



**Governor's Commission on Climate Change
Adaptation and Sequestration Workgroup**

**Revised Draft Recommendations
10/10/2008**

The Adaptation and Sequestration Workgroup of the Governor's Commission on Climate Change was charged with identifying what Virginia needs to do to prepare for the likely consequences of climate change. The Workgroup was also charged with developing recommendations on sequestration by natural systems.

Membership

The Honorable Joseph Bouchard (chair), The Reverend Richard Cizik, The Honorable John W. Daniel, II, The Honorable R. Creigh Deeds, Mr. Dale Gardner, The Honorable Penelope A. Gross, Mr. Michael L. Lipford, Dr. Roger Mann, Mr. William A. "Skip" Stiles, and The Honorable Frank Wagner.

Introduction

The goal of a comprehensive policy response to the challenges posed by climate change is to reduce emissions to mitigate the extent and severity of climate change impacts. There is a broad scientific agreement that even if we were able to dramatically reduce emissions immediately, human-induced climate change will continue to intensify through 2030 (IPCC, May 2007, p. 4). Several recent national and international climate change reports, including the Intergovernmental Panel on Climate Change's Fourth Assessment Report, recognize the urgency to address the causes and potential consequences of climate change. As noted in the Stern Review Report on the Economics of Climate Change (2006), "adaptation is the only response available for the impacts that will occur over the next few decades before mitigation measures can have an effect." Therefore, a plan for adaptation to these impacts represents an essential component of any climate change response.

Governor Kaine recognized the need for adaptation as a key component of the Commonwealth's response when he established Virginia's Commission on Climate Change under Executive Order 59 (2007). Among several other responsibilities, the Commission was charged with developing adaptation plans that would evaluate the expected impacts of climate change on Virginia's citizens, natural resources, and economy; and identify what Virginia needs to do to prepare for the likely consequences of climate change.

The Adaptation and Sequestration Workgroup under the Governor's Commission on Climate Change addressed expected impacts of climate change and developed the

recommendations included in this report. For our purposes, adaptation was defined as the following:

Actions taken or decisions made in response to actual or expected climate changes to society, ecology, or economy. Adaptation decreases vulnerability, or increases resilience to impacts.

In terms of sequestration, this workgroup concentrated only on sequestration by natural systems, such as forests and wetlands.

Based on expert testimony before the Commission, Virginia is likely to experience a number of serious impacts to its economy, infrastructure, natural systems, and public safety, including, threats posed by rising sea levels, increasing temperatures, and more volatile weather conditions.

Framework for Adaptation Planning

The Adaptation and Sequestration Workgroup members identified planning targets to establish an adaptation framework for Virginia. These targets for changes in sea level rise, temperature, and weather patterns drove the development of our recommendations. After reviewing several sources of information and predictions, the workgroup members decided to use estimates provided in the recent Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) report, “Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations” (Pyke, *et al*, 2008) because of its regionally-specific nature. The authors of the STAC report reviewed literature and several model runs to identify current projections specifically for the Chesapeake Bay region.

The full range of sea level rise expected throughout the Chesapeake Bay region was estimated to be between 2.3-5.2 feet. Air and water temperatures are projected to increase 3.6-10.8° F. In regards to precipitation and weather patterns, the STAC report states that, “Also likely, although less certain, are increases in precipitation amount (particularly in the winter and spring), precipitation intensity, and intensity of tropical and extratropical cyclones (though their frequency may decrease), and sea level variability. The greatest uncertainty is associated with changes in annual stream flow, though there is some confidence that winter and spring flows will increase.”

The Importance of Sequestration

A related and equally important responsibility of this workgroup was to examine the role that natural sequestration could play in both reducing atmospheric concentrations of CO₂ and how protecting or enhancing those sequestration opportunities might complement the Commonwealth’s overall climate change strategy.

A common definition of sequestration is, “Opportunities to remove atmospheric CO₂, either through biological processes (e.g. plants and trees), or geological processes through storage of CO₂ in underground geologic reservoirs.” For the purposes of its discussions

and subsequent recommendations, the workgroup concentrated only on sequestration through biological processes or by natural systems, such as forests and wetlands.

Recommendations

Adaptation recommendations are grouped into five areas: Overall Strategy, Natural Resources, Economy and Infrastructure, Health and Society, and Cross-Cutting.

A number of adaptation recommendations are provided in this report, but the workgroup did not attempt to catalogue all the adaptation measures that may be required in the years ahead. Thus, these recommendations should not be viewed as a comprehensive list; rather, they should be viewed as a starting point for state and local government agencies, boards and commissions, and regional commissions and authorities, to develop detailed adaptation plans.

Overall Strategy

Virginia should plan for:

- A 3.6 degree Fahrenheit increase in air temperature by 2100.
- A 2.3 foot rise in sea level by 2100.
- Increases in precipitation and intensity of severe weather events, and increasing instability of weather patterns that could cause difficult to predict periods of drought and intense precipitation.

Virginia should establish a program to closely monitor and assess trends in these climate change effects, adjust projections based on additional data and new scientific findings on climate change, and revise state adaptation policies accordingly. Such monitoring and assessment is critical to avoid either underestimating the impact of climate change and taking insufficient action to adapt to it, or overestimating the impact of climate change and implementing unnecessary or excessive adaptation measures.

These recommendations apply to all state and local government agencies, boards and commissions, and regional commissions and authorities, including but not limited to Planning Districts, Metropolitan Planning Organizations, Transit Authorities, Sanitation Districts, and other organizations responsible for regional planning, management of public utilities, transportation or other infrastructure, or providing public services. Private sector organizations are strongly encouraged to incorporate these recommendations into their planning, investment and operations.

Natural Resources

Protect and Enhance Virginia's Natural Carbon Sinks.

Virginia's forests, wetlands, farmland, and other undeveloped open space lands play an important role in removing CO₂ from the atmosphere. Vegetation on these lands absorbs carbon dioxide during photosynthesis and stores it as carbon within biomass, both above and below ground. Some of this carbon is recycled fairly quickly (much of the carbon absorbed by leaves, for example, is returned to the atmosphere via decomposition) but

millions of tons of carbon are stored for far longer periods in woody biomass and within soils rich with organic material. Recent studies indicate that even very old forests provide a net sink for carbon, meaning that while rates of sequestration differ, all Virginia forests likely represent a net sink for carbon emissions.

To date, most research on natural sequestration has focused primarily on forest systems. The Department of Forestry's Forest Inventory Assessment estimates that Virginia's forests sequester approximately 23.5 MMTe (million metric tons equivalent) of carbon dioxide each year. We currently know far less about the sequestration capacities of lands such as wetlands and farmlands.

What we do know is that Virginia is, on average, currently losing more than 50,000 acres of land to development every year, including roughly 27,000 acres of forestland and 25,000 acres of farmland. When that land is converted to developed uses, its ability to sequester carbon is greatly diminished, if not lost altogether. Thus, unless we can stop and reverse the current trends in forest, farmland, and open space in Virginia, atmospheric carbon dioxide removed through sequestration will decrease over time, and it will be more difficult for the Commonwealth to meet its emission reductions overall.

