

Maryland Department of Natural Resources Climate Adaptation, Mitigation and Education 2020 Report

Prepared as required in the State Environment Article § 2-1305(c), HB 514, Chapter 429 in 2015 and in accordance with § 2-1257 of the State Government Article, for the Governor and Commission

Introduction

Climate change is an important consideration given the mission and operations of the Maryland Department of Natural Resources (DNR). The department uses science, data, monitoring and modeling to inform investment decisions, determine impacts to habitat, and understand the potential effects on our waterways and our communities. The department also leads the Maryland Commission on Climate Change Adaptation and Response Working Group (ARWG), which recommends actions on preparedness from sea level rise and more intense storms.

The Maryland Greenhouse Gas Reduction Act (GGRA), requires a 25 percent reduction in greenhouse gas (GHG) emissions from 2006 levels by 2020. The law, reauthorized during the 2016 legislative session, further extended the goal to a 40 percent reduction by 2030 (the 40 by 30 Plan). The department contributes to mitigating greenhouse gases through managing public and private forests, planting trees, and restoring streams and wetlands. This report does not reflect changes in how we calculate carbon benefits of the programs for the 2030 plan unless specifically referenced. These will be included in the final 2030 GGRA plan, to be released by the end of 2020. This document details what the department has done in the past year to contribute to greenhouse gas mitigation and our progress towards the goals laid out in the GGRA plan. It also details our work providing guidance for climate adaptation and response and what we have done to educate the public on how climate change will impact them.

Highlight Facts/Figures

- 43,566 Forest Acres Managed in 2019 - 145% percent of yearly goal.
- 1,866 Forest Acres Planted in 2019 - 93% percent of yearly goal.
 - Both Planting and Managing Forests Have Exceeded 2020 Goal.
- The Chesapeake and Atlantic Coastal Bays Trust Fund restored 624 acres of wetlands in state fiscal year 2019 and 5,606 acres of wetlands since 2010.
- Created the nation's first state-led Climate Leadership Academy for state and local government officials, infrastructure executives, and business leaders.

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Greenhouse Gas Mitigation Programs

1. Managing More Forests to Capture Carbon

Program Description

Managing more forests to capture carbon will promote sustainable forestry management practices in existing Maryland forests on both public and private lands. Enrolling unmanaged forests into management regimes enhances forest productivity which increases rates of carbon sequestration in forest biomass and the amount of carbon stored in harvested durable wood products. This translates to economic benefits and increased availability of renewable biomass for energy production. This increased forestry management in Maryland is estimated to result in a 1.80 million metric tons of carbon dioxide equivalent (MMtCO₂e) cumulative reduction in the state's greenhouse gas (GHG) emissions by 2020. The 2020 goals of this program are to improve sustainable forest management on 30,000 acres of private land annually, and ensure 50 percent of state-owned forest lands will be third-party certified as sustainably managed. This program is performing as designed and the 2020 15 year target goal for cumulative acres managed was exceeded in 2018.

Program Objectives

The potential emission reductions from the program by 2020 are estimated to be 1.80 MMtCO₂e. This number represents a conservative estimate of the cumulative carbon sequestered through the program. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions for the 2020 goal, and the 2030 GGRA Plan provides details on the 2030 goal and methodology used to determine it.

Implementation Milestones

Public Lands:

- Since 2006, 211,000 acres of State Forests have been certified with dual third party certification for Forest Sustainability to the Sustainable Forestry Initiative and Forest Sustainability Certification standards.
- DNR is developing similar sustainable forest management practices on State Park and wildlife land.
- DNR's Wildlife and Heritage Service is developing Forest Stewardship Plans on several Wildlife Management Areas.
- DNR has accelerated the pace of silvicultural activity:
 - Savage River State Forest will increase the number of timber sales from 14 to 20. The Maryland Forest Service is continuing to work to decrease the backlog of timber sales.
 - State Forest Annual Work Plans included 2,324 acres of timber harvests for FY19 that will be naturally regenerated.

Private Lands:

- Since 2006 we have implemented:
 - 299,284 acres of stewardship plans
 - 179,858 acres of sediment control
 - 111,478 acres of forest stand improvements (eg., tree planting, timber stand improvements, wildlife habitat)

- Total of 590,621 acres of forest management planning activities on private lands
- DNR is currently on track to meet our goal by 2020.

Technical Assistance Provided:

- Forest Stewardship Plan preparation
- Forest Stewardship Plan implementation – expanded special rivers project
- Financial assistance – state and federal cost sharing
 - Woodland Incentive Program
 - Healthy Forests/Healthy Waters
 - Working on the next round of projects
 - Backyard Buffer Program
 - Environmental Quality Incentive Program (EQIP)
 - Conservation Reserve Enhancement Program (CREP)
 - Income Tax Modification (TAXMOD)
 - Expanded eligibility of forestry practices in 2014
 - Forest Conservation and Management Program
 - Woodland Assessment Program
- Completed the development and application of the University of Maryland remote sensing capability for forest carbon assessment.
- Launch of National Aeronautics and Space Administration, U.S. Department of Agriculture and U.S. Department of Energy climate science project for remote sensing, modeling and field-based measurements to quantify the carbon consequences of alternate development and management plans across rapidly changing forests in Maryland. Pending funding approval.
- Forest Management Study

DNR identified a forest management site that utilizes three forest management plans: Low Management (100 percent hardwoods), Moderate Management (50-70 percent pines: 30-50 percent oaks) and High Management (100 percent pine). DNR's Resource Assessment Service continues to evaluate the below ground carbon sequestration on these management plots to complement the determination of carbon sequestration in the above-ground forest. Baseline data was collected annually in 2011 thru 2014. After analysis of the 2014 data, this project was changed to a 5 year sampling interval. Expected project completion: 2030.

 - DNR is working with federal partners at the US Department of Commerce and an array of Maryland conservation and economic development agencies to conduct an Economic Adjustment Strategy for the forestry industry in Maryland.

Estimated Emission Reductions for CY19

- Forest management on private land in Maryland reduced carbon emissions by 0.26 MMtCO₂e.
- Forest management on public land in Maryland reduced carbon emissions by 0.21 MMtCO₂e.
- Both exceed yearly reduction goals.

Table 1 Acres of Forest Management

Calendar Year	Stewardship Plan ⁽¹⁾	Sediment Control ⁽¹⁾	State Forest Regeneration ⁽²⁾	Timber Stand Improvement ⁽¹⁾	Wildlife Habitat ⁽¹⁾	Total Acres
2006	13,834.1	9,113.1	2,417.0	3,092.9	2,172.6	30,629.7
2007	14,135.0	11,204.8	1,731.0	5,925.6	3,331.4	36,327.8
2008	26,787.3	11,692.2	1,823.5	5,611.2	4,146.4	50,060.7
2009	17,936.9	11,044.4	2,234.1	3,789.2	3,212.8	38,217.4
2010	14,921.2	9,539.8	2,158.2	3,178.0	2,070.6	31,867.8
2011	22,012.1	11,585.8	1,891.8	4,496.0	3,302.1	43,287.8
2012	19,486.4	12,177.6	1,723.6	3,910.0	2,705.8	40,003.4
2013	18,945.0	12,235.9	1,524.9	5,054.9	1,062.5	38,823.1
2014	16,580.0	13,100.6	1,249.2	3,072.9	434.0	34,436.6
2015	23,111.6	13,973.8	1,803.7	5,373.8	279.0	44,541.9
2016	35,224.3	18,022.1	1,866.6	3,802.1	696.2	59,611.3
2017	24,795.1	18,048.6	2,504.7	3,506.3	1,223.4	50,078.0
2018	26,369.1	16,571.8	2,469.6	3,233.8	525.6	49,170.0
2019	25,145.4	11,547.7	2,324	3,940.4	608.4	43,566.0
2020	18,000.0	11,000.0	1,500.0	4,500.0	2,800.0	37,800.0
Total	317,283.5	190,858.2	29,221.9	62,487.0	28,570.8	628,421.4
Average Annual	21,152.2	12,723.9	1,948.1	4,165.8	1,904.7	41,894.8
15 Year Target Goal	270,000.0	165,000.0	22,500.0	67,500.0	42,000.0	567,000.0

Percent of 2020 Goal Obtained	118%	116%	130%	93%	68%	111%
Estimated 2030 Target Annual Goal	21,000.0	13,000.0	1,600.0	4,000.0	2,000.0	41,600.0
(Red indicates projections)						
From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from for Q3 & Q4 of 2006 and Q1 & Q2 of 2007.						
State Forest harvest acres are only tracked by FY. Number reported from the annual State Forest Harvest Report. Includes harvest data from WMAs and demonstration forests for the same fiscal year.						

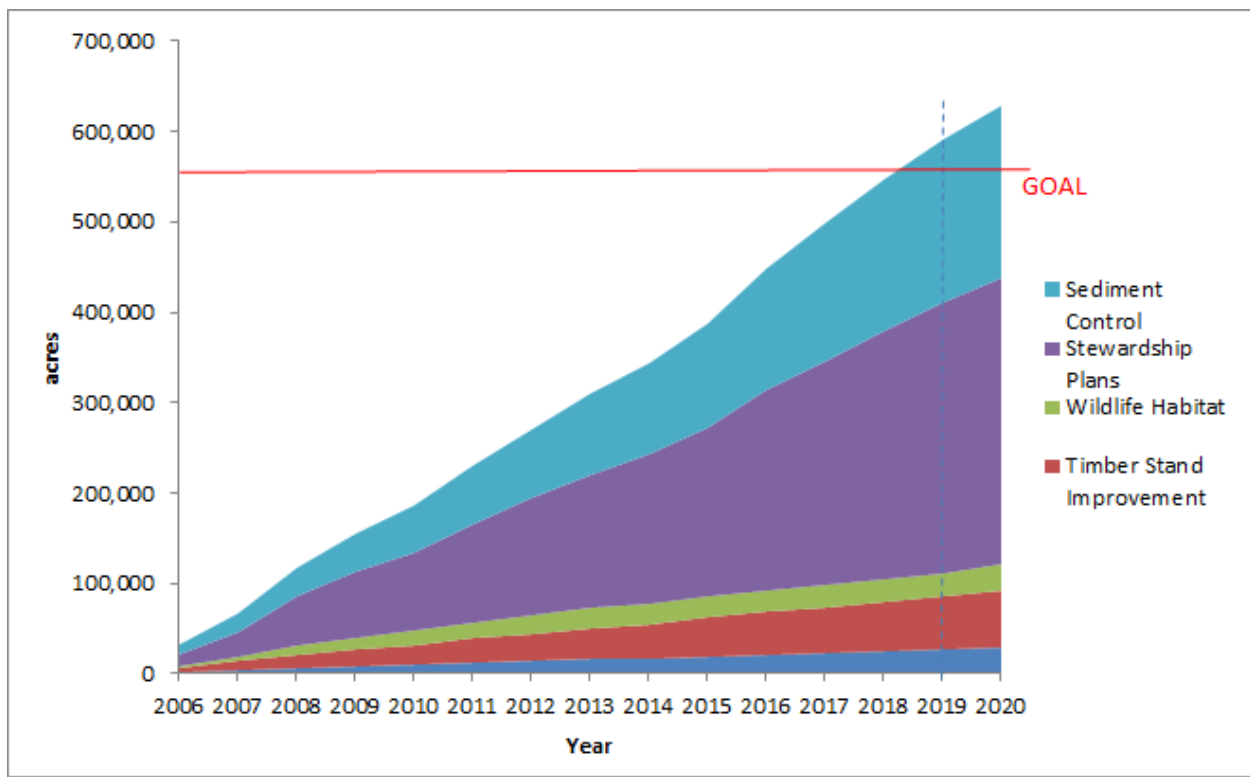


Figure 1: Managing Forests to Capture Carbon. The Maryland Department of Natural Resources is promoting sustainable forestry management practices in existing forests on public and private land through a suite of efforts, policies and programs.

