Climate Change Impacts:

Maryland Resources at Risk

Submitted to
Maryland Energy Administration

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Executive Summary

In Maryland, our climate is an important dimension of our way of life and our economy. Our sunny beaches, Maryland crabs, cool and forested mountains, the crops and greenery produced by sun and rain are all part of what it means to be in Maryland. Climate variability makes the news—examples include the current drought; recent tornadoes in College Park, La Plata and Calvert County; and icy winter conditions. Furthermore, Maryland's social systems and infrastructure are well adapted to current climate norms, if not to all extremes. Roads are built to expand and contract within the area's temperature ranges. Water systems can handle a range of situations, from drought to torrential rainfall. Agricultural production is geared to crops and animals that thrive in expected conditions. And Maryland's tourist industry exploits summer sun, winter snow, and spring and fall breezes.

Superficial analysis indicates that Maryland's industries and communities will be unaffected by climate change. The major economic sectors of the state (trade, transportation and utilities; and service industries of all kinds) are relatively resilient to changes in climate. However, even the initial stage of a more thorough analytic approach indicates that potential climatic changes—especially changes that may exacerbate current problems—should be of concern to state policymakers.

Maryland has many assets that depend upon climate, in direct and indirect ways. These assets may be "at risk" from climate change depending on how we prepare for the future. Human activities—recreation, farms, fisheries, food processing—are directly linked to these environmental features. Many environmental features of the eastern coastal regions depend on climate: beaches, wetlands, birds (including migratory species), and fish and seafood. Current rates of sea level rise, pollutant loadings, damages from severe storms, and declining fisheries may all be worsened if the climate does change as projected. In the central region of the state, high-density populations require sufficient amounts of clean water, livable urban spaces (including plants, trees, clean air, and tolerable temperatures), and access to recreational areas. They all depend on maintenance of climate within certain tolerances. The western part of the state, with its mountainous and low population-density areas, contains natural resources used for leisure and recreation (including skiing in winter and water and mountain sports in other seasons), forest products and maple syrup industries. Climate plays a crucial role in the viability of these industries and activities.

Problems resulting from climate change may arise in farming, forestry, fisheries, and tourism because they depend directly upon climate. In addition, problems of fresh water supply and quality will likely be associated with changes in climate. These problems, in turn, will have indirect but very real effects on activities associated with processing natural commodities into intermediate and finished goods; with trade and transportation; with insurance and real estate industries; and with our quality of life.

There are a number of options for the state to consider as part of an action plan for addressing natural and human-induced climate change. Encouraging businesses,

consumers, and government to reduce emissions of greenhouse gases can be an important component of such an action plan. But Maryland's actions alone cannot create a stable climate nor prevent climate change that is already occurring—whether caused by human actions or natural fluctuations. A key component of a state-level approach also needs to prepare for change: to anticipate potential vulnerabilities, identify adaptation strategies, and examine current programs and incentives to ensure that they encourage long-range planning and responsible development. This is an under-examined and inadequately developed component of climate change policy at all levels of government, from international negotiations, through US national policy, to approaches being developed at the state and local levels.

Identifying vulnerabilities and encouraging adaptation will require a more thorough process of assessment. This process should engage stakeholders who will be affected and draw on the many resources for research, monitoring, and other forms of information gathering that exist within Maryland. This study lays a foundation for such a process by (1) highlighting some resources and activities "at risk" from climate and other environmental changes, (2) identifying some of the major monitoring and research resources that will provide information for future decision making, and (3) suggesting relationships between climate change adaptation and current policies for economic development and protection of natural resources and the environment. It will also outline how an open process for identifying vulnerabilities and adaptation options might be structured with the involvement of stakeholders in various sectors (e.g., businesses, natural resource managers, researchers, and the general public) and emphasize the opportunities presented for interagency coordination to develop integrated, innovative paths forward.

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I. Background and overview

Global systems such as the climate system affect more localized regions such as Maryland. Thus, the question of whether or not the global climate is changing has immediate relevance to the state. And national and regional impacts of changing climate can alert us in Maryland of the need to examine impacts of and vulnerabilities to these changes. Therefore, this report begins with a brief description of changes and impacts that are occurring and their relevance for Maryland.

Experiencing Climate Change

All over the world, human activities are altering environmental conditions well beyond mankind's historical experience. The present concentrations of carbon dioxide, one of the "greenhouse gases" that trap the sun's energy in the Earth's atmosphere, are the highest they have been in the past 400,000 years; most likely these concentrations have not been exceeded in the past 20 million years. There are numerous observations of unequivocal changes in climate: atmospheric and oceanic temperatures, precipitation and atmospheric moisture, snow cover, extent of land and sea ice, sea level, extreme weather, and overall features of climate variability. Global mean temperatures of the last decade, for example, are highly likely to have been the warmest since a continuous record of temperatures by thermometers has been kept, starting in 1861. And, in a cautiously worded statement by atmospheric scientists, new research on changes in climate over the last 1,000 years indicate that temperature changes of the last 100 years "are unlikely to be entirely natural in origin, even taking into account the large uncertainties…."[1]

These changes are interacting with natural fluctuations in the climate such as El Niño Southern Oscillation (ENSO), a large-scale climate variation that shifts every few years in the equatorial Pacific Ocean and rapidly reverberates through the global climate to affect precipitation and temperature all over the world. These changes are also interacting with evolution in human activities and infrastructure, for example coastal development, changes in economic activities, or clearing of forests in one region for farming and reforestation of pastures in another.

The interactions of all these changes are leading those involved in activities that depend on climate and natural resources to confront conditions that fall outside the realm of their experience and to question how to better manage the effects of these conditions. Some of these changes are harmful, while others, if anticipated and coupled with appropriate policy and management approaches, can produce benefits. Some examples from several regions in the United States:

- US hurricane *losses* increased markedly during the 20th century in constant dollars, with the greatest increases occurring since 1980. However, the actual number and intensity of hurricanes have shown no similar increase. Recent research indicates that the losses are primarily a manifestation of the growing quantity and value of infrastructure placed in harm's way (e.g., in coastal zones).

[1] Intergovernmental Panel on Climate Change, *Climate Change 2001, The Scientific Basis*, Houghton, J.T., et al., eds., Cambridge, Cambridge University Press.

Even greater losses could result if increases in the intensity and frequency of hurricanes or other storms occur. What approaches to zoning, building codes, and insurance regulation can best reduce future losses?

- Water levels in the Great Lakes have decreased in recent years. Lower water levels result in reduced flows to river systems, with resulting effects on fisheries, hydropower production, and the availability of water for irrigation, navigation, and other purposes. The decline in water levels is consistent with increased evaporation due to rising summer temperatures. Climate change could accelerate the warming (and evaporation), but could also increase precipitation. How might these countervailing trends interact in the future, and what do they imply for national and international agreements that provide the framework for management of the Great Lakes?
- There seem to be more forest fires in the western United States, and losses from these fires seem to be increasing. Increased risk of forest fires has been suggested for the Mid-Atlantic region as well.[2] Contributing factors include the cumulative effect of decades of fire suppression that has increased the amount of fuel for fires; changes in seasonal climate conditions that have created drier, hotter conditions and more lightning strikes; and the construction of homes and other buildings closer to areas where the risk of fire is high. Under changing climate conditions, land uses, and development patterns, what fire prevention strategies will be most effective in the future at limiting loss of life and property?
- Commercial fisheries are an important economic asset and source of livelihood in many regions. The productivity of these fisheries fluctuates from year-to-year and decade-to-decade as a result of climate variability. Other factors also contribute to changes in abundance of fish stocks, including altered ocean temperatures and circulation patterns and changes in human harvesting of fish stocks, such as the introduction of new technologies or regulations. How do these factors interact, and what policies would be more effective for managing climatic and other impacts on fisheries in the future?
- Lake ice duration has decreased by nearly one month over the past 150 years at lakes in the upper Midwest, a change consistent with observed increases in temperature. Have there been past fluctuations in the extent of lake ice of comparable magnitude, and if so, with what environmental trends are these changes be correlated? What are the implications, both positive and negative, for fisheries, transportation, and other resources?

Preparing for an Uncertain Climate

Legitimate scientific questions remain about how much of these and other observed changes is natural in origin, how much is caused by human activity, and how much results from ill-advised development or use of natural resources. But mounting evidence of global changes, and the experience of environmental change in our immediate

[2] Moore, Marianne V., Michael L. Page, John R. Mather, Peter S. Murdoch, Robert W. Howarth, Carol L. Folt, Celia Y. Chen, Harold F. Hemond, Patricia A. Flebbe, Charles T. Driscoll, "Potential Effects of Climate Change on Freshwater Ecosystems of the New England/Mid-Atlantic Region," *Hydrological Processes* 11, 925-947, 1997.

environment in Maryland, indicate that it would be prudent to examine what the state can do to prepare for the future. An under-examined but essential component of preparing for future environmental change is anticipating potential vulnerabilities that may result from expected combinations of natural variability, human-induced climate change, socio-economic conditions, and other environmental problems.

A long list of potential consequences of and adaptation to climate change, sea level rise, and other changes has been identified in a series of international, national, and regional reports for agriculture, water resources, fisheries, forests and other ecosystems, human infrastructure, community health, insurance and financial services, and many other areas of human endeavor.[3] Other reports, such as those prepared by the Maryland Emergency Management Administration, identify vulnerabilities to current natural and man-made hazards in the state.[4]

But no comprehensive analysis has yet integrated these areas of research and assessment to identify the assets of Maryland that are most at risk, to assess options to reduce these vulnerabilities that are appropriate to Maryland's unique circumstances, or to prioritize monitoring and other activities that will provide information about evolving conditions and how we should adapt.

Vulnerability: Integrating Natural and Socio-economic Trends

This report takes as its starting point the concept of *vulnerability*. Most people have a good intuitive understanding of what it means to be vulnerable to something. Vulnerability combines potential exposure to a damaging event, how drastically the event could affect valuable assets, and the lack of easy or accessible options for avoiding damages. Researchers have developed elaborate approaches for assessing vulnerability to climate change, including complex computer models that simulate climate and are used for *projecting future changes*, painstaking monitoring and process research to define and measure the *sensitivity* of a variety of potentially affected resources and activities, and technical evaluations of the characteristics and implementation requirements of options for *adaptation*.

The most important point about basing assessment of the potential future implications of environmental change on the concept of vulnerability is that it takes account of the importance of both environmental/climate changes and changes in society, including technology, the economy, and civic life. As in the preceding examples, vulnerability can

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[3] See, for example, Intergovernmental Panel on Climate Change, *Climate Change 2001, Impacts, Adaptation, and Vulnerability,* McCarthy, J., et al., eds, Cambridge, Cambridge University Press, 2001; *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, A Report of the National Assessment Synthesis Team for the US Global Change Research Program, Cambridge, Cambridge University Press, 2001; *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, Mid-Atlantic Overview*, A Report of the Mid-Atlantic Regional Assessment Team for the US Global Change Research Program, Washington, DC, U.S. Environmental Protection Agency and Pennsylvania State University, 2000.

[4] Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000.

result from environmental or socio-economic causes, or from a combination of these factors.

This implies that in addition to identifying the likelihood of different environmental changes and hazards, it is equally important to collect and analyze data on the location and type of infrastructure, the demographic and socio-economic status of potentially affected populations, and the adequacy of social networks for assisting those who may be affected and who otherwise lack resources for coping or adaptation. Identifying resources and populations at risk, and analyzing the origins of this vulnerability are important, because different causes of vulnerability will call for different remedies. Carrying out this sort of analysis that focuses on both environmental and societal contributions to vulnerability is a challenging task. Even current weather-related hazard assessments such as the one prepared by the Maryland Emergency Management Administration focus primarily on the potential severity and frequency of occurrence of different natural hazards, not on detailed mapping of where assets may already be at risk or what resources are in place for coping with disasters.

Assessing Vulnerability and Options for Enhancing Resilience

Maryland has a unique and varied environment which encompasses forested ecosystems in the mountains of the western part of the state; coastal plains, estuaries, and bays (including the Chesapeake, the largest estuary in the United States) in the east; and a diverse and vibrant urban corridor extending from Baltimore to Washington, DC. These resources are all affected by the interaction of climate variability and change, pre-existing environmental conditions (e.g., acid deposition impacts or land-cover fragmentation), and changing patterns of human activity. The different population groups that live in the state each have unique assets and liabilities that result from their differing livelihoods, local infrastructure, and access to resources for implementing adaptation.

In order to identify vulnerabilities and develop options to reduce them and take advantage of new conditions, when possible, it is essential to undertake a thorough assessment of the relationship of Maryland's assets to interacting climate and societal trends. Such an assessment will have a number of characteristics.

Most fundamentally, a successful assessment will need to include public participation. In particular, outreach and participation must embrace those most affected by potential changes in climate and by any policies that are identified to enhance resilience. This will improve the analysis, because there is already a great deal of informal knowledge embodied in the population regarding successful approaches to adaptation. It will also help to increase public awareness of the connections between quality of life in Maryland and the state's environment and climate.

A worthwhile assessment of vulnerability will need to be based on carefully constructed scenarios of change and future conditions. Preparation of such scenarios is beyond the scope of this study, which is the primary reason that the study employs an "at risk" approach. These scenarios need to incorporate potential visions of what the future may

bring for the state, not only in terms of climate, but also with respect to environmental and economic conditions that will be affected by development and policy choices we make, and by broader national and international trends which will bound the range of opportunities and challenges.

An assessment will need to include processes for carefully collecting, integrating, and analyzing data on the varied pattern of conditions and resources in the state. This report lists some of the monitoring and other resources that we have identified that may be relevant to climate vulnerability assessment. Some research and monitoring programs address specific aspects of climate change, such as the effects of elevated levels of carbon dioxide on crops. Others address environmental problems that could be exacerbated by climate change. Still others measure and monitor important environmental indicators. However, the existing set of programs does not address important questions related to climate impacts; nor do the programs meet the need for a defined set of indicators and appropriate monitoring. Further analysis of these needs is required and should be included in the assessment process.

Finally, an assessment that is likely to produce feasible options for enhancing resilience within the constraints of tight budgets and pressing immediate needs will need to explore the relationship of vulnerability and resilience to current areas of public policy and resource management. Many of Maryland's existing programs, although they do not have a current focus on climate change, are already addressing problems that may be exacerbated by it. These include major development, environmental, air quality, and energy efficiency initiatives. Addressing climate change could provide additional impetus for these programs, as well as integrating them to contribute to safeguarding the long-term future.

This Report

The Maryland Energy Administration (MEA) initiated this study as part of the multi-agency effort to address climate change in the state. Although mitigation (emissions reduction, particularly from energy-producing sources) is a major focus of these efforts, MEA also recognized that, whether detected climate changes are human-caused or not, the state also needed to examine probable climate change impacts and options to adapt. MEA provided funding for this preliminary study, while recognizing that a subsequent, more thorough, systematic study would need to be undertaken.

The current study is preliminary, drawing on a first-order survey of existing resources and programs, and limited stakeholder input. Current resources could be employed and extended in a number of ways: (1) to develop projections of future change in the state, (2) to conduct more detailed mapping of resources, (3) to systematically collect, assemble, analyze, and present information on location of assets and sensitive systems, their current condition, the probability of hazardous events taking place, the options for adaptation, and what can be done to improve prospects for successful adaptation in the future. These steps are important because Maryland's environment and economy are already subject to

effects of variability and resulting losses within the state, and because a certain level of change is inevitable.

This report is organized according to the three major regions in the state: the Baltimore-Washington Corridor, the Coastal and Rural Area, and the Western Mountain Area. These regions are not based on any one legal, geological, ecological, or economic criterion, but rather on a combination of characteristics that give the locations within them similar sets of exposures to climate variability and change. They reflect broadly defined characteristics that could create similar patterns of vulnerability across many jurisdictions within each region.

The "Baltimore-Washington Corridor" is the largest area in population, geography, and economic importance, and is dominated by professional and business services, trade/transportation, and education/health. Jurisdictions within this region share a number of urban problems and attributes that might interact in similar ways with elevated temperatures, increased flooding and drought, and other changes associated with climate. These attributes include high population density and existing environmental problems such as poor air quality, water pollution, and associated stresses on urban ecosystems and public health. This region includes six counties and Baltimore City that are largely or partly classified as coastal plain in legal or geological perspective but that also cohere with the economic activities of the corridor region.

The "Coastal and Rural Area" includes ten counties whose economies and life-styles are influenced by their proximity to the Atlantic Ocean and the Chesapeake or other bays. Over 30 percent of the State's economic activities related to natural resources are conducted in this region. These jurisdictions are not as urbanized and share characteristics with other rural and coastal regions of the United States that would lead their infrastructure, economies, and environments to confront similar issues in developing responses to sea level rise and heightened storm surges, or to other aspects of climate change that could affect agriculture.

The "Western Mountain Area" consists of three counties and contains abundant natural wealth in forests and other natural resources. This is the smallest region economically, and it has relatively low population density compared to that of the Baltimore-Washington corridor. Forestry and related manufacturing are important sources of employment, and the region includes ecosystems that distinct from those in other areas of the state. In addition, the region is home to skiing and other mountain and water-based recreation opportunities that are unique and potentially affected by climate change.

Each of these regions has distinct natural resources, demographic and economic characteristics, and particular prospects for climate change impacts. However, they also share important ties and interests, such as water resources, recreational opportunities, and statewide values. For each region, we begin with a basic description and important assets, and then discuss vulnerabilities and resilience to potential impacts of climate change, current relevant research and monitoring programs, and opportunities for enhancing

resilience (including relationships to major policy areas). We end with a brief discussion of statewide opportunities for enhancing resilience and indicate next steps.

II. What's "at risk" in the Baltimore-Washington Corridor?

Basic Description and Important Values

The midsection of Maryland is the largest area in population, geography, and economic importance. More than 86 percent of the state's population lives in this area (4,577,673 people),[5] 46 percent of the state's land is in this area,[6] and 90 percent of the wages in the state are paid here. The state's population is growing, on average 11 percent; however, the Baltimore-Washington Corridor area has seen both growth and decline from 1990 to 2000. Calvert County led all other counties with a 45 percent increase in population, while Baltimore City's population has declined 12 percent. As a whole, the state's population density is 529 per square mile (1999), the sixth highest in the nation; the central area's density is higher, reaching a peak of 8,137 per square mile in Baltimore City. Yet the area also contains significant rural space, including parks, farms, and rural households.

Ten counties and Baltimore City comprise the Baltimore-Washington Corridor Area of Maryland. The ten counties are Frederick, Montgomery, Prince George's, Charles, Calvert, Anne Arundel, Howard, Carroll, Baltimore, and Harford. Physiographically, most of this area lies in the Piedmont Plateau Province. Western Frederick County is part of the Blue Ridge Province. The six counties near the Chesapeake Bay and Baltimore City lie in the Atlantic Continental Shelf Province.[7] (These coastal areas are discussed in Counties with Coastal and Metropolitan Characteristics on page 15.) Annapolis, the state capital, is located in Anne Arundel County on the western side of the Chesapeake Bay.

This area contain major north-south transportation routes, notably Interstate 95, which runs from Florida to Maine along the East Coast, and major freight and passenger rail routes that run through the DC Area and Baltimore. Light rail, commuter rail, bus systems, and 14 stations and associated rail for the DC Metro system are located in this area. Baltimore is also an important port on the east coast, and the BWI Airport is one of the fastest growing in the nation.

