Adapting to Climate Change in the Chesapeake Bay: A STAC workshop to monitor progress in addressing climate change across the Chesapeake Bay Watershed

STAC Workshop Report
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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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Cover photo of downtown Annapolis during a flood event, courtesy of the Chesapeake Bay Program (www.chesapeakebay.net)

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Executive Summary

On March 15th, 2011, the Chesapeake Bay Program's (CBP) Scientific and Technical Advisory Committee (STAC) convened an expert workshop to review current research and management action related to climate change impacts and adaptation relevant to Chesapeake Bay restoration efforts. The workshop included representatives from Virginia to Pennsylvania, representing federal, state, local, academic, and industry perspectives. The participants did not attempt to develop formal recommendations. However, they did identify several actionable areas for consideration by STAC and the CBP Partners:

1. **Embed climate change in decision making.** Climate is not a new silo or specific goal. It is an inter-related and cross-cutting set of issues and considerations relevant to many aspects of Bay restoration and protection.
2. **Focus on solutions to specific problems.** In the long-term, climate change cannot be adequately addressed "one decision at a time," however embedding the consideration of climate change in decision-making *can begin* to prepare a path forward by looking for win-win opportunities to incorporate up-to-date information about future conditions into specific management actions.
3. **Identify and prioritize vulnerabilities and adaptive opportunities.** Develop systematic criteria to recognize vulnerabilities and adaptive opportunities, including in critical decisions such as Watershed Implementation Plans (WIPs) and planned revisions to the Bay-wide Total Maximum Daily Load (TMDL).
4. **Build capacity.** Take action to train professional staff and key collaborators about the science of climate and its implications for resource policy, management and engineering.
5. **Research priorities.** The research community can accelerate progress on these issues by working to help reduce key uncertainties, improve and integrate modeling systems, and expand relevant dimensions of social science and communications research.

Introduction

The restoration of the Chesapeake Bay will take decades to achieve. The best available science indicates that this period is likely to experience rising sea levels, increasing temperatures, and changing precipitation patterns. These factors are central to the ecosystems, hydrology, and biogeochemical processes of Chesapeake Bay and, consequently, changes have the potential to alter restoration priorities and the efficacy of restoration strategies. On March 15th, 2011, STAC convened a workshop to continue its effort to understand the implications of climate change for the protection and restoration of the Chesapeake Bay and to identify practical next steps for the research and resource management community. The report below summarizes the workshop's presentations and discussions, and identifies possible actionable steps for the CBP and STAC.

Purpose and Scope

STAC has pursued work on climate change issues since 2006, including a state-of-the-science assessment released in 2008. STAC has repeatedly identified the need to consider climate change in the operations and decision-making processes of the Partnership. However, despite high-level goals, little tangible progress has occurred with respect to embedding climate change in day-to-day decision-making.

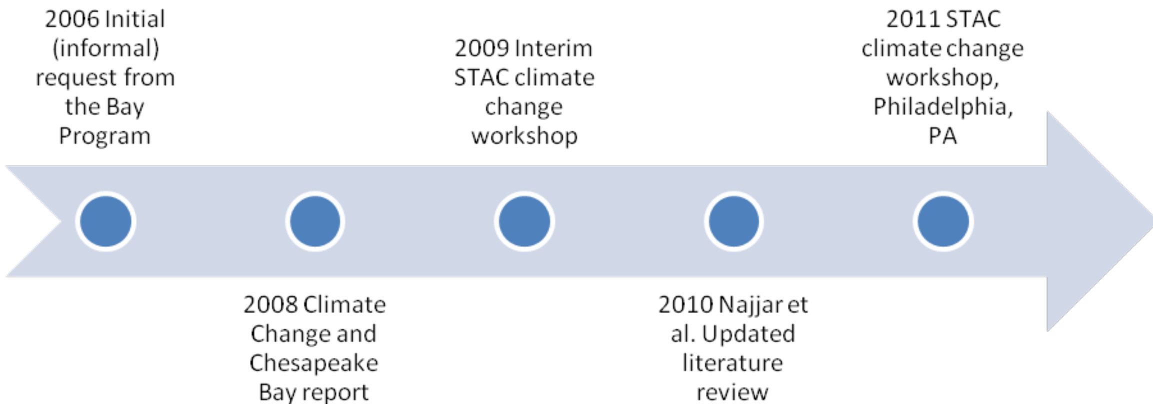
STAC convened this workshop to begin the process of envisioning an effective, state-of-the-art response to climate change by the CBP Partnership. This included reviewing on-going and planned activities among key stakeholders from Federal agencies, industry, and academia. This review set the stage for brainstorming next steps and future directions.