Enhancement Opportunities

There are many potential actions by federal and non-profit partners other than the Maryland state government that could result in increasing natural and working lands carbon sinks in the state, contributing towards our 40 by 30 goal and beyond. Market-based solutions that incentivize public-private partnerships, enhanced outreach to landowners, and additional incentives are examples. In 2019 the United State signed on to the UN Trillion Tree's Challenge and launched the US chapter of the effort in August of 2020. At its formation the chapter has commitments from 30 corporations, municipal governments, and NGO's to plant over 850 million trees in the United States by 2030, contributing towards the global 1 trillion trees planted goal. At this point there are no new federal incentives for contributing to the goal, but a bill was introduced at the beginning of 2020 (the Trillion Trees Act) that would have created regional reforestation goals and incentives for reforestation and forest management.

Another recently introduced federal bill, The Growing Climate Solutions Act of 2020, would create a USDA carbon credit certification program. The goals would be to break down barriers of entry for forest and agricultural landowners through technical assistance. It is costly for landowners to engage in the carbon credit certification and verification process; projects generating carbon credits are typically only cost-effective for large acreages (>2,000 acres). There are efforts in the Chesapeake Bay region by timber investment management organizations (TIMOs) and NGO's to overcome the cost barrier by grouping multiple landowners for single carbon credit projects. However, this is more challenging than dealing with single landowner large holdings. Similarly, the Nature Conservancy and the American Forest Foundation have partnered to create the Family Forest Carbon Program targeted towards smaller forest landowners. They are working with the carbon verifier Verra and are backed by Amazon to conduct carbon friendly forest management practices on smaller forest parcels and create a practice-based protocol with a much lower cost (~75% less) for verification than traditional approaches. This pilot program is currently offered to landowners in Pennsylvania but will likely expand to western Maryland in the coming years.

Funding

The Woodland Incentive Fund is the progenitor of much of the activity on private lands. This fund receives revenues from a number of sources including fees for service and assistance in implementation of an approved practice, funding from the Chesapeake and Atlantic Coastal Bays Trust Fund (under § 8-2A-04 of § 5-307), and subject to approval by the secretary and the Board of Public Works, a portion of the revenues derived from the forestry practices on designated lands owned and managed by DNR. Another important revenue source is property tax from the transfer of forest lands (up to \$200,000 per year). However, the property tax transfer allocation for the Woodland Incentive Fund has been variable for the last several years and a new source needs to be identified to make up this gap and provide more uniform program funding.

Challenges

See Funding section above.

Relevant Information

Towson University's Regional Economic Studies Institute (RESI) 2015 study estimated that the Managing Forests to Capture Carbon program, once fully operational, would support a total of 268 jobs by 2020, creating \$28,564,453 in net economic output and \$28,137,209 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

2. Planting Forests in Maryland

Program Description

Planting trees expands forest cover and associated carbon stocks by regenerating or establishing healthy, functional forests through practices such as soil preparation, erosion control and supplemental planting. These actions help to ensure optimum conditions to support forest growth. By 2020, the implementation goal of this program is to achieve the afforestation and/or reforestation of 43,030 acres in Maryland. This goal was exceeded in 2019 with 44,805 cumulative acres planted. Achieving the 43,030 acre target should cumulatively reduce greenhouse gas (GHG) emissions in the State by 1.79 MMtCO₂e by 2020. This program is performing as designed.

Program Objectives

The potential emission reductions from the Planting Forests in Maryland program by 2020 are estimated to be 1.79 MMtCO₂e. This represents a conservative estimate of the cumulative sequestration achieved through this program. Appendix C of the 2015 Greenhouse Gas Reduction Act Update provides a more detailed description of the process used to quantify GHG reductions by 2020, and the 2030 GGRA Plan provides the goal for 2030 and associated methodology.

Implementation Milestones

The department is implementing this program through a suite of efforts, policies and programs, including:

Public Lands:

- State forest system annual work plan implementation

Private Lands:

- Technical Assistance
 - Forest Stewardship Plan implementation
 - Forest Conservation Act (FCA) implementation

Financial Assistance – Rural Lands: State and Federal Cost Sharing:

- Woodland Incentive Program (WIP –MD Forest Service)
- Income Tax Modification (TAXMOD)- expanded eligibility of forestry practices in 2014
- Environmental Quality Incentive Program (EQIP – Federal/NRCS)
- Conservation Reserve Enhancement (CREP – Federal/NRCS)

- Chesapeake and Atlantic Coastal Bays Trust Fund

Estimated Emission Reductions for CY 2019

On track with previous years, reductions totaled 0.18 MMtCO₂e for 2019.

Table 2 Forest Planted in Maryland

	Year	Afforestation⁽¹⁾⁽²⁾	Reforestation⁽¹⁾⁽³⁾	Riparian Buffers⁽⁴⁾	Private Natural Regeneration⁽⁵⁾	Total Acres
	2006	845.7	3,318.0	388.2	1,400.0	5,951.9
	2007	343.4	1,990.2	242.8	1,400.0	3,976.4
	2008	404.9	1,598.2	191.2	1,400.0	3,594.3
	2009	531.1	1,497.4	162.6	1,400.0	3,591.1
	2010	596.0	417.4	545.6	1,400.0	2,959.0
	2011	1,223.6	633.9	503.1	1,400.0	3,760.6
	2012	433.7	615.3	320.1	1,400.0	2,769.1
	2013	198.1	593.6	237.0	1,400.0	2,428.6
	2014	409.8	559.2	287.3	1,400.0	2,656.2
	2015	294.1	633.1	213.7	1,400.0	2,540.9
	2016	180.0	638.9	263.0	1,400.0	2,481.9
	2017	97.6	434.0	127.4	1,400.0	2,059.0
	2018	134.2	423.4	212.9	1,400.0	2,170.5
	2019	107.3	254.2	104.4	1,400.0	1,865.9
	2020	100.0	400.0	100.0	1,400.0	2,000.0
	Total	5,899.5	14,006.8	3,899.3	21,000.0	44,805.4
	Average Annual	393.3	763.5	260	1,400.0	2,987.0
	15 Year Target Goal	6,000.0	10,500.0	6,000.0	21,000.0	43,500.0

	Percent of Goal Obtained	98%	133%	65%	100%	103%
	Estimated 2030 Target Annual Goal	350.0	600.0	200.0	1,400.0	2,550.0
	Indicates Projections)					
	From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year, and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 & Q4 o					
	PMAS field CREP/HEL Afforestation plus the Other Afforestation Acres.					
	PMAS field Reforestation Acres.					
	Acres reported by the Maryland Forest Service Riparian Forest Buffer Restoration Program. http://dnr.maryland.gov/forests/Pages/programapps/rfbrestoration.aspx					
	Estimated area of privately owned forest regenerated annually following timber harvest. Assumes 20 percent of Sediment and Erosion Control permitted acres reported by counties are actually harvested and regenerated. Historically, the average is 1,400 acre/year.					

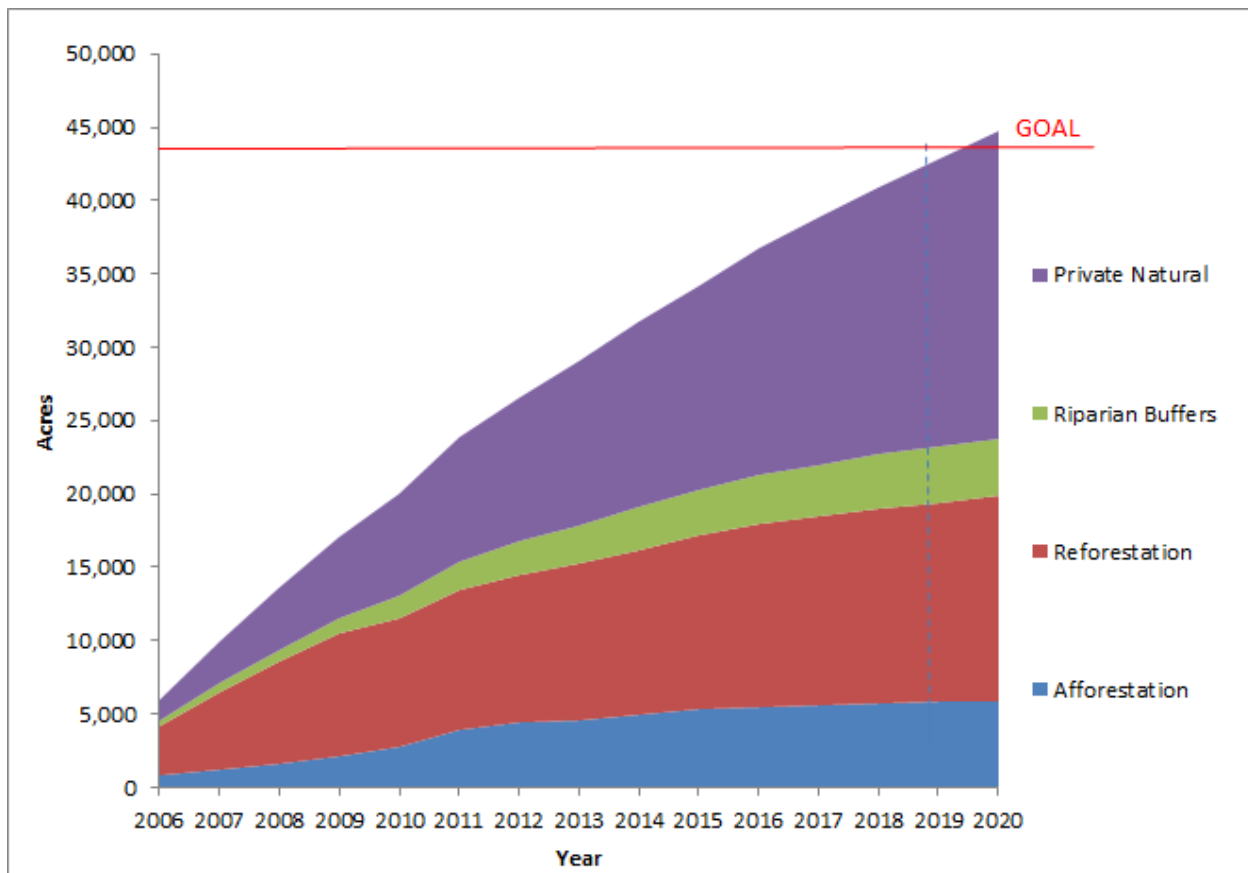


Figure 2 Planting Forests in Maryland.

