CHANGE POLICY

The Maryland Department of Natural Resources (DNR) has the lead role among State agencies in advancing the scientific understanding of Maryland's vulnerability to climate change, and in advocating for sound planning to avoid or minimize the anticipated impacts. In 2010, DNR released policy on *Building Resilience to Climate Change*.[6] This policy affirmed DNR's role in understanding Maryland's vulnerability to climate change and acting to mitigate impacts to the State's people, natural resources, public lands, and investments. Because habitat restoration practices enhance coastal resiliency,[7] Maryland's restoration activities were highlighted as a means of addressing climate change. Section VII.C of the Policy states:

> *Practices, Procedures and Implementation*
>
> ***C. Habitat Restoration***
> *Practice: The Department shall proactively pursue, design, and construct habitat restoration projects to enhance the resilience of the bay, aquatic and terrestrial ecosystems to the impacts of climate change and/or increase on-site carbon sequestration.*
>
> *Procedure: DNR units that engage in habitat restoration projects shall address and incorporate factors associated with climate change during habitat restoration project planning and design processes, including maintenance and monitoring needs.*
>
> *Implementation Guidance: DNR's Chesapeake & Coastal Service shall compile a compendium of best management practices for habitat restoration project design and conduct a GIS-based audit of DNR-owned lands to identify habitat restoration potential for enhancing ecosystem resilience and/or increasing on-site carbon sequestration.*

As directed by this policy, DNR is taking steps to incorporate climate change considerations into habitat restoration planning and design.

VI. BEST MANAGEMENT PRACTICES FOR CLIMATE RESILIENCY

A number of strategies exist to restore the Chesapeake Bay watershed, including water quality regulation through the Chesapeake Total Maximum Daily Load, Bay restoration through the 2014 Chesapeake Bay Agreement, and living resource protection and restoration.[8] Even as

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[6] Maryland Department of Natural Resources. 2010. *Policy on Building Resilience to Climate Change*. Policy Number 2010:11. Website http://www.dnr.state.md.us/dnrnews/pdfs/climate_change.pdf.

[7] Needelman, B. A., Crooks, S., Shumway, C. A., Titus, J. G., Takacs, R., and J.E. Hawkes. 2012. Restore-Adapt-Mitigate: Responding to climate change through coastal habitat restoration. Washington DC: Restore America's Estuaries.

[8] Pyke, C. R., R. G. Najjar, M. B. Adams, D. Breitburg, M. Kemp, C. Hershner, R. Howarth, M. Mulholland, M. Paolisso, D. Secor, K. Sellner, D. Wardrop, and R. Wood. 2008. Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. A Report from the Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis,

Maryland moves forward with these strategies, their effectiveness is threatened by climate factors. For example, intense storm events coupled with sea level rise may lead to increased shoreline erosion and wetland loss. Depending on site-specific elevations, migration barriers, and the speed at which climate impacts occur, shorelines may lose riparian or shoreline buffer zones. Riparian zones provide vital water quality and habitat benefits that are important components of State strategies to restore the Chesapeake Bay watershed. If these benefits are reduced or lost, then Maryland may fall short of its restoration goals.

The restoration community has proposed general guidance to direct habitat restoration decisions in light of climate change. Although a summary of that guidance is listed below, this list represents a living document. As these strategies are implemented in conjunction with ongoing research, climate guidance will ultimately be revised and improved.

General Restoration Guidance

- Build coastal resiliency. Methods may include living shoreline implementation, marsh and wetland restoration, invasive species management, or vegetation selection for future conditions versus historic conditions.[9, 10, 11]
- Employ a landscape approach to restoration/conservation. Maintain green corridors, protect land against fragmentation threats, and facilitate habitat migration by protecting upslope refugia and removing impervious surfaces or barriers that could impede wetland movement.[9, 10] Maintain, identify, and protect new marsh migration corridors.[12]
- Create habitat mosaics that may be more resilient to climate change impacts, such as sea level rise.[12]
- Reconnect streams with their floodplains to reduce the flashiness of storm flows, improve water quality, and increase habitat benefits.
- Understand interactions between climate change and other stressors that impact ecosystems, such as development or landscape change.[10, 13]

MD. 59 pp.

[9] M. Koslow, J. Berrio, P. Glick, J. Hoffman, D. Inkley, A. Kane, M. Murray, and K. Reeve. 2014. Restoring the Great Lakes' Coastal Future: Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects. National Wildlife Federation, Reston, VA and National Oceanic and Atmospheric Administration, Silver Spring, MD.

[10] Kane. A. 2011. Practical Guidance for Coastal Climate-Smart Conservation Projects in the Northeast: Case Examples for Coastal Impoundments and Living Shorelines. National Wildlife Federation, Reston, VA.

[11] The Interagency Mattawoman Ecosystem Management Task Force. 2012. The Case for Protection of the Watershed Resources of Mattawoman Creek.

[12] Cross, L.M. 2014. Gulf Coast Community Handbook: Case Studies from Gulf of Mexico Communities for Incorporating Climate Change Resiliency into Habitat Planning and Protection. EPA Climate Ready Estuaries Program.

[13] NOAA. 2012. Voluntary step-by-step guide for considering potential climate change effects on coastal and estuarine conservation projects. Office of Ocean and Coastal Resource Management Coastal and Estuarine Land Conservation Program

- Incorporate uncertainty into project planning and design by planning for multiple climate scenarios.[14]
- Target areas that will be sustainable under future conditions. For example, restore sites in the upper range of sea level rise projections, or target sites based on threats, likelihood of success, connectivity, or nitrogen reduction potential.[2]
- Consider slope and site elevation in planning and design to aid in vegetation migration and mitigate the immediate impacts of sea level rise.
- Monitor, review, and revise projects as needed.[2, 15, 16] Acquire baseline data, such as water and surface elevations or vegetation transects.[12]

VII. HABITAT RESTORATION AND CONSERVATION - PROJECT IMPLEMENTATION

DNR's Habitat Restoration and Conservation Division (HRC) implements a wide range of projects, which are aimed at improving water quality and aquatic and riparian habitat. These projects include:

- Shoreline enhancement and conservation (e.g., living shorelines);
- Riparian forest buffer restoration and enhancement;
- Stream and floodplain restoration;
- Wetland restoration;
- The establishment and retrofit of stormwater practices on state lands (e.g., bioretention and other innovative practices that address water quality and quantity);
- Vegetative and aquatic habitat enhancement practices, which may focus on individual species or a host of species; and
- Climate resiliency planning and policy.