Science-Policy Interface

Panelists: Chris Pyke (STAC/USGBC), Jim McElfish (ELI), Todd LaPorte (GMU)

The opening panel was charged with framing some of the high-level concepts relevant to the consideration of climate change in the CBP Partnership and providing personal perspectives on the characteristics of state-of-the-art responses.

Dr. Pyke opened with a short history of STAC's involvement with climate change issues, a perspective on the current state-of-affairs, and thoughts on immediate next steps.



Dr. Pyke's introduction included consideration of three ideas potentially relevant to the consideration of climate change by the CBP partners. The first idea is the case of the Colorado River. The Colorado River Compact allocates flows in the Colorado River to various states and stakeholders. When the Compact was negotiated, it used the then-best-available historic flow data to estimate an annual average flow of 17 million acre feet per year. Unfortunately, flows in the following decades averaged between 14 and 15 million acre feet per year. Consequently, the sum of apportionments and treaty obligations now exceed the Colorado River's flow in most years. Unlike the negotiators of the Colorado River Compact, the CBP partners have ample scientific evidence to suggest that historic data are unlikely to be representative of future conditions.

The implications of climate change extend beyond these "big picture" concerns into the myriad of "little decisions" made every day across the watershed. Climatic assumptions are embedded in many day-to-day decisions and changes in climate have the potential to undermine these assumptions. These changes may (or may not) jeopardize key aspects of efforts to protect and restore the Bay. Decision makers have a responsibility to understand the consequences of their decisions in light of widely available information about the plausible range of future conditions. The Council on Environmental Quality (CEQ) has clearly and repeatedly identified the need for such consideration with respect to federal decision-making. This includes recommendations from an interagency Climate Change Adaptation Task Force (October 2010), a memorandum from current CEQ Chair, Nancy Sutley (February 2010), and draft guidance from then-CEQ Chair, Katie McGinty in 1999. In each case, the recommendations were to expand and strengthen efforts to understand, prepare for, and respond to climate change through federal decision-making.

Dr. McElfish provided a broad introduction to some of the factors relevant to the effective consideration of a long-term, far-reaching issue like climate change for an environmental regulatory program. Specifically, McElfish cautioned participants to refrain from issuing broad, vague pronouncements regarding climate change, but instead encouraged them to identify climate-related problems and suggest specific solutions to these problems that might help decision-makers at the local, state and federal levels. McElfish also pointed to a number of statutes that indirectly grant authority to include climate change considerations, such as: NEPA §101, 102, and 105; Pennsylvania Const., Art. 1, §27; Virginia Const., Art.XI, §1; New York Const., Art XIV, §4; Delaware Planning Act, tit.29, Ch. 91; and Maryland Climate Change Commission Action Plan.

Dr. La Porte introduced some of the core concepts relevant to the issue of long-term governance in programs driven by short-term milestones and decision making.

Government
Panelists: Scott Phillips (USGS), Skip Stiles (Wetlands Watch), Glen Abrams (City of Philadelphia), Zoe Johnson (Maryland DNR)

This government panel was charged with providing a perspective on the activities and direction of the federal, state, and local agencies in addressing climate change impacts and preparing for changing climatic conditions.

Ann Swanson (moderator) emphasized the need to consider the Chesapeake Bay-wide TMDL as an action-forcing opportunity for the consideration of climate change potentially now and certainly in the 2017 revision. Consideration of climate change in the TMDL could be a first step in the broader consideration of climate change throughout the partnership. With respect to messaging, climate change means different things to different states and they vary in impacts and relative priority. These differences should be considered in any next steps.

Dr. Phillips reviewed USGS's role in the response to the Chesapeake Bay Executive Order and its on-going climate change-related research activities.

Ms. Johnson provided an overview of Maryland's sophisticated efforts to plan for climate change, including their recently released Phase 2 Adaptation Report.