Enhancement Opportunities

Provide dedicated staff to identify landowners interested in participating in programs like “Lawn to Woodland” and “Marylanders Plant Trees.” See prior section for emerging federal and non-governmental actions that present opportunities for tree planting beyond 2030.

Funding

Important challenges faced by this program include locating and obtaining funding to continue and build upon the “Lawn to Woodland” and “Marylanders Plant Trees” programs.

Challenges

See “Funding” section above.

Relevant Information

RESI’s 2015 study estimated that the Planting Forests in Maryland program, once fully operational, would support a total of 92 jobs by 2020, creating \$11,077,882 in net economic output and \$14,862,060 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

3. *Creating and Protecting Wetlands and Waterway Borders to Capture Carbon*

Program Description

In addition to forests, wetlands are known to be very efficient at sequestering carbon. DNR is planting forested stream buffers and pursuing the creation, protection and restoration of wetlands to promote carbon sequestration through several means including the Natural Filters Program, which restores wetlands and buffers on state and public lands to meet water quality goals and is provided through the Chesapeake and Atlantic Coastal Bays Trust Fund. The objectives of the Coastal Wetlands Initiative include restoring natural tidal marsh hydrology to coastal wetlands through ditch plugging practices and the development of a terrestrial carbon sequestration protocol.

The department is including another best practice for terrestrial carbon sequestration through its Shoreline Conservation Service projects to install Living Shorelines. These are additional coastal wetland restoration practices that function to sequester carbon.

Program Objectives

The cumulative carbon storage from the Creating and Protecting Wetlands and Waterway Borders to Capture Carbon program by 2020 are estimated to be 0.047 MMtCO₂e. See 2030 GGRA Plan for methodology.

Implementation Milestones

On the ground wetland and waterway restoration projects:

The Natural Filters Program restored 8.5 acres of wetlands on state and public land and planted 1.2 acres of streamside forest buffers on state and public lands in calendar year 2019, working towards the state's Watershed Implementation Plan (WIP) goals for state and public lands. Funded through The Chesapeake and Atlantic Coastal Bays Trust Fund, these projects are designed to accelerate Bay restoration by focusing limited financial resources on the most efficient, cost-effective non-point source pollution control projects, which include wetland and buffer restoration projects.

The Chesapeake and Atlantic Coastal Bays Trust Fund has, as of the end of state fiscal year 2020, funded the restoration of 2,926 acres of wetlands and 1,400 acres of riparian buffers. These totals include restoration gains from the Natural Filters Program, as documented above, and projects that have occurred on private lands. From this point onward, implementation tracking will be expanded to include both public and private land restoration projects that are funded through the Trust Fund, to more accurately reflect potential carbon sequestration gains.

Through a partnership between DNR, The Nature Conservancy (TNC), U.S. Fish and Wildlife Service, Natural Resources Conservation Service and National Oceanic and Atmospheric Administration, we were able to restore 2,174 acres via a 5 year grant agreement between TNC and DNR (Chesapeake and Coastal Bays Trust Fund). The Pocomoke project's primary focus was to reconnect the mainstem, and to channelize the Pocomoke River with its historic

floodplain. The wetlands restored were mostly forested riparian wetlands, with some emergent wetlands restored in agricultural fields in the watershed.

Coastal Wetlands Initiative Program: As of 2019, 505.6 acres of coastal wetlands have been restored by plugging existing drainage ditches to restore these drained wetlands.

Living Shorelines through the Shoreline Conservation Service: Between 2006 and 2019 13.24 acres of Living Shoreline have been created or restored.

Wetland restoration and enhancement by federal agencies: The US Fish and Wildlife Service has restored or enhanced 211 acres of tidal wetlands in the Blackwater National Wildlife Refuge over the past 10 years. The US Army Corps of Engineers has created, restored, or enhanced 1875 acres of tidal wetlands in the Maryland portion of the Chesapeake Bay since 2006, with the most significant projects being a wetland enhancement project on Deal Island and wetland creation on Poplar Island. Recent research has shown that the Poplar Island created wetlands are sequestering carbon at similar rates to natural wetlands.

Table 3. Shoreline and Marsh Creation in Maryland

Year	Linear Feet of Shoreline	Square Feet of Marsh Created/Restored	Acres Created/Restored
2006	2,901	55,779	1.28
2007	2,920	119,210	2.74
2008	2,485	87,670	2.01
2009	8,935	46,660	1.07
2010	1,944	37,871	0.87
2011	2,100	31,497	0.72
2012	None		
2013	2,000	24,000	0.55
2014	3,000	63,115	1.45

2015	None		
2016	3,100	66,000	1.52
2017	None		
2018	300	45,000	1.03
2019	None		
Total	29,685	576,802	13.24

Estimated Emission Reductions for CY 2019

For this estimate we only consider tidal wetlands restored from 2006 to 2019 and use the default rate of 2.17 Mt of CO₂e per acre per year for restored wetlands as determined by the Verified Carbon Standard. We estimate restored, created, and enhanced tidal wetlands in Maryland to be 2606 acres since 2006 and sequester approximately 0.0056 million metric tons of carbon dioxide equivalent per year in 2019.

Enhancement Opportunities

A key enhancement opportunity f]is to utilize market-based solutions to increase wetlands restoration and enhancement projects.

The Sea Level Affecting Marsh Model (SLAMM) has been completed for Maryland coastlines and is being actively used for a variety of wetland management practices including:

- Factoring climate change and resiliency into DNR's land acquisition scoring process
- Developing new easement opportunities for landowners that own land within these wetland adaptation area transition zones
- Identifying the value of current and future wetlands for protecting communities and infrastructure from coastal flooding and shoreline erosion through DNR's Coastal Resiliency Initiative.

Ongoing work funded by the NOAA Ecological Effects of Sea Level Rise project awarded to George Mason University, DNR, and the Maryland chapter of The Nature Conservancy will update the SLAMM model using the latest elevation and wetlands data to more accurately determine the potential loss or gain of tidal wetlands from 2020 to 2100 under six different global carbon emission scenarios. These results will provide input to the Maryland GGRA Draft Plan in understanding the effect of sea level rise on carbon storage pools in current and future wetlands.

The US Climate Alliance (USCA) has funded a collaboration with Duke University, North Carolina, Virginia, Delaware, New Jersey and New York on modeling coastal blue carbon and coastal resiliency. The coastal blue carbon model simulates change in wetlands over a 100 year period (2020-2120) under different emission scenarios spatially across Maryland and the other

participating states. The model results will help build our understanding of the range of outcomes for wetland carbon storage and sequestration, both informing our GGRA plan and helping us prioritize projects for increasing coastal resiliency.

The University of Maryland Center for Environmental Science (UMCES), partnering with Restore America's Estuaries and COMPASS, will be conducting a series of webinars on Blue Carbon starting in Summer 2020. These webinars will synthesize the state of knowledge on blue carbon, with one of the stated goals to better understand how blue carbon fits into Maryland's GHG inventory and reduction goals.

Maryland's Innovative Technology Fund (ITF) expanded its scope of eligible techniques and technologies to include consideration of climate aspects. In addition to the traditional technologies focused on nutrient and sediment reductions, the state will also invest in the research, development, and commercialization of solutions addressing climate mitigation to help accelerate the adoption of climate resiliency and GHG mitigation. The ITF has supported six solutions that have the co-benefit of mitigating Greenhouse Gas (GHG) emissions. Manta Biofuel has a system to grow, harvest and convert algae into biofuel that can be a substitute for fossil fuels. HyTek Bio uses an algae scrubber system to reduce GHG and NOx emissions from the Back River Wastewater treatment plant. DataKwip Holdings LLC, is a startup with a real-time energy and facility analytics platform that helps building operators and managers make their buildings an average of 15 percent more efficient using existing systems and equipment, without the need for additional hardware. Neighborhood Sun, a company that acquires and manages customers for community solar projects, is providing solar power to anyone who pays an electric bill. SolarCube LLC, provides photovoltaic and battery storage solutions to provide customers with an affordable option to install flexible, lightweight and efficient building integrated photovoltaics. SVE Technology LLC is designing, building, and testing a modernized sleeve valve engine that will contribute to significant reduction in fuel costs and to the development of an environmentally friendly small scale and high speed engines for various industrial applications.

The new protocol for tidal and seagrass restoration and other research efforts quantifying coastal wetland sequestration, opens up opportunities to account for the GHG benefits of carbon sequestration through Submerged Aquatic Vegetation restoration and re-establishment. There may also be emerging avenues for investing in coastal restoration to reduce the risk of damage to infrastructure from coastal flooding. A number of studies (Naryan et al. 2017, Costanza et al. 2011) have shown a direct causal link between coastal wetlands and damage from storms; if this benefit is better incorporated into the insurance market it could provide another funding source for coastal wetland protection, creation and enhancement.