The major economic sectors in the Baltimore-Washington Corridor Area, measured in wage data,[8] are Professional and Business Services ($3.4 billion); Trade, Transportation, and Utilities ($3.1 billion); and Education and Health ($2.4 billion). Other important sectors include Financial Activities ($1.6 billion), Manufacturing ($1.6 billion), and Construction ($1.5 billion). This area also generates 54 percent of the Maryland wages in

[5] Population statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/pop.htm and www.bea.doc.gov/bea/regional/reis/drill.cfm.
[6] Land area statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/o1glance/html/area.htm.
[7] See http://www.mgs.md.gov/esic/brochures/mdgeology.html.
[8] Wage data are from www.bea.doc.gov/bea/regional/reis/drill.cfm.

Natural Resources and Mining. Of these sectors, several are probably much more important to the state than wage data indicate; at the state level, personal income accounts for only 54.7 percent of the gross state product in Trade, Transportation, and Utilities; only 23.6 percent in Financial Activities, and only 61.4 percent in Manufacturing. Almost 10 percent of the businesses in the state (14,450) are located in Baltimore.[9] The Port of Baltimore is a significant economic engine for the entire region, generating $1.8 billion in economic benefits annually and employing 127,000 Marylanders in maritime-related jobs.[10]

Vulnerabilities and Resiliency

At first glance, the lives and livelihoods of the people in this area do not seem to depend upon climate in the direct ways usually analyzed in climate change impacts research. The important economic activities—services of all kinds, trade and transportation, education, and health—do not depend upon resources directly affected by climate. And the areas' cultural arts resources are resilient, being mostly housed indoors. The central region, like the rest of the state, also has a host of historical sites that may be resilient to climate change. But there are some obvious exceptions to the "climate-proof" nature of the area.

General Risks Related to Climate/Weather

Weather-related risks were estimated by the Maryland Emergency Management Agency (MEMA) in 2000 (see table below). According to this study, the Baltimore-Washington Corridor Area has a high risk of drought (6 counties and Baltimore City), extreme heat, tornado and thunderstorms, with a lesser risk of flash/river flooding and winter weather, and of tidal/coastal flooding in Anne Arundel and Calvert Counties. These current levels of risk may increase under climate change. If so, the risks may all become higher except for winter weather (snow and ice), which may decrease if snow is replaced by rain but may also increase if snow is replaced by ice storms.

Risks were generally estimated using historical data for frequency and severity of occurrences. For example, to estimate tornado risk, MEMA used National Weather Service data for 1950-1998 (events, jurisdiction, deaths, injuries, property/crop damage, F-class, and latitude/longitude) and created statistical summaries, typically total events by county (divided by number of years of data to compute events per year) or average/median severity per event. To convert to risk indicators, MEMA then (1) sorted measures from lowest to highest values and (2) examined the sorted values for natural breaks in the distribution, as a basis for assigning five risk categories.[11]

Alternative methods for estimating risk yield different results. Using data from 1990-2002, and computing the number of tornadoes per 100 square miles in each of the

[9] See http://www.choosemaryland.org/orientation/profiles/city/index.asp.
[10] See http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/port.html.
[11] Appendix A, Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000. Counties in the medium, medium low, and low risk categories are included in the MEMA report.

counties (rather than on a per-county basis, as in the MEMA report), the Acting State Climatologist[12] ranked the counties in this region from highest to lowest risk: Calvert, Prince George's, Charles, Baltimore City and County, Anne Arundel, Harford, Montgomery, Howard, Carroll, and Frederick. (Frederick County ranks highest in the MEMA study.)

However, each of these two methods estimates the risk of *occurrence* without consideration of the area's vulnerability or resilience to these occurrences. That is, the same extreme weather event can have very different outcomes depending upon how well people are prepared – with well-built infrastructure, emergency notification and management plans, for example – to minimize the potential harms and quickly recover.

	High Risk	Medium-High Risk
Drought	Frederick, Montgomery, Howard, Carroll, Baltimore City and County, Harford	None
Extreme heat	Baltimore City	Frederick, Prince George's, Charles, Calvert, Howard, Anne Arundel, Harford
Flash/River Flooding	Frederick	Montgomery, Carroll, Baltimore County, Anne Arundel
Thunderstorm	Frederick, Montgomery, Anne Arundel	Prince George's, Carroll, Howard, Baltimore County, Harford
Tornado	Frederick, Anne Arundel	Prince George's, Charles, Carroll, Baltimore County, Harford
Winter Weather (snow and ice)		Frederick, Montgomery, Prince George's, Anne Arundel, Howard, Carroll
Tidal/Coastal Flooding		Anne Arundel, Calvert

Source: Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000.

Water Resources

Sufficient amounts of clean water are a basic ingredient in our lives, and our water management infrastructure was developed for the current climate. However, climate change may bring both more floods and more droughts. These extreme events could be more frequent and severe. High-intensity precipitation can result in combined sewage overflows and consequent pathogen loading for drinking water systems. Health impacts from waterborne diseases are likely, although they may be controllable by good public health systems. The problems of drought have been felt in Maryland in recent years, with implications for the availability of water for agricultural, industrial, and household uses—as well as for recreational purposes such as boating and fishing. The drought emergency of 1999 challenged the longstanding perception that the State of Maryland had an

[12] Dr. Kenneth E. Pickering, University of Maryland, email communication, June 18, 2002.

adequate supply of water for all uses. That drought demonstrated that water quantity and quality are interdependent; salinity levels increased and dissolved oxygen (necessary for aquatic life) fell when surface water flows fell in some areas.[13]

Power outages from storms may be the most frequent weather-related problem for water resources because these outages affect the ability to pump water. The Mid-Atlantic Assessment Report states, "Perhaps surprisingly, larger systems report more weather-related problems than do smaller systems. Larger systems often draw on more than one source of water; this complexity may increase their vulnerability to extreme weather" and associated power disruptions.

Urban Areas

Because this area is the most densely settled in the state and the population is growing, the effects of climate on urban areas will be important here. Heat islands may get hotter; we may experience sweltering temperatures in paved-over urban areas. The combined effects of poor air quality, ground-level ozone, and urban heat islands will take a toll on health. For example, asthma and other respiratory diseases have been linked to fine particulates in the lower atmosphere;[14] larger urban populations and more traffic congestion in a warmer climate will worsen these health effects. Heat-induced deaths may increase, although this cause of death will continue to be minor compared to others. These dis-amenities may make our urban areas less desirable places to live. This in turn could have a multiplicative effect on real estate values, costs of health care and health insurance, tax revenues, and so on.

Much of Maryland's loss of forestland is occurring where the trees are needed most, in the urbanized areas of the state. Forests are especially crucial in urbanized areas. One acre of young healthy trees will absorb 2.5 tons of carbon dioxide and give off 2 tons of oxygen each year. Trees also contribute to the improvement of air quality, help control water runoff, moderate the effects of urban heat islands, and often occur in recreational and park spaces. However, the special conditions of urban areas require trees that will grow well in cities.

The air quality in parts of Maryland complies with most air quality standards. The notable exception is the ozone standard at times between May and September of each year, generally in the Baltimore and Washington metropolitan areas and Cecil County. In comparison to the 13 other states and DC in the Ozone Transport Region, Maryland ranks at the top of the scale in the number of exceedance days among the states. The table below shows large improvements since 1981, but ground-level ozone remains a problem, as evidenced by a jump to 10 Code Red days in 2001 (all occurring in the central corridor area).

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[13] http://www.dnr.state.md.us/watersheds/surf/indic/md/md_indic.html.

[14] "Air Pollution May Trigger Asthma in Young Athletes," National Institute of Environmental Health Sciences, February 2002, wysisyg://22/http://www.niehs.nih.gov/oc/crntnws/2002feb.air.html.

	Average number of ozone exceedance days	Maximum exceedance value--percent of federal standard
1981-1990	20	175 percent (1988)
1991-2000	11	125 percent
2000	4	117 percent
2001	10	120 percent

Source: *Maryland Department of the Environment End of Season Ozone Report*. Fall 2001.

Quality of Life, Recreation, and Tourism

Clean air, good health, sufficient water, and vibrant urban areas all contribute to the quality of life in the Baltimore-Washington Corridor Area of Maryland. An additional positive contributor is the proximity of the central corridor of Maryland to its mountains and seashore. Recreation and "quality-of-life" factors are often cited as among the major factors in a company's decision about where to locate, and people value these factors as they decide where to live and work. The recreation and vacation opportunities provided in the coastal and mountain areas are valued by businesses and their employees. If these assets are harmed, there will likely be downside impacts on economic development in the central corridor—difficult to predict quantitatively, but real nevertheless.

Trade and Transportation

Transportation, a bedrock activity of the economy in this area of the state, is a source of greenhouse gases and thus presents opportunities for mitigation (energy efficiency, fuel switching, transportation alternatives, carpooling, etc.). Mitigation activities will also provide co-benefits—improved health and visibility, reduced traffic congestion—and lessen potential impacts of a warming climate such as smog.

Counties with Coastal and Metropolitan Characteristics

Along the western shore of the Chesapeake Bay, tensions between economic interests and environmental concerns common to coastal areas may be heightened. The counties and Baltimore City that are both coastal and part of the Baltimore and Washington DC metropolitan statistical areas (MSAs)[15] are listed in the table below, along with their population, population density and rate of growth, number of businesses, and total wages.

[15] The Baltimore-DC Corridor Region can be described using the concept of a metropolitan statistical area (MSA). The general concept of an MSA is that of a geographic area consisting of a large population nucleus together with adjacent communities having a high degree of economic and social integration with the nucleus. The Washington, DC, MSA includes Frederick and Montgomery Counties, which are in the piedmont (at the foot of the mountains) of Maryland; and Calvert, Charles, and Prince George's Counties, which are in the coastal plain. The Baltimore MSA includes Carroll and Howard Counties in the piedmont; and Anne Arundel, and Queen Anne's Counties in the coastal plain (Because Queen Anne's County is on the western shore of the Chesapeake Bay and is largely rural, this report has included it in the Coastal and

Over half of the state's population (59%) lives in this area. The three counties (Calvert, Charles, and Harford) with the lowest population densities and numbers of businesses also have the highest population growth rates. The challenges of preparing for climate change impacts are different where growth rates are high (i.e., change is happening rapidly) than where they are more moderate. Baltimore City is yet another kind of challenge – an area with high levels of infrastructure and declining population and economy, where the desire for economic development is strong and resilience to climate change must be seen in the context of urban spaces.

	Population	Density/Growth 1990-2000	Number of Businesses	Total Wages
Calvert	74,563	350 per sq mi/ 45% growth	1,430	139,295,067
Charles	120,546	267 per sq mi/ 19% growth	2,460	267,000,149
Prince George's	801,515	1646 per sq mi/ 10% growth	14,240	2,911,803,462
Anne Arundel	489,656	1171 per sq mi/ 15% growth	11,975	1,818,367,242
Baltimore City	651,154	8139 per sq mi/ 12% decline	14,450	3,771,865,941
Baltimore	754,292	1261 per sq mi/ 9% growth	19,300	3,100,623,001
Harford	218,590	488 per sq mi/ 20% growth	4,530	558,749,549

Sources: http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/pop.html, http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/pop.html, http://www.mbed.state.md.us/orientation/commuity.asp http://www.bea.doc.gov/bea/regional/reis/drill/cfm

Four of these six counties and Baltimore City lie on the western shore of the Chesapeake Bay,[16] and all are wholly or partially classified as in the coastal plain. Although not as vulnerable to sea level rise as the eastern shore of the Bay, the western coast experiences all the Bay-related problems. The high levels of development and infrastructure in these areas make them highly vulnerable to coastal events that cause coastal flooding, storm surges, nutrient inputs, habitat loss, coastal erosion, salt water intrusion, and sea level rise. In addition, coastal areas support and impact important and sensitive natural resources, such as wetlands, submerged aquatic vegetation, commercial and non-

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Rural Region of the State); and Baltimore City, Baltimore County, and Harford County, whose southern sections are coastal (although they are mostly piedmont). For a list of counties and incorporated areas in MSAs, see http://www.bea.docs.gov/bea/regional/docs/msalist.htm#W.

[16] Charles County advertises itself as "The Wild Side of the Potomac," with "150 miles of spectacular shoreline," (http://www.explorecharlescomd.com/) although the county is not directly on the Bay. Prince George's County is classified as coastal plain and will experience coastal problems such as flooding; it does border on the Potomac and Patuxent Rivers.

commercial fisheries, and endangered or threatened species. Problems in any of these functions of coastal zones may be exacerbated by climate change. Potential impacts include those discussed in the Coastal and Rural section, including those on fresh water resources, farming, fisheries, wetlands, habitat, and quality of life (including health, recreation, and tourism).

An Example: The Port of Baltimore: The Port of Baltimore is a leading U.S. automobile port and one of the top ranking roll-on, roll-off ports in the nation. The Port's Foreign Trade Zone #74 has recently expanded from 286 acres to 1,464 acres and has eleven sites within close proximity of the Port, with over two million square feet of manufacturing, assembly, warehouse, and distribution space. Baltimore City has five state designated Enterprise Zones, which offer economic incentives and a federal urban Empowerment Zone. The City is also one of seven jurisdictions participating in the One Maryland Program, which offers significant tax credits for capital investments that create jobs. In addition, there is increasing interest in recycling waterfront industrial buildings to house technology firms, as part of Baltimore's new "Digital Harbor."

Water depth is critical to a port's viability. Since containerized vessels, a special capability of Baltimore, are becoming larger, dredging is an important continuing activity in the Port. The State has a 20-year "environmentally innovative" plan for managing dredged material,[17] but the need for intrusive and potentially damaging dredging could grow if the downstream flow of trash and sediment to the Bay increased as a result of flash flooding and erosion associated with increased intensity of precipitation and runoff.

One of the assets of the Port is its relative resilience to the effects of hurricanes and major storms. According to the US Navy's *Hurricane Havens Handbook*,[18] a total of 76 tropical storms and hurricanes threatened the Baltimore area during the 114-year period from 1886-1999. Only three produced winds greater than or equal to 34 knots—Able (September 1952), Hazel (October 1954), and Connie (August 1955)—during the period 1945-1998, for which detailed meteorological records are available. Storm surge and tides can combine to greatly increase the danger and damage associated with a major storm. Baltimore had a maximum surge of 6.2 feet during a hurricane in 1933 (8.3 feet at high tide) and a surge of 5.7 feet caused by Hurricane Connie in 1955. The 1933 surge was the largest from all known cases. According to port authorities, ships in the Port would not be expected to encounter problems at these surge levels. Further analysis is required to determine whether expected rates of sea level rise would, over time, lead to hurricane-related vulnerabilities.

There is pressure to develop the Port area (as well as nearby recreational areas such as the Inner Harbor); paving and construction are continuing activities. At the same time, strenuous efforts continue to improve the condition of the Bay, including the 2000 Chesapeake Bay Agreement, which, among other provisions, aims to preserve from development 20 percent of the watershed's land area.[19]

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[17] http://www.mpa.state.md.us/welcome/index.htm
[18] https://www.cnmoc.navy.mil/nmosw/tr8203nc/baltimor/text/sect4.htm
[19] http://www.dnr.state.md.us/bay/science/c2k/c2k.html

Current Monitoring and Research Programs

Many of Maryland's existing programs, although they do not have a current focus on climate change, are already addressing problems that may be exacerbated by it. These include major development, environmental, air quality, and energy efficiency initiatives. Addressing climate change could provide additional impetus for these programs, as well as an integrating theme of safeguarding the long-term future.

- Smart Growth and Neighborhood Conservation Initiative (Priority Funding Areas) (Office of Smart Growth)
- GreenPrint/Green Infrastructure (DNR)
- For counties near the Bay, see programs listed for Coastal-Rural Area
- The Coastal & Watershed Resources Advisory Committee (DNR)
- Maryland Environmental Indicators—ozone exceedance, drinking water quality, vehicle miles traveled (MDE)
- The Environment Project, Statewide Energy Pollution Prevention Program (SEPPP) (Community College of Baltimore County)
- Health and climate change research (Johns Hopkins School of Public Health)
- 2002 Transportation Plan (MDOT) (www.smarttransportation.com)
- Forest Conservation Act (DNR): In the five-year period 1993-1997, the majority of development-related clearing in Maryland occurred within the Route 301/Baltimore-Washington Interstate 95 Corridor, with 55 percent occurring in just three counties (Montgomery, Prince George's, and Charles), which also accounted for 43 percent of the retention and 56 percent of the planting statewide.
- Energy efficiency incentives (High Efficiency Green Buildings, Maryland Clean Energy Incentive Act, Green Energy goal of 6 percent, goals for reduced energy consumption per gross square foot, expanded use of renewable energy [e.g., Million Solar Roofs program], purchase of energy efficient produces, and increased alternative fueled vehicles)
- MDE's Managing Maryland for Results Goal 8, Objective 8.4 – Achieve attainment with the one-hour ozone standard by 2005 in the Baltimore and Washington metropolitan areas and Cecil County
- Ozone Transport Region members: Maryland, DC and 12 other states along the eastern seaboard from Virginia to Maine
- Carpooling, High Occupancy Vehicle lanes to reduce VMTs (MDE)
- Enhanced Vehicle Emissions Inspection program (MDE)
- Clearer Fuels and Emissions (MDE)
- Diesel Emission Reduction Activities—permitting and compliance (MDE)
- Cross Boundary Air Pollution (MDE)
- Ozone Pollution Map and Ozone Forecasting (MDE)
- Ozone Action Days (MDE).

Opportunities for Enhancing Resilience

Several opportunities to enhance resilience in the Baltimore-Washington Corridor focus on critical aspects of this high-density area. Current issues that link to climate change include urban forestry, air quality, transportation-related congestion, vulnerable infrastructure, energy efficiency, and the ability to monitor water abundance.

Green spaces in urban areas are important for the quality of life of city dwellers, and they may be important habitats in their own right for various plant and animal species, particularly those that migrate. Coordination among programs that affect the urban wilderness, such as GreenPrint/ Green Infrastructure (which identifies green links that may be needed for migration and species habitat, including urban spaces) and Smart Growth (which influences decisions about where development may occur), are important. Landscape architecture and identification of suitable tree and other plant species are crucial ingredients in effective design and implementation of urban green spaces. These dimensions may benefit by drawing on expertise available in the Maryland Department of Agriculture and agricultural research institutions in Maryland.

The state should continue work to improve compliance with the federal ozone standard and NO_x emissions generally, as outlined in the MDE goals.

Environmental and climate change issues need to be better integrated into transportation planning. Goal 5 of the 2002 Maryland Transportation Plan states, "Provide responsible stewardship of natural, community and cultural resources." The plan acknowledges conflict between this goal and traditional transportation goals of mobility and efficiency, and resolving this conflict will be important.

Adopting building codes for energy efficiency and the ability to withstand severe weather can increase resilience in the densely populated areas of the Baltimore-Washington Corridor.

Incentives provided to businesses that make "green" products and/or that adopt "green" building and infrastructure features can improve the resilience of the state, make urban areas more livable, and demonstrate leadership.