HRC conducts in-house projects, primarily on state-owned lands, and provides technical and financial assistance to federal, state, county and municipal governments who seek assistance for the implementation of the above practices within their respective jurisdictions. HRC recognizes the opportunistic nature of these collaborations. That being said, the general project implementation process has been documented to direct habitat and conservation practices when interested parties seek assistance. This process is described below, along with a discussion of current climate change considerations and opportunities to integrate climate

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[14] Needelman, B A , S Crooks, C A Shumway, J G Titus, R Takacs, and J E Hawkes. 2012. Restore-Adapt-Mitigate: Responding to Climate Change Through Coastal Habitat Restoration B A Needelman, J Benoit, S Bosak, and C Lyons (eds). Restore America's Estuaries, Washington D C , pp 1-63.

[15] Pyke, C. R., R. G. Najjar, M. B. Adams, D. Breitburg, M. Kemp, C. Hershner, R. Howarth, M. Mulholland, M. Paolisso, D. Secor, K. Sellner, D. Wardrop, and R. Wood. 2008. Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. A Report from the Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis, MD. 59 pp.

[16] NOAA. 2011. Planning for Sea Level Rise in the Northeast: Considerations for the Implementation of Tidal Wetland Habitat Restoration Projects. NOAA Restoration Center, Northeast Region Workshop Report.

change into future activities.

<u>DNR-Led/In-House Habitat Restoration and Conservation Efforts</u>

1. ***Project Targeting and Prioritization***

   Many of our impaired streams, waterways and wetlands are degraded due to high levels of impervious surface, habitat loss, nutrient and sediment runoff, and other historic anthropogenic impacts such as ditching. The Chesapeake and Coastal Service has undertaken a number of GIS-based targeting exercises to identify and prioritize areas and/or watersheds where these issues are most prevalent.[17, 18] Using this targeting framework, funding is directed towards areas with poor water quality.

   <u>Current Climate Considerations</u>: The DNR Climate Change Policy states that HRC will "*conduct a GIS-based audit of DNR-owned lands to identify habitat restoration potential for enhancing ecosystem resilience and/or increasing on-site carbon sequestration."* The GIS-based audit was conducted by CCS' Geospatial Information and Analysis Division in 2010. This analysis was conducted to support landscape-level analyses and project targeting. Furthermore, a NOAA Coastal Management Fellowship project yielded targeting models for riparian forest and wetland restoration sites within Maryland's coastal zone. These restoration opportunities were identified to focus restoration efforts in areas with greater potential for enhanced water quality improvement. Along with these targeting efforts, HRC seeks sites with migration potential to ensure long-term ecosystem benefits for each project.

   <u>Recommended Climate Considerations</u>: Additional targeting and prioritization work is necessary to identify where climate change may impact our streams, waterways, and wetlands over the long-term, particularly in our non-tidal/inland areas. Sea level rise and related factors are well documented in our region, but future precipitation and hydrology conditions are more difficult to predict. These factors will more directly impact upstream and non-tidal areas. By quantifying precipitation, stream flow, and other hydrologic changes, we will be better able to predict nutrient loading hotspots and target restoration in areas with the longest term benefits. Temperature and precipitation data can also be used to determine the vulnerability of representative plant species. If downscaled to the appropriate landscape level, then climate models can aid the identification of vulnerable vegetative pockets. As the restoration and conservation community expands its knowledge of climate impacts to current restoration practices and run-off intensity, existing targeting efforts can be revisited to identify sites at most risk to climate change impacts. HRC can then target sites that will

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[17] Maryland Department of Natural Resources. Chesapeake & Atlantic Coastal Bays Trust Fund Capital Improvement Grants. Website http://www.dnr.maryland.gov/trustfund/capitalgrants.asp

[18] Maryland Department of Natural Resources. Water Quality and Climate Change. Website http://www.dnr.state.md.us/ccs/coastal_fellowship.asp

most likely be sustainable under future conditions, as well as sites that may advance coastal resiliency and habitat migration as the climate transitions.

2. *Project Selection*

HRC works with many public and private partners to assess, prioritize, and implement restoration projects. Projects may be identified through partner networks, watershed assessments, watershed plans, or landowner inquiries. Additionally, HRC collaborates with a network of local and statewide wetland conservation organizations that work very closely with local conservation organizations and private landowners who are interested in enhancing the wetland resources on their properties. Because a willing and interested landowner is absolutely necessary for project fruition, most restoration and conservation projects are opportunistic in nature. Once potential projects are identified through one of the above avenues, HRC staff screen all opportunities for restoration and enhancement potential.

In addition to the above methods of project identification, HRC staff often review State properties that are under consideration for purchase or easement by DNR's Program Open Space (POS). Potential POS parcels are assessed for restoration and enhancement opportunities by CCS and POS staff. When such opportunities exist, both parties collaborate throughout the property evaluation and acquisition period. If the property is purchased, then both groups evaluate restoration opportunities, estimate costs associated with the proposed work, and identify available funding to execute that work.

<u>Current Climate Considerations</u>: As sea level rises, inundation and saltwater intrusion will alter the current wetland landscape. Maryland has identified future wetland areas based on sea level rise projections for 2050 and 2100.[19] These wetland areas were analyzed to identify potential wetland migration zones. The future wetland landscape is considered when selecting project sites. By conducting restoration activities within or adjacent to these areas, Maryland will facilitate future wetland migration and increase wetland connectivity. Migration potential is vital for any successful long-term restoration project. Projects are often selected if there is potential for infrastructure removal and habitat migration, and POS stabilization funds are available to remove infrastructure that impairs water quality or habitat migration, such as bulkhead or other hardened shoreline structures.

<u>Recommended Climate Considerations</u>: As mentioned previously, HRC has identified DNR-owned lands with restoration potential for enhancing ecosystem resilience. While sea level rise and marsh migration predictions are readily available to aid in project selection and restoration decisions, uncertainty surrounding future hydrologic conditions prevents restoration specialists from predicting climate impacts to upstream

[19] Papiez, C. 2012. Coastal Land Conservation in Maryland: Targeting Tools and Techniques for Sea Level Rise Adaptation and Response.

and non-tidal sites. As the restoration and conservation community expands its knowledge of climate impacts to current restoration practices, climate change may play a more pivotal role in project selection.