Funding

The Chesapeake and Atlantic Coastal Bays Trust Fund: In 2007, the Maryland General Assembly created the Chesapeake and Atlantic Coastal Bays Trust Fund (Trust Fund) to provide financial assistance to projects that advance Chesapeake Bay restoration. A large portion of this funding is targeted at local grants for counties and municipalities to reduce nutrient pollution to waterways which includes forested buffers, reforestation, wetland restoration, stream and

floodplain restoration, stormwater retrofits and other bioremediation projects. In FY20, \$23.82 million was allocated for these projects.

Resiliency through Restoration Initiative: Since 2011, Maryland has experienced six hurricane and flood events warranting presidential disaster declarations, resulting in more than \$130 million in federal public assistance. Recognizing that coastal habitats help buffer communities from these climate-related impacts, the Maryland Department of Natural Resources' Chesapeake and Coastal Service (CCS) launched a new Resiliency through Restoration Initiative. This Initiative, funded by Governor Hogan through the State Capital Budget, provides technical and financial assistance to restore, enhance and create coastal habitat with the goal of protecting Maryland communities and public resources from extreme weather and climate-related events. The Initiative has led to the design of 16 living shoreline, coastal, and inland restoration projects around Maryland.

Coastal Wetlands Initiative (CWI): There are no dedicated funds currently allotted to CWI. Funding is typically acquired through a competitive grant process which in the past have used state transportation and other federal funding sources.

Shoreline Conservation Services: This program is funded through the Shore Erosion Control Construction Loan Fund through DNR.

Department of Natural Resources/Department of Transportation Memorandum of Understanding: The Maryland Department of Natural Resources has partnered with the State Highway Administration (SHA) in an effort to lead by example in restoring the Chesapeake Bay and local waters. State parks will provide opportunities for the State Highway Administration to implement restoration projects required by their Federal Stormwater Permit (MS4) and their nutrient and sediment reduction goals required under the Bay Total Maximum Daily Load (TMDL). A Memorandum of Understanding was signed in 2013 to initiate this program, which will increase the rate of restoration projects on state and public lands. In addition, DNR is working with MDOT to develop a similar MOU that will extend the partnership to the other MDOT transportation business units.

Challenges

While wetland restoration, in both inland, freshwater and tidal environments, are practices that significantly contribute to terrestrial carbon sequestration rates throughout the state, the highly variable rate of methane emissions has a marked effect on net greenhouse gas benefits. Research at state, regional, national and global scales continues to evolve and narrow in on more precise methods to evaluate the greenhouse gas benefits of wetland restoration.

The laws that currently govern wetlands do a good job of protecting wetlands against human caused impacts, but do not consider natural impacts, like sea level rise. New wetlands will be created and many wetlands will migrate inland with SLR but our laws do not include provisions to mitigate for net wetland loss due to sea level rise, should it occur.

Measures of success for the various Coastal Wetland Initiative projects are currently being monitored. In some cases, ditch plugging has been very effective in establishing sheet flow

across the marsh and allowing sediment to naturally fill the plugged ditches. In other areas, the ditch plugging has resulted in excessive water pooling, creating a drowned marsh effect. Ongoing monitoring of these projects will improve the design, best practices and success of future efforts.

Removing barriers to accessing federal funds could also incentivize landowners to participate in restoration projects. DNR is actively working with the Maryland Department of Agriculture and the United States Department of Agriculture on removing those barriers

Relevant Information

RESI's 2015 Study estimated that the Creating and Protecting Wetlands and Waterway Borders to Capture Carbon program, once fully operational, would support a total of 62 jobs by 2020, \$28,717,043 in net economic output and \$15,045,166 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

4. Biomass for Energy Production

Program Description

Maryland is working to promote the use of locally-produced woody biomass for the generation of thermal energy and electricity. Energy from forest by-products can be used to offset fossil fuel-based energy production and associated GHG emissions. There are many end users in the United States that are successfully employing wood heating and cooling. Maryland would benefit from such a program. For example, schools, hospitals, and municipalities could utilize local woody biomass for their energy needs. Creating a woody biomass fuel market would provide an incentive for harvesting low grade wood, a key component of healthy forest management.

The goals of this program are to develop policies that recognize wood as a renewable energy source, recognize wood as the largest source of bioenergy production in Maryland, and offer incentives to utilize locally produced wood to meet thermal energy needs.

Program Objectives

The potential emission reductions from the Biomass for Energy Production program by 2020 were estimated to be 0.33 MMtCO₂e in the Greenhouse Gas Reduction Act plan, but we now estimate no greenhouse gas benefit from this program as there have not been any biomass to energy facilities built in the state, but Maryland is currently exploring opportunities for new facilities.

Implementation Milestones

- DNR is actively working with partners including the Maryland Energy Administration, and the Maryland Department of Commerce to facilitate installation of wood energy systems and has committed to a pilot program on the Eastern Shore and in Western Maryland.
- Maryland Energy Administration has an existing grant program that could be reinstated if adequate demand is demonstrated.

- A webinar series on the potential of woody biomass to energy in Maryland was presented in 2020. This series was sponsored by the Maryland Forestry Foundation and Maryland Clean Energy Center in partnership with DNR and the Sustainable Forestry Council. More information and recordings can be found at <https://www.mdcleanenergy.org/biomass/>.
- The U.S. Department of Commerce Economic Development Administration awarded a grant to the Western Maryland Resource Conservation and Development Council, who is partnering with DNR and the Maryland Department of Commerce to develop an Economic Adjustment Strategy for Maryland's forestry industry. Once finalized, the plan will serve as a roadmap for capitalizing on new opportunities in the forest industry including biomass for energy production and creating jobs, particularly in Opportunity Zones.
- Recognizing the need for an analysis of "woodsheds" where available wood resource is quantified will help raise confidence in the ability of an area to support industrial scale biomass to energy and in the feasibility of industrial scale biomass to energy. The Eastern Shore Regional GIS Center (ESRGC) at Salisbury University recently partnered with DNR, the Western Maryland Resource Conservation and Development Council, and the Maryland Department of Commerce to assist in answering that question. A [Maryland Forest Inventory Resource Viewer \(MFIRV\)](#) was also developed so potential investors and forestry-related businesses could have information on potential markets and market viability.
- Actions that still need to be implemented include developing comprehensive policy supporting thermal energy.

Estimated Emission Reductions for CY 2019

None.

Enhancement Opportunities

Allowing renewable energy credits (RECs) to be generated from combined heat and power systems using woody biomass, would provide an additional incentive to use this type of system. Additional educational outreach on the feasibility of biomass-to-energy to state agencies, academic institutions and the business community would likely help to establish this program. Because RECs are defined in Maryland's Renewable Portfolio Standard (RPS) statute, a statutory change would be needed to accomplish this.

Funding

See 'Challenges' section.

Challenges

Awareness of wood energy technology is the primary barrier to this program, in particular adequately informing the managers of commercial and institutional spaces of the opportunities to save money while improving environmental outcomes that are offered by the simple switch to wood fuels. Establishing some demonstration projects in Maryland would greatly assist with DNR's ability to showcase available technology.

Maryland Energy Administration has temporarily discontinued its Commercial Wood Boiler grant incentive program due to a lack of success in identifying suitable grant recipients. This removes \$1 million of leverage in accelerating the adoption of carbon displacing wood energy,

decreasing the likelihood of significant investment in future utilization of woody biomass to energy. The program could be reinstated if sufficient industry demand is demonstrated.

Relevant Information

RESI's 2015 Study estimated that the Biomass for Energy Production program, once fully operational, would support a total of 51 jobs by 2020, \$24,871,827 in net economic output and \$12,756,348 in wages over the lifetime of the program. Chapter 6 and Appendix K the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

5. Increasing Urban Trees to Capture Carbon

Program Description

Trees in urban areas are extremely important to Maryland's carbon budget because they help offset some of the greenhouse gas emissions from urban pollution sources such as power production and vehicle emissions, reduce heating and cooling costs and energy demand by moderating temperatures around buildings and slow the formation of ground level ozone as well as the evaporation of fuel from motor vehicles. Implementation is supported by several Maryland laws and programs that include outreach and technical assistance for municipalities to assess and evaluate their urban tree canopy goals and plant trees to meet those goals.

The goal of this program is to plant 12.5 million trees in urban areas through the Forest Conservation Act, Marylanders Plant Trees, Tree-Mendous Maryland and 5-103 State Highway Reforestation Act planting programs.

This program is performing as designed.

Program Objectives

The potential emission reductions from the Increasing Urban Trees to Capture Carbon program by 2020 are estimated to be 0.02 MMtCO₂e. This number represents a conservative estimate of the cumulative carbon sequestered through this program. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions.

Implementation Milestones

To date, 5,908,487 trees have been planted from 2006 to 2019 (total for this program and Planting Forests in Maryland).

The Department of Natural Resources – Forest Service (Maryland Forest Service) developed two tree planting assistance programs that reach landowners within the urban/suburban areas of Maryland. The new programs target the 1.1 million acres of turf statewide. Each targets different lot sizes and available planting space.

- The “Lawn to Woodland” program, a partnership with the Arbor Day Foundation, targets the small lot with 1-5 acres of plantable space or turf. The Foundation does outreach while Maryland Forest Service handles the tree planting at no cost to the lot owner. In the Spring of 2014, a pilot was done with 14 acres planted on 12 lots. In the Spring of 2015, 100 acres were

planted on 84 sites and in the Spring of 2016, 60 acres were planted on 55 sites. All total, 174 acres were planted on 151 sites. This program is on hold until funding is identified.

- The “Marylanders Plant Trees” program, is a \$25 coupon reimbursement program targeting individuals wishing to plant a tree. It enables very small lot owners to purchase a tree valued at \$50 or more and reduce the cost by \$25. There are 85 participating nurseries across the state. From the program’s inception in FY09 to FY19, 49,326 coupons have been reimbursed.
- Financial Assistance – Urban Lands: Public/Private Partnerships
 - Tree-Mendous/Arbor Day
 - 1,468 trees planted in 2019
- Marylanders Plant Trees/Private Nurseries
 - Reimbursed coupons for 3,781 trees in 2019
- Lawn to Woodland (e.g. National Arbor Day Foundation, etc.)
 - Kicked off in spring 2014 with 4.3 acres planted
 - 100.73 acres on 84 sites planted in spring 2015
 - 60.33 acres on 55 sites planted in spring 2016
- Maryland Urban and Community Forestry Committee Grants
 - In 2019, \$6,000 was awarded and contributed to seven tree planting projects throughout the state.
- Small Community Urban Tree Canopy (UTC) Grants lead to the planting of 301 trees in 2019.