Improved stream gauging would provide earlier warning of drought, enabling water resources managers and users to plan strategies to cope to reduced water supplies. The USGS and the Maryland Geological Survey report that stations with 21-40 year records have been discontinued, and there is a shortage of stations in the Valley and Ridge and Great Valley provinces of the state.[20]

[20] http://www.usgs/lookup/get?FS126-97

III. What's "at risk" in the Coastal and Rural Area?

Basic Description and Important Values

Ten counties are located in the geographic region we categorize as the Coastal and Rural Area of the state. Worcester County borders the Atlantic Ocean, while 7 counties border the eastern side of the Chesapeake Bay: Cecil, Kent, Queen Anne's, Talbot, Dorchester, Wicomico, and Somerset Counties; Caroline County lies near the eastern side of the Bay, and St. Mary's is located on the southwestern side of the Chesapeake Bay.[21]

Although comprising 38 percent of the State's land area,[22] less than 10 percent of the State's population (482,114 people)[23] resides in these 10 counties and only 7 percent of the wages in the state are paid here. Population density in these coastal and rural areas is only 112 people per square mile, in contrast to the state average of 529 people per square mile. The state's population is growing 11 percent per year on average and all of these counties have experienced growth, ranging from 1.4 percent in Dorchester to 32.9 percent per year in Worcester. The major economic sectors in the Coastal and Rural Area, measured in wage data,[24] are Trade, Transportation, and Utilities ($239 million); Education and Health ($164 million); and Professional and Business Services ($154 million). Other important sectors include Leisure and Hospitality ($106 million), Construction ($80 million), and Financial Activities ($50 million).

Over 30 percent of the State's Natural Resource and Mining economic activities (mainly farming and fisheries), as measured by wages, are conducted in these 10 counties, while 12 percent of the Leisure and Hospitality activities and 10 percent of the Manufacturing activities occur here. Agricultural output includes corn, soybeans, and hay, as well as chicken growing and processing. Dockside value for commercial fisheries landings in the Chesapeake Bay, including Maryland's signature species, the blue crab, totaled more than US $172 million in 2000 or five percent of the harvest value from all states combined.

Wetlands (tidal and nontidal) are the dominant ecosystem on the eastern shore area, where most of the land area is only five feet above sea level.[25] In addition, many waterways that are important for agricultural and recreational activities bisect this region, including the Wicomico, Choptank, Wye, Sassafras, and Elk Rivers. Ocean City and Assateague Island in Worcester County are some of the most popular East Coast tourist destinations, and Blackwater National Wildlife Refuge in Dorchester County provides tourists with wildlife and bird watching recreational activities.

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[21] The other six counties and Baltimore City that are wholly or partially coastal are included in the Baltimore-DC Corridor Area described in the previous section.
[22] Land area statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/o1glance/html/area.htm.
[23] Population statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/pop.htm and www.bea.doc.gov/bea/regional/reis/drill.cfm.
[24] Wage data are from www.bea.doc.gov/bea/regional/reis/drill.cfm.
[25] Johnson, Zoë Pfahl, *A Sea Level Rise Response Strategy for the State of Maryland*, Maryland Department of Natural Resources, Coastal Zone Management Division, Annapolis, MD, October 2000.

Vulnerabilities and Resiliency

The Coastal and Rural Areas of Maryland may be the most affected area in the state by both the direct and indirect effects of climate change. Because these Coastal and Rural Areas rely heavily on the estuarine, ocean, and wetland ecosystems for many of the fisheries and recreational activities for which the state is known, these ten counties may become among the most significantly impacted by climate change. And because climate change may have different effects on different plant and animal species and economic sectors, there may be some "winners" and some "losers."

General Risks Related to Climate/Weather

Weather-related risks were estimated by the Maryland Emergency Management Agency (MEMA) in 2000 (see table below). The coastal and rural counties show a relatively high risk for a variety of climate-change induced storm events, particularly tidal/coastal flooding and tropical cyclones.

Risks were generally estimated using historical data for frequency and severity of occurrences. For example, to estimate risk of tidal and coastal flooding, MEMA used data from the National Weather Service and Maryland Department of Natural Resources for 1970-1998 (events, jurisdiction, deaths, injuries, property/crop damage, and Q3 Flood data derived from Flood Insurance Rate Maps) and created statistical summaries, typically as total events by county (divided by number of years of data to compute events per year) or average/median severity per event. To convert to risk indicators, MEMA then (1) sorted measures from lowest to highest values and (2) examined the sorted values for natural breaks in the distribution, as a basis for assigning five risk categories.[26]

	High Risk	Medium-High Risk
Drought	Cecil	
Extreme Heat		Cecil, Kent, Caroline
Tidal/Coastal Flooding	Dorchester Worcester	Kent, Talbot, Queen Anne's
Tropical Cyclone	Somerset Worcester	Talbot, Dorchester, Wicomico
Thunderstorm		Cecil
Tornado		St. Mary's

Source: Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000.

However, this method estimates the risk of *occurrence* without consideration of the area's vulnerability or resilience to these occurrences. That is, the same extreme weather event can have very different outcomes depending upon how well people are prepared –

[26] Appendix A, Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000. Counties in the medium, medium low, and low risk categories are included in the MEMA report.

with well-built infrastructure, appropriate siting and insurance, emergency notification and management plans – to minimize the potential harms and quickly recover.

Coastal Infrastructure

Average sea level along Maryland's 4,360-mile coastline has been rising approximately one foot per century. Over 30 percent of Maryland's coastline currently undergoes some degree of shore erosion, which results in the loss of about 260 acres per year.[27] Climate change may increase the rate to nearly two to three feet by the year 2100. Impacts of sea level rise include shoreline erosion, flooding, inundation, and changes in salinity and water temperature.

The level of impact of climate change will be determined by the characteristics of a given region. These eastern shore counties tend to have lower topographic elevations than western shore counties. Areas of lower relief will be more vulnerable to storm surge and sea level rise, since rising waters will travel further inland along low elevation shorelines for each foot of increased water level. A one-foot rise in sea level may result in a one-foot rise in flood level, thus exacerbating the impact of episodic storm flooding in coastal communities.[28] Counties toward the southern end of the Chesapeake Bay like Dorchester, Wicomico, and Somerset may experience the most damage from sea level rise, because a significant portion of the these counties is less than five feet above sea level; large portions of the land area may be inundated at high tide if sea level rises a foot and a half or more.

Beach replenishment, used to counter shoreline erosion, is already an annual cost to many coastal communities and governments. In addition, costs of sea level rise may include damage to valuable beachfront real estate, scenic roads, and infrastructure such as sewers.

Fresh Water Resources

Over 80 percent of Marylanders in the Coastal and Rural Area of the state rely on groundwater for their source of drinking water.[29] Should precipitation levels fail to recharge the aquifers faster than water is withdrawn for agricultural and residential purposes, the aquifers could fail to meet the needs of the nine counties on the Eastern Shore. In addition, saltwater intrusion into the wells from subsidence and sea level rise could contaminate the wells and make them too salty for drinking and irrigation purposes.

Farming

Climate change is likely to bring with it both negative and positive agricultural impacts. Some agricultural sectors may benefit from rising atmospheric concentrations of carbon dioxide (CO_2). Crops use carbon dioxide in photosynthesis, so, as atmospheric

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[27] *Governor's Shore Erosion Task Force Final Report*, January 2000.
[28] *Sea Level Rise Response Strategy for the State of Maryland*, Maryland Department of Natural Resources, October, 2000.
[29] *2000 Annual Report*, Maryland Department of the Environment, Baltimore, MD.

concentration increases, growth rates may also increase. The extent of this "CO_2 fertilization effect" is the subject of much current research. In particular, if farmers are able to adapt to climate change, soybean, corn and tree fruit production may increase.[30] However, increased carbon dioxide may also promote the growth of weeds and may result in the need for higher doses of herbicides.

It is uncertain how changes in temperature, precipitation, and extreme weather may impact agriculture. Contrary to the benefits of increased carbon dioxide on crops, warmer temperatures may increase the survivability of insect pests over winter and encourage fungal disease development. In addition, more frequent droughts may increase stress to crops, which would lower food production. Finally, salt-water intrusion into agriculturally important waterways on the Eastern Shore from rising sea level may increase salinity beyond crop tolerance. Corn, for example, can only tolerate salinity of one to two parts per thousand and soybeans about three-tenths part per thousand.[31] Where irrigation intakes are located in tidally influenced areas, farmers may have to avoid using irrigation water from tidal rivers; this, in turn, may put more pressure on groundwater aquifer withdrawal.[32] While poultry production may be unaffected by climate change, the state may wish to ensure that poultry house ventilation systems are sufficiently capable of regulating the temperature and humidity in the houses, given likely warmer temperatures.

Fisheries, Wetlands, and Habitat

Climate change may have a variety of direct and indirect impacts on the Chesapeake Bay, which ranks third (after the Atlantic and Pacific Oceans) in the nation's fishery catch. A primary response to climate change in the state may be a 2º F rise in air temperature by 2030 and 8º F increase by 2100.[33] Because air temperature accounts for 70 to 90 percent of the variance in upper Chesapeake Bay water temperature, researchers estimate Bay water temperature may increase by the same amount. Warmer water temperatures may shorten the winter season in the Bay and allow earlier spring immigration and later emigration of many coastal species that use the Bay as a seasonal feeding ground or nursery area. Some of the most sought-after species by both commercial and sport fisherman are the migratory species, such as the Maryland blue crab.

Because warmer water holds less oxygen, dissolved oxygen level (an indicator of the general ecological health of water bodies) may decrease. Drought conditions would reduce flow from the Bay's three largest tributaries, the Susquehanna, Potomac and James, resulting in greater salinity conditions in the Bay. "Winners" under drought

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[30] *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, Mid-Atlantic Overview*, A Report of the Mid-Atlantic Regional Assessment Team for the US Global Change Research Program, Washington, DC, U.S. Environmental Protection Agency and Pennsylvania State University, 2000.

[31] Horton, Tom, "Drought Raises Salinity," *The Sun in Anne Arundel*, May 10, 2002.

[32] Statewide, less than 1% (ca. 97 million gallons per day) of permitted surface water and more than one-third (ca. 47 million gallons per day) of permitted groundwater withdrawals are used for irrigation purposes. See http://www.dnr.state.md.us/watersheds/surf/indic/md/md_indic.html.

[33] Johnson, Zoë Pfahl, *A Sea Level Rise Response Strategy for the State of Maryland*, Maryland Department of Natural Resources, Coastal Zone Management Division, Annapolis, MD, October 2000.

conditions could include oysters, anchovies, and hard clams. Oysters, should they fall prey to their diseases that thrive under saline conditions, could become "losers" during drought conditions, as could underwater grasses that cannot tolerate too much salinity.[34] The fishing industry as a whole could become a major loser if drought conditions affect the health of fish, as in the outbreak of dead and diseased fish attributed to *Pfiesteria* in 1997, triggering fishing closures and bans on fish consumption.[35] Climate change could undermine the efforts to restore the Bay's underwater grasses, which provide essential habitat for many important Bay creatures, especially during the juvenile stage of their life cycle. In addition to higher salinity problems, higher sea levels could deepen the habitat for the submerged aquatic vegetation (SAV) and, together with shoreline erosion, could reduce the plants' ability to receive sunlight due to increased suspended sediment.

> Wetlands such as freshwater and salt marshes dominate the shoreline in the eastern side of the Chesapeake Bay. Wetland ecosystems provide habitat for food, shelter, spawning, nesting and predation activities for commercially important species such as striped bass, herring, spot, summer flounder, blue crab, eastern oyster and horseshoe crabs. Wetlands reduce erosion, mitigate flooding, and slow runoff so that nutrients and pollutants are trapped before entering coastal waters. Climate change could essentially "drown" marsh grasses and wetlands faster than they could migrate upland; migration potential is not only topography dependent, but also dependent on coastal development levels. A similar problem could affect the barrier islands, especially Assateague, which already migrate. If sea level rises too rapidly, the whole of Assateague Island could disappear. Blackwater Wildlife Refuge has experienced particularly severe wetlands deterioration from the combination of shoreline erosion, and subsidence caused by groundwater aquifer withdrawal for agricultural purposes, and sediment and nutrient problems.

Quality of Life, Recreation, and Tourism

Warmer temperatures may encourage more tourist visits and permanent residences on the coasts, if warmer air and water extend the recreation season. However, the economic benefits of longer coastal recreational seasons could be more than offset by frequent or intense storms and rising sea level, which would damage properties along the coastline and discourage tourism. Sea nettle jellyfish may also keep tourists away should the warmer and saltier water encourage them to arrive in greater numbers earlier in the summer and migrate northward into normally freshwater upper reaches of the Bay. In addition, red tide algal blooms and outbreaks of fish disease could keep people from enjoying swimming in the Bay and eating seafood. This could lower the quality of life for Marylanders in general, and specifically the citizens that depend on a robust tourist and seafood season for their livelihood. The bird-watching tourist industry may benefit from climate change. Birds that spend their winter in the Bay may stay longer if winters are milder and those that arrive in the spring to breed may stay on through summer. However, climate change could also damage the wetlands habitat, as discussed above, to which these birds are drawn every year.

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[34] http://www.dnr.state.md.us/bay/monitoring/river/drought/bay_salinity_2002.html
[35] Horton, Tom, "Drought Raises Salinity," *The Sun in Anne Arundel*, May 10, 2002.

Current Monitoring and Research Programs

Some research and monitoring programs that are focused on Maryland address specific aspects of climate change, such as the effects of elevated levels of carbon dioxide on crops and wetlands. Others address environmental problems that could be exacerbated by climate change. Still others measure and monitor important environmental indicators. However, the set of programs does not address important questions related to climate impacts; nor do the programs meet the need for a defined set of indicators and appropriate monitoring.

- Experiments on the effects of elevated levels of carbon dioxide and ground-level ozone on agricultural crops important to the state: soybeans, wheat, and corn (University of Maryland College of Agriculture and Natural Resources and the Smithsonian Environmental Research Center)
- Experiments on the effects of elevated carbon dioxide and sea level rise on salt marsh ecosystems (Smithsonian Environmental Research Center)
- Repetitive Loss Database: identifies 296 properties with two or more flood losses totaling $1,000 or more on each loss (or insurance claim), claims at least 10 days apart and within 10 years from each other (MDE)
- Flood Insurance Rate Map (FIRM) effort to be able to better assess risk, implement regulations, and appropriately insure floodplain properties (MDE)
- *2000 Governor's Shore Erosion Task Force Report* (DNR)
- *A Sea Level Rise Response Strategy for the State of Maryland* Report which was adopted in 2001 as an Interim Planning Guide (DNR) to developing a *Comprehensive Shore Erosion Control Plan*
- Dorchester and St. Mary's Shoreline Erosion Management Planning pilot projects (DNR)
- Proposal to conduct the first statewide high-resolution digital topographic data (LIDAR) mapping project. Estimated cost is $4.1 million to map all of the coastal counties in the State (DNR, MEMA, Army Corps of Engineers)
- Monitoring the regional climate change signal from pollen/sediment cores from the Chesapeake Bay (USGS)
- Wetland Loss-Wetland Gain Project in Dorchester County documenting the rate at which woodlands may be converted to upper marsh surface in future decades (USGS)
- Blackwater National Wildlife Refuge "Habitat Displacement and Sea Level Change" study (USGS)
- Long-term monitoring of the 2,700-acre Smithsonian Environmental Research Center site, including continuous water and nutrient discharge from the Rhode River watershed into Chesapeake Bay; forest growth; fish, crab and phytoplankton population sizes; aquatic invasive species; salt marsh growth; and ultraviolet radiation levels.

Opportunities for Enhancing Resilience

Sea level rise and shoreline erosion are recognized problems that will be exacerbated by projected climate changes. Other relevant research programs may become more linked and focused as relevant Maryland-related questions and information needs with regard to climate change are identified.

Because economically important assets may be lost to sea level rise and flooding events, mitigating damage to coastline properties may become a top priority. One option involves adopting a statewide one-foot freeboard requirement (i.e., elevating the lowest floor of occupied areas one foot above the 100-year flood level). Several counties (Worcester, Somerset, and Dorchester) in this geographic area have not adopted any freeboard ordinances.

For improved risk assessment, regulation implementation and appropriate floodplain insurance, a statewide effort to use advanced technology to improve the accuracy of the Flood Insurance Rate Maps (FIRMs) may be an attractive option. LIDAR technology could be used to generate detailed topography to be used in models to predict areas of flooding and flood heights in new digital FIRMs.

To assess the potential need for adaptation for irrigated crops near the coast, a study could be undertaken to determine where irrigation intakes are located relative to current and projected tidal freshwater areas.

In order to assess the contribution to sea level rise of melting glaciers and polar ice caps, and land subsidence, the state could consider conducting a coastal area sea level rise fine-scale digital mapping effort.

When considering enhancing or modifying key state statutes to remedy barriers and advance statewide sea level rise planning initiatives, policy makers should refer to the recommendations in the *Sea Level Rise Response Strategy for the State of* Maryland Report (2000).

IV. What's "at risk" in the Western Mountain Area?

Basic Description and Important Values

The Western Mountain region consists of 3 counties – Garrett, Allegany, and Washington – and comprises only about 16 percent of the total land area in Maryland.[36] It is bounded by West Virginia, Pennsylvania and the Potomac River. Lying in the west of the state, the region includes the land areas of the Appalachian Plateau, the Appalachian Ridge and Valley, and the Blue Ridge.

[36] Land area statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/o1glance/html/area.htm.

This region is known primarily for its natural beauty and abundant opportunities for outdoor recreation. It contains 4 of the 7 state forests in Maryland, 5 wildlife management areas, 13 state parks, the Appalachian Mountains, three rivers and the state's largest body of fresh water, Deep Creek Lake. Attractions include whitewater rafting and kayaking, fishing, swimming, wilderness hiking, mountain biking, bird watching, camping, golfing and skiing.[37]

The region contains less than 5 percent of the state's population,[38] and has a low population density of 146 people per square mile compared to the state average of 529. The growth rate of population between 1990 and 2000 ranged from zero in Allegany County to 9 percent in Washington County, compared to the state average of 11 percent.

Despite its abundant natural wealth, only 3 percent of total wages accrue to this region.[39] The major economic sectors in this area measured in wage data are Trade, Transportation, and Utilities ($130 million); Manufacturing ($123 million); and Education and Health ($109 million). Other important sectors include Financial Activities ($62 million), Construction ($44 million), and Professional and Business Services ($42 million). Leisure and Hospitality accounts for only $26 million, or 3% of the economic activity in this region.

From the above distribution of economic activities, it appears that this region is not very climate sensitive. However, closer inspection shows that this is not the case. For instance, the importance of the forest products industry cannot be seen from the above data. However, if we disaggregate these data, it can be seen that the 'forest products industry' is distributed between two economic sectors – Natural Resources and Mining, and Manufacturing, the latter of which is in fact very important to the State's economy. Moreover, the importance of the forest products industry is evident in the employment data, which show that this industry is the largest employer in two of the three counties in the region. Therefore the region is not as climate proof as it may initially appear.

Vulnerabilities and Resiliency

This section outlines some of the ways in which the Western Mountain region may be vulnerable or resilient to climate change.

General Risks Related to Climate/Weather

The table below indicates weather-related risks estimated by the Maryland Emergency Management Agency (MEMA) in 2000. It points out the high risk of changes in winter weather in Garrett County and a medium-high risk for the rest of the region. However, it is difficult to say what the outcome of changes in winter temperatures will be – on one hand, snow may be replaced by rainfall, which would decrease risks associated with

[37] See http://areas.wildernet.com/pages/area.cfm?areaID=MDTRWM&CU_ID=1.
[38] Population statistics are at http://www.mdarchives.state.md.us/msa/mdmanual/01glance/html/pop.htm and www.bea.doc.gov/bea/regional/reis/drill.cfm.
[39] Wage data are from www.bea.doc.gov/bea/regional/reis/drill.cfm.

snow, but, on the other hand, snow may be replaced by ice storms, in which case the risk may increase.