Under current DNR policy, lands less than 2 feet above sea level are not prioritized for land acquisition and conservation by POS. This policy is based on sea level rise projections and the risk of inundation over the next century. This site selection metric, however, does not necessarily translate to coastal restoration decisions. Low-elevation restoration projects may enhance wetland and species migration while increasing coastal resiliency over the short and long-term. The costs and benefits of restoration opportunities at the land-water interface should be considered in regards to climate impacts on a project-by-project basis.

3. Site Analysis

Following project selection, site analyses are conducted through desk audits and field assessments. These analyses are critical to the design and implementation of any project.

- **Desk Audit:** Nearly all potential projects start with a GIS analysis, which includes evaluation of the site location, closest water source, adjacent activities, soils, and surrounding influences such as land use and drainage area. Additional data are required for shoreline projects, including fetch, orientation, channel proximity, SAV coverage, tidal amplitudes, nearest structures, and habitat or species in the vicinity. This type of data collection is easily done in the office through ArcGIS, Google Earth, and DNR's online data viewing platform – the Coastal Atlas.

  <u>Current Climate Considerations</u>: Just as sea level rise is considered in conservation and land acquisition decisions, it is also relevant for restoration activities. Sea level rise data is inherently referenced and considered in living shoreline and other tidally-influenced restoration projects to inform project design.

  <u>Recommended Climate Considerations</u>: A holistic understanding of future conditions aids the development of more resilient restoration designs. Sea level rise data, erosion vulnerability assessments, floodplain maps, and accepted models such as SLAMM should be utilized to understand predicted conditions for all project types.

- **Field Assessment:** Existing conditions are assessed at all proposed sites, although assessments will differ with each project. The table below outlines common site assessment factors by project type.

Project Type	Example Assessment Factors
Shoreline Enhancement	Submerged bottom sediment analysis (note grain size) Near shore depth/s Bank height
Riparian Restoration	Native and invasive vegetation survey Forest health assessment Tree density Landscape position Soil type Hydrological connection to stream/s
Stream or Floodplain Restoration	Level of incision/disconnection with floodplain Channelization presence/stream condition Bank stability condition Woody debris presence Channel profile Slope Historic structure presence Legacy sediment Riparian health assessment
Wetland Restoration	Wetland presence Upland presence 100 yr floodplain presence Drainage area Soil type Floodplain condition Invasive species presence or threat
Stormwater Retrofit	Effectiveness of existing facility
Vegetative or Aquatic Habitat Enhancement	Native and invasive vegetation survey Soil type Connectivity to other habitats

Along with the common assessment factors listed above, field assessments may include site surveys to collect additional information necessary to properly assess and design a project. Additional survey asks may include:

- Topography/bathymetry;
- Descriptions of existing on-site resources (e.g., rare, threatened, or endangered species);
- Wetland delineation;
- Stream channel erodibility index; and
- Documentation of existing historic structures and cultural resources that may require preservation.

Current Climate Considerations: Managers can anticipate the location of future wetlands and floodplains based on site-specific factors, such as site elevation or the presence of ditches. These factors are noted during site level analysis to aid in project design and ensure project success over the long term.

Recommended Climate Considerations: Site analyses provide opportunities for HRC to assess and document existing conditions. The documentation of existing conditions provides reference points for monitoring the effects of climate change. This step is vital because it helps project managers understand systems prior to restoration and climate change. Pre-restoration data collection should align with post-project monitoring efforts to document the successes or setbacks of each project and assess how systems are responding to climate impacts.

On-site observations also enable project managers to predict future conditions. For example, distance to tidal waters or head of tide can be noted during site analyses to predict how conditions may change with sea level rise. Habitat migration potential can also be noted by assessing migration barriers and adjacent land conditions. If opportunities exist to remove migration barriers and impervious surface, then the site analysis may influence project design and landscape connectivity.

4. *Design*

Design guidance exists for many types of resource restoration and enhancement projects, both through professional publications and regulatory agency guidance. These resources are utilized in the design of stream, wetland, and shoreline projects.

Current Climate Considerations: Climate change is currently addressed during project design by restoring hydrologic connections, facilitating infiltration, and selecting appropriate species. Design criteria that improve resiliency include maximizing wetland area to increase on-site water storage, and increasing floodplain connectivity to slow water discharge downstream. These design qualities reduce the flashiness of stormflow while increasing water storage capacity and infiltration in the watershed. By identifying areas with high flow risk, HRC can alter designs to handle future precipitation events. Species diversity also represents a vital component of coastal resiliency. Rising temperatures and salinity changes will result in altered coastal conditions, and these changes may influence the composition and abundance of native species. To assist natural species succession, managers utilize a diversity of native species in their project designs.[20] Furthermore, the USDA Forest Service has identified potential changes in species ranges under various climate scenarios.[21] These predictions serve as guides for

[20] Slattery, B.E., K. Reshetiloff, and S.M. Zwicker. 2003. Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. 82 pp.

[21] USDA Forest Service. Climate Change Atlas. Website http://www.fs.fed.us/nrs/atlas/

what restoration projects could look like in the future. Invasive species are a major concern for many completed and ongoing projects, and managers must address this issue both in the early stages of project implementation and throughout project maintenance.

Recommended Climate Considerations: Climate change is typically considered and addressed in the assessment and design process. Understanding future climate scenarios is critical to incorporating future impacts into project design. Climate scenarios are typically referenced for shoreline, coastal, and stormwater management projects where we have accepted predictions for sea level rise (SLR). These predictions particularly inform the design of backshore areas within shoreline projects and allow for migration route/corridor planning to aid future species migration.

Design practices along non-tidal/inland areas should also be addressed as we gain a better understanding of climate impacts to streams, waterways, and wetlands. This understanding will come by quantifying predictions of precipitation, streamwater flow, and other hydrologic changes. HRC has a great deal of influence on project designs and, where appropriate, climate change considerations can be incorporated into the design process.

Design Examples

- Living Shorelines: Living shorelines can de designed to address future climate impacts while reducing erosion in the present. Local sea level rise projections, slope, elevation, upland migration barriers, invasive species, and native or salt-tolerant vegetation should be considered throughout the design phase to ensure a lengthy project lifespan. The use of native species with greater underground root biomass, for example, may enhance shoreline stabilization while addressing inundation and storm impacts.