Estimated Emission Reductions for CY 2019

Urban tree plantings are estimated to sequester 0.002 MMtCO₂e in 2019.

Table 4. Urban Tree Planting (number of trees).

Year	Forest Conservation Act (FCA) ⁽¹⁾	Reforestation 5-103 ⁽¹⁾	Tree-Mendous & Marylanders Plant Trees Programs	Total Trees
2006	623,700	33,750	8,178	665,628
2007	473,400	27,000	6,057	506,457
2008	499,500	9,900	2,160	511,560
2009	450,900	13,950	39,020	503,870

2010	337,950	308,250	23,000	669,200
2011	481,050	15,750	17,200	514,000
2012	42,300	68,850	21,700	132,850
2013	119,250	23,850	23,800	166,900
2014	140,580	24,615	21,500	186,695
2015	142,875	6,251	8,435	157,561
2016	341,640	37,557	8,798	387,995
2017	412,300	8,388	12,545	433,233
2018	256,050	5,913	7,718	269,681
2019	158,535	10,697	10,166	179,398
2020	269,757	2,560	5,249	277,566
Total	4,749,787.0	597,281.0	215,526.0	5,562,594
Average Annual	316,652.5	39,818.7	14,368.4	370,839.6

Average of Last 3 Years (Rounded)	228,100.0	6,400.0	7,700.0	242,200.0
(1).	Assumes 450 trees planted/acre.			
Totals for 2020 are based on preliminary data and subject to future revisions				

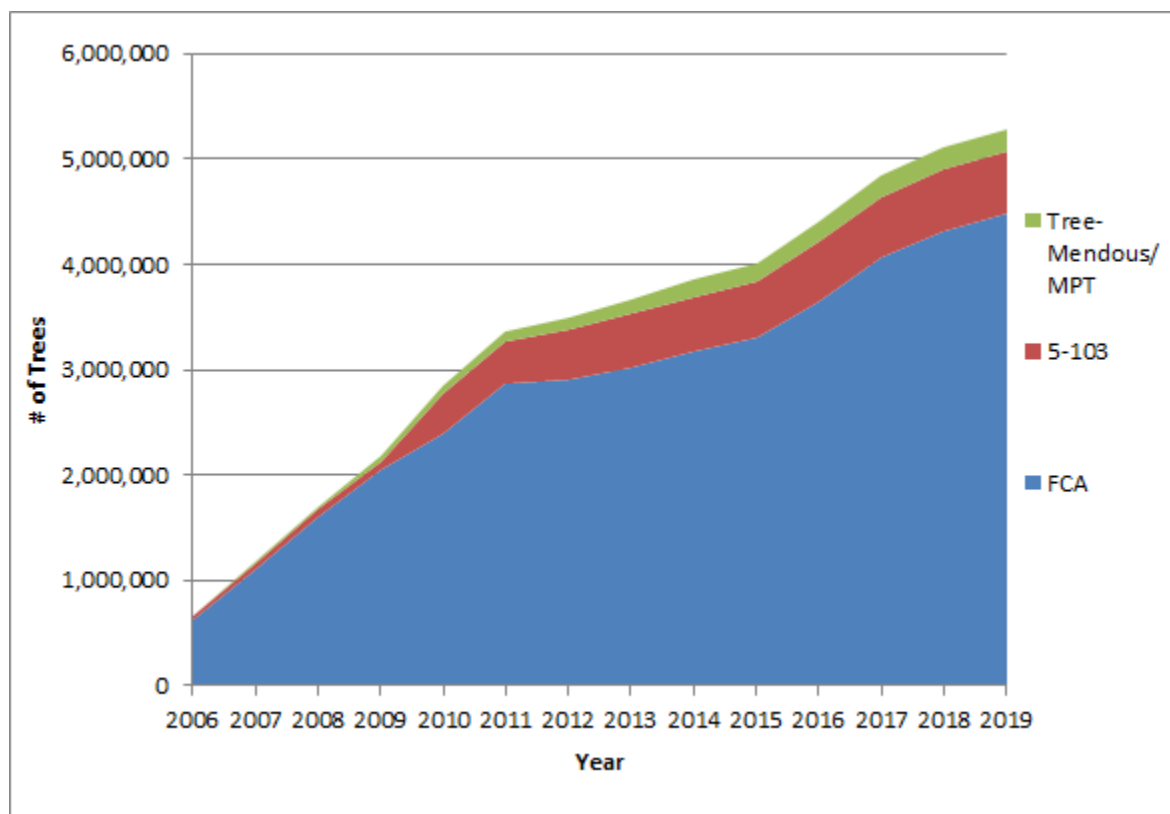


Figure 3. Increasing Urban Trees to Capture Carbon.

Enhancement Opportunities

Efforts to expand and diversify buffer and urban tree canopy plantings related to Chesapeake Bay restoration will also benefit greenhouse gas reduction efforts. New funding mechanisms are being explored, from revolving loan funds repaid through purchase of MS4 credits or local

government climate resilience bonds. The quantification of carbon sequestration for tree planting, soil carbon sequestration, and forest management estimates could form the basis for aggregating private forest management and tree planting for the voluntary carbon credit market.

Funding

The “Lawn to Woodland” and the “Marylanders Plant Trees” programs are both funded through forest mitigation funds received as a result of highway construction projects complying with Reforestation Law (NRA 5-103). This makes the funding variable from year to year, and for the past several years the “Lawn to Woodland” program was on hold due to limited available funds. Identifying an alternative funding source when mitigation funds are limited or not available would allow for the programs to be consistently offered to the public.

Challenges

See Funding section above.

Relevant Information

RESI’s 2015 Study estimated that the Increasing Urban Trees to Capture Carbon program, once fully operational, would support a total of 375 jobs by 2020, \$288,146,970 in net economic output and \$93,017,577 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

6. Geological Opportunities to Store Carbon

Program Description

Geological carbon sequestration differs from other discussed sequestration methods because it captures carbon at the source, transports it to a sequestration site, and then sequesters it. Maryland, through DNR’s Maryland Geological Survey, is one of eight partner states in the Midwest Region Carbon Sequestration Partnership whose role is to identify, locate, and characterize potential geologic storage opportunities. This has evolved into the MidWest Region Carbon Initiative which is a coordination of over 12 states, the non-profit Battelle Memorial Institute, and the U.S. Department of Energy. More than 10 gigatonnes of storage capacity has been identified within the terrestrial portion of Maryland (103 years of storage capacity at current CO₂ estimated production rate of 97 million metric tons per year). In the offshore region ranging from Maryland to New York, an estimated 450 gigatonnes of geologic capacity has been calculated.

The goal of this program is to identify and assess geologic storage opportunities. However, no quantification target has been assigned.

This program is performing as designed.

Program Objectives

The potential emission reductions from the Geological Opportunities to Store Carbon program have been aggregated with the estimated emission reductions from the Terrestrial Sequestration bundle (Forestry and Wetlands).

Implementation Milestones

Previous Geological Carbon Sequestration funding has come from the US Department of Energy through Battelle. Research funds for geologic carbon sequestration ceased in 2020 with a refocusing of DOE funds into implementation of geologic carbon sequestration. Twenty thousand dollars per year is provided through the state's Environmental Trust Fund.

The Department of Natural Resources' Resource Assessment Service (RAS) has completed or is currently working on the following implementation milestones.

- Total organic carbon content in Maryland black shales (e.g., Marcellus) has been evaluated as a precursor for determining the viability of these as storage units for carbon dioxide. This data is incorporated into regional and national databases for various integration projects. This project is completed.
- The potential for offshore carbon sequestration has been evaluated in partnership with Harvard University, Battelle, US Department of Energy, Rutgers University, University of Texas and the surrounding Mid-Atlantic States. Focus areas of this study included geologic characterization, capacity evaluations, injectability and risk analyses. This project has provided foundation knowledge and an assessment of potential for carbon sequestration offshore in the Baltimore Canyon Trough. Projections from this study state over 450 gigatonnes of carbon sequestration are possible within our region using offshore sequestration targets.
- The potential of saline aquifers located under the Coastal Plain in Maryland as a target for carbon sequestration is being evaluated in cooperation with multiple state Geological Surveys. There is currently no funding for this research and saline aquifers remain a potential option, but unvalidated sink for the greenhouse gas carbon dioxide (CO₂).
- Baseline data has been collected to provide the foundation for conducting risk analyses for potential development of stray gas migration into potable aquifers. The final report is in review.
- Research is ongoing to assess the CO₂ chemical adsorption capacity of power plant combustion by-products and the organic shales and clays in the closest geologic formations.
- Research has been completed to assess the possibility of CO₂ sequestration as both structural and chemical storage within triassic rift basins. The exposed Gettysburg-Culpepper basin has been characterized and documented as a proxy of the buried rift basins located throughout Maryland. Further research is planned to study the collected cores through the Taylorsville Basin, however those cores are currently difficult to access and located out of state. Phase I of this project is complete. Phase II is pending the availability of collected cores.

Other Resources Assessment Service program notes include:

- Site testing (carbon capture, transport and storage) continues in Michigan and Ohio (regional partners to Maryland in CO₂ sequestration projects) and has been completed in Kentucky. A large scale project is currently being performed in Illinois capturing 6.5 million tonnes of CO₂ annually. These programs are being evaluated at a national level and the results continue to be favorable at this time.
- Depleted gas fields present the most immediate option for permanent storage of carbon dioxide in Western Maryland. Maryland Geological Survey is currently working on

identifying the site characteristics of individual wells to assist MEA in determining a pilot project injection site.

- A methane emissions study of the Deer Park Anticline by the Western Maryland Regional GIS Center has ruled out using this Anticline for structural storage of CO₂ due to observed methane leaks primarily from the old Mountain Lake Park Gas Field. It could still have potential for chemical adsorption of CO₂.
- In collaboration with Maryland Energy Administration, a CO₂ Sequestration conference was held in November 2019. MEA recorded the talks and are using these talks as educational material for legislators and their staff.
- Maryland Geological Survey is working with NASA to identify any technologies that would assist in identifying methane emitters such as transmissive geologic faults, poorly abandoned wells, fissures, etc. There is no funding for this and this project is in its infancy.

Estimated Emission Reductions for CY 2019

None.

Enhancement Opportunities

A federal, regional, or state action to put a cap on carbon emissions would potentially create a demand for geologic sequestration, if it is cost-competitive with other options to offset emissions. If the price of carbon offsets reaches parity with the cost to do geologic sequestration this would also spur action.