	High Risk	Medium-High Risk
Drought		Allegany, Washington
Extreme Heat		Washington
Flash/River Flooding	Allegany	Washington
Thunderstorm		Washington
Tornado		Garrett
Winter Weather (snow and ice)	Garrett	Allegany, Washington

Source: Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000.

Risks were generally estimated using historical data for frequency and severity of occurrences. For example, to estimate risk of winter weather (snow and ice), MEMA used data from the National Weather Service for 1970-1998 and the National Climatic Data Center for 1949-1996 (events, jurisdiction, deaths, injuries, property/crop damage, and daily snowfall amounts by weather station) and created statistical summaries: total events by county (divided by number of years of data to compute events per year) or average/median severity per event. To convert to risk indicators, MEMA then (1) sorted measures from lowest to highest values and (2) examined the sorted values for natural breaks in the distribution, as a basis for assigning five risk categories.[40]

However, this method estimates the risk of *occurrence* without consideration of the area's vulnerability or resilience to these occurrences. That is, the same extreme weather event can have very different outcomes depending upon how well people are prepared – with well-built infrastructure, emergency notification and management plans, for example – to minimize the potential harms and quickly recover.

Water (Quality, Quantity, and Flooding)

As can be seen, there is a high risk of flooding in Allegany and a medium-high risk in the rest of the region. In fact there has been a continuous occurrence of flooding for many years in the 1990s that has resulted in considerable loss of property. It is possible that the increase in water, which has caused the flooding, is on account of the change in winter weather, although this has to be researched further. It would also be interesting to look into whether it would be possible to use the abundant water from this region in the more drought-prone populous regions of the state.

[40] Appendix A, Maryland Emergency Management Administration, *Maryland Hazard Analysis*, Koontz, Michael, et al., GEOMET Technologies, Inc., and Towson University, Department of Geography, January 2000. Counties in the medium, medium low, and low risk categories are included in the report.

Forestry

The mountain areas of western Maryland contain a variety of oak forests and northern hardwoods (beech, birch and maple trees). Forest products are a large industry in Maryland, employing more than 15,500 people; the industry is the largest employer in Garrett and Allegany Counties. The forest products industry is diverse, including sawmills, a paper mill, pulpwood operations, family-owned logging companies, firewood operators, whole-tree chippers, and veneer log buyers, as well as producers of furniture, cabinets and other secondary wood products. In 1993, income from timber sold in Maryland was estimated to be $29.3 million. Studies show that for every $1 paid to landowners for the sale of timber in 1993, $14 was generated for the State's economy.

Climate change is likely to reduce the dominance of maple-beech-birch forests in the mid-Atlantic region with an increase in oak-hickory forests, and to a lesser extent, southern pine and mixed oak-pine forests. However, we do not know how these changes will take place. If the changes take many decades, people will have the opportunity to adapt and to slowly change their forestry practices as the species mix changes. However, the shifts in forest types and their location could diminish the competitiveness of the many small hardwood processors of the western region in the short or medium term. Since there are strong inter-linkages between this industry and the rest of the economy – studies indicate that the primary wood manufacturing industry has the highest employment multiplier of all industries in the state – ripple effects will be felt across the state. Moreover, if the rate of change is faster than that of new tree growth, existing species may die before replacement species can mature unless tree planting programs are implemented.

Yet another industry at risk is the current maple syrup industry in this region. According to the New England regional assessment study, there is a migration of this industry towards the north due to climate factors. The study explains that maple syrup production in New England depends on the proper combination of freezing nights and warmer daytime temperatures, as well as prolonged cold temperatures in February and March. However, climate conditions appropriate for sustained sap flow are now more favorable in Canada and less so in New England, which has warmer daytime and nighttime temperatures, and therefore the industry has moved north. In this context the study mentions the interesting fact that in 1928 the center of maple syrup production in the United States was in Garrett County, Maryland.

Quality of Life, Recreation, and Tourism

The western part of this state derives its identity from its associations with nature in general as well as certain recreational activities that it has come to be known for. To the extent that these are at risk from climate change, the quality of life in this region will certainly be affected.

For example, Western Maryland, particularly Garrett County, is well known for trout. Brook trout is the only native trout of Maryland, but there are several other stocked trout

present. However, the trout population has significantly reduced over time; from 3 million to only around 300,000 brook trout in Maryland streams today. One important reason cited for this decline is the increase in water temperature. While this temperature rise has been to a large extent due to trees that have been felled, exposing the trout to direct sunlight, global climate change would also contribute to heating up the waters in the long run and therefore place additional stress on the trout population.

Reduction of biodiversity is a concern in this region, as in the other regions of the State. If climatic and ecological zones shift as expected, thousands of species of plants and animals will need to migrate to new habitats. Scientists question whether all of these plants and animals can migrate sufficient distances in the time available and re-establish themselves in the new habitats. Although common and widely distributed species will survive, many rarer species could face local or global extinction. Examples in the Western Mountain area include forest understory wildflowers, rare species of reptiles and amphibians (including salamander species that have survived from the last glacial age in high elevations), and plants and animals of unusual and rare habitat/ecosystem types.

The region is also associated with its skiing, an industry that is also likely to be affected by rising temperatures, which may shorten the length of the winter recreation season. The skiing industry in the northeast part of the United States in general is extremely climate-dependent with a narrow margin of profitability, such that even a small difference in the duration of favorable weather can affect the economic viability of the sport in the region. For dual-season resorts, the loss of winter revenues may affect their overall viability.

Current Monitoring and Research Programs

Several programs are already in place that address the issues of forest conservation. These programs do not have explicit climate change objectives, yet their goals are consistent with establishing and maintaining carbon sinks. Addressing climate change may give these programs added impetus. In addition, flood mitigation is a particular concern in this area and could benefit from the long-term perspective of climate change adaptation.

- The Forest Conservation Act (DNR)
- The Stream ReLeaf Program (DNR)
- Strategic Forest Lands Assessment (DNR)
- Conservation Reserve Enhancement Program (MDA)
- Forest Conservation and Management Program (DNR)
- Forest Stewardship Program (DNR)
- Woodland Incentive Program (DNR)
- Rural Legacy Program (Smart Growth)
- Maryland Environmental Trust (DNR)
- Maryland Agricultural Land Preservation Foundation (MDA)
- The Governor’s Flood Mitigation Task Force for Western Maryland (MDE)
- Maryland Tree Farm Program (DNR)
- Cost-Share Assistance (USDA)

Opportunities for Enhancing Resilience

Several programs address in particular the issue of how to protect the forests. However, the main focus of most of the programs seems to be to protect forestland from being converted to non-forest land on account of development. The Strategic Forest Lands Assessment, which adopts a multi-disciplinary approach in assessing the vulnerability of the forests (socio-economic as well as ecological), does not consider climate change as one of the sources of vulnerability. There should be more research in the direction of assessing what the likely impacts of climate change will be on these forests.

Moreover, whenever reforestation is done, due attention should be given to ensuring that the trees planted will be resilient to the projected climatic conditions of the future. This would be useful to keep in mind for a program like the Conservation Reserve Enhancement Program (CREP), which tries to restore land taken out of agricultural production and convert them into forests.

Another positive outcome of planting more trees would be that the trout population would find it easier to survive, as they are primarily under threat from sudden exposure to direct sunlight when overhanging trees are cut.

There should also be consideration given to the water in this region being channeled for use in the drought-prone areas.

Monitoring water resources is important for early detection of droughts. Improved stream gauging programs to monitor water resources (and climate change impacts) will allow water managers to take earlier proactive measures to mitigate the effects of drought.

V. Statewide Opportunities for Enhancing Resilience

Stakeholder Involvement

Developing effective responses to climate variability and change requires involving those whose interests will be affected by change and/or whose cooperation is required to implement a response. This is true whether the response involves reducing greenhouse gas emissions to mitigate change by reducing emissions, or adapting to change by altering infrastructure or resource use. Involving stakeholders can help to educate them about what is known, what is uncertain, and what strategies may be effective. Stakeholders can also educate policymakers about what is valuable to them and what they are willing to do. This interaction is particularly important for an issue such as climate change, views of which have become polarized in the political process. Stakeholder participation also strengthens development of response options, because stakeholders often have specific knowledge about how climate change affects their locality, livelihood, or sector, knowledge that can affect implementation.

Because development of responses to climate change and its potential effects touches so many groups in various situations and walks of life, it is important that a broad set of outreach and stakeholder activities be developed as part of a state-level effort to address potential vulnerabilities and strategies for increasing resilience. However, it is also important to *focus* specific activities so that they address the unique needs of each set of stakeholders who are involved. A major aspect of developing effective stakeholder participation is to be clear about the goals of involvement from the start. Stakeholders can help set the agenda for examining potential impacts, refine research questions so the results will yield useful information, contribute to scenario-building, and evaluate outcomes of various analyses. Stakeholders can help to design effective decision support systems to deliver and apply information on climate variability and change in management of natural resources, such as water. Stakeholders can also provide access to important information, such as insurance risks.[41]

Maryland has demonstrated its willingness to involve stakeholders in programs such as the Governor's Shore Erosion Task Force and the planned involvement of the Green Building Council in developing the "Maryland Greenhouse Gas Reduction Action Plan." Several academic and civic programs are also involving stakeholders. Examples include the Environment Project, Statewide Energy Pollution Prevention Program (SEPPP) at the Community College of Baltimore County and research into the prospects for wetlands to survive sea level rise at the Smithsonian Environmental Research Center and the University of Maryland-College Park.

Multiple strategies for stakeholder involvement can engage people at different levels and in various ways. Innovative activities have been designed and implemented for general issues such as examining the basis for projecting climate change as well as for specific issues such as how to plan for sea level rise and mitigate damage from intense storms and floods, and droughts.

Stakeholder activities oriented towards development and application of research in applied settings have been the focus of recent activities conducted under the auspices of the United States Global Change Research Program (USGCRP), specifically the U.S. National Assessment of the Consequences of Climate Variability and Change.[42] Several federal research agencies working with the USGCRP have established stakeholder-driven decision support processes that have improved application of knowledge in water resources, agriculture, fisheries, and other natural resources. The aim of these activities is to enhance economic vitality, while maintaining environmental quality and limiting threats to property and lives.

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[41] *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, Mid-Atlantic Overview*, A Report of the Mid-Atlantic Regional Assessment Team for the US Global Change Research Program, Washington, DC, U.S. Environmental Protection Agency and Pennsylvania State University, 2000.

[42] *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, Overview Report*, National Assessment Synthesis Team, New York, Cambridge University Press, 2000.

The approach builds on the observation that most locations are characterized by multiple environmental and human stresses, and that the effect of a combination of environmental stresses is seldom simply additive but can amplify or dampen responses, cross thresholds, and lead to unexpected outcomes. It also takes account of the fact that there are multiple stakeholders in adaptation processes and several layers of public and private interests that have independent activities and goals. Finally, it assumes that enhancing the resilience of different groups in society requires acknowledgment that citizens are more effective in shaping their own choices and futures if they are not passive consumers of general scientific information but are actively involved in assessments, including framing and guiding the questions being addressed. The approach, which is still under development, involves stakeholders to identify the types of information required, when information is most needed, and the types of uncertainty that affect decisions.[43]

Educational and outreach programs, via academic courses at all levels (elementary to college levels), radio and television programs, news items, and web pages, should involve a broad set of audiences (although feedback may be limited outside classroom situations). The "at risk" approach taken in this report bypasses many problems of trying to make understandable the highly scientific descriptions of climate change, focusing instead upon the climate-related resources they know and value. Educational courses could be designed to be general or specific by location or issue; media communications would likely be focused on localities or issues.

One technique for gaining citizen input is conducting a Citizen's Jury. In March 2002, with funding from the US Environmental Protection Agency, such a group was convened by the Jefferson Center[44] in Baltimore. For five consecutive days, the 18 members of the jury heard expert witness presentations focusing on potential impacts of climate change. The jury members were ordinary citizens (department manager in a retail store, recruiter, retired deputy sheriff, etc.), demographically diverse, who responded to the presentations by identifying and prioritizing impacts and responses to climate change.

The Environment Project (SEPPP)[45] has employed survey instruments and focus groups in its efforts to involve Maryland citizens in climate change and other environmental issues. The project includes an online survey, Maryland Global Warming Workshops, and a list-serve.

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[43] A revised strategic plan for the USGCRP is currently under preparation that includes further development of these sorts of integrated stakeholder-research-decision support systems. The draft is not yet a public document but draws heavily on two publicly-available reports of the National Research Council: *Our Common Journey: A Transition Toward Sustainability*, Washington DC, National Academy Press, 1999; and *The Science of Regional and Global Change: Putting Knowledge to Work*, Washington DC, National Academy Press, 2001.

[44] Located in Minneapolis, MN, the Jefferson Center is "a nonprofit, nonpartisan organization committed to promoting citizen involvement in publish policy decision-making." See www.jefferson-center.org. The activity in Maryland was sponsored by the US Environmental Protection Agency, Global Programs Division.

[45] See http://student.ccbc.cc.md.us/envproj/seppp/index.htm.

The US National Assessment's Mid Atlantic Report, like the other regional assessments that were part of the USGCRP assessment process, made extensive use of stakeholder input.[46] The core team held an initial workshop (92 participants) focusing on the watersheds for the Chesapeake and Delaware Bays. Members of the Advisory Committee included representatives from the research community, mining companies, government, and nongovernmental voluntary organizations; the committee met for two 2-day sessions to identify important issues and to review the draft report. The committee also included corresponding members who provided input via e-mail, phone, and written comments. Some committee members became active collaborators.

Examples of stakeholder involvement mechanisms outside the State and region include the ULYSSES project conducted in Europe and the UK's Climate Impacts Programme. The **U**rban **L**ifest**y**les, **S**u**s**tainability and Integrated **E**nvironmental A**s**sessment (ULYSSES) project,[47] a research project on public participation in support of decision-making for sustainability, used moderated group discussions into with a computer-based modeling tool. These groups used the tool to construct scenarios and policy options, looking at the results to support their discussions, and formulated citizen recommendations as the result of their deliberations. A typical design of an Integrated Assessment Focus Group is as follows:

- Each group consisted of approximately 6 to 8 citizens, sampled according to recruitment criteria yielding a broad heterogeneous mix of participants.
- Each focus group meets for five individual sessions of about 2.5 hours each, or for two consecutive days.
- In the first session, environmental problems and climate change are discussed in a general way and in some groups the participants are encouraged to produce collages to illustrate their concerns.
- In the second session, global issues are addressed using an integrated assessment tool to stimulate the discussion.
- The third and fourth sessions focus on regional and local issues, using a regional integrated assessment tool to stimulate discussion.
- In the fifth session, the participants produce a "citizens report" on the basis of preparatory work drafted during the previous sessions.

The UK Climate Impacts Programme used extensive stakeholder involvement in developing socioeconomic scenarios of the future, scenarios that included climate change. Stakeholders were drawn from the business and policy communities and invited to comment on four general "storylines" or coherent pictures of the future, and to give input on climate impacts that would be important for the society of the future.

Integrating climate change concerns into other issues and programs can point out links among issues that may otherwise go unnoticed. Climate change issues often go hand-in-hand with other environmental issues, such as coastline erosion, loss of biodiversity, and

[46] See http://www.essc.psu.edu/mara/.
[47] Jaeger, Carlo C., Ralf Schuele, and Bernd Kasemir, *Focus Groups in Integrated Assessment: A Micro-cosmos for Reflexive Modernization*, Innovation Vol.12 (2), pp 195-219, 1999. Also see http://zit1.zit.tu-darmstadt.de/ulysses/index.htm.

flood and drought emergency management. Understanding that climate change impacts may include increased erosion, rate of species change, and extreme weather can provide both an initial impetus to action and a long-term perspective often missing from the discussions of these issues. Involving stakeholders in issue-focused discussions that include climate change can provide a broader perspective and increase the willingness to take action in the short term that will yield benefits in the long term.

In Maryland's case, stakeholders include state and local government employees, researchers working in the area, industries located in the area, citizens' groups (not only environmental groups, but other civic and social organizations), homeowners, and workers. The table below provides some specific examples for each area discussed in this study (see also Appendixes 1 and 2).

	Baltimore-DC	Coastal and Rural	Western Mountain
State government	MEA, DNR, DOT, MDE, Smart Growth, MBED, Agriculture, Planning	MEA, DNR, DOT, MDE, Smart Growth, MBED, Agriculture, Planning	MEA, DNR, DOT, MDE, Smart Growth, MBED, Agriculture, Planning
Local government	Mayor's office (Baltimore, Rockville, Frederick …), zoning officials, Port of Baltimore, county-level Parks & Recreation	Mayor's office (Annapolis, Ocean City, St. Michael's, Cambridge …), Blacklands staff	Mayor's office (Hagerstown, Cumberland …)
Researchers	BES, CBF, JHU SPH, NIH	UMCES, SERC, CBF	Appalachian Lab
Industries	Examples: Marriott, Constellation Energy Group; General Motors; DeutscheBanc Alex. Brown; Allfirst, Aether Systems, Black & Decker, McCormick & Company, Sweetheart Cup	Fishing, tourism, farming; examples from Dorchester County: Airpax Corp. LLC, Allen Family Foods, Cambridge Inc., Coldwater Seafood Co., Hi-Tech Plastics Inc., Interstate Corrpack, Maryland Wire Belts Inc., Nabisco Foods Inc., Mail-Well Graphics, Regina USA; Perdue, Inc.	Recreation (skiing, boating, fishing); examples from Washington County: Allegheny Energy, C.M. Offray & Son Inc., CertainTeed Corporation, Citicorp, D.M. Bowman Inc., First Data Merchant Services, Fleetwood Travel Trailers, Garden State Tanning, Good Humor - Breyer's Ice Cream, Mack Trucks, Phoenix Color Corporation, Rayloc Inc., Review & Herald Publishing Association, Staples Distribution.
Other	NSA, NASA, NIST, DOE, University of Maryland, BWI Airport	Blackwater and other conservation areas, Watermen's Assn.	Frostberg State University, foresters, state parks/forests/ wildlife management areas
Citizens' groups	E.g., religious, recreational, cultural, and civic groups		
Homeowners	All counties; urban and rural; single-family, condo, apartment…		
Workers	All income categories		

Business examples from http://www.mdbusiness.state.md.us/orientation/community.asp

Building stakeholder involvement into the process of planning and implementing an adaptation and resilience strategy for Maryland will be challenging and resource intensive, but success will not be possible without it. During the near term, stakeholders should be involved to the extent permitted by financial and other resources to contribute to refining our knowledge of how climate variability and change may affect important assets and natural resources. Some specific examples are given below. In the longer term, businesses and public interest groups need to participate with researchers and officials from various levels of government (federal, state, county, and local) to develop decision support activities that will deliver information to help improve environmental management in the face of a changing climate.

- In outreach educational activities, relate climate change impacts and vulnerabilities to people's personal decisions about where to live, how to travel, how to make consumer decisions, and so forth. For example, the current incentives to live near one's workplace and to take public transportation or carpool should be more widely known and, where possible, strengthened.

- A survey (or several surveys) could help to define the value of rural, coastal and mountain opportunities for recreation and vacation. Businesses could indicate how important these are in siting decisions, and people would have a chance to define what part these natural resources played in their decisions to live here and in their ongoing satisfaction with Maryland as a place to live and work.