Wetlands provide carbon sequestration options as well, although they are not as well studied as forest lands. The US Global Climate Change Research Program cites estimates that wetlands currently could hold 35% of the terrestrial carbon. Non-tidal, fresh wetlands also emit methane and CO₂, which complicates the calculation of net sequestration of carbon. However, tidal wetlands have different biochemistry and, according to one research paper, "could be more valuable C sinks per unit area than other ecosystems in a warmer world." (Choi and Wang, 2004). Unfortunately, Virginia through at least 2006 was still experiencing a net loss of its tidal wetlands (DEQ, 2008).

Virginia's tidal wetland inventory, providing detailed information on wetland types and location, is too badly out of date to provide a suitable basis for determining the total amount of carbon sequestered by tidal wetlands. The Virginia Institute of Marine Science Center for Coastal Resources Management has historically conducted the Tidal Marsh Inventory and complimentary shoreline inventories for Virginia. Their updates stopped in the early 1990's due to lack of funding. They are conducting many of these services for Maryland and restarting them in Virginia would provide a consistent set of data for the Chesapeake Bay. National inventories, including the National Wetlands Inventory by the US Fish and Wildlife Service, are similarly out of date and often contain many inaccuracies due to issues of scale.

Recommendations

- Virginia needs high resolution statewide land cover data to accurately assess the land use status over time. This data is critical to quantify Virginia's land cover categories and to identify large natural sequestration areas (forests, wetlands, agricultural lands, parks and other open space, etc.) in Virginia and monitor their change over time. The Department of Conservation and Recreation, Virginia Geographic Information Network, Department Of Forestry, Department of Game and Inland Fisheries, and Virginia Institute of Marine Science should work together to develop database criteria and to pursue federal or other funding

sources for this data. Collection and compilation of this statewide land cover data should be completed by January 13, 2010 to establish a baseline inventory of natural carbon sequestration areas. This inventory of natural carbon sequestration areas should be updated annually based on data reporting by state and local agencies, and a comprehensive survey should be conducted every four years to validate the accuracy of the inventory.

- Establish a ***no net loss*** policy for natural carbon sequestration areas based on the 2010 baseline. In order to achieve progress on a goal of no net loss of natural carbon sinks, the Commonwealth should set ambitious goals to protect forests, wetlands, and farmland to maximize protection of natural carbon sinks. Particular focus should be given to large blocks of functional forest, wetlands and farmland that not only sequester carbon but demonstrate multiple economic and ecologic benefits. Existing Federal, state and local government programs for preservation of forests, farmland, wetlands and open space should be used to the maximum extent possible in implementing this no net loss policy. Current efforts to promote consumption of agricultural products grown in Virginia, such as the Virginia Farm Bureau Federation's "Save Our Food" campaign, should be sustained and expanded in order to support the economic viability of Virginia's farms and help preserve farmland for carbon sequestration.
- Both the Virginia Department of Conservation and Recreation and the Virginia Department of Game and Inland Fisheries have established planning documents (ex. Natural Heritage Plan and the Wildlife Action Plan) that identify important habitat types, specific habitat sites, areas important for maintaining biodiversity, and conservation actions needed to conserve all of Virginia's wildlife and native habitats. Areas and conservation actions identified within these plans should be given priority protection measures to ensure that they are preserved for sequestration and ecosystem values. In order to fully implement Virginia's Wildlife Action Plan, the Department of Game and Inland Fisheries would require an additional \$3.5 Million per year over the next 7 years. This money would be used to implement "on the ground" conservation projects, support baseline research, and enhance efforts being made by conservation partners.
- Working with federal, state, industry, non-profit and academic partners, Virginia should invest in and catalyze research on (a) the current carbon sequestration rates and total capacities of forestland, farmland, wetlands and other open space; and (b) how those capacities may change over time. This research will provide a quantitative basis for recognizing emission reduction benefits associated with land conservation and management policies and to further the development of best practices.
- Given the potential of tidal wetlands to sequester carbon in large amounts, special research needs to be conducted on the sequestration rate of Virginia's tidal wetlands. In addition, Virginia needs an updated wetlands inventory as part of this sequestration database work. The Virginia Institute of Marine Science's Center for Coastal Resources Management has historically conducted the Tidal Marsh Inventory (that is now over eighteen years old) and complimentary shoreline inventories for Virginia. Their updates stopped in the early 1990's due to lack of funding. They are conducting many of these services for Maryland however, and beginning them again in Virginia would provide a consistent set of

- data for the Chesapeake Bay. National inventories, including the National Wetlands Inventory by the U.S. Fish and Wildlife Service, are similarly out of date and often contain many inaccuracies due to issues of scale. There may be opportunities for federal financial assistance or data collection to help with this recommendation.
- Using information from the inventory of natural carbon sequestration areas and the sequestration research outlined above, the Commonwealth should develop a ***natural sequestration carbon crediting system***. This would provide carbon credits for permanent increases in the area available for natural carbon sequestration above the 2010 baseline, or for increasing the carbon sequestration rate and total capacity of existing or new natural sequestration areas, such as through reforestation, restoration of wetlands or adoption of farmland management practices enhance carbon sequestration. Such a crediting system should assure that forest or other land-based carbon credits are of high quality by requiring that such credits represent real, permanent, and verifiable emissions reductions, with reliable measuring and monitoring and appropriate accounting for leakage.
 - The Commonwealth should use information from its database and the research outlined above on sequestration capacities of Virginia lands to seek certification by the Voluntary Carbon Standard (<http://www.v-c-s.org/index.html>) or a similar program for carbon storage and sequestration projects (including forest conservation, afforestation, reforestation, and other working forest and agricultural lands management). Such a certification provides quality assurance by ensuring that offsets are real, additive (beyond business-as-usual activities), measurable, permanent (not temporarily displaced emissions), independently verified, and unique (not used more than once). Project certification will provide immediate benefits for landowners seeking to participate in existing carbon trading markets and will position Virginia to take full advantage of the much larger and more lucrative carbon market that is very likely to develop following passage of federal climate change legislation.
 - Issues regarding permanence of the carbon sequestered could be addressed using the Chicago Climate Exchange approach that withholds a set percentage of agricultural and forestry generated-carbon credits as ‘insurance’ against unanticipated carbon losses. The Commonwealth should pursue integration of its own natural sequestration carbon crediting system with current or future programs of this nature at the Federal or regional level. Virginia should be proactive in shaping the development of Federal climate change policies to ensure that future efforts to reduce greenhouse gas emissions, such as a cap-and-trade system, incorporate a natural sequestration carbon crediting system.
 - Recognizing that enhanced land management activities can both decrease emissions associated with certain agricultural practices and increase the sequestration capacities of agricultural lands, the Virginia Department of Agriculture and Consumer Services, the Department of Conservation and Recreation, and local Soil and Water Conservation Districts should vigorously promote increased adoption of high-priority agricultural best management practices that reduce agriculture’s fuel and fertilizer consumption and associated greenhouse gas emissions, and that provide methods for increasing carbon

sequestration on Virginia's agricultural lands. The Virginia Department of Conservation and Recreation and the local Soil and Water Conservation Districts should serve as the lead agencies. Furthermore, Department of Conservation and Recreation and Soil and Water Conservation Districts can only promote agriculture best management practices as long as they have sufficient cost share and technical assistance; therefore, the Virginia General Assembly should provide adequate and consistent funding to implement this recommendation. This recommendation would serve multiple goals including reducing non-point source pollution to Virginia's streams, rivers and the Chesapeake Bay. Further justification of this recommendation is provided in Appendix A, "Greenhouse Gas Reduction Opportunities Associated with Achieving Virginia Tributary Strategy Agricultural Best Management Practice Adoption Goals."