A pilot project currently being discussed at Maryland Energy Agency will allow Maryland to understand the execution of a geologic carbon sequestration program.

Funding

Previous Geological Carbon Sequestration funding has come from the US Department of Energy through Battelle. Research funds for geologic carbon sequestration will cease in 2019 with a refocusing of DOE funds into implementation of geologic carbon sequestration. Twenty thousand dollars per year is provided through the state's Environmental Trust Fund.

Challenges

The cost of capturing CO₂ using current technologies involves a parasitic loss of approximately 20 percent at the generation site. This cost has decreased over the last 10 years by 30 percent. It is anticipated this will only decline to an 18 percent parasitic loss unless a vastly improved technology is identified. However, the IRS has created a section 45Q tax credit incentive which allows businesses that geologically sequester carbon to receive a significant offset which will mature to \$50 per metric ton by 2026. This tax incentive significantly offsets the cost of carbon capture and geological sequestration allowing for profit making business plans using current technology.

A significant, but often overlooked cost for sequestration, is transportation of the CO₂ from its source to the sequestration site. Ideally, the sources would be located on top of the sequestration site making this cost minimal. However, it is likely that pipelines will need to be created to efficiently pipe the CO₂ from the production location to the sequestration location.

Retrofitting equipment onto existing powerplants and industrial processing plants is often cost and space prohibitive. CO2 capture will need to be part of the design of new power generation plants.

Relevant Information

RESI's 2015 Study estimated that the Geological Opportunities to Store Carbon program, once fully operational, would support a total of 217 jobs by 2020, \$312,011,719 in net economic output and \$62,194,826 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

7. *Creating Ecosystems Markets to Encourage Greenhouse Gas Emission Reductions*

Program Description

Increased attention to the benefits and cost efficiencies that ecosystem markets could provide has spurred evaluation of the potential its programs and policies may have for fostering carbon market development. Maryland's Forest Conservation Act and Critical Area Act require mitigation for natural resource impacts generated through land development, and mitigation banking is an option to address these mitigation requirements.

The goal of this program is to explore the establishment of ecosystem markets, create a tracking mechanism and develop protocols to assess/quantify GHG benefits of individual markets. However, no quantification target has been assigned.

Program Objectives

The potential emission reductions from the Creating Ecosystems Markets to Encourage greenhouse gas (GHG) Emission Reductions program in 2020 are estimated to be 0.11 MMtCO₂e. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify GHG reductions.

Implementation Milestones

- Ecosystem co-benefits from forests, wetlands, cropland, and pasture land have been spatially quantified across Maryland. Spatial models for co-benefits have been completed and are available on Maryland GreenPrint (www.geodata.md.gov/greenprint/).
- The Nontidal Wetlands Mitigation Banking bill passed in 2016 removes barriers to mitigation banking in Maryland, with the goal of reducing the cost for meeting mitigation requirements in an ecologically beneficial way.
- Under Forest Conservation Act (FCA) banking, several counties in Maryland allow off-site mitigation for forest loss through purchasing credits in a forest bank. Over 2,000 acres of forest loss have been mitigated in this way over the past 15 years.
- The Maryland Department of Agriculture received a National Fish and Wildlife Foundation (NFWF) grant to enhance healthy soils practices in the state. One of the outcomes will be to create a carbon sequestration module of the Nutrient Trading Tool, allowing for the quantification of carbon sequestration by different Best Management Practices alongside the nutrient benefits.

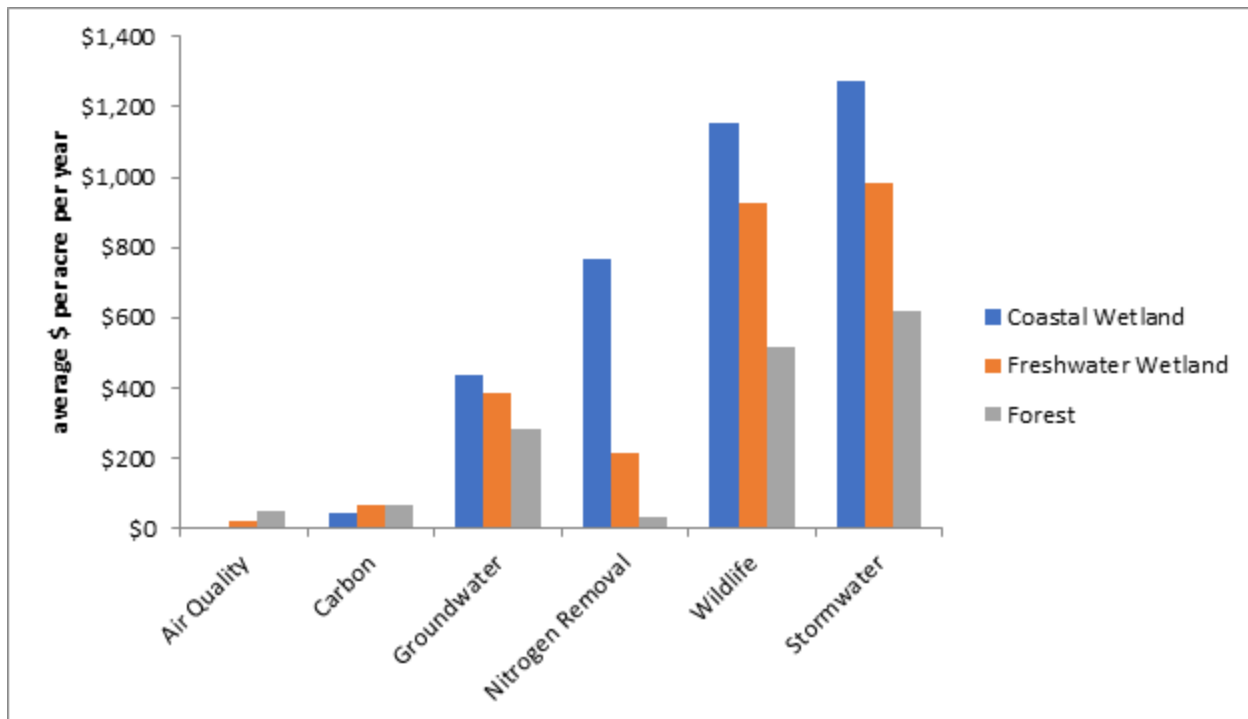


Figure 4. Ecosystem Service Non-Market Value in Maryland.

Enhancement Opportunities

One enhancement opportunity would be the expansion of voluntary, market-based approaches for carbon offsets. Another enhancement opportunity would be to streamline the verification and certification process for existing carbon markets available to Maryland landowners. For example, Maryland landowners can potentially sell offsets on the California Air Resources Board market, the voluntary carbon market or through the Regional Greenhouse Gas Initiative (RGGI). However, given the typical size of forest land held by a landowner, the cost of going through the verification and certification process is not typically worth it. As a result, there have not been carbon credits generated from Maryland sold on these markets. The price of offsets for all three of the aforementioned markets is projected to increase from the current prices ~\$5 (VCS), ~\$7 (RGGI) and \$15 (CA) per Mt of carbon reduction. An increase in price, combined with efforts by NGOs and for profit companies to lower the barrier of entry for smaller forest landowners, could very well allow for participation of many more landowners in these markets. In the mitigation sector, banks for forests and wetlands could prioritize habitat types that have high potential for carbon sequestration, like higher salinity coastal wetlands, forested wetlands, or deciduous forests on productive soils. Generally, increasing investment in conservation and restoration of natural lands, and projects that promote co-benefits, will create a positive trend in ecosystem services provided, including the sequestration of carbon.

Funding

See “Challenges”.

Challenges

Working within the boundaries of currently functioning ecosystem marketplaces for wetlands, forests and habitat presents limited opportunities for generating net carbon reductions. RGGI does allow for carbon emissions offsets to be generated through forest planting or management activities, but at this

time there have not been any offsets generated in this way because they are not currently cost competitive with emission allowances on the RGGI market.

Relevant Information

RESI's 2015 Study estimated that the Ecosystem Markets program, once fully operational, would support a total of – 1,758 jobs by 2020, \$423,431,394 in net economic output and \$358,169,556 in wages over the lifetime of the program. Chapter 6 and Appendix K the 2015 GGRA Update provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

Adaptation, Education, and Outreach

Adaptation refers to action to prepare for and adjust to new conditions, thereby reducing harm or taking advantage of new opportunities¹. Climate change adaptation is an extremely complex process with no single means of response. As stressed in a recent report by the National Academies,² climate change adaptation must be a highly integrated process that occurs on a continuum, across all levels of government, involving many internal and external partners and individual actions, and often evolves at different spatial and temporal scales. Maryland recognizes the need to include robust adaptation and resiliency efforts alongside the aggressive greenhouse gas mitigation (GHG) measures put in place to effectively address and protect the state from climate change impacts. These actions are increasingly dependent on one another and any program or policy to mitigate the effects of climate change will complement steps to reduce the state's risk to those impacts. Mitigation without adaptation, or vice versa, would render Maryland, its people, and resources vulnerable to harm from current and future climate impacts³

Recognizing the critical need for adaptation in addition to mitigation efforts, DNR continued to research, fund, and support adaptation efforts across the state in 2020. Below is a summary of the progress made in the last year on adaptation activities by DNR through funding, capacity support or partnerships. Adaptation efforts included continued support of existing efforts and the expansion of adaptation programming through establishment of new programs or partnerships.

Adaptation Implementation Updates (2020)

1. *Practice and Place*

Adaptation Indicators: Between 2015 and 2020, the state implemented many high-priority elements of Maryland's Phase I and II Adaptation Strategies. In 2020, DNR's Chesapeake and Coastal Services funded the University of Maryland Center for Environmental Sciences - Integration and Application Network (UMCES-IAN) to develop an Adaptation Report Card and indicators to track Maryland adaptation progress. UMCES-IAN in partnership with DNR, the Adaptation & Resiliency Working Group (ARWG), its members, and expertise within their organization, began research, and held a series of stakeholder workshops to research and review existing adaptation metrics, discuss targets and goals of state climate adaptation work, and develop a series of adaptation metrics to track progress towards these goals. The effort faced many challenges in 2020 due to societal response to the COVID-19 pandemic, but UMCES-IAN, DNR and ARWG were able to continue the effort successfully, moving Maryland forward on climate adaptation even in the face of unexpected challenges. When finalized in 2021, the report card will provide high-level synthesis of findings to decision- and policy-makers in order to inform management.