- For specific issues where climate change can add an important dimension in planning, such as shoreline erosion, sea level rise, smart growth, wetlands preservation, or transportation planning, outreach mechanisms such as those described above could be used to engage stakeholders in finding ways to design long-term strategies that will build resilience to climate change.

Cross-Jurisdictional Coordination

As described in this report, changes in climate—whether anthropogenic or natural in origin—have the potential to interact with other environmental changes, a growing population, changing life styles, and increasing levels of economic activity to place environmental, economic, and societal assets of the state at risk. It will be a challenge to plan effectively to meet these issues for many reasons. The amount of change, how quickly it unfolds, and even the types of changes are uncertain and thus increase the range of future conditions for which resource managers, businesses, and communities must plan. In addition, the long-term nature of climate change clashes with immediate goals of the marketplace and term-in-office political imperatives. In some cases, development of long-lived infrastructure that will be resilient under a wide range of future conditions will likely have higher initial costs.

Under these conditions, the role of state and local government, in partnership with scientific researchers and stakeholders in the private sector, becomes ever more important. A focus on climate change vulnerabilities and adaptation in the state can

provide an impetus for balancing short-term and long-term problems and coordinating across agency and geographic/political boundaries. The State of Maryland, its counties, and its communities have many of the necessary assets to meet the short-term and long-term challenges. The environment, especially in and around the Chesapeake Bay, is a focus of coordinated efforts by state and county agencies, and many citizen groups. State government has begun to deal proactively with zoning, development (Smart Growth), conservation (e.g., wetlands, farmland), water management, and other issues that have climate change dimensions.

A crucial challenge that can be met, at least in part, by a focus on the integrated nature of climate change vulnerabilities and adaptation is that of crossing functional and geographic jurisdictions. Policies and programs tend to be managed within limited geographic areas or specific sectors of the economy. To make issues more tractable, government agencies are often structured to meet narrowly construed mandates. Planning to adapt will require creative thinking about how to design governmental institutions and processes to reach across limited jurisdictions, minimize tradeoffs, and improve coordination.

The complexity associated with managing the potential effects of climate change on water supply and demand provides an illustration of the challenges. Climate change can affect the quantity and quality of water resources in a variety of ways:[48] Periods of drought during some times of the year may become longer and more intense. Precipitation, when it does fall, may come in more intense outbursts, thus increasing the potential for flooding (e.g., combined sewer overflows or flooding of low-lying areas), runoff, erosion, and sedimentation. And water quality problems in streams, rivers, lakes, and bays may be exacerbated by increased water temperatures and reduced stream flows that alter salinity and/or increase pollutant concentrations. These changes are of concern to many sectors of the economy, diverse populations, and government authorities from local to national. Local water and sanitary commissions such as the Washington Suburban Sanitary Commission and the Upper Potomac River Commission must manage the effects of both drought and intense water flows, in some cases by impounding a higher percentage of water flows in reservoirs, and in others, by releasing untreated waste water into rivers that serve as the source of water for downstream communities. Without coordination, jurisdictions can take actions that make the management problems for their colleagues in other jurisdictions more difficult. Cross-jurisdictional management of water resources seems particularly important between Maryland's western and central/coastal areas. Other agencies and objectives will also be affected, however.

The Departments of Agriculture, Natural Resources, and Environmental Protection all manage programs that contribute to water conservation and restoration objectives such as

[48] See Houghton et al., *Climate Change 2001: The Scientific Basis*, Cambridge, Cambridge University Press, 2001, especially Chapter 7, "Physical Climate Processes and Feedbacks" for information on changes in the global water cycle and precipitation. See also Intergovernmental Panel on Climate Change, *Climate Change 2001, Impacts, Adaptation, and Vulnerability*, McCarthy J., et al., eds, Cambridge, Cambridge University Press, Chapter 4, "Hydrology and Water Resources," for a review of research on the impacts of changes in physical climate on water resources management.

the Conservation Reserve Enhancement Program, nutrient management from farms, watershed management and restoration, soil and water cleanup, maintenance of urban parks and forests, and comprehensive management of coastal bays and the Chesapeake Bay. Increasing probability of drought periods and more intense periods of precipitation may affect the strategies required in each of these programs. For example, more intense periods of precipitation could affect the strategies required for creating effective riparian buffers that limit pollutant runoff from farms or impervious surfaces; changes in average precipitation or temperature could affect the types of vegetation that should be recommended for planting in buffer zones. Without adequate coordination, the effectiveness of policies that are intended to serve multiple objectives may in fact be limited.

There are a number of other adaptation-related policies that would also benefit from improved cross-jurisdictional coordination, for example those that focus on *urban agriculture, forestry, and wilderness* issues. Coordination is required because all of these land uses impinge on one another in Maryland, where the traditional concept of agriculture as farming in rural settings is not appropriate because "urban centers blend into suburbs, which in turn blend seamlessly into a countryside where farms and bedroom communities exist side by side."[49]

As the potential for impacts and the need for adaptation options is identified within the state, formulation of effective policies that are not narrowly framed, incorporate the potential for synergies, and reduce undesirable tradeoffs will require cross-agency and cross-jurisdiction goal-setting. This will entail bringing agencies and stakeholders together to address the implications of particular changes and to evaluate potential responses. In particular, a process that includes coordinated setting of objectives, so that individual agencies can then develop plans within each of their individual spheres that are consistent with the overall objectives, is extremely important.

A key issue to consider in a coordinated process is the establishment of indicators that can be used to monitor progress towards reducing vulnerability or enhancing resilience. Many agencies already collect data that could be suitable with limited modifications for this purpose in the course of their normal operations. In some cases, agencies may make redundant sets of observations, and working together, could redirect some resources to fill gaps that would benefit all cooperating entities. Research agencies of the Federal government such as the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the National Science Foundation (NSF), the US Geological Survey (USGS), and others currently use such a coordination process to plan and implement monitoring and observation related to climate change and its impacts. Developing an analogous process within the state around a limited number of key vulnerabilities will help to increase resilience by using existing resources and enabling groups to consider these issues as they carry out their normal mandates.

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[49] Council for Agricultural Science and Technology (CAST), *Urban and Agricultural Communities: Opportunities for Common Ground*, CAST, Ames, IA.

VI. Next steps

This section outlines a candidate strategy for developing vulnerability assessments and adaptation options for the State of Maryland. The strategy includes a continuation of data collection on current, relevant activities and programs; case studies of vulnerability assessment, matching potential climate impacts with existing resources to cope with or adapt to the effects of climate change; and the development of an analysis of what additional resources should be developed to increase resiliency in the state. In every step of the process, stakeholder involvement is a key element.

The state should continue to develop a list of research activities and relevant studies that will contribute to the identification of potential impacts, vulnerabilities, and adaptation. These may be conducted at or funded by state or federal agencies, universities, and other research institutions.

In addition, the state should identify and characterize state programs that are relevant to climate change adaptation strategies. This includes programs or initiatives that have been implemented for reasons other than climate change but that have an added benefit of providing information, services or incentives that will facilitate adaptation to the climate change risks identified in this report. Relevant state agencies include the Maryland Department of Natural Resources, Maryland Emergency Management Administration, Maryland Office of Smart Growth, Maryland Department of Environment, Maryland Department of Planning, Maryland Department of Transportation, and Maryland Department of Business and Economic Development. In addition, the State's research institutions, U.S. Environmental Protection Agency, the Chesapeake Bay Programs Office, and the U.S. Military (Patuxent River Naval Air Base and Aberdeen Proving Ground) should be considered resources of information. The adaptation programs should be classified according to the specific climate change vulnerability or risk they are addressing and geographic location if applicable.

As part of these efforts, key state and local stakeholders should be identified. The state should engage people within the state that would be valuable contributors to the development of state adaptation strategies. This stakeholder list may include program managers, research scientists, land developers, planners, or others who have an interest in adaptation to climate change.

The data collection and analysis effort will lay the groundwork for identifying and characterizing, in greater detail than in this "at risk" report, potential effects of climate change and the potential of existing programs to provide the basis for climate change adaptation strategies.

Existing studies and programs identify the nature of impacts (e.g., storm surges, warmer winters) for different locations within the state, but they do not provide a systematic review of the potential vulnerabilities within the state. Nor do these studies match the location of these impacts with the resources of people in that location to cope with or

adapt to changing climate. To accomplish this matching, the state should select several locations and issues to analyze with respect to matching potential impacts and coping/adaptation resources in that specific location or for that specific issue. For example, the state could examine disaster and emergency preparedness programs, insurance in effect (or likely to be in effect), zoning/building requirements, current research studies, civil society networks (e.g., local Red Cross, churches, neighborhood associations), and other resources that may be available within the community and from state and federal government programs. Or the state could study water resource issues, examining cross-boundary dependencies, water quality, and other issues. To the extent possible, relevant key stakeholders will be engaged in this vulnerability analysis. At a minimum, key stakeholders will be asked for substantive input and will have an opportunity to review and comment on the written product. If possible, stakeholder meetings and workshops should provide ample opportunity for people to explore various options for the future.

Once potential impacts and current efforts related to adaptation are better understood and mapped according to geography, climate risk, and resources for coping/adaptation, the state should conduct a gap analysis to identify where the state is lacking important adaptation efforts. The analysis will use the information provided in this report and the Mid Atlantic Regional Assessment, and the vulnerability analyses in an effort to identify "gaps" in Maryland's adaptation capacity with respect to climate change.

Using the gap analysis, the state should hold a workshop designed to inform the stakeholders of the potential climate change risks. An important component of the workshop will be a brainstorming session to develop new, coordinated adaptation strategies. Potential participants in the workshops include state program managers, economic development officers, planning coordinators, and other identified key stakeholders. Adaptation experts may be included as guest speakers.

The state can then synthesize the insights gained from the process to encourage long-range planning and responsible development within Maryland state and local governments. A report should identify a *vision* of how the state should address the potential vulnerabilities to climate change. The vision should look ahead 10-20 years and should describe a state well prepared to deal with the selected climate change vulnerabilities. Once the vision has been defined, a *roadmap* may be developed for activities and initiatives that need to be created, modified, or expanded in order to achieve the vision of a prepared, responsible state.

Appendix 1: Results from Focus Groups

For the present study, we conducted two focus groups to discuss climate change impacts issues for the State of Maryland. The two-hour focus groups included Maryland citizens and researchers who participated in the U.S. National Assessment of the Consequences of Climate Variability and Change, State employees in affected agencies, and others with experience in climate change issues from various perspectives. Because all the focus group participants were familiar with the issues, the discussions were informed, lively, and useful to Maryland policymakers. Below are summaries of the two groups, held on February 25 and March 4 2002.

Summary of Focus Group Discussion:
Maryland Impacts and Vulnerability
February 25, 2002

Participants: Tom DeMoss (EPA), Julie LaBranche, John Joyce, Ken Shanks, Johnathan Patz (Hopkins School of Public Health), Ken Pickering (UMCP). And Michelle Perez, Antoinette Brenkert, Sangamitra Ramachander (JGCRI graduate assistant for vulnerability analysis), Richard Moss, Elizabeth Malone.

Impacts of Climate Change in Maryland
Impacts will be experienced in the coastal zone, including wetlands; forests and agricultural land; mountains; and urban areas. Furthermore, unintended feedbacks and connections may increase the severity of impacts, and it is important to realize that if you do something to adapt or ameliorate effects in one sector, that action may be harmful in another sector.

Loss of wetlands, especially in the lower Bay, will result from sea level rise. The seven basic functions of wetlands will be affected, including providing habitat and the basis of the food chain for crabs, fish, juveniles, shallow water species and their prey. The rate of loss may be high, with implications for replacement (no replacement for very fragile wetlands). In addition, wetlands may not be able to migrate inland even if the rate of loss might otherwise allow migration, because of human development.

We can look to North Carolina or southern Virginia to see what future ecosystems in Maryland may look like, especially tree species and pests. A few rare species of salamanders in high elevations, left in the last glacial age, will be lost.

Heat islands may get hotter. The temperature averages are misleading; we may experience sweltering temperatures in paved-over urban area. There are potential interactions with land use/cover change, especially increasing urbanization. Compounding the issue, ground-level ozone may increase.

The Chesapeake Bay may be destabilized in several ways. There may be more jellyfish and other species changes. More frequent and intense storms would mean increased sedimentation and runoff, interfering with restoration efforts in the Bay.

More frequent and intense storms, and more flooding (combined with sea level rise) would have highly variable impacts because of topography; it's been suggested that Maryland could lose Dorchester County (or at least 60-70% of it). A climate change workgroup is studying this. There will be a loss of developable land and a question about whether to pay increased costs for maintenance of infrastructure (e.g., sewage treatment) subject to flooding or sea level rise. Should the state protect or abandon such infrastructure?

Salinization, resulting from sea level rise and saline flooding of agricultural lands, will cause losses of agricultural land. If cropland is flooded three times with salt water, it becomes too saline; eventually, if flooding halts, the land can be restored by rainfall, but the restoration time is unknown. Saltwater intrusion will affect groundwater as well, and recharge areas may be paved over.

Health impacts from waterborne diseases are likely. High-intensity precipitation can result in combined sewage overflows and consequent pathogen loading for drinking water systems. (Note: Dan Morhane was referred to as knowledgeable on the climate issue and combined sewage overflow problem.) And 64% of Maryland's farms have tested positive for cryptosporidiosis infection; via agricultural runoff, most shellfish populations in the Bay can be infected. Lyme disease may be linked in its complex effects. (Note: Jonathan Patz provided handouts on climate and health.)

Monitoring

Suggestions for indicators to monitor included the following:

- Use of state-level climatological data. Much more detailed information is available than went into the MARA process.
- Ozone alert days (Annapolis)
- Recurring losses, e.g., floods
- Increased number of extreme events (precipitation and drought)
- Keep doing what we are doing—protecting resources aggressively
- Examine assumptions of future scenarios to assess the problem
- Electrical demand
- Increased heat mortality (perhaps as an indicator). The problem with monitoring health effects is extremely difficult (because health outcomes may have many causes), with the exception of heat effects (although causes of death are often debatable).
- Wetlands extent and loss: there are extensive data (e.g., Blackwater); much depends on funding; aerial photography and topographical changes; shoreline position maps.
- Disappearing islands (e.g., at Edgewater). Sea level rise must be measured relative to Eastern Shore subsidence, which adds to the global rate of change.

- A current project in St. Mary's, Anne Arundel, and Dorchester Counties is looking at projected sea level rise—the shoreline position and what would be flooded in 100 years. The impacts may be very expensive.
- Numbers of declared disasters and of bailouts (FEMA and MEMA data). Include other costs, e.g., costs that individuals just bear and rescue costs.
- Can elevate structures, but what other issues (rescue costs, well water, septic system flooding, etc.)
- Amount of sand the pumped up for Ocean City Beach—can get data on this (include subsidy identified as another program name).
- Only track very specific things definitely linked to climate change, like salinity, SLR, precipitation/storms.
- Number of hurricanes in North Atlantic and/or storm losses within the state over time.
- Asthma incidence—associated with ground-level ozone pollution? (A California study indicates that, with the right dose analysis, there is increased incidence, not just severity given incidence). Maryland and NASA have an asthma/air pollution study going on.
- Quality of life indicators? Do you plan on living here 5, 10, 20 yrs from now, and why? If what people say changes dramatically, this could indicate that something could be going on. The USFS starts assessments with this kind of survey.

Policy Needs

Little analysis has been focused on quantifying the changes; the USGS attempts to correlate biological and atmospheric change. Many data sets would be useful to increase this understanding of changes. Cross correlation of data from the recent past (~50 years) may point to causality. For example, stocks are down, but why? A look at other data on salinity change, etc. may indicate answers. Examining climate, ecology, *and* biology gives a more complete picture of how the Chesapeake Bay is responding to human loadings. The Chesapeake Bay Foundation's *State of the Bay* is a mix of science and politics/anecdotal evidence that examines 13 factors.

We should also make an effort to identify implications of second-order effects, e.g., loss of wetlands to, for example, biodiversity.

Zoning ordinances need to be kept current with expectations of impacts. The current freeboard ordinance specifies the need to build structures so they are above the 100-year flood level, which is now 1 ft—should it be more? Policies could mandate the elevation of structures in flood-prone areas, but there will still be problems resulting from flooding land/infrastructure under the elevated structures. There is also a Repetitive Loss project (John Joyce) for flood management.

For rank-ordered common stressors, we should analyze the risk of damage.

Policies should encourage or provide for growth of trees in urban areas and use of bricks or paving stones instead of pavement to help control runoff.

To reduce emissions of greenhouse gases and air pollution, the state could increase taxes on or remove subsidies to the price of gasoline.

Two-thirds of the state is coastal zone, much of it in private hands. There is a 1 km buffer zone around the Chesapeake Bay. Under the Forest Conservation Act, a forest buffer of 25 ft to 100 ft is identified for critical areas between streams and agricultural lands. These, however, are not mandatory and, where they need to be established, require years. Relevant government institutions include the CREP program and Living Resources (on biodiversity) (Julie LaBranche).

Population growth and migration are issues that get overlooked.

Better coordination among groups working on climate change should be a goal. Many people are interested, but their efforts may be uncoordinated with other activities for lack of management attention. Johns Hopkins researchers (Hugh Ellis) are using Models3 to look at air pollution (ozone and particulates) and health effects; this effort should be connected with others.

Communication with the public is a big issue. The concern is how to relate climate change with people's personal decisions to translate at that level. People who know the issue are elites who need to "market" these concerns to the public. For planning, local level efforts and clear, concise messages (e.g., show the area that will be inundated in some period) are needed, as well as hardcore evidence on which politicians can act. People will listen to the cost factor, for example, sea level rise and the costs of repair/replacement. Communications should use nontechnical language (e.g., inches, not millimeters).

We can be clearer in relating problems to risks to things we would like in the future. We need to provide a relative risk perspective; e.g., fisheries are at risk first from overfishing, then from nutrients. We should be careful not to attribute everything to climate change. However, climate change impacts can be linked to other efforts, e.g., climate change and current Bay problems, such as nutrient loadings.

We can't take people's interest for granted; not all are going to be interested. People should only have to take responsibility for what's of concern for them. For example, farmers are mostly interested in agriculture.

Summary of Focus Group Discussion:
Maryland Impacts and Vulnerability
March 4, 2002

Participants: Christine Conn, Bert Drake, Brian Fath, Chris Fox, Vic Kennedy, Pat Megonigal, Christina Mudd, Albert Nunez
Facilitators: Elizabeth Malone, Richard Moss

Impacts of Climate Change in Maryland
Any natural resource in Maryland will be affected by climate change and by other global changes. However, it is not always clear what the response of the affected natural resource will be. Wetlands provide a good example of the potential for positive and negative responses. Usually the expectation is that sea level rise and intense storms (possible impacts of climate change) will inundate wetlands and that the wetlands will be unable to migrate inland because of human infrastructures. However, this expectation may underestimate the ability of wetland plants, especially grasses, to produce more carbon (as they would in a CO2-enhanced atmosphere) and migrate *up* (water level determines their mobility). However, additional sediments may be needed to allow this upward migration.

Marine species will change; blue crabs may be helped by warmer winters, but soft crabs are stressed by warmth and may be wiped out. *If* it's just temperature that is limiting the northward spread of shrimp, we may find that shrimp can live in Maryland under climate warming. Some fish will be lost, some will increase, and commercial fisheries will have to adapt.

Terrestrial system will also be affected. Tree species will change; maples may die out, to be replaced by chestnut and oak. Peatlands and their rare plants, sensitive to hydrologic changes (drought) more than to warming, may be lost. In fresh water systems, trout are sensitive to warming and may die out.