Conserve Priority Species and Habitats

The Commission heard from several experts regarding projected climate impacts to ecosystems and species. Virginia is likely to see species range shifts (both in and out of our state), local extinctions, and habitat loss. Many new exotic or invasive species may move into Virginia. Exotic species are typically opportunists that can readily adapt to a wide range of conditions, and out-compete native species. Another concern is that pest species (e.g., emerald ash borer, gypsy moth, and pine beetles) may flourish under changing conditions and cause much more widespread damage than they are now.

Coastal wetlands and shallow water systems are vital to the health of the Chesapeake Bay, and some of the most at risk from climate changes. Tidal wetlands support a variety of plant and animal species, including many commercial fisheries species. These habitats face existing stresses, including habitat loss and pollution. Climate changes, particularly sea level rise, will further threaten these essential habitats as they become 'squeezed' between rising water and our built environment.

It is unclear how climate change will ultimately affect Virginia's wildlife and wildlife habitats. While some species may become extirpated or extinct, a changing climate may allow other species to establish themselves within the Commonwealth. It is likely these changes will force agencies to deal with issues that have no legal, administrative, or management precedents. As issues arise, it may be necessary to review the responsibilities and authorities described within Virginia's wildlife laws and regulations.

Following an August 2005 heat wave, more than 15,000 acres of underwater grass (eelgrass) died in the lower Chesapeake Bay. Much of this has yet to return, which has had negative consequences on water quality and fisheries habitat. Rising air and water temperatures will mean that many of our native species of plants and animals may no longer be able to survive in the Chesapeake Bay.

As illustrated above, the challenges climate change poses to Virginia's wildlife populations and our forests, wetlands, rivers, beaches, and other natural systems are severe. One principle emerging in the study of adaptation responses is that the species and ecosystems most likely to be able to adjust to disturbances or changes in their environment are those that are healthy and intact to begin with. For this reason, a cornerstone

of Virginia's adaptation strategies for wildlife and natural habitats should be to conserve and enhance its most viable, important, and resilient lands and waters.

Recommendations:

- The Virginia Institute of Marine Science should assess the vulnerability of living resource restoration efforts to climate change, particularly those for oysters and submerged aquatic vegetation, to climate change and recommend specific steps to increase the likelihood of success under changing conditions.
- The Commonwealth should direct the Virginia Department of Conservation and Recreation and the Virginia Department of Game and Inland Fisheries to develop a process documenting climate change impacts on native species and ecosystems, building on the work in progress by NatureServe and DCR's Division of Natural Heritage to develop a Climate Change Susceptibility Rank. This process should (1) identify those species and ecosystems most vulnerable to climate change; (2) identify populations most susceptible to near-term (less than 10 years) extirpation due to climate change; (3) forecast future (10, 25, 50, and 100 years) species distributions for Virginia's species of greatest conservation needs; (4) identify key sites and corridors essential for maintaining ecosystem resilience, using tools such as the Virginia Conservation Lands Needs Assessment and Virginia's Wildlife Action Plan; and (5) develop recommendations regarding how to prioritize and implement actions that could be used to respond to these changes. The recommendations should address measures for preserving Virginia native species when feasible under conditions of climate change; and promoting introduction of beneficial, native American species suitable for warmer climatic conditions, while preventing the spread of invasive and nuisance species that would be harmful for Virginia's natural resources.
- Using Virginia's Natural Heritage Plan and Virginia's Wildlife Action Plan to identify critical conservation areas, Virginia should implement a statewide effort to conserve 15% of these areas by 2015 and 50% of these areas by 2025. This effort should utilize an assortment of management tools including education, financial incentives, appropriate regulations, and additional state investments. It is also possible that additional Federal resources could become available to support this effort.
- The Secretary of Natural Resources should direct state agencies and universities to work with federal partners (National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, U.S. Geological Survey, and US Environmental Protection Agency), neighboring states, and regional non-profits to develop regional adaptive resource management plans that incorporate climate change impacts.
- Reduce the loss of critical natural habitats and native species by incorporating data from the Virginia Natural Heritage program, the Department of Game and Inland Fisheries, and other information as appropriate as a factor to consider in biomass conversion incentive programs for agricultural and forestry based biomass production, and alternative energy facility development planning.
- The Virginia Marine Resources Commission should be provided statutory authorities to require implementation of the no net loss policy for natural carbon

sequestration areas in coastal areas by taking climate change effects such as sea level rise into account when reviewing permit applications. Specifically, the Commonwealth should adopt a policy of increasing coastal resiliency and preventing development practices, such as hardening shorelines or building retaining walls that would interfere with the natural process of tidal wetlands migrating inland as sea level rises.

Water Quality Management

A changing climate will impact Virginia's water quality and aquatic resources. Detrimental impacts will result from increasing water temperature, sea level rise and altered intensity and frequency of precipitation. Scientists involved in restoration of the Chesapeake Bay and protection of inland (fresh water) rivers and streams have concluded that eliminating human-caused "stressors," such as introduction of pollutants and harmful nutrients into the Chesapeake Bay and Virginia's rivers and streams will be important for mitigating the negative impact of climate change on native aquatic species. That, in turn, is important for preventing serious degradation of commercial and recreation fisheries, particularly crab and shellfish harvests. The Commonwealth must begin to incorporate information about the impacts of changing climatic conditions into analyses and decision making regarding ecosystem protection and restoration.

While the scope and complexity of the climate change challenge will require new ideas, new investments and new approaches, Virginia already has a number of strong and effective environmental statutes and programs. Additionally, implementation of many of these adaptation recommendations will complement many of the Commonwealth's existing goals and commitments, such as those for land conservation and water quality. Full advantage should be taken of opportunities to utilize existing state programs in lieu of creating new state programs. This will require ensuring that existing state programs are appropriately staffed and funded and that their authorities include consideration of climate change impacts.