- Dunal Areas: Although known for their presence along the ocean, dunal areas also occur within Maryland's Chesapeake and Coastal Bays. Dunes, albeit smaller than typical ocean dunes, are a natural landscape feature along much of the coastal shoreline. Maintaining, restoring, and enhancing these dunal structures can provide resiliency to surrounding habitats and communities.

- Forest and Scrub/Shrub Buffers: The presence of woody vegetation (e.g. shrubs and trees) above mean high water can be critical in reducing wave energies during high tide and storm events. Restoring, enhancing and maintaining these important ecotones should be a high priority when addressing future climate impacts.

- Riparian Buffers: While climate impacts to the functionality of riparian buffers is unknown, wider riparian buffers may become necessary for buffers to consistently function as filters during intense storm events.[22] HRC may consider expanding riparian buffer width at potential high-flow areas to address habitat and water quality goals as climate change impacts these systems.

- Wetland Restoration and Enhancement: The State expects changes in precipitation patterns, storm frequency, hydrology, and sea level with future climate change. HRC can alter wetland design and maximize wetland areas to handle high flows and other hydrology changes.[6] Precipitation and storm frequency should also be considered when designing upland projects that will be minimally impacted by sea level rise. During project evaluation and design, HRC considers bathymetry, habitat/vegetation zones, tidal elevations, critical infrastructure, anthropogenic and natural barriers to wetland migration, historic conditions, wetland accretion rate, freshwater inflows, water velocity, suspended sediment concentrations, and potential flooding from storm events.[16]

- Stream Restoration and Enhancement**:** Maryland will likely experience higher energy and more frequent storms in the future, which can degrade existing streams and waterways. Channel structure, sediment type, water flux, vegetation presence, and adjacent land uses all play a role in stream health and associated ecological benefits. Understanding and incorporating this knowledge during design is imperative to restoring our waterways in a sustainable way. The reconnection of floodplains that have been abandoned due to stream incision and other factors are also imperative for maintaining and enhancing stream function and stability within a changing climate.

5. Environmental Review

HRC adheres to an environmental review process for all proposed restoration projects. Any project on DNR-owned land is vetted through an in-house review process. All other Department-supported and implemented projects involving construction or significant management activities are coordinated through an intra-Departmental review process. This process includes Unit Contacts for environmental review throughout the Department, as well as the Project Review Division of the Integrated Policy and Review (IPR) Unit. Projects requiring wetlands or waterway permits are submitted to the appropriate regulatory agencies for review after intra-Departmental coordination is complete. CCS and HRC staff meet with IPR staff monthly to review current projects. This process provides an opportunity for land managers to assess how each project fits with the overall property management plan.

[22] EPA. 2010. A Method to Assess Climate-Relevant Decisions: Application in the Chesapeake Bay. Website http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=227483

Current Climate Considerations: Climate change is considered in the environmental review process through sea level rise and associated data, most notably for projects with long expected lifespans. Projects should be designed to withstand current and future storm events, especially as climate change leads to more frequent and intense storms. Long-term temperature predictions are also relevant for projects that impact sensitive species and habitats, such as coldwater streams. Reviewers consider the degree to which climate factors may impact the project site over its lifespan. Less consideration is typically given for projects with short to moderate lifespans (e.g. 5 – 15 years, depending on project type/purpose).

Recommended Climate Considerations: The environmental review processes represents a unique opportunity to address climate change before project implementation. A number of questions can be asked at this stage to ensure climate change is considered moving forward. Examples include: How might the property be impacted by climate change in the long-term? Does the property management plan incorporate climate change? If not, how might the proposed project address climate change to ensure continued use of the property? Does the project provide a unique opportunity for climate-related research or adaptive learning?

6. Permitting

Permits are typically pursued once a concept plan has been developed. If a project requires a permit, HRC meets with the permit reviewers for a pre- application meeting. These meetings provide state regulatory agencies with an opportunity to offer input prior to the submittal of the permit application. Permit applications are submitted once 90% of the design plans are complete, although plans typically undergo changes pursuant to regulatory comments prior to permit approval.

Current Climate Considerations: COMAR 27.02.05 includes provisions related to climate change and sea level rise within the Critical Area Commission's regulations for State development projects on State land. These provisions ensure that climate resilient practices that address coastal hazards, extreme weather events, sea level rise, and other climate impacts are considered when developing within vulnerable areas. All proposed development activities by a State agency on State-owned land must consider the following: preservation and protection of potential wetland migration areas; likelihood of inundation by sea level rise over the course of the design life of the project; climate resilient practices that may avoid or minimize structural damage associated with coastal hazards, extreme weather events, sea level rise, and other climate impacts; detrimental impacts on potential wetland migration areas; and coastal hazard and sea level rise impacts to public access, when applicable.

Recommended Climate Considerations: As with environmental review, the permitting process represents a unique opportunity to address climate change before project implementation. Executive Order 01.01.2014.14, *Strengthening Climate Action in*

Maryland, tasks the State with the review of planning, regulatory and fiscal programs to identify actions that can more fully integrate the consideration of climate change impacts; including sea level rise, increased precipitation and temperature, and extreme weather. For planning, regulatory and fiscal programs that currently include climate considerations, the Executive Order tasks the State with quantifying and assessing performance and effectiveness, as well as recommending programmatic, regulatory or fiscal changes that would enhance Maryland's preparedness and resilience to future climate change impacts.

7. Project Construction

HRC addresses changing environmental conditions during project construction as needed. For example, high intensity rain events, seiches, and tropical storms may impact construction progress and timing. As the climate becomes less predictable, HRC will continue utilizing adaptive management techniques to alter restoration practices as necessary and ensure long-term project success.

Current Climate Considerations: Climate change is not currently considered during project construction, although it may require adaptive measures in the future.

Recommended Climate Considerations: Improve adaptive management techniques and plan for possible storm-related delays.