We may be able to characterize some species changes, but we cannot predict the *ecosystem* consequences of species changes. The food webs, including predators and prey, may undergo dramatic changes that may require control strategies or adaptation.

Climate change will have impacts on human settlements and health. The combined effects of poor air quality, ground-level ozone, and urban heat islands will take a toll on health. The distribution of disease vectors will change, although Maryland and the United States in general have good public health systems. In cities, consideration is already being given to what plants survive in urban conditions; for example, elms can take urban abuses.

Several economically important activities will be affected. Some industries will be at risk and may already be approaching thresholds, notably the skiing industry, trout fishing, and maple syrup. Insurance costs for property and health may increase. There are also costs associated with the impacts identified in the *Mid-Atlantic Regional Assessment*.

Monitoring
Suggestions for indicators to monitor included the following:

- Magnitude of the biological sink (need a regional network)
- Ecosystem production (using remote sensing)
- Emissions inventory and sink estimates (in 1990 Maryland was a net source of carbon)
- Health of wetland (and test for ability to withstand sea level rise)
- Health of peatlands
- Attitudes of people in affected industries (survey: do they only care about short-term payback?)
- Soil temperature
- Status of forests
- Status of Chesapeake Bay
- Stream Survey

Policy Needs
Clearly, climate change policy needs to be connected to immediate problems. If resources could be allocated to either reducing current nutrient and pollutant loadings or to adapting to climate change, the former would be preferred. Climate change will be an additional stress, but current problems are more serious.

Nevertheless, education and communication are needed. Visual images can help people picture some likely consequences where they live (e.g., Chesapeake Bay recreational activities) as well as adaptive responses that are possible. Simple and/or draconian arguments do not work; complex, future-oriented arguments should include multiple lines of evidence. People are often urged to plant trees in urban spaces, but the type of tree, heat stress, and the effects of elevated CO_2 should be considered in these kinds of planting schemes.

Similarly, motivations for change are varied. Economic constraints and opportunities (taxes and subsidies) certainly have effects but are probably not sufficient. Efficiency standards can change the way products are made and buildings built; for example, structures can be designed for the worst-case scenario. Changes in natural resource use must start with the concern that most people feel and provide behavioral options that will be acceptable.

Maryland should also explore opportunities to participate in carbon trading.

Final Thoughts

- It's important to get a grasp of the impacts. We need to plan.
- The Chesapeake Bay is a system under stress; we need to remove the stressors. We also need a national-level energy policy.
- Education needs to be a major initiative. Also, long-term objectives for research need to be defined.

- Monitoring is important, but key monitoring programs are threatened (e.g., USGS monitoring of water). Be aware of ongoing programs, e.g., the Smithsonian has the longest record of UV measurement, etc. *Be proactive*.
- We need a US Global Change *Education* Program to go along with the Research Program.
- Every urban area needs an action plan, including energy consumption by sector and fuel. The plan should establish a baseline, set a target/goal, and monitor.
- We should find out about and *use* existing data for communication and planning.
- Climate change is just one of many stressors; land-use management relates to many of the stressors. We should see the costs of preparing for climate change as *investments*.
- We shouldn't focus only on research. We can't predict changes in Maryland (precipitation, etc.) but should analyse the potential impacts of the range of potential changes; and we must continue to monitor biological systems. We must deal with the climate change issue, using scenarios to evaluate possible impacts, and not wait for research results.

Appendix 2: Current Programs and Activities Related to Climate Change Impacts

Telephone and Internet Surveys
Conducted April – May 2002

Arranged by:
State of Maryland Agencies: Maryland Department of Natural Resources and Maryland Department of Environment
Other Agencies: Research Programs and Stakeholder Programs

Methodology

Over 60 individuals were contacted by telephone or electronic mail over the course of two months to determine which individuals or institutions are involved in activities assessing Maryland's vulnerability to climate change. Overall, very few individuals were involved in a specific vulnerability assessment project. A few individuals are involved in activities relating to various aspects of climate change: experimental studies, monitoring, etc. The topic focused on by the most number of individuals surveyed was sea level rise. The results of the informal survey are listed below.

During each telephone personal communication, the following information was collected:

- Name of effort having to do with assessing climate change vulnerability in the state of Maryland or climate change activities in general as related to the state of Maryland
- Agency Category: Federal, State, Municipal, University, Interagency and Interstate workgroup, etc.
- 5 Functional Categories: Ecosystem, Food, Human health, Settlements, and/or Water
- Geographic Area Category: Statewide, Chesapeake Bay, Counties, etc.
- Contact(s) for Effort: Name, Title, Organization, Address, Phone, Fax, Email
- Website addresses if available
- Focus of the effort: issue of focus and level of effort
- Magnitude and Timing of the Effort and time frame of the effort
- Links to Decision Making: how the information generated is communicated to and used by decision makers

I. State of Maryland Agencies

A. Maryland Department of Natural Resources

Name of Effort	**Regional Shoreline Erosion Planning in Dorchester and St. Mary's Counties**
Agency Category	*Maryland Department of Natural Resources*
5 Functional Categories	Ecosystems, Settlements, Water
Geographic Area	Two counties only: Dorchester and St. Mary's Counties
Contact for Effort	Rachel Smyk-Newton Coastal Zone Management Program Maryland Department of Natural Resources 580 Taylor Avenue, E-2 Annapolis, MD 21401 410-260-8743 rsmyk-newton@dnr.state.md.us
Website	Project website: http://www.dnr.state.md.us/bay/czm/erosion_control.html Governor's Task Force on Shoreline Erosion Final Report: http://www.dnr.state.md.us/sccreport.html
Focus of the Effort	This project is one of a series of recommendations that came out of the Report by the Governor's Task Force on Shore Erosion (2000). The General Assembly endorsed the Task Force Report but did not provide any funding. Currently, no one is looking at the cumulative impact of shoreline erosion, so DNR initiated this small project. DNR is working with Dorchester and St. Mary's Counties to identify and prioritize stretches of shoreline for erosion control measures based on four criteria: (1) erosion rates; (2) environmental impacts; (3) impacts to public and private infrastructure; and (4) vulnerability to sea level rise. Erosion control measures will target areas suitable for structural erosion control devices, non-structural erosion control devices, designation as natural erosion areas, land acquisition, and establishment of erosion-based setback requirements.
Magnitude and Timing of the Effort	Both projects started in October 2000. Both will be completed by September 2002. Smyk-Newton is the only full-time employee (FTE) associated with the project. However, there is an advisory committee within DNR that oversees the project and meets periodically. Federal funds through NOAA Coastal Zone Management Act grants are being used for both of these projects worth $234,727.
Links to Decision Making	These partnerships will be used as templates for the development of the Statewide components of the Maryland Comprehensive Shore Erosion Control Plan, which will assist in

	planning and prioritizing areas in need of assistance on a Statewide basis. The project will provide information to decision makers about where to permit construction in shoreline areas.

Name of Effort	**Three Impact Studies on Sea Level Rise**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Settlements, Water, Ecosystem
Geographic Area	Three shoreline areas in the state: Shadyside Peninsula, Hooper's Island, St. George Island.
Contact for Effort	Rachel Smyk-Newton Coastal Zone Management Program Maryland Department of Natural Resources 580 Taylor Avenue, E-2 Annapolis, MD 21401 410-260-8743 rsmyk-newton@dnr.state.md.us
Website	Project website: http://www.dnr.state.md.us/bay/czm/erosion_control.html
Focus of the Effort	These three sea level rise (SLR) impact pilot studies focus only on 15 miles of shoreline in the following three areas: Shadyside peninsula, in Anne Aundel County, Hoopers Island in Dorchester County, St. George Island in St. Mary's County. These sites were chosen because they represent SLR impacts on three different shoreline types and three different sectors (residential, natural, industrial). Shadyside is already SLR protected but heavily residential. Dorchester is a high marshland island chain. St. Mary's site has Stewart Petroleum industry along the coast. Detailed topographic data will be collected. Erosion rates and sea level rise scenarios will be projected across current land conditions to establish future shoreline positions. Costs associated with loss of public and private infrastructure will be calculated to illustrate the need for comprehensive planning for coastal erosion and sea level rise.
Magnitude and Timing of the Effort	They are trying to finish the project in September 2002.
Links to Decision Making	These partnerships will be used as templates for the development of the Statewide components of the Maryland Comprehensive Shore Erosion Control Plan, which will assist in planning and prioritizing areas in need of assistance on a Statewide basis.

Name of Effort	**Unfunded project idea:** **Proposed Sea Level Rise LIDAR Modeling Project**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystems, Settlements, Water
Geographic Area	State-wide
Contact for Effort	Cornelia Wikar Coastal Hazards Planner (SLR) DNR-CA Management Division E-2 580 Taylor Avenue Annapolis, MD 21401 410-260-8737 cpaschewikar@dnr.state.md.us
Website	None
Focus of the Effort	There is no definitive funding for a statewide sea-level rise high-resolution digital topographic data (LIDAR) mapping project yet. DNR would like to collect statewide LIDAR data. DNR is partnering with Maryland Emergency Management Authority (MEMA) and the Corps of Engineers to plan the project. The Corps has estimated it will cost about $4.1 M to LIDAR map all the coastal counties in Maryland. That estimate was extrapolated from the current project in the three counties being coordinated by Rachel and based on the number of square miles of coastal areas in the state. The point of the project is to gain an accurate understanding of the topographical changes in the coasts and develop an sea level rise model. She knows that existing erosion rates will change if they factor in SLR so it is a "numbers reassessment project."
Magnitude and Timing of the Effort	Would be $4.1 M if funded.
Links to Decision Making	It would be the first, statewide sea-level rise assessment project.

Name of Effort	**Report: Governor's Shore Erosion Task Force Final Report**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystem, Settlements, Water
Geographic Area	State
Contact for Effort	Maryland Department of Natural Resources Shore Erosion Control Tawes State Office Building, E1 580 Taylor Avenue Annapolis, MD 21401 Toll Free: 877-620-8DNR Or 410-260-8531 Website:www.dnr.state.md.us
Website	http://www.dnr.state.md.us/download/shoreerosion.pdf
Focus of the Effort	In August 1999, Governor Glendening appointed a Shore Erosion Task Force, charged with investigating shore erosion in Maryland, its causes and effects, effective solutions, and available resources. In January 2000, the Task Force published a set of nine recommendations to be implemented under the umbrella of a Comprehensive Shore Erosion Control Plan. As the name suggests, the Comprehensive Plan is designed to move Maryland from the current uncoordinated approach towards shore erosion control to an approach that quantifies regional shore erosion impacts and uses sound planning, based on best available data, to achieve the objectives outlined by the Governor's Task Force.
Magnitude and Timing of the Effort	
Links to Decision Making	This document guides the work of DNR's Coastal Zone Management and Shore Erosion Control offices.

Name of Effort	**Report: A Sea Level Rise Response Strategy For the State of Maryland. By Zoe Pfahl Johnson, NOAA Coastal Management Fellow**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystem, Settlements, Water
Geographic Area	State
Contact for Effort	Rachel Smyk-Newton Coastal Zone Management Program Maryland Department of Natural Resources 580 Taylor Avenue, E-2 Annapolis, MD 21401 410-260-8743 rsmyk-newton@dnr.state.md.us
Website	Report homepage: http://www.dnr.state.md.us/bay/czm/sea_level_rise.html Short download time version of report: http://dnrweb.dnr.state.md.us/download/bays/sea_level_strategy_small.pdf
Focus of the Effort	*The report is a sea level rise response strategy for state of Maryland and includes:* (1) An extensive review of related technology, data, and research; (2) An assessment of Maryland's vulnerability based on the range and magnitude of impact, the physical characteristics of the coastline, and population and growth patterns; (3) An assessment of Maryland's existing response capability; (4) Specific recommendations for reducing the State's overall vulnerability to sea level rise.
Magnitude and Timing of the Effort	Two-year project completed October 2000.
Links to Decision Making	Adopted last Spring, 2001 as an Interim Planning Guide.

Name of Effort	**Key publications on DNR's Coastal Zone Management Website**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystem, Human Health, Settlements, Water
Geographic Area	Statewide
Contact for Effort	
Website	http://www.dnr.state.md.us/bay/czm/publications.html
Focus of the Effort	• Governors Task Force on Shore Erosion • An Assessment of the Economic Value of the Coastal Bays' Natural Resources to the Economy of Worcester County, Maryland • Chesapeake Bay National Estuarine Research Reserve in Maryland, Annual Report 2000 • Non point Source Management Plan • Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds: A Preliminary Assessment Report • Coastal Zone Management Program Section 309 Assessment & Strategy • A Sea Level Rise Response Strategy for the State of Maryland
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**Group: The Coastal & Watershed Resources Advisory Committee – CWRAC**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystem, Settlements, Water
Geographic Area	State
Contact for Effort	Mary Conley Mconley@dnr.state.md.us 410/260-8730.
Website	http://www.dnr.state.md.us/bay/czm/cwrac.html
Focus of the Effort	From website: CWRAC, established in 1976, is comprised of representatives of local government, concerned local citizens, special interest groups, state and federal agencies and academic institutions. Located, administratively under the Maryland Department of Natural Resources, CWRAC acts as an independent advisory body to the Secretary of Natural Resources and to Maryland's Coastal Zone Management Program on policy issues affecting the coastal areas of Maryland. Funding is provided by the National Oceanic and Atmospheric Administration under the Coastal Zone Management grant. Each CWRAC member represents one clearly defined constituency and acts on that constituency's behalf in the activities of the Committee. Members come to CWRAC with a clear understanding of the opinions and priorities of their constituency as they relate to the policies and issues before the Committee. Information received and actions taken by the Committee are reported back to member agencies or organizations, by CWRAC members.
Magnitude and Timing of the Effort	--
Links to Decision Making	These are the policy makers.

Name of Effort	**Group: Watershed Restoration Action Strategy process**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystem, Settlements, Water
Geographic Area	Statewide
Contact for Effort	For further information regarding the Watershed Restoration Action Strategy process, contact Katharine Dowell, DNR's Coastal Zone Management Division, (410) 260-8741, or by e-mail at kdowell@dnr.state.md.us.
Website	
Focus of the Effort	
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**Current project: Strategic Forest Lands Assessment**
Agency Category	Maryland Department of Natural Resources
5 Functional Categories	Ecosystems
Geographic Area	State
Contact for Effort	John Wolf: 410-260-8794. (Talked to Christine Conn) Dr. Christine E. Conn Maryland Dept of Natural Resources Chesapeake and Coastal Watershed Service Watershed Management and Analysis Division 580 Taylor Ave, E-2 Annapolis MD 21401 cconn@dnr.state.md.us 410-260-8792
Website	http://www.dnr.state.md.us/forests/publications/sfla/index.htm
Focus of the Effort	The project identifies Maryland's ecologically and economically valuable forestland in an attempt to prioritize forest stewardship and land conservation initiatives. The project deliverable is an electronic atlas. The concept is that Maryland decision-makers would manage their forests in the way established by the Montreal Santiago Indicators for Forest Sustainability.
Magnitude and Timing of the Effort	Started Jan. 2000 and is a three-year project that will finish this year.
Links to Decision Making	To prioritize forest stewardship and land conservation initiatives.

Name of Effort	**Remote Sensing Applications for Forest Resource Assessment: A State-University Government Partnership**
Agency Category	Maryland Department of Natural Resources and University of Maryland
5 Functional Categories	Ecosystems
Geographic Area	State
Contact for Effort	Dr. Christine E. Conn Maryland Dept of Natural Resources Chesapeake and Coastal Watershed Service Watershed Management and Analysis Division 580 Taylor Ave, E-2 Annapolis MD 21401 cconn@dnr.state.md.us 410-260-8792 Dr. Scott J. Goetz Dept. of Geography University of Maryland College Park, MD 20742-8225 sgoetz@geog.umd.edu 301-405-1297
Website	
Focus of the Effort	*Christine is the co-principal investigator with Scott Goetz, UMD Geographer who is using Remote Sensing Data to make Net Ecosystem Productivity Maps. They're looking at various criteria for promoting carbon sequestration and forest carbon flux.* She's working on the applications side of things: land conservation activities, functional assessments of wetlands, forest productivity and forest health.
Magnitude and Timing of the Effort	$600,000 budget from NASA for 3 years, 2 co-PIs and 2 co-Investigators. They will have a graduate RA – one each year. Started Jan. 2002.
Links to Decision Making	There will be multiple users of these Maps but mainly policy and management personnel related to the forest service.

B. Maryland Department of Environment

Name of Effort:	**Repetitive Loss Program and the Floodplain Managers' Database**
Agency Category:	Maryland Department of Environment Flood Plain Management Division
5 Functional Categories	Settlements
Geographic Area Category	Statewide and County focus.
Contact(s) for Effort:	Project Coordinator: Kevin Wagner 410-631-3582 Talked to John Joyce MDE, Flood Management Division 2500 Broening Avenue Baltimore, MD 21224 (410) 631-3914 jjoyce@mde.state.md.us
Website	Repetitive Loss Project/GIS Summary page: http://www.mde.state.md.us/environment/flood/gissummary.html *Maryland's Flood Hazard Mitigation Program:* http://www.mde.state.md.us/environment/flood/index.html
Focus of the effort:	MDE's Repetitive Loss Program started three years ago. The National Flood Insurance Program began compiling properties in each state that were filing insurance losses repeatedly. MDE has finished visiting all the properties on the list and have compiled a database with the following information: first floor and ground level elevation, 100-year flood elevation, etc. The data are presented to the appropriate local jurisdiction contacts that deal with flood issues, requesting them to prepare flood mitigation plans for each property. Freeboard Ordinances. One message that John has been trying to deliver to each of these county representations during the Repetitive Loss presentations is MDE's recommendation of "additional freeboard" for new construction or substantially improved construction (defined as 50% or more repair to damage or voluntary reconstruction). There is currently a one-foot "model" freeboard requirement and most communities in the state have adopted it. The areas that have not adopted any freeboard ordinances are Somerset County, City of Crisfield, Dorchester County, and Worchester County. However, Worchester County is currently considering a two-foot freeboard requirement. John is manager of the Community Assistance Program that provides technical assistance to 115 communities that have decided to adopt a freeboard ordinance in order to apply for flood insurance from the National Flood Insurance Program. He

	works full time on this program and his budget is $75,000 per year.
Magnitude and Timing of the effort	The Repetitive Loss Program received $80,000 over the 3 years from funds from FEMA via MEMA. There are three FTE in the Flood Management Division at MDE. He'd say that the Project has taken one full-time employee's time.
Links to Decision Making	The information in the database is being presented to flood insurance and emergency managers in each county and a few cities who will use the information to develop and implement mitigation plans with the identified repetitive loss properties. The two cities they're working with are Baltimore City and Ocean City. The appropriate contacts are mainly in the County Planning Departments or in the Public Works Departments. Mitigation options include (1) acquisition of property, (2) elevation of lowest floor, (3) filling in of the basement, and (4) building a protective floodwall. The database is for use in house only. If the counties request help developing or adopting their mitigation plans, MDE will offer technical assistance.