Mr. Stiles provided an overview of efforts to incorporate climate change and sea level rise into local government decision making, particularly land use planning. Given the critical role of local government in development decisions that are critical to successful adaptation, he stressed the need for more attention to be directed at providing technical tools, legal authorities, and social marketing on climate change impacts to localities across the Chesapeake Bay Watershed.

Mr. Abrams provided specific examples of climate change mitigation and adaptation strategies being implemented by project managers in the City of Philadelphia.

Industry
Panelists: Chris Pyke (STAC/USGBC), Debra Ballen (Institute for Business and Home Safety), Joe Manko (PENNVEST)

The industry panel was charged with providing perspectives on private-sector activities related to climate change impacts and adaptation.

Dr. Pyke led off the panel with an overview of connections between climate change and green building. The green building movement is dedicated to transforming markets to create buildings and communities that benefit people and the environment. The notion of green building encompasses specific skills and training, tools, and processes to evaluate and reward superior practices. Climate change is recognized as an important issue for the green building community; however, this is preliminarily interpreted to refer to the reduction of greenhouse gas emissions. Climate change impacts and adaptive opportunities are rarely considered. The US Green Building Council's Research Program is conducting work to understand the implications of climate change for specific green building practices and, when possible, to identify specific opportunities for adaptive design and operation. During the panel, Dr. Pyke highlighted a number of specific adaptive opportunities available to residential and commercial buildings, including:

- Use of orientation, insulation, and reflective surfaces to reduce cooling loads.
- Physical barriers to prevent damage from pests that may expand their ranges with warming winter temperatures.
- Technologies for rainwater harvesting and reuse.
- Strategies to avoid hazardous areas, such as storm surge zones or flood plains.

Dr. Pyke presented a new database being developed in partnership with the Department of Urban Planning at the University of Michigan that describes these strategies in greater detail and links them with widely-used green building practices.

Debra Ballen provided an overview of work conducted by the Insurance Institute for Business & Home Safety (IIBHS) to understand and reduce risks associated with coastal development. IIBHS conducts applied research on issues such as floods, hail, high winds, and hurricanes. They are using a state-of-the-art experimental facility to identify strategies to improve the resilience of homes. This is conveyed to home owners, policy makers, and industry through activities such as the *Fortified Homes* program.

Research

Panelists: Susan Julius (EPA), Denice Wardrop (PSU), Lewis Linker (EPA), Dana Dolan (GMU), Raymond Najjar (PSU)

The Research Panel was asked to provide a snap-shot of their current research activities, emphasizing connections to the needs and challenges identified by the Government and Industry panelists.

Dr. Wardrop provided an overview of a current project investigating the hydrologic forecasting for characterization of non-linear response of freshwater wetlands to climatic and land use changes in the Susquehanna River Basin. The project analyzes global climate model output, and develops future land cover scenarios, to provide forcing for an integrated surface water – groundwater hydrologic model (Pennsylvania Hydrologic Integrated Model, PHIM), to ultimately provide ecologically-relevant and spatially-explicit hydrologic scenarios in a series of five watersheds in the Susquehanna River Basin, across a range of physiographic provinces and predominant land covers. These hydrologic scenarios are utilized as a basis for the prediction of wetland-associated ecosystem services in headwater wetlands and stream reaches, most specifically plant and macroinvertebrate diversity, community composition, and function. While each step of this process represents a technical challenge, three were highlighted and described as an illustration of both the state-of-the-science and the necessary considerations for use in informing policy:

1. Selection of climate models as drivers for an ecological endpoint
2. Emerging hydrologic models and the innovations required for use in scenario-building
3. Expected ecological impacts

According to Wardrop, the study succeeded in developing and executing a process to select an individual climate model (out of 21 available models) that represents the most appropriate driver for specific ecological endpoints within wetland habitats. The model was selected using an index that ranked each model based upon 1) temperature and precipitation and 2) wind, solar radiation, and humidity. This ranking resulted in only one model that was ranked in the top six for both groups of variables. That model was the Bjerknes Centre for Climate Research (Norway) Model.

Wardrop added that the PHIM proved to be a reliable and extremely useful tool to provide hydrologic scenarios at a fine grain of spatial resolution. The PHIM was able to predict the occurrence of wetlands across a small watershed, and climate change a land cover change scenarios are now being run for all sub-basins.