8. Monitoring

Monitoring is usually conducted pre- and post-construction to track project success. Post-project monitoring is typically accomplished over a 5 year period, although each project permit may specify a unique monitoring timeframe. These monitoring efforts normally require vegetative surveys and evaluation of the structural stability of all project components. Vegetation and structural stability failures are addressed by HRC as needed within the 5 year timeframe. In addition to on-site monitoring, HRC utilizes a mobile restoration application (MD Restoration App) to track project progress and communicate with restoration partners about ongoing, planned, and completed projects.[23]

Current Climate Considerations: Monitoring and adaptive management allow HRC to address climate change during current and future projects. Although restoration projects are often designed for existing conditions, adaptive management allows for design improvement over the long-term. Therefore, if the vegetation and/or structural stability of a project are threatened, actions can be taken to ensure long-term project success. Adaptive management provides the flexibility DNR requires to adapt policies,

[23] Maryland Department of Natural Resources. Habitat Restoration and Conservation. Website http://www.dnr.state.md.us/ccs/restoration.asp

designs, plantings, and restoration techniques in response to a changing climate.

Recommended Climate Considerations: Monitoring and restoration have been highlighted as priorities in the 2014 Chesapeake Bay Watershed Agreement to enhance Bay and aquatic ecosystem resiliency.[24] The two are intrinsically connected within the climate resiliency discussion. To meet the Bay Agreement goals, pre- and post-project monitoring efforts should be aligned with climate change monitoring to detect changes at the landscape and species levels. Documenting site-level responses to climate factors will inform future restoration designs and practices by detecting challenges as early as possible. By allowing adaptive management and flexibility within project designs and monitoring efforts, HRC can build on existing restoration guidance and add to the currently available case studies on how climate change may be incorporated into habitat planning and protection.[12] The MD Restoration Mobile Application (MAPPLER) represents a unique opportunity to flag and track climate change related monitoring in the future.

A number of monitoring protocols exist to track climate impacts on-the-ground. The Mid-Atlantic Tidal Wetland Rapid Assessment Method can be implemented to track tidal wetland conditions.[25] This assessment includes data collection on vegetation composition and structure, soil attributes, above and below ground biomass, soil stability, macro invertebrate composition, bird community composition, hydrology, surrounding land use, and other nearby stressors. Vegetation surveys can be conducted in the field or via camera-monitored field plots. A System-Wide Monitoring Program also already exists within the National Estuarine Research Reserve (NERR) system for tracking climate impacts and other long-term trends.[26] Monitoring protocol includes water quality monitoring, biological monitoring,[27] and habitat mapping. Universities have partnered with NERR sites across the nation to document and analyze these trends. Collaboration in the Northern Gulf of Mexico, for example, has led to data collection to feed predictive models, which will address marsh response to SLR, hydrodynamics, salinity, sedimentation, vegetation, and oyster dynamics.[28, 29] These

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[24] Chesapeake Bay Program. 2014. Chesapeake Bay Watershed Agreement: Climate Resiliency. Website http://www.chesapeakebay.net/chesapeakebaywatershedagreement/goal/resiliency

[25] Jacobs, A., E. McLaughlin, and D.L. O'Brien. 2008. Mid-Atlantic Tidal Wetland Rapid Assessment Method. Delaware Department of Natural Resources and Environmental Control, Maryland Department of Natural Resources, and Virginia Institute of Marine Science. Available at http://www.epa.gov/reg3esd1/wetlands/pdf/rapid_assessment.pdf

[26] National Estuarine Research Reserve System. System-Wide Monitoring Program. Website http://nerrs.noaa.gov/RCDefault.aspx?ID=18

[27] NERRS SWMP Bio-Monitoring Protocol. Available at http://nerrs.noaa.gov/Doc/PDF/Research/TechReportSWMPBio-MonitoringProtocol.pdf

[28] Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico. Fact Sheet. Available at http://grandbaynerr.org/wp-content/uploads/2013/07/Fact-sheet-2013_Final.pdf

[29] NOAA. Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico. Website http://champs.cecs.ucf.edu/research/EESLR-NGOM.htm

monitoring systems can be adapted to fit HRC projects as needed.

As monitoring is conducted, managers can note invasive species presence, SAV presence, native species expansions, hydrologic or salinity changes, sea level rise or inundation threats, disease presence, structural stability, and/or migration patterns, among other factors. Dataloggers can be employed at pivotal state-owned sites to document water quality changes over time, or HRC can draw on pre-existing long-term water quality sampling conducted by DNR's Eyes on the Bay Program[30] or USGS.[31] Maryland's Trust Fund Evaluation Workgroup has also developed a Water Quality Monitoring Strategy that can be modified and applied where applicable.[32] Climate impacts such as changing rainfall patterns, maximum spring flows, or migration patterns may impact the optimal season or time for recording these observations.[33] Therefore, adaptive monitoring protocols may be necessary to capture changing conditions.

Unfortunately, very few projects are currently monitored specifically for climate change impacts. This shortfall is due to a number of obstacles, including the long-term nature of climate change monitoring and uncertainty over where monitoring efforts should be focused. To infuse climate change into the monitoring process, continual long-term monitoring is required. To that end, a dedicated funding source and responsible party must be identified to realize long-term monitoring goals. Predictive models such as SLAMM can then be used to identify appropriate monitoring areas. Representative projects within those regions should be identified or targeted for climate modeling in order to maximize funding while evaluating climate change impacts to various restoration techniques.

VIII. FINANCIAL ASSISTANCE

A number of dedicated funding sources currently exist to implement habitat restoration and conservation projects.

1. Chesapeake & Atlantic Coastal Bays Trust Fund: Natural Filters Special Funding

The Chesapeake & Atlantic Coastal Bays Trust Fund allows Maryland to accelerate Bay restoration by focusing limited financial resources on the most effective non-point source pollution control projects as identified in the State's Tributary Strategies and the 2-Year Milestones. State agencies must work with our local and federal partners to administer funding through new and innovative approaches that leverage the funds to

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[30] Maryland Department of Natural Resources. Eyes on the Bay. Website http://mddnr.chesapeakebay.net/eyesonthebay/

[31] USGS. Water Quality Data for the Nation. Website http://waterdata.usgs.gov/nwis/qw

[32] Trust Fund Evaluation Workgroup. 2010. Trust Fund Water Quality Monitoring Strategy.
[33] Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, D.C.

the greatest extent possible, target the funds to the most cost effective locations and practices, engage the community at large, and hold everyone accountable.

CCS leads the effort for implementing the *Natural Filters on Public Lands Two-Year Milestone*. This effort includes the identification of “Natural Filters” projects on all public lands (federal, state, and local) and provides technical assistance and funding to those who are eligible to implement on-the-ground restoration in the form of riparian buffers (grass and trees), wetlands, reforestation, and other forms of bio-remediation. The Natural Filters Special Funding is often used opportunistically. Funding may be distributed through a RFP, oral solicitations, or the submission of a letter of intent. Proposal rewards are driven by water quality concerns and the targeting of high priority counties or regions.