Recommendations

- The Virginia Department of Environmental Quality should incorporate assessment of the current and potential impact of climate change on in stream flow into the state water resources plan (§ 62.1-44.38:1) and evaluate the impact of climate change induced alterations in stream flow on in-stream beneficial uses when assessing a Virginia Water Protection Permit (§ 62.1-44.15:20) application.
- The Virginia Department of Environmental Quality should amend the comprehensive water supply planning regulation (9 VAC 25-780) to require that localities or regional planning units assess the potential impacts of climate change on existing or proposed water supplies.
- Stormwater management calculations must also take into account anticipated changes in precipitation associated with climate change in the Mid-Atlantic region. Stormwater regulations currently under development would require calculations to be based on 1-year, 2-year, and 10-year 24-hour storms using site-specific rainfall precipitation frequency data recommended by the U.S. National Oceanic and Atmospheric Administration (NOAA) 1200 Atlas 14; however, stormwater management infrastructure constructed under these calculations may prove inadequate if precipitation patterns change as they are expected to do. The

Department of Conservation and Recreation should monitor available forecasting tools and amend the regulation as needed to ensure the implementation of stormwater management measures that will continue to function effectively in an altered precipitation regime.

- The State Water Control Law (at § 62.1-44.2) should be amended to include as a policy of the Commonwealth consideration of changing climatic conditions in protection and restoration of state waters and living resources.
- Modify existing state regulations, including Virginia's Fisheries and Habitat of the Tidal Waters (Section 28.2 et.seq.), the Powers and Duties of the Soil and Water Conservation Board (Section 10.1-603.2:1 eq.seq.), and the Chesapeake Bay Preservation Act (Section 10.1-2100 et. Seq.), to incorporate climate change authorities to relevant agencies.
- The Virginia Department of Conservation and Recreation should assess the consequences of climate change on the effectiveness of non-point source urban and agriculture best management practices.

Economy and Infrastructure

Economic Impact

Climate change will affect the economy of Virginia in a variety of ways, many of which are not yet well understood. Economic impacts will be felt across all sectors, including military, agriculture, forestry, commercial and recreational fishing, energy, and transportation. A recent University of Maryland study examined the cost of inaction in 13 states, including Maryland and North Carolina (CIER, 2007). By not developing proactive plans to adapt to climate changes, lives, property and livelihoods may be put in danger.

Agriculture and forestry are weather dependent activities, vulnerable to changes in temperature and precipitation patterns. The Weldon Cooper Center for Public Service's September 2008 report, *The Economic Impact of Agriculture and Forestry on the Commonwealth of Virginia* (Rephann, 2008), highlights the importance of these industries to the economic health of Virginia, as well as its history, quality of life, and culture. The report states:

- The total economic impact of agriculture and forestry-related industries in Virginia was almost \$79 billion in total industry output in 2006, the base year for this study. The total employment impact is approximately 501,500 jobs, which makes up 10.3 percent of state employment.
- Every job created in agriculture and forestry related industries results in another 1.5 jobs in the Virginia economy. Every dollar generated in value-added results in another \$1.75 value-added in the Virginia economy.
- Although this study did not examine the full effects of agri-tourism and forest-related recreation, such as wildlife recreation, horse events, wine tourism, and agricultural festivals, results from other Virginia studies suggest that the impacts on output may amount to several billions of dollars.
- Agriculture and forestry activities have significant societal and ecological effects in addition to their economic benefits. Forests provide benefits in the form of

carbon sequestration, wildlife habitat and biodiversity, flood mitigation and improved water quality. Rural scenic amenities may also improve quality of life.

Thus, climate change has the potential to negatively affect two of Virginia's most critical economic engines. These industries and the Commonwealth must plan for these effects and develop plans for adaptation.

Recommendations:

- The Secretary of Commerce and Trade should oversee an analysis of the impact that climate change will have on Virginia's economy, with special emphasis on those industries and economic sectors most sensitive to changing climatic conditions. Virginia's recreational and commercial fishing, forestry, and agricultural, industries will have to respond to species range shifts, invasive species, diseases, precipitation and temperature changes, and other climate related changes. Although less understood, other sectors, such as tourism, outdoor recreation, manufacturing, construction, military, and energy will also be impacted. This analysis should also consider the opportunities climate change may offer Virginia's economy, including potential new crops and agricultural products, increasing investments in alternative energy, and greater emphasis on conservation and efficiency.
- As part of the economic impact study, Virginia economists should develop an analysis of the economic and social costs of not responding to climate change through adaptation planning and mitigation.
- Virginia should exercise strong leadership in the development and commercialization of renewable fuel technologies and promote growth of these industries in the Commonwealth. As was noted above, farmland, managed using best practices, can make a significant contribution to natural carbon sequestration; yet thousands of acres of farmland are lost to development every year due to the difficulty of keeping farms economically viable. One potential approach for improving the economic viability of farming in Virginia is to capitalize on Virginia's natural resources and advance renewable fuel technologies. This also will help ensure reliable and sustainable sources of fuels for electrical generation and transportation. Opportunities for sustainable feedstock production in Virginia include canola for biodiesel, and hullless barley and warm season grasses for ethanol. Virginia should proactively seek for-profit companies to demonstrate and evaluate start-up energy production systems that ideally achieve the following multiple goals (Chesapeake Bay Commission, 2008):
 - Strengthens rural economies by expanding options for sustainable income for farmers, foresters and local communities from biofuels;
 - Supports state and regional environmental goals, including the restoration of the Chesapeake Bay and state climate change and energy independence strategies;
 - Develops and facilitates a holistic approach to the siting, permitting, and business planning of biofuels facilities that considers the full environmental impacts of feedstock sources and transportation and distribution of the final product, as well as the operation of the plant itself; and
 - Eliminates or minimizes conflicts among these three goals.

Infrastructure

Climate change poses serious and growing threats to Virginia's roads, railways, ports, utility systems and other critical infrastructure. In the coastal zone, existing hazards such as storm surge, coastal flooding and erosion will become more severe because of sea level rise. Across the Commonwealth, increased frequency of severe storms may produce more frequent and intense flooding and other hazards. Ironically, unstable weather patterns also could produce periods of drought that threaten municipal water supplies. Temperature rise and the threat of more frequent and intense heat waves can seriously impair the functioning of critical infrastructures.

While the challenges posed to our infrastructure are complex and multifaceted, two complementary approaches provide our best strategy for adapting to these threats. First, the state needs to begin to quantify the extent of the threats to existing infrastructure and develop cost-effective measures to address those threats. Second, the state needs to factor likely climate change impacts into its various infrastructure planning processes to ensure that new infrastructure is both located and designed to minimize its vulnerability future threats.