Finally, a rapid assessment was conducted to determine expected ecological impacts between the following different site classifications: 1) the active channel zone located between or adjacent to the main stream banks and connected (inundated) below bankfull; 2) the floodplain area that is created and maintained primarily by flood pulses (inundated above bankfull); and 3) groundwater-supported wetlands within the riparian zone that may or may not be located within the adjacent floodplain or active zone.

The results of the rapid assessment varied between site classes. Large floodplain sites revealed a significant decrease in the area of active zone and floodplain habitats across a land use gradient. Forested sites averaged 3,711 m^2 of active zone compared to only 1,724 m^2 in agricultural and urban reaches. Both aquatic and terrestrial floodplain area also decreased in agricultural and urban sites (512 to 19m^2 and 3,572 to 2,028 m^2, respectively). The amount of wetland area declined but not significantly, although this was expected, since the floodplain sites did not contain substantial areas of wetland. The area represented by large woody debris piles also declined significantly. Forested sites contained nearly ten times the amount of large woody debris than agriculture and urban sites. Unlike the floodplain sites, habitat areas did not change significantly between forested and agricultural/urban sites in the mixed and wetland classifications. However, mixed and wetland sites in agricultural and urban areas contained fewer cover types (defined by differing hydrology and vegetation), greater dominance of invasive plants, and received lower condition scores (stream habitat condition, stressor checklist, etc.). This suggests that measures of complexity and condition are more responsive to disturbance than areal extent in groundwater-supported wetland habitats.

Dr. Julius explained that in conducting assessments of impacts and adaptation, the key questions in climate science need to be reframed to be useful and answerable today. The relevant question is not, “What will happen in the future?” but rather, “What do we care about, how do the linked human and natural systems that we are concerned with work, and how do we protect the vulnerable elements of these systems?”

There are currently two competing paradigms in the community of researchers working to understand how global change science can best support effective decision-making about adaptation. The first paradigm is the belief that developing effective adaptation strategies is contingent on improvements in modeling, which lead to improvements in the accuracy and reliability of climate (and related process-level) predictions at the regional scales of relevance for decision makers. Such probabilistic forecasts will then support arriving at the “optimal” decision for a “most likely” future. The second paradigm is the belief that the climate change problem is ill-suited to a reliance on predictions, due to inherent limitations in climate science and modeling, and uncertainty should instead be managed by identifying the greatest vulnerabilities and policy trade-offs across the broadest possible range of plausible futures. For example, the use of scenario-based approaches to support decision-making that is “robust” across the “highest risk” futures.

The first paradigm is not well suited for local-scale environmental and health endpoints that are far “downstream” from the stressor of global climate change, and thus least amenable to a prediction-based approach. The state of knowledge about future climate in specific places does not currently, and may never, provide sufficiently accurate predictions to support a “predict-then-act” framework for the types of consequential (and potentially controversial) decisions many localities confront. In assessing vulnerabilities and evaluating subsequent management strategies to build resilience to these vulnerabilities, we are confronted with conditions of deep uncertainty, where parties to a decision do not know (or do not agree on) the system models (and inputs to these models) that relate actions to consequences.

Some science-based alternatives to prediction do exist. One such approach EPA developed seeks to maximize the effectiveness of existing management practices by using a decision framework to identify climate change impacts and their effects on the performance of specific management practices. EPA tested this approach using the Chesapeake Bay as the study area by (1) compiling a list of key water quality and aquatic ecosystem decisions, (2) developing criteria to evaluate the relevance of climate change to those decisions, (3) selecting and prioritizing decisions, (4) evaluating prioritization results with the stakeholder community, (5) testing the sensitivity of results to alternative prioritization schemes, and (6) developing a plan to provide needed research to support the highest priority decisions. For this study, the most effective selection criteria to identify decisions for which climate change impacts are relevant were (1) the climate adaptation potential (e.g., the sensitivity of the system to climate stressors and the capacity of the decision to ameliorate the impacts of climate change); (2) dimensions of timeliness (e.g., planning horizon, implementation period, and project lifespan); and (3) reversibility of the decision. Once decisions have been selected, examples of categories that could be used to prioritize decisions in addition to degree of climate sensitivity might be:

- Capital investment: high capital investment, high design flexibility, high adaptive capacity of managing institution
- Resource value: highly valued resource or high expected benefit from providing decision support

- Information availability: extensive information available on environmental / ecological functions of resource and on climate change impacts on resource / management practice

The test of our theoretical approach using the CBP's environmental management decisions revealed that in practice, this approach provides useful information on adaptation measures for local decision makers and direction for fruitful research endeavors that will further improve our provision of information. Results of this study are immediately useful to decision makers by informing them on the degree to which management of ecosystems depends on practices that are sensitive to climate change and whether their environmental goals are in danger of not being met. It also gives decision makers some sense of the magnitude of effort needed to address climate change effects in their plans. Decisions that were not selected using broad criteria are generally ones that are not influenced by climate-related variables, are made more frequently, or involve projects with a limited lifespan.