2. Shore Erosion Control Construction Loan Fund

DNR administers this non-lapsing fund to provide interest-free loans or grants to persons, municipalities, or counties for design and construction of shore erosion control projects. The Fund is maintained by three means. First, by repayments of principal on loans made from the Fund. Second, by repayment of administrative costs. Third, by annual appropriation of funds that restore the Fund to a level that will support the loan program during the succeeding year. Loans are designed to be repaid over a 25-year period. These funds are often distributed opportunistically as the State is contacted by property owners and other applicable parties concerned with shoreline erosion.

3. Accelerated Wetland Restoration Fund (McNair FUND)

The Accelerated Wetland Restoration Fund was established by the General Assembly in 2007 for statewide wetland restoration projects. This general funding is often used opportunistically and distributed through oral solicitations, or in conjunction with USDA Farm Bill cost-share programs such as the Wetlands Reserve Program or the Conservation Reserve Enhancement Program.

4. Maryland’s Ecosystem Enhancement (ME2)

The ME2 program provides a better model for mitigation by targeting our limited funding resources towards mitigation that enhances Bay Restoration. CCS staff works with other state agencies to construct agricultural best management practices (BMPs) in areas with high ecological value, thereby implementing each BMP in the best location to accelerate restoration. DNR staff conducts GIS targeting exercises to identify areas where ME2 funding is applicable.

5. Stateside Program Open Space

Program Open Space (POS) was established in 1969 to provide financial and technical assistance to local subdivisions for the planning, acquisition, and/or development of recreation land or open space areas. POS symbolizes Maryland's long-term commitment to conserving natural resources while providing exceptional outdoor recreation opportunities. The Stateside of POS acquires parklands, forests, wildlife habitat, and natural, scenic and cultural resources for public use. More than 5,000 individual county and municipal parks and conservation areas exist today because of the program. Furthermore, almost all of the land purchased by DNR in the last 37 years was funded at least partially by POS.

To enhance Maryland's land conservation programs, DNR maximizes available funding through a strategic targeting process that highlights ecological priorities. HRC takes part in this successful stateside targeting procedure, which has three components. First, POS uses an ecological screen that selects "Targeted Ecological Areas." Second, POS uses a programmatic screen to identify "Annual Focus Areas." Third, POS uses a parcel screen to assess, score, and prioritize parcels within the focus areas. The creation of this transparent targeting process was based on scientific data, management priorities, and public needs. Outside of this targeting process, a small portion of State POS funds are still used to acquire high priority recreational, cultural, and historic sites, especially those providing key Chesapeake Bay access points, trails connections, and state park in-holdings.

6. Small-scale Construction and Acquisition Program (through CZM Section 306A)

Small-scale Construction and Acquisition Program funding is provided through the Coastal Zone Management Act of 1972. This federal funding opportunity is designated for the acquisition of fee simple and other interests in land, low-cost construction projects, or habitat restoration projects. Examples include easement acquisition or public access improvements. Additional documentation is required from NOAA before these 306A projects can be approved. Section 306A funding must be matched 1:1 by non-federal fund sources.

<u>Recommended Climate Considerations</u>: Incorporate a screening process into all funding opportunities to identify and prioritize projects that will increase resiliency to climate change. Exclude projects that may increase vulnerability or be undermined by sea level rise within 50 years. Identify a funding source for long-term monitoring across a variety of sites with diverse designs and techniques to determine climate impacts and project success.

IX. TECHNICAL ASSISTANCE

HRC provides a range of technical assistance services to State and local partners to help them meet their water quality and habitat restoration goals. In providing technical assistance, HRC has the opportunity to engage and educate State and local partners on climate change related issues and provide guidance on best management practices to enhance resiliency of habitat restoration and conservation efforts. For example, HRC provides guidance on both general projects and recommended best management practices through a variety of teaching and training opportunities, such as:

- Websites
- Fact Sheets
- Volunteer Opportunities
- Webinars
- Workshops
- Site Visits
- Trainings
- Coastal Training Program

X. TOOLS/RESOURCES

Many tools and resources are available to aid restoration professionals in planning, implementation, and decision-making.[34] This section addresses tools that may help integrate climate change throughout the course of project planning and implementation, from targeting and site selection to adaptive management and monitoring.

Available Data: These data layers are available on CCS's online data viewing platform – the Coastal Atlas[35] – and DNR's Climate Change Impact Area mapping tool.[36]

1. Sea Level Rise Vulnerability: DNR's online data viewing platforms house sea level rise (SLR) vulnerability layers. Inundation layers are available for 0-2, 2-5, and 5-10 feet SLR scenarios. These layers may be used during project targeting and design to select for sites with low risk of inundation or design practices that are adaptable to future conditions.

2. Sea Level Affecting Marshes Model (SLAMM): SLAMM predicts future shoreline modifications and wetland change for 16 various wetland classifications as defined by the National Wetland Inventory. Inundation, erosion, overwash, saturation, and accretion parameters are used to indentify future wetland distribution. The model was run under accelerated sea level rise conditions (1.3 feet by 2050 and 3.4 feet by 2100) to identify Wetland Adaptation Areas and Wetland Migration Corridors. These data layers help DNR prioritize lands that will facilitate landward movement of coastal wetlands subject to dislocation by sea level rise. Wetland migration corridors and adaptation areas should be used to predict future conditions on and adjacent to potential

[34] EBM Tools Network - Tools for Coastal Climate Adaptation Planning. Website https://connect.natureserve.org/toolkit/ebm-tool-network/climate-adaptation-planning-tools

[35] Maryland Department of Natural Resources. Coastal Atlas. Website http://dnr.maryland.gov/ccs/coastalatlas/

[36] Maryland Department of Natural Resources. Sustainable Maryland. Website http://www.dnr.state.md.us/sustainability/

restoration sites. These data layers can be used to prioritize restoration projects that will migrate with sea level rise.