Recommendations

- Local governments and regional commissions and authorities in the coastal area of Virginia should include projected climate change impacts in all planning efforts, including local government Comprehensive Plans and local and regional land use plans.
- Local governments should revise zoning and permitting ordinances to require projected climate change impacts be addressed in order to minimize threats to life, property, and public infrastructure and to ensure consistency with state and local climate change adaptation plans.
- Climate change impacts, particularly sea level rise and storm surge vulnerability in coastal areas of Virginia, should be taken into account in all transportation planning, project design, prioritization of projects for funding, and transportation systems management, operations and maintenance. The Secretary of Transportation should lead transportation adaptation, supported by the Commonwealth Transportation Board, Virginia Department of Transportation (VDOT), Virginia Department of Rail and Transit, Virginia Department of Aviation and Virginia Port Authority. The Virginia Institute of Marine Science and other research institutions as appropriate should provide scientific and technical advice. Commonwealth agencies should coordinate their transportation adaptation efforts with local governments and with regional Planning District Commissions, Metropolitan Planning Organizations, and Transit Authorities. Commonwealth agencies also should coordinate their transportation adaptation efforts with Federal agencies, including the US Department of Transportation and its agencies, Federal Aviation Administration, US Maritime Administration, US Army Corps of Engineers, National Oceanic and Atmospheric Administration, the Department of Defense and others as appropriate. Where existing transportation infrastructure is already vulnerable to sea level rise, more intense storm events and other climate change impacts, state, regional and local transportation agencies should develop plans to minimize risks, move infrastructure from vulnerable areas when necessary and feasible, or otherwise reduce vulnerabilities.

- Climate change impacts, particularly sea level rise and storm surge vulnerability in coastal areas of Virginia, should be taken into account in all critical infrastructure planning, project design, prioritization of projects for funding, and infrastructure management, operations and maintenance. Critical infrastructure includes but is not limited to public utilities such as water and sanitation systems, storm drain and other drainage systems, public safety and emergency management facilities, public education buildings, and any other state or local government infrastructure critical for public safety, delivery of critical public services, and continuity of government. State agencies, local governments, and regional commissions and authorities should develop climate change adaptation plans for critical infrastructures for which they are responsible.
- The Commonwealth should require that all state, regional or local infrastructure projects comply with state climate change adaptation requirements to be eligible for state funding. All infrastructure projects should be designed to be resistant to climate change impacts over the projected life of the project.
- The Commonwealth should require that all regional or local infrastructure projects comply with state climate change adaptation requirements, as applicable to the specific conditions in the region or locality, to be eligible for local funding. Additionally, the Commonwealth should establish policies that discourage expenditure of public funds on development of public infrastructure in areas highly vulnerable to climate change effects, especially sea level rise and increased risk of flooding from intense precipitation events.
- The Commonwealth should require that all private sector critical infrastructure owners and operators conduct a climate change vulnerability assessment, develop a climate change adaptation plan, and submit them to the State Corporation Commission and appropriate state agencies. Compliance with state climate change adaptation plans should be a condition for approval of all infrastructure development applications and related permitting requests. Privately owned or operated critical infrastructures include electrical power generation and distribution, telecommunications, natural gas, and others as may be designated by the Assistant to the Governor for Commonwealth Preparedness with the concurrence of the Governor.
- The Assistant to the Governor for Commonwealth Preparedness, supported by the Adjutant General of the Virginia National Guard and other state agencies as appropriate, should coordinate with Department of Defense installations and facilities in the Commonwealth to explore ways the Commonwealth and Department of Defense can work together to address climate change impacts to critical military installations in Virginia. The Assistant to the Governor for Commonwealth Preparedness should work with appropriate state agencies, local governments, and regional commissions and authorities to ensure that state, regional and local climate change adaptation plans and programs adequately cover critical infrastructure and services provided to Federal facilities, the Federal employees who work on those facilities, and their families. Such infrastructure includes transportation (roads and transit), utilities such as water and sanitation systems, public education, and many others.

Land Use and Insurance

Property owners in coastal areas of Virginia already are experiencing increasing difficulty purchasing property insurance at affordable rates. Some insurance companies have stopped selling insurance entirely in coastal areas. Sea level rise and an increase in the intensity of precipitation events and severe storms could result in flood insurance being required by an increasing number of homeowners. These insurance issues could have a serious negative impact on the economies of communities affected by them.

Recommendations:

- Based on the revised floodplain maps accounting for sea-level rise, increasing storm surge and flooding from more intense rainfall events, Virginia's Insurance Commissioner should work with the insurance industry and other partners as necessary to develop an analysis of the areas most vulnerable to insurances losses due to increased storm activities and inundation.
- The Department of Conservation and Recreation should revise the Virginia Floodplain Management Plan and update model floodplain management ordinances to address more specifically sea-level rise and increasing storm surge impacts due to climate change.
- Local governments should then be directed to update floodplain ordinances and maps to incorporate sea-level rise and increasing storm surge impacts where applicable.
- State and local agencies should establish policies such as rolling easements, tax incentives, or mandatory setbacks to discourage new development in vulnerable coastal areas. Persons purchasing or developing property in vulnerable coastal areas or floodplains should have ready access to accurate data on the current and potential future vulnerability of their property.
- Adaptation policies and programs for the built environment should take into consideration impacts on natural systems, particularly in coastal areas, and minimize negative impact on natural areas that are important for mitigating the impact of climate change. Adaptation policies and programs for the built environment should make use of nature-based strategies such as natural shorelines and should be coordinated with fish and wildlife adaptation strategies.

Sea Level Rise Adaptation Strategy

The impact of sea level rise cuts across natural resources, economy and infrastructure, and virtually every other policy area. A fragmented approach to adapting to this wide range of impacts would have high risk of resulting in disjointed, conflicting or duplicative policies and programs, wasted taxpayer dollars, and ineffective implementation. Prudent use of scarce state and local resources dictates that all state and local government efforts to adapt to sea level rise should be coordinated under an overarching adaptation strategy.

Recommendation:

- The Secretary of Natural Resources should lead an inter-agency and intergovernmental effort to develop a Sea Level Rise Adaptation Strategy. The Virginia Marine Resources Commission should be supported by all other state agencies whose expertise would be needed to develop the strategy, and by the Virginia Institute of Marine Science and other research institutions as appropriate

for scientific and technical advice. The Virginia Marine Resources Commission should coordinate development of the strategy with local governments and regional commissions and authorities in the coastal area of Virginia, and with applicable Federal Agencies, including the National Oceanic and Atmospheric Administration, US Coast Guard, US Maritime Administration, US Army Corps of Engineers, Department of Defense and Military Services, U.S. Fish and Wildlife Service, U.S. Geological Survey, US Department of Forestry, US Environmental Protection Agency, and other as appropriate. The Sea Level Rise Adaptation Strategy should encompass the full range of policies, programs and initiatives that will be required to adapt in the areas of natural resources, economy and infrastructure, and any other area impacted by sea level rise.

Recommendations:

- The Virginia Institute of Marine Science, Center for Coastal Resources Management has developed guidance for integrated shoreline management that can be adopted by all state and local government agencies, boards and commissions, and regional commissions and authorities, whose activities impact shoreline management. The Virginia Marine Resources Commission should be given the lead in coordinating implementation of this guidance.
- All local governments whose jurisdictions encompass Virginia's shoreline should be required to develop integrated shoreline management plans in coordination with the Virginia Marine Resources Commission and other state agencies as appropriate. Those local governments will require additional funding to develop and implement integrated shoreline management plans.
- The Virginia Department of Conservation and Recreation should assess the need to expand Virginia's Resources Protection Area buffer designations beyond the current 100-foot requirement to accommodate the impact of sea-level rise.