¹ Bierbaum, R., A. Lee, J. Smith, M. Blair, L. M. Carter, F. S. Chapin, III, P. Fleming, S. Ruffo, S. McNeeley, M. Stults, L. Verduzco, and E. Seyller, 2014: Ch. 28: Adaptation. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 670-706. doi:10.7930/J07H1GGT.

² National Research Council. 2010. *Adapting to the Impacts of Climate Change*. National Academies Press, Washington, DC

³ *Climate Change in Maryland: Adaptation*. Maryland Department of the Environment. <https://climatechange.maryland.gov/adaptation/>

Adaptation Framework: Building off past years' efforts, DNR Chesapeake and Coastal Service with Coastal Zone Management funding from NOAA, partnered with the University of Virginia Institute for Engagement and Negotiation to begin the process of evaluating and updating the state's adaptation strategy through the Maryland Climate Adaptation 2030 Framework Project (Framework). The intent of the Framework is to guide and prioritize action over the next 10 years, specifically in vulnerable and under-served communities. In 2020, the team established five sectors: Natural Resources, Natural and Working Lands, Human Health, Water Resources - Quality and Quantity, and Protecting Critical Infrastructure and three focus areas that will be integrated into all of the sectors: Diversity and Environmental Justice, Climate Jobs and Training, and Local Government Action and State Service Delivery. Bringing together over 80 experts from state and local government, and partner organizations, the Framework effort has begun the initial steps towards development of a guiding framework for climate adaptation in the state.

Water Quality and Climate Change Resiliency Portfolio: The Department of Natural Resources (DNR) is in the process of identifying Resiliency Opportunity Zones to define areas with restoration and conservation potential that provide high value resiliency benefits for communities, economies, public lands and important ecosystems. In close coordination with climate affected communities and public/private/non-profit sectors, a portfolio of projects within these zones, solicited through Grants Gateway, will be assembled that work together to avoid random acts of restoration, optimize resiliency benefits and leverage important habitat, water quality and GHG mitigation gains. This approach lends itself to longer budgeting timeframes, beyond a one year cycle, which provides fiscal certainty, and generates new financing opportunities with other partners. In addition, existing state land conservation programs such as Stateside Program Open Space, the Conservation Reserve Enhancement Program (CREP) permanent easements, Maryland Environmental Trust and Maryland's Rural Legacy Programs have the ability to both compliment and, depending on location, permanently protect properties identified for the portfolio of projects in the different Resiliency Opportunity Zones.

Innovative Technology Fund: Expanded the scope of eligible techniques and technologies to include consideration of climate aspects of Innovative Technology Fund project proposals. In addition to nonpoint source water quality projects, the state will also invest in the research, development, and commercialization of solutions addressing climate mitigation to help accelerate the adoption of climate resiliency and GHG mitigation.

Chesapeake and Atlantic Coastal Bays Trust Fund (Trust Fund): Although the focus of the Trust Fund is to support the most effective and efficient non-point source pollution reduction projects, many of these projects also yield climate resilience and mitigation co-benefits. Since its inception in 2009, the Trust Fund has provided more than \$506 million in support of over 2,780 projects, including wetland restoration, stream buffer planting, stream restoration, and

bioretention facilities. Wetland restoration and forest buffer planting practices are very efficient at sequestering carbon. Establishing broad riparian buffers along stream corridors also allows for channel migration resulting from increased precipitation. The Trust Fund prioritizes stream restoration practices that enhance and restore wetlands by reconnecting the stream to its floodplain, which also helps to spread and slow flood waters. Bioretention projects have been identified in federal and state vulnerability studies as a recommended best management practice for water quality improvement, increasing stormwater retention capacity, and tidal flooding resiliency.

Coast Smart Council Construction Program: The Coast Smart Construction Program (Program) and the siting and design guidelines within were updated in 2020 to include an expanded scope and applicability per Chapters 628 and 629 of the 2018 Laws of Maryland and Chapter 442 of the 2019 Laws of Maryland. Additionally, the vulnerable areas within which the Program applies was updated to include areas outside of the Special Flood Hazard Area. This new boundary, the Coast Smart Climate Ready Action Boundary (CS-CRAB), conveys resiliency by adding a vertical extent above the Base Flood Elevation and is currently the most technologically feasible and accurate approach to achieve resiliency within the scope of the Coast Smart Program. The Coast Smart Project Screening Form provides projects with a form to use when applying the Program requirements. The screening form and additional information can be found at the Coast Smart Councils website - https://dnr.maryland.gov/climateresilience/Pages/cs_Council.aspx

Community Resilience Grants/Resiliency through Restoration: DNR solicited and funded community-based resilience projects in 2020 through the Community Resilience Grant Program. The program leverages federal dollars with state “Resiliency through Restoration” capital funding to promote and support comprehensive, holistic planning and implementation projects that address both water quality and quantity issues. Through these projects, DNR is helping Maryland communities become more resilient to flood risks, and enhance the protection and management of the state’s resources including the bay and the ocean. Projects funded in 2020 included risk reduction planning in Princess Anne, Calvert County, Talbot County, Dorchester County, Montgomery County and Cecil County, and implementation projects in Anne Arundel and St. Mary’s counties. This work continues a decade-long effort to provide support to local communities to assess risk, plan risk-reduction efforts and implement projects.

Resiliency and Land Conservation: In 2020, the Stateside Program Open Space scorecard, used to evaluate potential acquisition of properties for their coastal community resilience to climate change benefits, continued to provide the ecological, resiliency and management justifications for the Board of Public Works. These benefits are provided by areas along the shoreline where natural habitats, such as marshes and coastal forests, have the potential to reduce the impact of coastal hazards to the adjacent coastal communities by dampening waves, stabilizing sediment and absorbing water. Board of Public Works approval of these acquisitions allows our land

conservation programs - Stateside Program Open Space, the Conservation Reserve Enhancement Program (CREP) permanent easements, Maryland Environmental Trust (MET) and Maryland's Rural Legacy Program - to permanently protect land that provides coastal resilience to climate change as well as land important for priority wetlands to migrate inland as sea level rises.

Maryland's Parcel Evaluation Tool: As a compliment to the Stateside Program Open Space scorecard, DNR also developed a public-facing, web-mapping tool which allows for rapid valuation and comparison of parcel level ecological benefits and values provided by Maryland's natural resources. The Parcel Evaluation Tool - accessible through the Maryland Greenprint Map - can be used to support stateside land conservation in all of the programs mentioned above as well as to support the activities of external conservation partners. The tool generates an instant report, that includes an Ecological Benefits Assessment and an Economic Co-Benefits Assessment. Among the Ecological Benefits assessed are the Coastal Community Resiliency and Future Wetland Habitat scores. The Coast Community Resiliency score describes the potential of a parcel's existing natural habitats, such as marshes and coastal forests, to reduce the impact of coastal hazards to adjacent coastal communities. The Future Wetland Habitat score identifies areas important for inland wetland migration resulting from sea level rise that will support high value coastal habitats of the future. Among the ecological co-benefits assessed are the parcel-level biophysical and economic values of annual Net Carbon Sequestration in forests and wetlands. Carbon sequestration directly offsets carbon emissions within the state of Maryland and represents a critical component to the GGRA work plan. This component of the tool allows for identification and conservation of natural habitats providing high carbon sequestration benefits.

Utilizing Continuous Monitoring and Adaptive Control (CMAC) Retrofits for Flood Control in Howard County: CMAC systems have been installed by several Maryland counties in order to provide cost-efficient water quality management in compliance with Municipal Separate Storm Sewer System (MS4) permit requirements. However, these systems can also be used to provide water quantity management and reduce flood hazards. DNR provided funding support to Howard County to evaluate the use of CMAC technology to meet both water quality and flood risk management goals. The County partnered with OptiRTC, Inc. to assess the County's existing stormwater assets as well as the locations of its flood vulnerabilities in order to develop a prioritization methodology for selecting ponds to be retrofitted with the technology. It also analyzed the water quality and quantity benefits that would be achieved by retrofitting several priority ponds and developed conceptual plans for three priority pond retrofits.

Beneficial Use of Dredged Material: In 2020, DNR finalized a policy and supporting processes to proactively identify environmentally and economically sound beneficial use of dredged material practices to improve coastal resiliency. Through the development of a mapping tool - Beneficial Use: Identifying Locations for Dredge (BUILD) - project managers will be able to

quickly identify beneficial use opportunities. BUILD has been merged into the Maryland Coastal Atlas where the data is now available.

Clean and Resilient Marinas: The Maryland Clean Marina Initiative continues to provide extensive climate change and severe weather resiliency information to marinas via workshops, on line, and via newsletters. Updated resources related to adaptation and resiliency have also been added to the Maryland Clean Marina website:

<http://dnr.maryland.gov/boating/Pages/Hurricane-Storm-Preparations.aspx>

Climate Change and Chesapeake Bay Restoration: In 2019, Maryland's Phase III WIP to reduce nutrients and sediment entering the Chesapeake Bay devoted a chapter to climate change. The plan identifies nutrient and sediment control strategies that can both help mitigate the increase in GHGs and adapt to anticipated climate impacts. The Plan acknowledges Maryland's role in helping to understand how nutrient control practices might be impacted by climate change. It also affirms Maryland's partnership with the Chesapeake Bay Program to estimate the effects of climate change on future nutrient and sediment loads to the Bay by March 2021 and to account for any projected climate-induced increase in pollutant loads beginning in September 2021.

Maryland Park Service (MPS) Strategic Management Planning: MPS is actively engaged in a methodic park-by-park strategic management planning effort. These plans identify specific threats to park resources (such as storm-related flooding) and identify tasks to address those threats. An example can be found here:

https://dnr.maryland.gov/publiclands/Documents/Smallwood_StrategicMmgtPlan.pdf

Building resilient landscapes - MPS is working with Land Acquisition and Planning and Chesapeake and Coastal Service staff to identify marginal agricultural lands on Park properties that can be converted to more resilient, natural landscapes such as wetlands, meadows and forests. This has resulted in the protection of sensitive resources (e.g., hydric or highly erodible soils) while also improving park aesthetics and addressing identified erosion concerns.

EV Charging station placement: MPS has facilitated the installation of electric vehicle charging stations as part of larger park improvement projects at several locations around the State. MPS is also working with DNR leadership to identify numerous additional locations to add EV charging facilities at DNR properties in partnership with various utility companies.