3. Erosion Vulnerability Assessment Tool (EVA): EVA is a shoreline planning tool developed by the Baltimore District Army Corps of Engineers and Maryland Department of Natural Resources to identify shorelines with historic patterns of instability, as well as shorelines that support valuable natural, social, or economic resources.[37] EVA uses a 50-year planning window to predict future shoreline positions. These projections inform local planners about risks to current infrastructure and valued resources. Erosion at these sites may be exasperated by climate change without action to lessen climate impacts. EVA is available to prioritize erosion control measure sites.

4. Storm Surge Risk: The US Army Corps of Engineers completed two hurricane evacuation studies for the eastern (2007) and western (2010) shores of Maryland. Storm surge areas were developed using the Sea, Level, and Overland Surges from Hurricanes (SLOSH) model. SLOSH estimates storm surge heights from historical, hypothetical, or predicted hurricanes. These areas are used in local planning, as they predict flooding likelihood during major storm events.

Water Quality/Water Quantity/Nutrient Loading Models: These online and desktop tools are available from federal agencies or academic institutions.

5. OpenNSPECT: OpenNSPECT is the open source version of NOAA's Digital Coast Nonpoint Source Pollution and Erosion Comparison Tool.[38] While this tool has historically been used to estimate nutrient loading impacts from development and land use changes, it can also be applied within a climate change framework. By running OpenNSPECT under multiple precipitation scenarios, users can predict changes in run-off volumes under various climate change scenarios. This tool can inform restoration designs by predicting future conditions that each BMP will need to address. Examples of design changes may include BMP size, buffer width, or vegetation diversity.

6. Soil and Water Assessment Tool (SWAT): SWAT is a small watershed to river-basin scale model developed by USDA and Texas A&M University within an ArcGIS platform.[39] This tool estimates surface and ground water quality and quantity due to climate, land use, and land management changes. Climate change impacts are predicted within SWAT by modeling CO_2 impacts on plant development and evapotranspiration. Data requirements include land use, soil, topography, daily precipitation, minimum and

[37] VIMS. Center for Coastal Resources Management. GIS Data & Maps: Erosion Vulnerability Assessment Tool (EVA). Website http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/index.html

[38] NOAA Digital Coast. OpenNSPECT. Website http://www.csc.noaa.gov/digitalcoast/tools/opennspect

[39] Soil and Water Assessment Tool. Website http://swat.tamu.edu/

maximum air temperature, solar radiation, wind speed, relative humidity, potential evapotranspiration and point sources, among others (see http://swat.tamu.edu/media/69302/ch01_overview.pdf). Model results may be used by restoration specialists to prioritize erosion prevention and control measures and other natural filter restoration practices. The use of this tool requires knowledge of ArcGIS and training through the Grassland, Soil and Water Research Laboratory and Blackland Research Center. Model outputs are currently available from the U.S. Environmental Protection Agency for the Susquehanna River Basin.[40]

7. Climate Assessment Tool: The BASINS 4.0 Climate Assessment Tool (CAT) is an EPA-developed model that allows users to assess future climate risks to water and aquatic resources.[41] The tool modifies historical weather data to estimate long-term seasonal, short-term, or year-to-year climate change or variability. Users alter baseline temperature and precipitation data to predict system changes and determine hydrologic and water quality metrics such as 100-year flood, annual water yield, or annual pollutant load. A calibrated Hydrologic Simulation Program FORTRAN (HSPF) watershed model and input files are required for this tool. CAT can also be used in conjunction with SWAT to simulate climate scenarios.[42] As with SWAT, CAT can be used to target priority areas where restoration will do the most good under future climate scenarios.

8. EPA National Stormwater Calculator (SWC): This desktop tool estimates the annual amount of rainwater and frequency of runoff from specific sites based on a number of parameters including land cover, soil, and historic rainfall.[43] SWC was updated in January 2014 to include climate change factors such as seasonal precipitation, average temperature, extreme event rainfalls, and evaporation rate. Scenarios are developed using the World Climate Research Programme's CMIP3 multi-model dataset. Because this tool is site-specific, it may be more applicable for resource managers as long as local data inputs are available (e.g. nearby rain gauges and weather stations).

9. Chesapeake Bay Watershed Model: The Chesapeake Bay Program is planning for a 2017 mid-point assessment of the Chesapeake TMDL. The Bay Watershed Model will be updated to estimate watershed, airshed, and estuary conditions under future climate scenarios.[44] The model will use temperature, precipitation, and potential evapotranspiration values based on estimated conditions in 2050. The results of this

[40] EPA. Global Change Impacts & Adaptation. Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds. Website http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=256912

[41] EPA. BASINS 4.0 Climate Assessment Tool. Website http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203460

[42] EPA. Modeling Climate Change Impacts Using SWAT and the Climate Assessment Tool. Available at http://water.epa.gov/scitech/datait/models/basins/upload/ExerciseCAT_5-UsingSWAT.pdf

[43] EPA. National Stormwater Calculator. Website http://www.epa.gov/nrmrl/wswrd/wq/models/swc/

[44] Linker, L. 2013. Assessment of Climate Change Influence on the Chesapeake TMDL. Available at http://www.chesapeakebay.net/channel_files/19066/4_lew_linker.pdf

effort may be useful in targeting restoration practices to improve water quality.

10. Spatially Referenced Regressions on Watershed Attributes (SPARROW) Model: The US Geologic Survey developed a SPARROW Model that evaluates nitrogen transport and delivery to the Chesapeake Bay. Nutrient source, stream network, elevation, and land-surface data are used to spatially predict nutrient loads. Land-surface characteristics include air temperature, precipitation, slope, soil permeability, stream density, and wetland area. Model outputs have been used by MD DNR to identify priority funding areas for the Chesapeake Bay Trust Fund.[45] If SPARROW was modified with a range of land-surface characteristics based on 2050 and 2100 climate predictions, then model outputs could evaluate future nutrient deliveries under various climate change scenarios.

11. Low-Flow Calculator Tool: The Low-Flow Calculator Tool was developed by the Consortium of Atlantic Regional Assessments to project future climate change impacts on stream or river flow in the mid-Atlantic region.[46] Within a simple online platform, this tool provides low flow predictions within rivers with extensive streamflow records under four climate models. Site-specific information, however, is not available.

Climate Change Vulnerability Assessments, Guides and Databases

12. NatureServe Climate Change Vulnerability Index: NatureServe developed an index to help environmental managers and local planners assign climate change vulnerability scores at the species level.[47] This index allows managers to use regionally-specific climate models, species-specific distribution, and natural history information to predict climate change vulnerability at the species level. Wildlife and Heritage Service is using NatureServe to update DNR's wildlife action plan. This index could be applied to representative habitat or natural filter species to provide CCS with a list of vulnerable vegetative species.