Health and Society

Public Health

Climate change is likely to have wide-ranging and mostly adverse impacts on human health. Climate change can affect the health of Virginians directly and indirectly. Extreme weather events (e.g., floods, droughts, hurricanes or windstorms, wildfires and heat waves) can directly affect health through injuries, drowning, or mental health problems. These extreme weather events could lead to compromised water and food supplies, resulting in increases in waterborne and food-borne illnesses.

Climate change also will lead to the alteration or disruption of natural systems, making it possible for vector-borne diseases (i.e., arthropod-borne diseases such as West Nile virus, malaria, dengue and Lyme disease) to spread to or emerge in areas where they had been previously limited or non-existent. These alterations or disruptions could result in the disappearance of some vector-borne diseases by making the environment less hospitable to the vector or pathogen. Climate change is also expected to increase the incidence of diseases associated with air pollutants and aeroallergens and exacerbate other respiratory and cardiovascular conditions. Existing disease surveillance systems are capable of tracking and identifying changes in diseases and illness that might be associated with climate change.

Certain groups of people are recognized as being more vulnerable to the health impacts of climate change. These vulnerable populations include children, the elderly, people of low socioeconomic status, members of racial and ethnic minorities, people living in coastal areas and flood plains, and people with pre-existing health conditions and disabilities.

Recommendations:

- The Virginia Department of Health (VDH) should use disease surveillance programs to track vector, water and food-borne morbidity and mortality that might be associated with climate change. Focus on vector-borne diseases (e.g., diseases transmitted by mosquitoes or ticks such as malaria, dengue (den' gee), West Nile virus and Lyme disease), emerging infectious diseases, and heat-related, or extreme weather-related morbidity and mortality as early indicators of impacts of climate change on human health. Conduct or modify prevention/intervention efforts based on information gained through surveillance. Surveillance can be covered using existing resources, however, additional prevention or intervention will require resources not presently available.
- Develop one or more syndrome definitions for climate change related disease or illness for inclusion in a syndromic surveillance system, e.g., ESSENCE (Electronic Surveillance System for Early Notification of Community-based Epidemics). ESSENCE records information on disease syndromes, such as rash and fever, respiratory, gastrointestinal symptoms, etc. and automatically downloads that information on a regular basis from participating hospitals in Virginia. Syndromic surveillance can be used as a tool to determine the existence or the absence of an outbreak; the size, spread and location of an outbreak; or to monitor disease trends.
- Monitor changes in harmful algal blooms (HABs) frequency, toxicity, and geography and any impacts on human health through the existing Harmful Algal Bloom Illness Surveillance System (HABISS), a VDH surveillance database used for tracking illnesses related to HAB exposure.
- Develop a system able to track changes in allergic or respiratory illnesses and cardiovascular disease that might be associated with increasing temperatures and/or air pollution. Additional resources to pay for surveillance staff and IT staff would be necessary to carry out this initiative.

Emergency Preparedness

Climate change effects are likely to increase the complexity of emergency preparedness efforts and extent and difficulty of emergency response and recovery operations of natural disasters. Some existing public safety and emergency preparedness facilities and infrastructure, such as medical facilities, police and fire department buildings, and schools used as emergency shelters, may be vulnerable to sea level rise, storm surge or flooding. Current emergency response and recovery plans and resources may not be adequate to deal with the severity of future natural disasters.

Recommendations:

- The Assistant to the Governor for Commonwealth Preparedness should lead a state-wide assessment of the impact of climate change on emergency

preparedness, response and recovery plans and capacity in Virginia. This assessment should involve all state, local and regional public safety, public health and emergency preparedness agencies and officials, and assess the vulnerability of existing public safety and emergency preparedness facilities and infrastructure, and the adequacy of emergency response and recovery plans and resources. This assessment should be coordinated with appropriate Federal agencies, including the Department of Homeland Security, Federal Emergency Management Agency, US Coast Guard, and Department of Defense. It should identify vulnerable populations based on projected climate change impacts, provide recommendations for mitigating vulnerabilities in existing public safety and emergency preparedness facilities and infrastructure, and improving emergency response and recovery plans. The assessment should focus on Homeland Security Planning Scenarios 3, Biological Disease Outbreak, modified based on recommendations from the Virginia Department of Public Health on additional diseases of concern due to climate change; and 10, Natural Disaster – Major Hurricane. The assessment should address an additional planning scenario: prolonged extreme heat event. The assessment should identify the additional funding that would be required to implement the recommendations.

- The Assistant to the Governor for Commonwealth Preparedness should coordinate a review of all state agency Continuity of Government and Continuity of Operations plans to ensure that they are adequate for projected climate change effects and develop recommendations for correcting weaknesses in those plans. The Assistant to the Governor for Commonwealth Preparedness also should provide guidance to local governments on updating their plans.
- The Assistant to the Governor for Commonwealth Preparedness should coordinate a review of the Virginia Homeland Security Exercise and Evaluation Program (HSEEP) and regional and local exercise and evaluation programs to ensure that they are adequate for projected climate change effects and develop recommendations for correcting weaknesses in those exercise and evaluation programs.
- The Virginia Department of Public Health should work with local health departments and planning district commissions to conduct an assessment of vulnerable populations in Virginia based on different climate change impact scenarios including the following: sea level rise, increased air temperatures, and heat-related illnesses and deaths. The assessment should include an understanding of the vulnerability of populations as well as its capacity to respond to new and changing conditions. Additional resources would be needed to conduct this assessment.
- The Virginia Department of Public Health should promote the Virginia Medical Reserve Corps (VAMRC) to strengthen local public health initiatives and enhance local emergency response efforts during extreme weather events related to climate change. The VAMRC is dedicated to establishing teams of local volunteer medical and public health professionals to contribute their skills and expertise throughout the year as well as during times of community need.
- The Virginia Department of Public Health should ensure that every Health District in Virginia has a heat emergency response plan.

Social and Cultural Impact

Certain groups of people – those of low socioeconomic status, members of racial and ethnic minorities, and people living in coastal areas and flood plains – are recognized as being more vulnerable to the impacts of climate change. Family farms and other property that have been handed down for generations, and even entire towns and ways of life, are threatened by sea level rise and other effects of climate change. Historic resources in the coastal zone are threatened by inundation, erosion and increased storm surge. Flooding caused by severe precipitation events could cause similar problems across Virginia. The Commonwealth and local governments will be faced with difficult decisions on allocating scarce resources to protecting property and historic and cultural resources threatened by climate change.