Next steps include refining our understanding about which attributes of decisions are particularly sensitive to climate, identifying the types of adjustments needed to decision-sensitive practices to maintain their effectiveness, and determining how feasible it is to generalize place-based adaptation best practices to a national-scale set of guiding principles and practices for building resilience to climate change.

Dana Dolan offered a perspective on the emerging climate change adaptation policy ecosystems. Anticipatory adaptation to climate change offers long-term benefits that outweigh immediate costs, yet while some societies take action in advance, many only react after crises occur. Ongoing research in the San Francisco and Chesapeake Bay regions comparing the emerging policy network interactions across organizational, jurisdictional, and sectoral boundaries suggests that the capacity for long-term governance may be correlated to interactions across the disciplinary boundaries of 1) physical sciences, 2) social sciences, 3) ethics and religion, and 4) creative arts.

Lewis Linker presented an update to the ongoing efforts by the CBP to investigate potential climate change effects on flow rates. In an initial, preliminary study of climate change in the Chesapeake Bay Watershed the CBP examined the flows and associated nutrient and sediment loads in several major river basins within the Watershed under three climate change scenarios. The scenarios represented the widest range of potential changes in temperature and precipitation in the year 2030 based on projections from seven GCM models, two IPCC SRES storylines, and three assumptions about precipitation intensity in the largest events. Weather data reflecting each climate change scenario were created by modifying a 16-year period of historical data of precipitation and temperature from 1984 to 2000 and run in the Phase 5 Watershed Model. Climate change estimates were combined with a 2030 estimated land use based on a sophisticated land use model containing socio-economic estimates of development throughout the Watershed. The assessment was supported by use of tools developed for EPA's BASINS 4 system including the Climate Assessment Tool (CAT). Key basins of the Watershed were examined and differences among the basin responses to future climate change were noted through a comparison of a 2030 scenario without the estimated effects of climate change.

Dr. Najjar provided a brief overview of the state of the science regarding impacts of climate change on the Chesapeake Bay and its restoration. Recent reports emphasize that climate change during this century is likely to have a profound impact on restoration activities. For example, the combination of warming with increased streamflow during winter and spring will likely increase the extent of summertime hypoxia. Also, increases in stratification, temperature, and carbon dioxide levels will likely make conditions more favorable for harmful algal blooms. Interdisciplinary research is needed to make these inferences more quantitative so that restoration strategies can be modified accordingly as described in the research priorities section included below.

Next Steps

The above panel presentations set the stage for a vigorous round of brainstorming about a vision for the consideration of climate change in the CBP. Participants explicitly recognized the daunting challenges of the moment, including budget constraints and political polarization. These constraints colored the discussion, but they did not detract from the sense of urgency for action.

Workshop participants identified five components for an effective, practical response to climate change by the CBP Partnership.

1. Embed climate change in CBP decision-making
In early work, STAC emphasized the need for a singular lead or champion to support the consideration of climate change within CBP decision making. The participants affirmed this position, emphasizing the climate change must be someone's job. However, they balanced and complemented this perspective with the need to embed climate change across the organization and into a wide range of decisions.

2. Focus on solutions to specific problems
It is important for the conversation about climate change to move beyond potential impacts to specific strategies that can demonstrably reduce vulnerabilities, while, ideally, providing co-benefits.

Perhaps inspired by Dr. McElfish's introduction, the participants generally agreed with the importance of identifying specific solutions to tangible problems facing the Partnership. The elegance of this argument was somewhat complicated by the nature of the climate change problem itself. Climate change itself is a new problem, a new issue facing the Partnership. Participants have worked hard and, to some degree, continue to struggle to have climate change and variation recognized as an actionable issue by the Partnership. Consequently, we face something of a Catch-22 as participants are anxious to offer practical solutions to a problem that has yet to be fully recognized by decision makers.