Name of Effort	**Digital FIRM (Flood Insurance Rate Map) Project**
Agency Category	Maryland Department of Environment Flood Plain Management Division
5 Functional Categories	Settlements
Geographic Area	Only a few counties currently.
Contact(s) for Effort	FEMA FIRM contact is John Kanowitz 215-931-5534 (Philadelphia). Talked to John Joyce Maryland Department of Environment Flood Management Division 2500 Broening Avenue Baltimore, MD 21224 (410) 631-3914 jjoyce@mde.state.md.us
Website	http://www.mde.state.md.us/environment/flood/gissummary.html
Focus of the effort	Currently MDE is contracting out to consulting firms to develop Digital FIRMs for a few select counties. FEMA may be doing a major re-mapping effort in the entire state of Maryland, which might occur in 2003. The Digital FIRMs are being prepared to better define the floodplains, the flood zone properties, and what kind of flood insurance they would need. Harford County has finished its FIRM Project and the results are available in paper map format. Evidently there is a disk version available. Harford County mostly self-funded the project. Several other FIRM projects in progress include Baltimore, Prince George's, and St. Mary's counties. Frederick County is starting its FIRM project this year.
Magnitude and Timing of the Effort	Most of the work is being contracted out and coordinated by MDE.
Links to Decision Making	The information will be used by the insurance industry, the real estate industry, local planners and state planners. Each county will receive paper maps, as well as, CD-ROM disks with multi-level GIS system capabilities. Evidently, there's a major effort going on in North Carolina to put their FIRM maps on the web.

Name of Effort	**Maryland Environmental Indicators**
Agency Category	Maryland Department of Environment
5 Functional Categories	Human Health, Water, Settlements.
Geographic Area	State
Contact for Effort	John Mitchell Special Assistant Office of the Secretary Maryland Department of Environment Jmitchell@mde.state.md.us
Website	http://www.mde.state.md.us/enpa/2000_enpa/envi_indicators/index.html
Focus of the Effort	There are a series of graphs and summary statistics about the various federal and state environmental quality indicators for Maryland. Some indicators include: ozone exceedance days, drinking water quality, vehicle miles traveled, etc. Publication of the indicators on the website was last updated Summer 1999. However, the indicators are still monitored and the results are published in the following documents: Managing for Results (for the General Assembly) and the state Annual Report. From the website: The *Maryland Environmental Indicators 1999* report was the second in a series that provides a concise characterization of some of Maryland's key environmental and public health conditions. The earlier report, issued in draft in 1997, was the first step in a strategic planning process through which the Maryland Departments of Environment (MDE) and Natural Resources (DNR) and the U.S. Environmental Protection Agency (EPA) have been redefining the federal-state relationship to promote a results-based approach to environmental protection issues. The resulting 1998 Environmental Performance Partnership Agreement (EnPA) and a subsequent one for Fiscal Year 1999, provide Maryland an important opportunity to refine environmental goals and outcomes, focus its programs toward results-based management, and improve the relationship between the State and EPA. The EnPA process also helps fulfill Governor Parris N. Glendening's mandate for improving state agency performance through the results-based strategic planning process known as Managing Maryland for Results. This process also is consistent with the directives that state agencies have received from the Maryland General Assembly to improve various units of measurement and to focus management towards environmental

	and public health outcomes.
Magnitude and Timing of the Effort	Report was last updated in a stand-alone report in Summer 1999.
Links to Decision Making	Results are being included in other MDE publications.

II. Other Agencies

A. Research Programs

Name of Effort	**State Climatological Indicators**
Agency Category	University of Maryland
5 Functional Categories	Ecosystems
Geographic Area	State
Contact for Effort	Dr. Kenneth E. Pickering Senior Research Scientist Department of Meteorology University of Maryland College Park, MD 20742 301-405-7639 301-314-9482 FAX pickerin@atmos.umd.edu
Website	The web site for the MD State Climatologist Office is: http://meto.umd.edu/~climate/sc.html
Focus of the Effort	The purpose of the Maryland State Climatologist Office is to document climate changes such as temperature and precipitation and maintain historic records. Most attention to date has been on the airport stations but there are 20-some stations throughout the state that are managed by the National Weather Service. Data are made available to his State Climate Office and they are also archived in North Carolina at the National Climatic Data Center. The data on the website includes trend graphics and other climatological indicators such as first frost in the fall, last frost in the spring, average number of days over 90 F and less than 32 F. The City of Baltimore has a 100-year record but unfortunately, it reflects the urban signal. The rest of the stations in the state are over 60 years old. There are changes in the data that show mostly warming occurring. They see a downward trend (cooler) between the 1940s and 1970s and then an upward (warmer) trend. So most stations are demonstrating a net warming. As for precipitation, a running 30-year average shows an upward trend (more rain).
Magnitude and Timing of the Effort	2002 is the first year with substantial funding beyond $8,000/year, which supported a part-time graduate student to maintain the office, the records and to respond to requests. This year, they received $50,000. Funds this year are from MDE, MD Dept. of Meteorology, and the College of Computer, Math and Physical Sciences. In 2004, the program will be funded from the Dean of the Graduate School. MDE funding is part of their air quality in Maryland work. Ted Aburn of MDE is his contact.

Links to Decision Making	Other than on the website, they have not published the information. There don't appear to be any reports on the website either – only data.

Name of Effort	**Radiative forcing model of ozone and aerosols.**
Agency Category	University of Maryland
5 Functional Categories	Ecosystem
Geographic Area	Global
Contact for Effort	Dr. Kenneth E. Pickering Senior Research Scientist Department of Meteorology University of Maryland College Park, MD 20742 301-405-7639 301-314-9482 FAX pickerin@atmos.umd.edu
Website	http://meto.umd.edu/~climate/sc.html
Focus of the Effort	His research focuses on trace constituents, primarily aerosols and stratospheric ozone to assess their impact on radiative forcing. Some particles radiate heat while others absorb heat. His modeling effort uses a single-column model to look at a vertical column of the atmosphere to observe the vertical transport of these gases. His radiative transfer program calculates the amount of solar radiation received at various levels and infrared re-radiated to space. This results in either warming or cooling. He is developing a global 3-dimensional model. One of their single-column model runs was with Maryland data from the 1995 heat wave where both ozone and aerosol pollution shot up and built up in the Baltimore–Washington region. The event lasted 5 days in mid-July and he saw in the model that the aerosol concentration was active in cooling temperatures at surface layers but at higher levels there was a warming influence. Recent publication: Park, R.J., G. L. Stenchikov, K. E. Pickering, R. R. Dickerson, D. J. Allen, S. Kondragunta, Regional air pollution and its radiative forcing: Studies with a single-column chemical and radiation transport model, J. Geophys. Res. 106, 28,751-58,770, 2001.
Magnitude and Timing of the Effort	$250,000 per year sponsored by NASA.
Links to Decision Making	Journal publishing.

Name of Effort	**Journal Article: "Future consequence of climate change for the Chesapeake Bay ecosystem and its fisheries"**
Agency Category	Chesapeake Biological Laboratory, University of Maryland Center for Environmental Studies University of Maryland
5 Functional Categories	Ecosystem, Water
Geographic Area	Chesapeake Bay
Contact for Effort	Dr. Robert Wood Assistant research scientist Chesapeake Biological Laboratory University of Maryland Center for Environmental Science Solomons MD 20688 410-326-7211 bwood@cbl.umces.edu
Website	www.cbl.umces.edu
Focus of the Effort	The in-press article focuses on how projected changes in water temperature, sea level, and streamflow between the years 2000 and 2030 may affect the Chesapeake Bay ecosystem and its fisheries.
Magnitude and Timing of the Effort	
Links to Decision Making	Paper will appear in Transactions of the American Fisheries Society.

Name of Effort	**Impacts of elevated carbon dioxide and ozone on carbon cycling processes in soil.**
Agency Category	University of Maryland
5 Functional Categories	Food, Ecosystem
Geographic Area	State
Contact for Effort	*Dr. Raymond Weil* Professor College of Natural Resource Science and Landscape Architecture University of Maryland H.J. Patterson Hall, Room 1103C College Park, MD 20742 P: 301-405-1314 F: 301-314-9041 rw17@umail.umd.edu
Website	http://www.nrsl.umd.edu/faculty/weil/
Focus of the Effort	Here are a couple of ways that global climate change is affecting Maryland food production: 1. Increasing atmospheric carbon dioxide (CO2) definitely makes most crops grow better and resist drought better. His group did some research that suggests that the high CO2 will also improve Maryland soils by promoting greater plant biomass and root exudation of carbon to the soil. Weil, R.R., K.R. Islam and C.L. Mulchi.2000. Impacts of Elevated CO2 and Ozone on Carbon Cycling Processes in Soil. Agronomy Abstracts, p. 47. Presented at annual meetings of the Soil Science Society of America in Minneapolis, MN. November 5-9, 2000. 2. But, climate is also becoming more variable and droughts more frequent, so that is increasing stress to plants and reducing food production. 3. Warmer temperatures may increase insect pest survival over winter and fungal disease development.
Magnitude and Timing of the Effort	
Links to Decision Making	Journal publications and conference presentations.

Name of Effort	**Carbon dioxide and ozone effects on soybeans, corn, wheat, and soils.**
Agency Category	University of Maryland
5 Functional Categories	Food
Geographic Area	State
Contact for Effort	Dr. Charles Mulchi Professor College of Natural Resource Sciences and Landscape Architecture University of Maryland College Park, MD 20742 Rm 1108 HJ Patterson Hall P: 301 405-1328 F: 301-314-9041 cm48@umail.umd.edu
Website	http://nrsl.umd.edu/faculty/NRSLFacultyInfo.cfm?ID=34
Focus of the Effort	Dr. Mulchi has been working on carbon dioxide (CO_2) and plant issues for 30 years. His recent work involves experiments with plants in climate-controlled chambers that have been under study for 6 years at a USDA site and looks at changes in carbon and nitrogen. Their basic finding is that carbon is easily metabolized and not highly lignant; i.e. carbon gets easily broken down by fungi. Under high ambient ozone levels, soil carbon was very resilient to breakdown and only bacterium could break it down to get nitrogen. <u>Six-year ozone & CO_2 study</u>: Assessed respiration rates in soybean and wheat over 2 cycles of the growing season. They found that more soil efflux of carbon occurs under the high CO_2 plots. Much of the carbon is going to the root zone and is being metabolized immediately. Under high CO_2 conditions there was a net build up of carbon in the soil but the carbon to nitrogen (C:N) ratio was greatly increased. This means that the bacteria were mining the soil for nitrogen. The legumes were not fixing enough nitrogen to take care of their own needs; thus, the microbes in the soil were breaking down the soil organic matter to supply nitrogen – even in the presence of a legume that is supposed to fix its own nitrogen. Thus, they predict that plant productivity will level off in Maryland if farmers don't apply extra nitrogen. This has huge implications for an already nutrient over-enriched farm sector in Maryland.

	They started the experiment at 350 parts per million (ppm) and then it rose to 365 ppm so a 15 ppm rise occurred over the six years. On top of that, they modeled a 150 ppm increase in global atmospheric carbon dioxide and observed this elevated CO_2 condition counteracted the negative impact of ozone on the crops. With time, there is less impact on vegetation from ozone as CO_2 levels rise. As ozone increases as in the Maryland experience, 150 parts per billion (ppb), the photosynthetic system in plants can be damaged and its ability to sequester CO_2 decreased. At moderate levels of ozone (not in MD areas), you'd expect to see a counteracting effect. He was the first to report this result in 1988 in Elsevier's Agriculture, Ecosystem and Environment Journal. <u>Current small project: Screening soybean cultivars for ozone tolerance</u>. Some crops were bred in the Midwest under low ozone backgrounds so when planted in Maryland where ozone is higher, they experience yield loss. Mulchi is looking at grain quality (nutrient quality). So far he's screened 50 lines of soybeans. He did observe changes in oil and fatty acid in seed, which are value-added traits. Some of the fatty acid is critical to the value of the seed. Higher ozone concentrations do alter the value while some lines are more tolerant. Dr. Mulchi recommends Dr. Cooper of the University of Minnesota who is a world renown expert on air quality effects on plants. His book <u>Air Pollution, People, and Plants</u> is what Mulchi uses in his class Environmental Issues Affecting Plants and Soils – NRSC 454.
Magnitude and Timing of the Effort	His six-year study was a USDA Global Climate Study that had 5 graduate students paid through NASA and 8 students working on it at one time and the international students had their with own money. It was about $300,000 a year but its over now. His work screening multiple cultivars is funded through the regional USDA-University project. He doesn't know the dollar amount but guesses its about $50 – 100,000 per year at sites throughout the country.
Links to Decision Making	In addition to publishing extensively in journals, Mulchi has given presentations in Congressional offices on the impact of global climate change on agriculture. He gives lectures at other campuses. He's participated on several EPA Task Forces on pesticides.

Name of Effort	**Forest health research**
Agency Category	University of Maryland
5 Functional Categories	Ecosystem
Geographic Area	Western Maryland
Contact for Effort	Dr. Lou Pitelka, Director University of Maryland Center for Environmental Science Appalachian Laboratory Gunter Hall Frostburg, MD 21532 301-689-7101 pitelka@al.umces.
Website	www.al.umces.edu
Focus of the Effort	The lab would like to get involved in climate-change specific research but so far the Lab is focused on watershed issues, ecosystem health, forest indicators, acid mine mitigation, etc. Ecosystem health – forest indicators (EPA-funded) Can a single indicator can illuminate different aspects of ecosystem health and be assessed remotely? For example, researchers are developing a forest-interior bird indicator that can predict water quality in Western Maryland forests. Steve Seagal is the Principal Investigator: 301-689-7123 Effects of Gypsy moth defoliation on Nitrogen runoff: This project may have climate change implications. There is some concern about increased temperature impacts on moth populations. Under higher temperature conditions, moths might have to eat more leaves to get more nitrogen out of the vegetation because the ratio of carbon to nitrogen changes in the leaves with elevated temperatures. Keith Eshleman is the Principal Investigator: 301-689-7170. Pitelka helped organize a workshop on plant migration in Europe due to climate change and is writing a journal publication right now. Another project at the lab assesses carbon remotely in forests in Bolivia. Vic Kennedy is the other main CES scientist on climate-related issues.
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**Health research**
Agency Category	Johns Hopkins University
5 Functional Categories	Human Health
Geographic Area	Nationwide
Contact for Effort	Jonathan Patz Johns Hopkins School of Public Health 615 N. Wolfe St., Room 7041 Baltimore, MD 21205 410-955-4195 jpatz@jhsph.edu
Website	www.jhsph.edu/globalchange
Focus of the Effort	Patz mentioned several researchers who work on health issues related to climate change in the Mid-Atlantic Region: Anwar Haq, Rita Caldwell – Cholera in the Bay Jonathan Samet – heatwaves in the region Hugh Ellis – ozone and temperature changes using EPA Model Three Dana Focks – Lyme Disease *The following abstract describes a study that assesses what impacts development in the Chesapeake Bay watershed has on human health.* Environ Res 2000 Mar;82(3):263-71 Environmental and geographical factors contributing to watershed contamination with Cryptosporidium parvum oocysts. Graczyk TK, Evans BM, Shiff CJ, Karreman HJ, Patz JA. Department of Molecular Microbiology and Immunology, Johns Hopkins University, Baltimore, Maryland 21205, USA. Cryptosporidium parvum is a waterborne parasite that infects cattle and produces life-threatening zoonosis in people with impaired immune systems. Digital maps of 100-year floodplain boundaries, land use/cover, and livestock operations were used to select and characterize cattle farms in the floodplain area in Lancaster County, Pennsylvania, U.S.A. Over 21% of the cattle farms were located within 100-year floodplain boundaries. On average, a single farm comprised 12.8 ha of pasture (including buildings and farmyard) at risk of inundation. In all farms cattle had unlimited access to the creek. Manure samples collected from closed-in calf pens, cow/heifer yard runoff, and cattle

	paths through the creek were tested for C. parvum. On 64% of the farms (n=50) at least one sample was positive for C. parvum, and 44% of the farms had oocysts in all manure samples. Concentration varied from 90 to 371 oocysts/g and was significantly higher (P<0.02) in calf samples than in manure from cow and cow/heifer. Copyright 2000 Academic Press. PMID: 10702335 [PubMed - indexed for MEDLINE]
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**"Susquehanna River response climate change"**
Agency Category	Pennsylvania State University
5 Functional Categories	Water
Geographic Area	Susquehanna River, MD
Contact for Effort	Raymond Najjar Associate Professor Departments of Meteorology and Geosciences The Pennsylvania State University Department of Meteorology 503 Walker Building University Park, PA 16802-5013 email: najjar@essc.psu.edu phone: 814-863-1586 fax: 814-865-3663
Website	Homepage: http://www.essc.psu.edu/~najjar
Focus of the Effort	According to Tom Cronin, Raymond Najjer is one of the major scientists working on climate change impacts in the Mid-Atlantic region. Najjer wrote three reports for the Mid-Atlantic Resource Assessment Report. Maryland-focused journal publications include "The water balance of the Susquehanna River Basin and its response to climate change." (Journal of Hydrology, 1999) and "The response of Chesapeake Bay salinity to climate-induced changes in streamflow." (American Society of Limnology and Oceanography, Inc. 2000)
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**New project: Atlantic Slope Consortium (Developing Estuarine Indicators for EPA)**
Agency Category	Smithsonian Environmental Research Center (SERC) and Pennsylvania State University
5 Functional Categories	Water, Ecosystem
Geographic Area	Chesapeake Bay
Contact for Effort	Dr. Dennis Whigham is the Principle Investigator for SERC. (Spoke with Dr. Charles Gallegos, SERC) Contacts for Pennsylvania State University: Patricia Craig (814) 863-0037 plc103@psu.edu Barbara Hale (814) 865-9481 bah@psu.edu EDITORS: Dr. Brooks is at (814) 863-1596 rpb2@psu.edu
Website	Psu.edu/ur/2001/errigrant.html
Focus of the Effort	SERC has joined Penn State to conduct a four-year study on the Chesapeake Bay as part of EPA's "Estuaries and Great Lakes" Indicators campaign. The information will allow EPA to conduct broad-scale assessments of estuaries with indicators such as an Index of Biotic Integrity (IBIs). A map showing the area under study is available from Patricia Craig.
Magnitude and Timing of the Effort	SERC's budget is $6 M over 4 years. Started February 2001.
Links to Decision Making	Purpose of project is to develop and test indicators for EPA's nationwide estuarine indicators effort.

Name of Effort	**Direct effects of elevated atmospheric CO2 on wetlands: a mid-Atlantic study**
Agency Category	Smithsonian Environmental Research Center (SERC)
5 Functional Categories	Ecosystem
Geographic Area	Conducted on a wetland on the Rhode River in Maryland
Contact for Effort	Dr. Bert Drake *Smithsonian Environmental Research Center (SERC)* *P. O. Box 28* *Edgewater, Maryland 21037* Phone: 443-482-2294 FAX: 443-482-2380 E-mail: drake@ serc.si.edu
Website	http://www.serc.si.edu/carbon/carbon_teco.htm
Focus of the Effort	Study findings: Plants respond to increased carbon dioxide (CO_2) by increasing photosynthetic capacity and decreasing respiration and have done so over the last 15 years of the study. They've learned that most of the extra CO_2 is allocated not above ground in plant materials but in the roots where it is dissolved into inorganic carbon and "taken away" in the marsh tides. They were surprised that CO_2 is not building up in the marsh soil around the plans but that seems to be the common experience with other gases in marshes. They conclude that the marsh ecosystem processes are not fundamentally changed, just sped up. Other findings of an increase in CO_2: Increase in methane production. Increase in foraminefera and nematodes feeding on CO_2 below ground. Increase in rhizome and roots. Increase in dissolved inorganic carbon in marsh roots. Increase in nitrogen fixation and a depletion in the available nitrogen.
Magnitude and Timing of the Effort	*This project is funded jointly by the U.S. Department of Energy, which has granted $1 million over 6 years, and the Smithsonian Institution, which provides in-kind support through salaries, fellowships, and other measures. Drake said its about $200,000 a year from DOE and they hope to continue the study indefinitely. Since 1985 when the grant started, DOE has given them over $5 M. He estimates there are about 10 full-time Federal and Trust Fund employees on the project.*
Links to Decision Making	His main avenue for information dissemination is though scientific journals. SERC does a monthly lecture series for the general public and they have a school children outreach program.