Recommendations:

- The Weldon Cooper Center for Public Service and the Old Dominion University Center for Regional Studies, supported by state and local government agencies, other research organizations and local non-profit groups as appropriate, should conduct an assessment of the impact of that climate change will have on persons of low socioeconomic status, members of racial and ethnic minorities, and people living in coastal areas and flood plains. This assessment should provide recommendations on (1) the feasibility and cost of trying to preserve communities threatened with destruction by the effects of climate change, such as those in low-lying coastal areas and flood plains; (2) the feasibility and cost of providing relocation assistance to low income individuals and families living in low-lying coastal areas and flood plains before they are forced out of their homes and become a burden on the Commonwealth; and (3) the extent to which the impacts of climate change will fall disproportionately on persons of low socioeconomic status and members of racial and ethnic minorities, and any consequent implications for the level of services being provided by existing Commonwealth programs that support needy members of these groups.
- The Department of Historic Resources, supported by other state and local government agencies, research organizations and local non-profit groups as appropriate, should oversee an assessment of the social and cultural impact that climate change will have on Virginia, including the impact on historic resources. This assessment should provide recommendations on (1) the feasibility and cost of trying to preserve important cultural or historic resources from being destroyed by the effects of climate change, (2) measures to ensure that a historical record of those communities and important cultural or historic resources that cannot be protected from destruction is preserved. This should include relocation of important documents to archives and artifacts to museums, gathering oral histories, photographic and video records of important sites, and other appropriate measures.

Cross-Cutting

Climate Change Response Coordination

The Commission recognizes that the value of the Climate Action Plan depends on its successful implementation, and that this implementation will require the coordinated and unified action of elected officials, agencies, colleges and universities, industry, non-

governmental organizations and, ultimately, the general public. In addition, the Commission recognizes that the scope and complexity of the climate change challenge means that the Climate Action Plan, however complete at present, is nevertheless a work in progress. Currently, there are many gaps in our knowledge and as the true nature and extent of the problem becomes clearer over the coming years, we will need to refine the plan accordingly.

Additionally, the Commission recognizes that implementing certain aspects of the Climate Action Plan will require that policy makers and the general public gain a more in-depth understanding of the costs and benefits of key actions, as well as the costs of inaction. Quantifying some of those costs and benefits is possible at present, but some calculations will improve dramatically over the coming years.

Currently there is no single agency or entity within state government that is positioned to carry this work forward and unify and coordinate the Commonwealth's response. Unless corrected, this lack of oversight on the issue will undermine the effectiveness and efficiency of the Commonwealth's response.

Recommendations:

- The Commonwealth should establish the Governor's Office of Climate Change Response. The Director of the Office would serve as a member of the Governor's cabinet. The mission of this office would be disseminate critical information and data on climate change to elected officials, policy makers, and the general public and to coordinate the Commonwealth's response to all aspects of climate change in Virginia, using the Virginia Climate Action Plan as its initial work plan. Tasks of Office of Climate Change Response should include:
 - Facilitate development of coordinated programs and policies among state agencies, and between state agencies, local governments and regional commissions and authorities, when their responsibilities overlap in key aspects of climate change response.
 - When required, facilitate drafting of Memoranda of Agreement or Memoranda of Understanding between state agencies, and between state agencies, local governments and regional commissions and authorities.
 - Assess progress in implementing recommendations and achieving goals in Virginia's Climate Action Plan and provide annual reports on progress to the Governor and General Assembly.
 - Recommend revised planning targets and guidance to local governments and Planning District Commissions as more information becomes available.
 - Serve as liaison between state and local governments on implementation and planning issues associated with climate change.
 - Ensure local governments have the information and resources necessary to include climate change response into their comprehensive planning process.
 - Develop a public engagement strategy for implementation of the Virginia Climate Action Plan, coordinate development of informational and educational materials on climate change mitigation and adaptation, and

- ensure public participation in development of detailed policies and regulations implementing the Virginia Climate Action Plan.
- Develop and maintain a dedicated website as key delivery platform for climate change information for resource managers, policy makers, the private sector and the general public.

High Resolution Topographic Data

Virginia currently lacks comprehensive elevation data of sufficient resolution for effective climate change adaptation planning. Light Detection and Ranging (LiDAR) is generally recognized as being the standard elevation data for state planning efforts. High resolution elevation data, combined with adequate post-processing, is essential for states and localities to plan for specific sea level rise scenarios, storm surge predictions, or more intense rainfall and associated flooding. Once available, a variety of planning and analytical tools can be developed, such as identifying critical infrastructure at risk, developing guidance for coastal development, identifying natural resources at risk from inundation, or economic assessments of future losses under various rise or surge scenarios. High resolution elevation data, with adequate post-processing, can also support applications outside of climate change planning, like engineering, transportation, etc. LiDAR data can also be used to help assess land use categories types to further the accuracy of a statewide land cover database.

LiDAR data collection, with no post-processing, costs approximately \$360/mi² for 1' contours, or approximately \$275/mi² for 2' contours (based on estimates received by Virginia Geographic Information Network in 2007). Post-processing work is estimated to be approximately 50% of the cost of data collection. Coastal counties, as defined under the Coastal Zone Management Act, should be given highest priority for LiDAR data collection and analyses because Virginia's coastal zone is expected to bear the most significant brunt of climate change in the near future. Many of Virginia's coastal counties are so low-lying that they necessitate 1' or better contours. The current estimate for data collection for Virginia coastal counties, representing about one quarter of the land area in the Commonwealth, is approximately \$4 million. Post-processing work may add an additional \$2 million to the overall cost requirement. Without this data, local governments and their partners are unable to effectively plan for climate changes. Background information on LiDAR can be found on the Virginia Geographic Information Network website (www.isp.virginia.gov/lidar.shtml). Their website provides a LiDAR needs assessment survey, information on similar programs in neighboring states, and recent estimates from vendors to complete this type of survey.

Recommendations:

- Virginia should acquire LiDAR data for the coastal zone in the next two years. In order to do this, the Virginia General Assembly would need to allocate approximately \$6 million to the Virginia Geographic Information Network, or identify other available funding sources to cover the costs of acquisition and processing required. Federal or other external financial support may be available to assist with acquisition and/or tool development.
- The resulting LiDAR data should be made publicly available through Virginia's Geographic Information Network.

Review of Existing Authorities

Local governments are critical to the success of Virginia's efforts to adapt to climate change. Local governments and regional commissions and authorities appear not to have sufficient statutory authorities to implement effective climate change adaptation policies and programs. As an example, local governments currently cannot base permitting or zoning decisions on future climate change projections, such as sea level rise. In order for localities to effectively protect human health, the economy and infrastructure, and the ecosystem, localities will have to plan for changing climate conditions and must have requisite authorities to implement those plans.

Recommendations:

- The Commonwealth, through the Joint Legislative Audit and Review Commission, should conduct a statewide review of regulatory and non-regulatory authority of local governments and regional commissions and authorities to implement effective climate change adaptation policies and programs.
- Where the statutory authority of local governments and regional commissions and authorities are not adequate, the Governor should submit legislation to the General Assembly to provide essential authorities necessary to implement effective climate change adaptation policies and programs

Federal Legislation, Policies and Regulations

Virginia should be proactive in shaping the development of Federal climate change legislation and policies to ensure that the Commonwealth's interests are protected and successful programs already being pursued by the Commonwealth that contribute to mitigation of, and adaptation to, climate change are taken into consideration. Conversely, Virginia must take evolving Federal statutes, policies and regulations into account in the development and revision of Commonwealth policies.