Energy upgrades at existing park buildings: Two parallel efforts are being made to improve energy efficiency at existing park facilities. First, all park sites are being analyzed for the potential installation of solar panels on existing park buildings. A successful installation at Sandy Point State Park is documented here: <https://news.maryland.gov/dnr/2018/01/29/energy-efficient-upgrades-completed-at-sandy-point-state-park/>. In addition, MPS is working with the

Maryland Energy Administration to conduct energy audits of existing park facilities that will examine everything from HVAC systems to light fixtures. Wherever possible, inefficient fixtures or equipment will be replaced.

Targeted climate change acquisitions: In recognition of the increasing frequency of flooding and storm events and the resulting impacts on park operations and visitors, MPS is working with Land Acquisition and Planning to identify potential sites for relocating popular campgrounds and day use areas if the time comes where "retreat" is the only viable option. While some level of further investment in existing facilities are likely, catastrophic storm events are not out of the realm of possibility. Planning ahead and ensuring sites meet the needs of our visitors will make such retreat possible.

Nuisance Flood Plan Guidance: After the publication of the Nuisance Flood Plan Development Guidance in October of 2019, DNR and MDP received nuisance flood plan (NFP) from nine coastal counties and Baltimore City and have three pending submissions. DNR, MDP and MEMA have collaborated on the review of all the plans submitted.

9.4.2 Community Engagement and Communication

2020 Mid-Atlantic Climate Change Education Conference: The Mid-Atlantic Climate Change Education Conference (MACCE) was a unique convening of formal and non-formal educators to share and learn about the latest trends in climate change education. Due to COVID-19, the MACCE Conference was hosted virtually on June 29-30. There were four session tracks for the conference: Environmental Justice & Climate Change; Climate Change in the Classroom; Climate Change & Estuaries; Individual & Community Level Climate Change Solutions. The conference was made possible through partnership and collaboration with the following agencies: CBNERR-MD, National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Office, DE Sea Grant, DE NERR, CBNERR-VA, Goucher College, PA Sea Grant, NJ Sea Grant, and VA Sea Grant. Funding through SeaGrant made the conference fee affordable to participants (\$20).

Teachers on the Estuary: The 2019 & 2020 Teachers on the Estuary (TOTE) teacher professional development opportunities offered through a partnership with CBNERR-MD, Chesapeake Bay Foundation, and NOAA Chesapeake Bay Office made the curriculum come alive with real data collected by both students and environmental science professionals from throughout the watershed to address real questions (often including climate change or change over time). Participants from throughout the watershed learned to integrate local and national environmental data into the classroom through cross-disciplinary, hands-on field activities, and online resources. This dynamic online course reinforces confidence in learning outside through conducting investigations of participants' local environments. Investigations were

supported/facilitated by community leaders, scientists, and educators from NOAA and the CBNERR. This course is designed to model a Meaningful Watershed Educational Experience (MWEE) through participant-driven field experiences and authentic research. In 2020, TOTE was conducted remotely, incorporating outdoor, inquiry-based investigations in participants yards and communities.

Shoring Up Resiliency Through Education (SURE): This project aims to support Somerset County Public Schools in addressing regional vulnerability to climate impacts and community resilience through understanding how environment, science and cultural heritage work together to strengthen a community. Students in fifth, seventh and ninth grades experience, study and understand trends in local conditions such as weather and water quality that affect the natural resources upon which much of their local economy depends. Participating teachers receive professional development annually, through which they are supported in writing lessons to support this project. In 2020, professional development focused on how to create a virtual field trip, so that students would still be able to participate in their SURE activities to understand what it means to be a resilient coastal community. Partners include the Maryland Department of Health, Chesapeake Bay Trust, and Somerset County Public Schools.

Maryland's Climate Leadership Academy: Maryland's Climate Leadership Academy (Academy) is the nation's first state-sponsored institution providing continuing education and executive training programs specifically designed for state and local government officials, infrastructure executives and business leaders. Through extensive partnerships and guidance from a body of Maryland leaders and nationally recognized experts, the Academy's programming is coordinated with universities and community colleges throughout the state, as well as other convening organizations, to deliver training programs statewide. In 2020, over 250 individuals took part in training or educational opportunities that the Academy offered. The Academy was successful in transitioning to an all online operation to continue providing necessary training to professionals in Maryland during the public health response to COVID-19.

Maryland Marine Debris Emergency Response Plan: NOAA's Marine Debris Program staff led the planning and preparation of an emergency marine debris response plan for Maryland. The plan's goal is to improve preparedness for response and recovery operations following an acute waterway debris incident in coastal Maryland. As severe weather events become more frequent, the plan will allow better communication and clarify responsibilities and capabilities among agencies.

Maryland Forest Service: The Maryland Forest Service with other partners - including the US Forest Service, UMCES and Extension - released topic-related fact sheets and technical guidance on woodland and climate change stewardship principles. The Forest Action Plan for 2016-2020 now includes the strategy 'Make Landscapes More Resilient to Climate Change' to help guide

forest management on state and public lands.

http://dnr.maryland.gov/forests/Documents/2015_DRAFT_percent20_ForestStrategyUpdate.pdf
http://extension.umd.edu/sites/extension.umd.edu/files/_docs/programs/woodland-steward/MD_Climate_Adaptation_Guide_for_Forest_Landowners_2013.pdf

Communicating Risk to the Public: DNR staff engaged audiences throughout the year regarding climate communication, including during the Eastern Shore Land Conservancy's Culture and Climate Change Conference where staff presented Communicating About Climate Change With Confidence to approximately 125 individuals. Staff also participated in conferences for teachers, including the Maryland Association for Environmental and Outdoor Education (MAEOE) where staff presented lessons for understanding climate and Next Generation Science Standards. Partners included NOAA, Audubon Maryland-DC and Partners Advancing Climate Change Education.

9.4.3 Advancing the Science

Climate Sensitivity Study: DNR, in partnership with NCCOS, UMCES, Chesapeake Environmental Communications and the CBNERR, analyzed climate data from the NERR locations and the National Weather Service. By examining 114 years of meteorological data, the team found clear evidence that physical climate changes are well underway and that species and habitats are responding to those changes. This study provides localized impact data which can inform how we manage our natural areas on a watershed scale. For more information, visit: <http://www.chesapeakeedata.com/changingchesapeake/>

Thin-layer Sediment Placement: Evaluating an Adaptation Strategy to Enhance Coastal Marsh Resilience: The department is a participating investigator in a NERR Science Collaborative Grant aimed at gathering data to inform thin-layer placement as a restoration technique to promote marsh resilience in the face of sea level rise. Through this project, replicated restoration experiments are being conducted at several reserve sites across the nation, with the purpose of examining the effectiveness of thin-layer sediment placement as a marsh adaptation strategy. Novel aspects of the project include the broad distribution of sites, the examination of the effectiveness of thin-layer sediment placement at different marsh elevations, a standardized monitoring protocol and the incorporation of biochar (carbon material produced through the conversion of biomass in an oxygen limited environment) to improve soils and plant health. Monitoring guidance developed as part of this study is now being used to inform a marsh enhancement project with the Army Corps of Engineers on the Deal Island Wildlife Management Area.

Margaret A Davidson Fellowship: The Margaret A. Davidson Graduate Fellowship is a new fellowship program that places a graduate student in each of the 29 NERRs to address key coastal management questions through cross-discipline research projects. CBNERR welcomed Daniella Hanacek as the 2020-2021 fellow. Daniella will be working to assess wetland condition

and management actions for Maryland's tidal wetlands through a project evaluating the carbon sequestration potential of natural and restored tidal marshes in Chesapeake Bay.

Her research with the reserve is focused on quantifying atmospheric methane and carbon effluxes from Chesapeake Bay marshes, which can then be used in combination with plant productivity and carbon burial rates to estimate the net amount of carbon sequestered by these marshes. Information generated on the role of Maryland's tidal wetlands in capturing carbon will inform future climate mitigation strategies through the conservation and restoration of blue carbon ecosystems.

Ecological Effects of Sea Level Rise: DNR partnered with George Mason University and The Nature Conservancy to launch Maryland's Ecological Effects of Sea Level Rise Project to monitor and model the wave attenuation and flood reduction benefits of marshes, seagrass and other nature-based features. This three-year project will quantify the protective services of Maryland's natural features and investigate how those services may change as sea levels rise. Wave, water level, and current sensors were deployed in the summer of 2020 and the department engaged state, federal and local partners through a Management Transition Advisory Group. This study expands on previous monitoring conducted in Somerset County and will assist managers with identifying restoration needs and priorities in areas where natural features can enhance community resiliency to climate change impacts.

Future Projections of Rain Storm Intensity: Climate change is expected to cause more extreme precipitation events in the future. To know whether or how to adapt regulatory permits for stormwater management, sediment and erosion control and waterways construction (culverts and bridges that span streams) it's necessary to have a better sense of how climate change will affect the intensity, duration and frequency (IDF) of rain storms. A research project that will help provide useful information to these considerations is a State-funded Restoration Research Grant that was awarded to a consulting firm in 2019 to estimate potential precipitation IDF curves at 79 Atlas 14 sites across Maryland for mid-century (2055) and late-century (2085). This study also analyzed how peak runoff rates may change in the future, and applied those results to evaluate the potential impact on certain types of urban stormwater controls, stream stability and roadway flooding associated with culvert sizing. The deliverables of this research project are fueling discussion among scientists, engineers and the regulatory community about how the research results can appropriately be applied to State programs and what next steps are needed to continue learning about these trends. <https://cbtrust.org/grants/restoration-research/>

Resource Assessment Service Monitoring: Based on climate change projections, Maryland's streams are likely to become warmer and the flows are likely to become more extreme. Some coastal streams could also become inundated as a result of sea level rise. These changes may alter the ecology, water quality and physical habitat of streams. The Maryland Biological Stream Survey (MBSS) tracks trends in factors such as aquatic species distributions, water temperature

and erosion that are indicators of potential climate change influences on Maryland's streams. Based on temperature and species distribution information, the MBSS has also specifically identified stream animals that prefer cold water and, as a result, may be particularly sensitive to stream temperature increases. Detailed stream temperature information from the MBSS may also help identify streams with particularly cold water and thus are likely to be resilient to temperature increases.

In addition to representative sampling of Maryland's streams, the MBSS has been monitoring 29 "Sentinel" streams since 2000 to specifically examine for potential influences of factors such as climate and weather on Maryland's stream ecology, temperature, water quality and physical habitat. For more information -

<http://dnr.maryland.gov/streams/Publications/2014SentinelSiteReportWEB.pdf>



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