Name of Effort	***Key journal articles on Dr. Drake's website***
Agency Category	
5 Functional Categories	
Geographic Area	
Contact for Effort	
Website	
Focus of the Effort	Drake, B.G.,Gonzalez-Meler, M.A. and S.P. Long. 1997. More Efficient Plants: A consequence of rising atmospheric CO_2? *Ann Rev Plant Physio Plant Mol Biol.* 48-607-637. Drake, B.G. Jacob, J.,, Muehe, M.,Peresta, G. Gonzalez-Meler,M., Matamala, R. 1997. Acclimation of photosynthesis, respiration and ecosystem carbon flux of a Chesapeake Bay wetland after eight years exposure to elevated CO_2. *Plant and Soil*.187:111-118. Drake, B.G., Jacob, James, and M. A. Gonzalez-Meler. 1998. Photosynthesis, respiration and global climate change. Ch 21. 273-282. In: A.S Raghavendra, ed *Photosynthesis: A Comprehensive Treatise*, Cambridge University Press. Drake, BG Azcon-Bieto, J., Berry, J., Bunce, J., Dijkstra, P., Farrar, J., Gifford, R.M., Gonzalez-Meler, M.A., Koch, G., Lambers, H., Siedow, J., and Wullschleger, S. 1999. Does elevated atmospheric CO_2 concentration inhibit mitochondrial respiration in green plants? *Plant Cell and Environment* 22:649-657. Dakora, F. and B.G. Drake. 2000. Elevated CO_2 stimulates associative N_2 fixation in a C_3 plant of the Chesapeake Bay wetland. *Plant Cell and Environment*, 23:943-953.
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**Current project: Long-term ultraviolet light (UV) effects on wetlands**
Agency Category	Smithsonian Environmental Research Center (SERC)
5 Functional Categories	Ecosystems
Geographic Area	Chesapeake Bay and other estuaries
Contact for Effort	*Dr. Pat Neale* *Smithsonian Environmental Research Center (SERC)* *P. O. Box 28* *Edgewater, Maryland 21037* Phone: 443-482-2285 FAX: 443-482-2380 neale@serc.si.edu
Website	http://www.serc.si.edu/uvb/uvb_index.htm
Focus of the Effort	*From website:* *The Smithsonian Institution is a participant in the US interagency ultraviolet radiation monitoring network, whose overall goals are to define short- and long-term variation in spectral UV-B; study the variation of UV-B over latitudinal gradients; and study the effects of clouds and other factors, such as aerosols, on UV-B. The program also supports SERC's program of UV-B effects research, which is conducted by the Smithsonian Environmental Research Center's (SERC) Photobiology/Solar Research Laboratory (SRL).* A priority in the SRL research program has been the development of an instrument that provides sufficient spectral resolution for evaluation of wavelength-dependent UV-B responses, yet is less complicated and easier to operate than the available high-resolution scanning instruments. A basic objective is to design simple and rugged instruments that are serviceable for continuous monitoring under a wide range of temperature and weather conditions. Findings: They have compiled over 25 years of data. There have been increases in average mid-day UV that are larger than what would have been expected based on ozone trends. Thus, an additional climatic factor is contributing. Currently they are investigating what factor that is: for example, change in cloud cover. There has been work on responses of phytoplankton populations to UV in local waters. Results suggest that despite high turbidity of the water, populations are sensitive enough in 1 m. or less that there is a significant effect of UV on productivity. That is, productivity is decreased by incident UV. Global change: www.globalchange.si.edu includes information

	by location. Smithsonian Institution (mall museums and research institute, one of which is SERC also in Front Royal, VA, Panama, Cambridge, MA) *Forest canopy studies on site that looks at canopy-atmosphere interactions: radiation budgets, gas composition. Jeffrey Parker is a principal investigator.*
Magnitude and Timing of the Effort	Smithsonian Institution direct support around $150K/year External grant support around $250K/year (National Science Foundation, EPA, and USDA, and National Institutes for Science and Technology.) Typical staffing (in addition to Neale): 3 full-time technicians, 2 post-doctorate students, 2 volunteers, 2 graduate students and 1 summer intern.
Links to Decision Making	Actual UV data are used by USDA to assess agricultural effects and by the National Institute of Science and Technology (NIST) to assess effects of UV on materials. NASA has also used their information as groundtruthing data for global UV modeling efforts. They directly work with the USGCRP program.

Name of Effort	**Current project: Climate change affecting wetlands in Maryland**
Agency Category	Smithsonian Environmental Research Center (SERC)
5 Functional Categories	Ecosystems
Geographic Area	Maryland and other estuaries
Contact for Effort	Dr. Pat Megonigal Smithsonian Environmental Research Center (SERC) P. O. Box 28 Edgewater, Maryland 21037 Phone: 443-482-2346 FAX: 443-482-2380
Website	
Focus of the Effort	According to Dr. Drake, Pat Megonigal is focusing on the effects of elevated carbon dioxide concentrations on wetland systems below ground. From SERC's website: Decomposition seems to slow down in plants growing in elevated levels of CO2.
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**Ecological Effects of Environmental Stressors Using Coastal Intensive Sites: an Interagency Research Program.** **The Rhode River CISNet: Estuarine Optical Properties as an Integrative Response to Natural and Anthropogenic Stressors.**
Agency Category	Smithsonian Environmental Research Center
5 Functional Categories	Water, Ecosystem, Settlements
Geographic Area	Rhode River, MD research site
Contact for Effort	Dr. Charles L. Gallegos Smithsonian Environmental Research Center P. O. Box 28 647 Contees Wharf Road Edgewater, Maryland 21037 Voice: 443.482.2240 Fax: 443.482.2380 Email: gallegos@serc.si.edu
Website	Project homepage: http://www.serc.si.edu/uvb/CISnet.htm Diagnostic tool home page: http://www.chesapeakebay.net/cims
Focus of the Effort	*CISNet is an interagency effort between EPA, NOAA, and NASA to develop an intensive coastal site network of monitoring and research stations throughout the United States.* Dr. Gallegos thinks of his eutrophication work as falling under the rubric of global change but not under climate change. He has been monitoring nutrient, chlorophyll, and dinoflagellate concentrations in the Rhode River for this project for three years to determine timing and frequency and magnitude of plankton blooms as a function of "freshets" from the Susquehana River. Nutrient content is tied to farming practices in New York and Pennsylvania.
Magnitude and Timing of the Effort	Three-year budget for $510,000 extended to 4 years for 2-3 FTEs. CISNet is an EPA-funded grant that began in October 1998 and ends in November 2002. Final Report due in December 2002
Links to Decision Making	Information has been used in the development of a tool for Managers that is being used to help set water quality targets for restoring submerged aquatic vegetation. Principal Investigator for the Diagnostic Tool is Richard Batiuk, Science Director at the Chesapeake Bay Program.

Name of Effort	**Climate change signals in the Chesapeake Bay sediment cores.**
Agency Category	US Geological Survey
5 Functional Categories	Water, Settlements
Geographic Area	Chesapeake Bay
Contact for Effort	Dr. Thomas Cronin 926A National Center US Geological Survey Reston, Va. 20191 703-648-6363 Fax 703-648-6953 tcronin@usgs.gov
Website	Geology.er.usgs.gov/eespteam/ches/
Focus of the Effort	Tom says that he is one of three real experts on climate change impacts in the Chesapeake Bay. His work over the last 20 years has focused on how the Chesapeake Bay captures the regional climate signal from pollen cores. He also works on the Florida Bay system, which is primarily El Nino-driven. They have real, long-term sea level rise data from cores in the Bay. He's on many of the Bay committees and workgroups and works with Julie LaBranche. He also teaches at Mason University. The other two major climate scientists focused on the Chesapeake Bay are Ray Najjer who wrote three reports for the Mid-Atlantic Resource Assessment Report and Debra Willard (**Dwillard@usgus.gov**). He attended the Woods Hole "Estuarine Response to Climate" Conference.
Magnitude and Timing of the Effort	Chesapeake project is funded by 4 different programs, each having different goals. One program does have paleoclimate as a main research area ($200 k) for about 1.2 or 1.3 FTE research grade scientist and an intern, expenses. But the project is much larger, only others in it obtain funding from other programs (like Geologic Mapping) and focus on the ecosystem, mapping, sea level etc. He also benefits from students in lab field work from a diversity program, volunteers, piggybacking with work in Florida Bay, university students, colleagues funded independently at University and State institutions, etc.
Links to Decision Making	Very active on several Chesapeake Bay Committees and Workgroups.

Name of Effort	**Key Chesapeake Bay-related publications on USGS website**
Agency Category	US Geological Survey
5 Functional Categories	Ecosystem
Geographic Area	Chesapeake Bay
Contact for Effort	Dr. Thomas Cronin 926A National Center US Geological Survey Reston, Va. 20191 703-648-6363 Fax 703-648-6953 tcronin@usgs.gov
Website	http://water.usgs.gov/wid/index-state.html#MD
Focus of the Effort	Maryland **FS-125-01:** The U.S. Geological Survey Chesapeake Bay Science Program **FS-116-00:** Effect of Climate Variability and Human Activities on Chesapeake Bay and the Implications for Ecosystem Restoration **FS-021-99:** USGS Programs in Maryland **FS-115-98:** Freshwater use in Maryland, 1995 **FS-114-98:** Fungal Infections, and Pfiesteria: The Role of the U.S. Geological Survey **FS-184-97:** Geology of the Mid-Atlantic Urban Corridor (GOMAC) **FS-126-97:** Evaluation of the stream-gauging network in Maryland, Delaware, and Washington, D.C **FS-124-97:** Overview of the U.S. Geological Survey Chesapeake Bay Ecosystem Program **FS-213-96:** Ecosystem Trends and Response: Chesapeake Bay **FS-140-96:** January 1996 Floods Deliver Large Loads of Nutrients and Sediment to the Chesapeake Bay **FS-020-96:** USGS Programs in Maryland and the District of Columbia **FS-161-95:** Nitrate in streams in the Great Valley carbonate subunit of the Potomac River Basin **FS-055-95:** Chesapeake Bay: Measuring Pollution Reduction
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**USGS in-house reviews of sea level rise literature.**
Agency Category	US Geological Survey
5 Functional Categories	Water
Geographic Area	State, Chesapeake Bay
Contact for Effort	Curt Larsen Geologist Eastern Earth Surface Processes Team US Geological Survey 703-648-6342 clarsen@usgs.gov
Website	
Focus of the Effort	Dr. Larsen is working on three projects that are funded in-house. From an email, Dr. Larsen explains: The major thrust of our work is developing an detailed land use model of net changes in wetlands in the area of the Blackwater National Wildlife Refuge. This project is termed "Wetland Loss or Wetland Gain in Chesapeake Bay." In this case we are developing a predictive model of the types and areas of wetland that are developing and will develop over the next decades relative to the historic rate of sea level rise as well as IPCC estimates for future sea level rise scenarios. This work involves biologists from the USGS Patuxent Research Center, Tree ring specialists from our Water Resources National Research Program, GIS and remote sensing specialists from our Mapping Applications Center, and geologists from our Earth Surface Processes Team. The core of this study is a detailed topographic base map derived from LIDAR surveys which have just been completed. This survey presently covers portions of Dorchester County and will allow us for the first time to view wetland encroachment on a decimeter vertical scale rather than relying on the current 1 m contour interval topographic maps. Our biologists are documenting actual wetland vegetation zonation at Blackwater to use as a standard for use in our land use model. Our tree ring specialists are documenting the stresses imposed on wetland forests by rising sea level and increasing salinity. In essence we wish to document the rate at which woodlands will be converted to upper marsh surface in future decades. The geological portion of the study uses a compilation of existing core information as well as new cores to document the rate of sea level rise over the past 7000 years, the past 1000 years and over the past century to

	understand sea level change in comparison with documented increases in atmospheric CO2. Another project focused on Dorchester County examines the changes in elevation of the marsh surfaces at the Blackwater NWR. This study is called "Habitat Displacement and Sea Level Change" and involves detailed measurement in change in the marsh surface through time as compared with fixed datum elevations. We seek in this case to measure habitat zonation changes on marsh surfaces that may or may not relate to rising sea level. Finally, we are making a comparative study of sea level in the Chesapeake Bay, Delaware Bay, and Long Island Sound to look for similarities or differences in the records of sea level rise. This project is best referred to as "Searching for a Sensible Scale to Sea Level Rise." These three studies are interrelated and are running concurrently. The funding has been thus far, from internal USGS sources.
Magnitude and Timing of the Effort	All funding is USGS internal funding.
Links to Decision Making	

Name of Effort	Sea Level Rise Mapping Efforts
Agency Category	U.S. Environmental Protection Agency
5 Functional Categories	Water
Geographic Area	Maryland, Chesapeake Bay
Contact for Effort	Jim Titus Global Programs Division (6205J) U.S. Environmental Protection Agency Washington, DC. 20460 Phone: 202-564-3483 Fax: 202-565-2095/2096
Website	
Focus of the Effort	In an email, Mr. Titus recommended the following contacts, publication/website information, and current EPA–Maryland partnership activities: • For Sea Level Rise Elevation Mapping-- Bill Burgess, DNR • Sea Level Rise planning maps--planning studies with counties http://www.indecon.com/slr/slr_main.htm • Worcester County Commissioners voted 5-0 on 4/2/2002 to partner with EPA on planning for sea level rise • Informal work with Ocean City to alter drainage policy to anticipate sea level rise. • See also Maryland Law Review articles which summarizes our emerging efforts with Rural Legacy/POS, MD EnTrust, and small trusts: http://www.epa.gov/globalwarming/publications/impacts/sealevel/takings.html
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**More EPA efforts.**
Agency Category	U.S. Environmental Protection Agency
5 Functional Categories	Ecosystem, Settlements, Water
Geographic Area	State, Chesapeake Bay
Contact for Effort	Karen Scott Gibbons Communications Specialist U.S. Environmental Protection Agency Gibbons.Karen@epamail.epa.gov
Website	See below
Focus of the Effort	In an email, Ms. Scott Gibbons provided the following website and contact information: • "Assateague Island and Chesapeake Bay". http://www.epa.gov/globalwarming/publications/outreach/orwkit.html#studies • Brian Czech of US Fish and Wildlife Service (brian_czech@fws.gov) has studied the economic impacts of sea level rise, especially as it relates to the loss of coastal refuges, and Blackwater National Wildlife Refuge has done a bit of study and public outreach on this issue as well. • There's a URL of our state impact sheets, particularly Maryland (we could send you as many copies of those as you want): http://www.epa.gov/globalwarming/impacts/stateimp/maryland/index.html
Magnitude and Timing of the Effort	
Links to Decision Making	

B. Stakeholder Programs

Name of Effort	**Ad-Hoc Climate Change Workgroup for the Living Resources Subcommittee of the Chesapeake Bay Program**
Agency Category	Interagency and Interstate workgroup
5 Functional Categories	All
Geographic Area	Chesapeake Bay
Contact for Effort	Julie LaBranche Natural Resources Planner Chesapeake Bay Critical Area Commission Tawes State Office Building 580 Taylor Avenue Annapolis, MD 21401 (410) 260-3475
Website	
Focus of the Effort	*An Ad-Hoc Workgroup on Climate Change has been established with members from Bay state agencies involved in implementing the Chesapeake Bay Agreement. The second Workgroup meeting was held on May 6, 2002.* *The Workgroup might devise a questionnaire for all the Bay Program subcommittees to find out how their activities are climate-related. The Workgroup's goal is to get a climate change action item on each subcommittee's (there are seven subcommittees) agenda.* *LaBranche is suggesting the Bay Program committees coordinate with Maryland DNR Tributary Teams. She knows that the Upper Eastern Shore Tributary Team is trying to develop Living Shorelines project (marsh creation instead of riprap and bulkhead) and thinks that is climate-change related. She wants to suggest that data collected by the Chesapeake Bay Program be analyzed from a climate perspective. She wants to develop an "analysis protocol." Perhaps the Bay Program's GIS Workgroup could do this.*
Magnitude and Timing of the Effort	--
Links to Decision Making	These are the key Chesapeake Bay Program participants.

Name of Effort	**The Environment Project, Statewide Energy Pollution Prevention Program (SEPPP)**
Agency Category	Community College of Baltimore County
5 Functional Categories	Human Health
Geographic Area	Statewide
Contact for Effort	Chris Fox Catonsville Community College 800 South Rolling Road Baltimore, MD 21228 410-455-4538 cfox@ccbs.cc.md.us
Website	www.environmentproject.org
Focus of the Effort	From the website: Project Outline A. Curriculum to be Developed 1. Environmental Impacts of Energy Generation, Distribution, & Use. 2. Energy Use and Global Warming B. Courses to be Developed 1. Environmental Impacts of Energy Generation, Distribution, & Use. 2. Energy Use and Global Warming C. Workshops to be Held - follow this link for our online survey. 1. Three regional business and institutional environment & energy workshops in spring 2001. 2. Two statewide environment & energy workshops in fall 2001. 3. Community college energy faculty train-the-trainer program in spring 2002. D. Project Outreach Underway 1. State and local government environment, energy and economic development offices. 2. Business/institutional groups and organizations. E. Project Research Underway 1. Current scientific assessment and consensus on global warming. 2. Potential impacts of global warming on Maryland & Chesapeake Bay. 3. International global warming negotiations. 4. U.S. federal government initiatives on global warming. 5. Global warming initiatives underway in other states and provinces. *6.* Business and institutional global warming and energy

	use survey.
Magnitude and Timing of the Effort	
Links to Decision Making	

Name of Effort	**"Implementing Takoma Park's Local Climate Action Plan"**
Agency Category	City of Takoma Park
5 Functional Categories	Policy
Geographic Area	City of Takoma Park
Contact for Effort	Albert Nunez MD/DC/VA Solar Energy Industries Association and ICLEI 8 Sherman Ave. Takoma Park, MD 20912-5742 202-270-5000 301-270-0313 solarnrgman@juno.com
Website	There is no website but we can borrow a CD-ROM that has their Local Action Plan on it.
Focus of the Effort	The City of Takoma Park accepted the Local Action Plan in 2000 and is having trouble implementing the goal to reduce the city's carbon dioxide emissions by 20% from 1990 levels by 2010. They have strategies but the city's laws are the barriers. Technical barriers aren't nearly as difficult as institutional and legal barriers. They are trying to "municipalize their own electric company." They're also doing group appliance purchasing for apartment buildings with Energy Star appliances and trying to purchase green power as a group. Pepco and Washington Gas & Electric currently supply the City of Takoma park. Pepco is providing Landfill Gas electricity as green power. They're trying to put together a Green Roof and Solar water heating demonstration project on a Community Center.
Magnitude and Timing of the Effort	They received $8,000 from ICLEI to City of Takoma Park to develop the plan and Albert was the only paid consultant. The implementation phase of the Plan is not funded at all.
Links to Decision Making	The Mayor and City Council are trying hard to implement it but so far to no avail.