3. Identify and prioritize vulnerabilities and opportunities for adaptation
Climate is a pervasive driver of Chesapeake Bay processes and climate change has the potential to have far-reaching consequences. Yet, the notion that everything is "climate sensitive" and thus in need of reconsideration with respect to climate change can be paralyzing. The

participants identified the need to clearly and systematically prioritize impacts based on criteria such as risk, vulnerability, and opportunity. Susan Julius' Chesapeake Bay decision assessment was seen as one potential model for a structured approach to this problem.

Examples of important vulnerabilities and adaptive opportunities, include:
The *Total Maximum Daily Load*: Consider opportunities to incorporate climate change into planned revisions to the TMDL, and the WIPs. The implementation and revision of the state WIPs provides immediate opportunities to consider the impacts and implications of climate change. Studies such as those conducted for the Monocacy River watershed illustrate approaches to assessing climate change impacts on small watersheds and even individual Best Management Practices (BMPs).

4. Build capacity
STAC and other CBP institutions can work to build capacity among professional staff to understand and address the consequences of changing climatic conditions. Particular attention should be given to building the capacity for informal collaboration across organizational and disciplinary boundaries. Capacity building efforts will ultimately provide the foundation for effective management responses.

5. Research priorities
The research community can help reduce barriers to more sophisticated consideration of climate and improve long-term outcomes with coordinated programs of work. Specific areas of opportunity identified by participants included:

Reduce uncertainties while recognizing the need to take action in the face of uncertainty
Numerous uncertainties exist in the projections of climate change and the impacts of such change on the Chesapeake Bay. These were summarized in the STAC report on climate change (Pyke et al. 2008) and an updated literature review (Najjar et al. 2010), and are briefly reviewed here. An overarching research priority is to develop improved projections of precipitation and streamflow in the Chesapeake Bay Watershed because these projections are currently highly uncertain (particularly in summer and fall) and of potentially high impact. Climate and land-use controls on watershed-wide nutrient and sediment budgets controls are also poorly constrained and of high relevance to the Bay. The direct impacts of warming on Bay biogeochemistry and living resources are highly uncertain as a result of the lack of warm-year analogues in the monitoring record. Continued long-term monitoring of the Bay as it warms—coupled with analysis and modeling that can identify the climate signal—thus emerges as a high research priority. Finally, synergistic effects of climate and other human impacts (e.g., land-use, fishing, and invasive species) remains an area of high uncertainty and likely high impact.

Calibrated estuarine model
Many researchers identified limitations in the current generation of estuarine models as a barrier to understanding the implications of climate change for key metrics, such as deep water hypoxia. Strategic investments in the next generation of modeling tools are needed to reduce uncertainty and understand the implications of changing conditions for management targets.

Connections between estuary and watershed models

Improved estuarine models are necessary, but their real value comes with full integration with the Chesapeake Bay Watershed Model. To date, the participants are not aware of a climate change impact study for the Bay which utilizes a fully integrated and coupled watershed-estuarine analysis. The foundation for such work is underway by researchers at Penn State University, USGS, and the US EPA.

Social science and communications perspectives
Participants identified opportunities for social science researchers to address issues associated with the study of behavior and decision-making, communications, and the emerging concept of long-term governance.

Opportunities for policy learning exist in recent experiences addressing governance and policy responses to climate change adaptation in the San Francisco Bay Area, and other highly urbanized estuaries, bays, and deltas similar to the Chesapeake. Evidence suggests that more and better scientific data, though necessary, is insufficient to reduce climate-induced risks. Case study research on the policy dynamics across organizational, jurisdictional, sectoral, and disciplinary boundaries promises to have a salutary effect, both on advancing the consideration of novel institutional options, and on coordinating climate change adaptation actions across diverse stakeholder networks.

Specific Opportunity

Participants felt that one of the most practical "next steps" was a focus on building understanding and technical capacity within professional staff of the Partnership. Participants suggested that STAC could play a role in defining a cross-cutting climate change curriculum for staff that introduced core concepts and helped developed skills necessary to consider climate change in a wide-range of different types of decisions. This type of training could be delivered by existing education and outreach programs and serve as the basis for professional recognition.

Sources

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Participants

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