Recommendations:

- Federal climate change legislation and policies should include incentives to preserve and enhance natural carbon sequestration by forestland, farmland, wetlands and other open space.
- Federal legislation and policies to reduce greenhouse gas emissions, such as a cap-and-trade system, should incorporate a natural sequestration carbon credit system.
- Federal climate change legislation and policies should dedicate funding of auction revenues from a greenhouse gas emission cap and trade program or other revenue-generating greenhouse gas reduction programs to implement adaptation strategies for fish, wildlife, and natural systems impacted by climate change.
- Federal climate change legislation and policies should include an overarching national adaptation strategy that recognizes the primary burden of adaptation will fall on state and local governments, whose resources may not be sufficient to fully implement the measures necessary to protect human health, the economy and infrastructure, and the ecosystem. Federal agencies should be tasked to provide scientific, technical and planning assistance to state and local governments, and when appropriate to partner with them in the implementation of adaptation plans.

- Federal climate change legislation and policies should recognize that local governments and state agencies often play a vital role in providing critical infrastructure and services for Federal facilities, the Federal employees who work on those facilities, and their families. Such infrastructure includes transportation (roads and transit), utilities such as water and sanitation systems, public education, and many others. To the extent that state and local governments will incur additional costs in adapting infrastructure and services to climate change in order to ensure the long-term viability of Federal facilities, the Federal government should help defray the costs of state and local adaptation efforts.
- Federal statutes, policies, programs and regulations that may impede or prevent effective implementation of climate change adaptation measures in Virginia should be identified, and the Governor should work with Federal agencies and Virginia's Congressional delegation to revise those statutes, policies, programs and regulations. Particular attention should be paid to addressing projected climate change impacts, such as sea level rise, in the US Army Corps of Engineers permitting process and National Environmental Policy Act (NEPA) environmental impact assessment process.

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Appendix A.

Greenhouse Gas Reduction Opportunities Associated with Achieving Virginia Tributary Strategy Agricultural Best Management Practice Adoption Goals

There is a wealth of opportunity in Virginia to sequester carbon (C) and reduce greenhouse gas (GHG) emissions through the adoption of best management practices traditionally used by farmers to protect water quality, and through changes in land management. Best management practices such as continuous no-till, cover crops, forest and grass stream buffers increase soil carbon concentrations providing an important storage reservoir for carbon dioxide (CO₂). No-till, cover crops and nutrient management planning also avoid emissions associated with crop production. For example:

- In Virginia's coastal plain soils, continuous no-till has been shown to increase soil carbon sequestration by 308 ± 193 kg C ha⁻¹ per year (Spargo et al., 2008). Further, continuous no-till can reduce diesel fuel consumption by up to 95%, the equivalent of 17 kg C ha⁻¹ per year in avoided emissions (USDA-NRCS, 2008).
- Winter cover crops store approximately 200 kg C ha⁻¹ per year (West and Post, 2002) while capturing nitrogen and avoiding the use of commercial nitrogen fertilizer and associated greenhouse gas emissions (3.9 to 7.8 kg C ha⁻¹ per year).
- Forest stream buffers sequester 3,500 kg C ha⁻¹ per year and grass buffers sequester 500 kg C ha⁻¹ per year (Galang et al., 2007).
- The Chesapeake Bay Program estimates that adoption of nutrient management plans reduce nitrogen application by an average of 20%. Based on IPCC (2006) estimates that 1% of applied nitrogen is lost as N₂O, for every 1 kg of nitrogen fertilizer not applied, GHG emissions associated with N₂O production (agriculture's largest contribution to GHGs, EPA 2007) are reduced by 3.1 kg (N₂O = approx. 310 CO_{2equiv}). Further, every kg of N requires on average 0.86 kg of C to produce and transport (West and Marland, 2002). Hence for every 1 kg of nitrogen fertilizer not used, approx 4 kg of CO_{2equiv} emissions are avoided.

Because the aforementioned best management practices are among the most cost-effective methods for reducing nonpoint source pollution, goals for increasing their adoption have been included in the Virginia Tributary Strategy, which lays out a path for restoring Virginia's portion of the Chesapeake Bay. If the Tributary Strategies goals were met, Virginia could not only improve water quality, but also reduce Virginia agricultural GHG emissions (based on 2010 estimates prepared by the Virginia Department of Environmental Quality) by 22%, or 1.35 million metric tons of CO₂ (Table 1). This is equivalent to the annual CO₂ produced from 153 million gallons of gasoline, or 247,116 passenger vehicles (EPA, 2008).

Statewide, Galang et al. (2007) calculated that changes in forest and land management, particularly afforestation (i.e. planting forests) on marginal lands, afforestation on agricultural riparian lands, and changing tillage practices had the most promise for sequestering carbon. The total carbon sequestration potential of these three practices, if implemented on all available lands in Virginia, is estimated at 6.23 million metric tons of CO₂ per year (Table 2). This is equivalent to annual CO₂ emissions from 707.5 million gallons of gasoline or 1.14 million passenger vehicles (EPA, 2008).

Regarding the permanence of CO₂ sequestration from agricultural practices, future CO₂ emissions trading should be modeled after the Chicago Climate Exchange (CCX), which allows for carbon emissions credits to be generated from afforestation, planting and maintaining grasses, and continuous no-till. The CCX requires participating farmers to sign contracts committing to maintaining carbon sequestration for a set period of time. The CCX withholds a percentage of generated agricultural soil carbon CO₂ emissions credits as ‘insurance’ to address the possibility of potential carbon storage reversals.

Table 1. Carbon sequestration and greenhouse gas reduction benefits of fully achieving Chesapeake Bay Tributary Strategy goals for implementation of high-priority agricultural best management practices.

Best Management Practice	Tributary Strategy Goal* (hectares)	GHG reduction (metric tons CO₂ per yr)
Nutrient Management Planning	412,782	74,301
Cover Crops	167,249	34,453
Continuous No-till	16,870	5,483
Forest Buffers	82,023	287,082
Grass Buffers	44,455	22,227
Total		1,349,253

* From 2006 estimate by the Virginia Department of Conservation and Recreation

** Based on the IPCC estimate that 1% of applied nitrogen is emitted as N₂O and assuming NMPs reduce N application by an average of 45 kg ha⁻¹ per year.

Table 2. Estimates from Galang et al. (2007) on Virginia terrestrial carbon sequestration potential of three land and forestry management practices.

	GHG Reductions (metric tons CO₂ per year)
Afforestation of marginal lands	5,133,333 (over the first 20 years)
Afforestation of agricultural riparian lands	733,333 (over the first 20 years)
Conversion to continuous no-till	366,667 (over the first 14 years)
Total	6,233,333

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