13. Integrated Valuation of Environmental Services and Tradeoffs (InVEST): InVEST maps and models ecosystem services and their variation under a variety of management and/or climate change scenarios.[48] This tool could be used to simulate fluctuations in ecosystem services, such as water filtration or habitat, due to climate impacts. The Habitat Risk, Water Purification, or Sediment Retention models could be used to estimate future climate impacts to existing or in-progress restoration sites.

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[45] Maryland's Chesapeake and Coastal Bays Trust Fund: SFY12 Trust Fund Priority Areas. Available at http://www.dnr.maryland.gov/ccs/funding/pdfs/TrustFundPriorities.pdf

[46] Consortium for Atlantic Regional Assessment. Low-Flow Calculator. Website http://www.cara.psu.edu/tools/low_flow/

[47] NatureServe. Climate Change Vulnerability Index. Website https://connect.natureserve.org/science/climate-change/ccvi

[48] Natural Capital Project. InVEST Models. Website http://www.naturalcapitalproject.org/models/models.html

14. Northeast Climate Database: The National Wildlife Federation, in collaboration with NOAA, the North Atlantic LCC, and the EPA, recently released a database for use in planning and management purposes.[49] The database consists of an inventory of climate change data, needs, tools, and projects. The database allows managers to search for available data and form collaborations with other climate programs and partners in the Northeast.

15. NOAA National Climatic Data Center (NCDC): NCDC provides access to climate and historical weather data.[50] These datasets can be used in the abovementioned tools when estimating future climate impacts.

16. NOAA Precipitation Frequency Data Server: This online map server provides precipitation frequency estimates at NOAA Atlas 14 point locations.[51] Estimates can be displayed as tables, graphs, or spatial distributions via ASCII grids or heavy rainfall temporal data.

17. OpenClimateGIS: OpenClimateGIS is a Python package that allows users to manipulate, subset, compute, and translate climate datasets stored in NetCDF files or files served in THREDDS data servers.[52] A web-based interface will become available through ClimateTranslator. These tools are currently in Beta release, but may be useful when exploring and mapping climate data.

18. North Atlantic Coastal Comprehensive Study: The US Army Corps of Engineers released a study addressing coastal storm and flood risks associated with climate change.[53] The report identifies risks to vulnerable populations, property, ecosystems, and infrastructure affected by Hurricane Sandy. The study produced a Risk Assessment for the affected region, a nine-step Coastal Storm Risk Management Framework, and guidance on the use of natural and nature-based infrastructure (NNBF) when addressing coastal hazards.

Statewide Restoration Targeting and Registry Initiatives

19. Stormwater Management and Restoration Tracker (SMART Tool): The SMART Tool tracks 20 different stormwater BMPs, including rain barrels/cisterns, rain gardens, bioretention, permeable pavers, living shorelines, green roofs and tree plantings, among

[49] Northeast Climate Database. Website www.neclimateus.org

[50] NOAA National Climatic Data Center. Website http://www.ncdc.noaa.gov/

[51] NOAA. Precipitation Frequency Data Server. Website http://dipper.nws.noaa.gov/hdsc/pfds/

[52] OpenClimateGIS. Website https://earthsystemcog.org/projects/openclimategis/

[53] US Army Corps of Engineers. 2015. North Atlantic Coast Comprehensive Study. Website http://www.nad.usace.army.mil/compstudy

other practices.[54] This tool can be used to assess surrounding conditions at each project site.

20. Watershed Resources Registry: The Watershed Resources Registry (WRR) is a collaborative mapping effort between the U.S. Environmental Protection Agency, Army Corps of Engineers, U.S. Fish and Wildlife Service, Federal Highway Administration, Maryland State Highway Administration, Maryland Department of the Environment, Maryland Department of Natural Resources, and Maryland Environmental Service. WRR can be used to map priority natural resource areas for preservation and restoration. The registry includes suitability analyses for upland preservation, upland restoration, wetland preservation, wetland restoration, riparian preservation, riparian restoration, natural stormwater infrastructure preservation, and compromised stormwater infrastructure restoration. WRR can be used to identify potential restoration opportunities.[55] Although this targeting tool does not incorporate climate change, model outputs can be compared with sea level rise, marsh migration, and other climate-related data.

Design Guidance

Shoreline Enhancement

- 2013 Mid-Atlantic Living Shorelines Summit. Maryland Department of Natural Resources, Chesapeake Bay Trust, and Restore America's Estuaries. PDF.
- Living Shorelines: A Natural Approach to Erosion Control. Galveston Bay Foundation. PDF.
- Living Shoreline Design. Living Shoreline Summit. PDF.
- Evaluation of Living Shoreline Techniques. Living Shoreline Summit. PDF.
- Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments. Virginia Institute of Marine Science. PDF.
- Living Shorelines: Design and Build Criteria. Virginia Institute of Marine Science. Website.
- Living Shoreline: For the Chesapeake Bay Watershed. Chesapeake Bay Foundation. PDF.
- The Green Book for the Buffer. Maryland Department of Natural Resources. PDF.
- Design Recommendations for Riparian Corridors and Vegetated Buffer Strips. USACE. PDF.
- Conservation Buffers: Design Guidelines for Buffers, Corridors. USDS. PDF.
- Practitioner's Guide to Shellfish-Based Living Shorelines for Salt Marsh Erosion Control and Environmental Enhancement in the Mid-Atlantic. Partnership for the Delaware Estuary. PDF.

[54] University of Maryland. Stormwater Management and Restoration Tracker. Website http://extension.umd.edu/watershed/smart-tool

[55] Watershed Resources registry. Website http://watershedresourcesregistry.com/

- Shoreline Management in Chesapeake Bay. C.S. Hardaway and R.J. Byrne, Virginia Institute of Marine Science. PDF.

Stream and Floodplain Restoration

- Federal Stream Corridor Restoration Handbook. Natural Resources Conservation Service. Website.
- Stream Restoration Design (National Engineering Handbook). Natural Resources Conservation Service. Website.
- Stream Restoration: A Natural Channel Design Handbook. North Carolina Stream Restoration Institute. North Carolina Sea Grant. PDF.