Chesapeake Bay Modeling Laboratory Recommendation

Modeling Laboratory Action Team Report

Chesapeake Bay Program
A Watershed Partnership

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I. Executive Summary

The Chesapeake Bay Program (CBP) Management Board formed the Modeling Laboratory Action Team in response to a recommendation from the National Research Council (NRC) of the National Academy of Science (NAS) in the report, “Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation”.

“Establishing a Chesapeake Bay modeling laboratory would ensure that the CBP would have access to a suite of models that are state-of-the-art and could be used to build credibility with the scientific, engineering, and management communities.”

The Modeling Laboratory Action Team (MLAT) was charged with developing a definitive set of implementation options. Specific elements of the charge included:

1. Evaluating other existing modeling laboratories and adaptive management programs that encompass modeling to document how those programs function and how applicable their structures and mandates are to the CBP Partnership.
2. Considering the range of options for structuring a Chesapeake Bay Modeling Laboratory (CBML), a virtual laboratory, or responsive program reorganization that is capable of carrying out the functions outlined by the NRC committee and addressing the series of existing Scientific and Technical Advisory Committee and the jurisdictions’ recommendations on modeling.
3. Developing options and recommendations for institutional sponsorship and laboratory functions and assessing the possible financial investments and funding mechanisms.

MLAT agreed upon 11 Guiding Principles for the CBML:

1) Research, development, and operations must all be addressed
2) Sustainable dedicated core funding
3) Research and development is management focused
4) Research must be of publishable quality and should be peer reviewed
5) Formal methods to track and openly distribute model input data and products of the data (with meta data meeting accepted standards) must be included
6) Consider both regional and local issues across the watershed and estuary
7) Supports development of open-source, modular code
8) Transparency and communication should be considered in development and operations
9) Support co-development of a suite of models to support Chesapeake Bay modeling needs
10) Transferability
11) Regional focus with the ability to expand

MLAT identified four essential functions of models that must be integrated to provide models with the highest possible scientific credibility and high confidence from managers and stakeholders.

Operations: the rapid and automated development of scenarios to support the TMDL, the WIPs, Progress runs, Milestones, and other requests. The CBP Partnership currently undertakes 100-200 Scenario Builder and Watershed Model runs per year and a lesser number of land use change model and estuarine model scenarios.

Operational Development: the programming and development work that supports the ability of the CBPO to efficiently run scenarios and to quickly respond to decisions made by the partnership.

Research-Oriented Development: the development of new models or modification of old models to add new processes. This type of model development consists of conceptual modeling, code development, testing, and model validation.

Research: the application of models and analysis of model output to answer questions that the current CBPO suite of models is not ideally equipped to answer.

To provide the greatest management effectiveness, the four functions of CBP modeling must be tightly linked to each other for management. The closest linkages are needed between neighboring functions. However, the governance structure must provide an overarching framework to coordinate efforts among all the functions.

Governance of a Chesapeake Bay Modeling Laboratory

A governing body or Board of Directors would be appointed by the Management Board. The Board would have ability to decide on activities and budgeting of the CBML. It would determine the work elements related to research, research-oriented development, and operational development that would be incorporated into an annual work plan of the CBML. The Board would prioritize input from the Goal Implementation Teams (GITs) and the Workgroups and work interactively with the CBML to determine the scope of each annual work plan. This Modeling Laboratory Board (ML Board) would periodically brief the Principal Staff Committee and Management Board on CBML activities and direction. The final make-up of the ML Board would be decided by the Management Board.

MLAT Recommended Actions to Create a Chesapeake Bay Modeling Laboratory

Recommendation #1: A Chesapeake Bay Modeling Laboratory should be established to take on research, research-oriented development, and some operational development of Chesapeake Bay Program models. A modeling laboratory is a critical component in addressing the significant issues brought up by the NRC/NAS report and STAC recommendations. Resources at a modeling laboratory would help close an existing gap in research and model development at the Chesapeake Bay Program and improve integration of knowledge, expertise, and development skills of the academic community into the modeling program,

Recommendation #2: The state representatives on MLAT strongly recommended that the Modeling Laboratory should also assemble and calibrate the operational models. Under this recommendation, the existing Modeling Team at the CBPO office would be incorporated into the Modeling Laboratory.

Recommendation #3: A Modeling Laboratory Board of Directors appointed by the Management Board should be created from a re-constituted Modeling Workgroup. The appointees must have both the technical expertise and the authority to make the technical decisions related to modeling at the CBP.

Funding a Chesapeake Bay Modeling Laboratory

Expanded, sustained funding is needed to ensure the essential modeling functions. Without sustained funding, new and emerging issues requiring substantial model revision will not be incorporated, thereby jeopardizing the model as a credible tool for simulating local/regional water quality and projecting future scenarios through an increasing population, changing land use, and climate change. The CBML will require approximately $1.5M annually to meet research objectives that have been identified for improving the CBP modeling system, and $0.5M annually for enhancing the operational component. This would be new funding above the funding that the CBP and its partners currently use to support the Modeling Team. Offered through a Request for Services (RFS) or Request for Proposals (RFP), the funds would support a permanent/core staff and modeling expertise for management-specific modeling needs.

II. Background

Formation of the Modeling Laboratory Action Team

The Chesapeake Bay Program Management Board formed the Modeling Laboratory Action Team (MLAT) in response to a recommendation from the National Research Council (NRC) of the National Academy of Science (NAS) in the report , "Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation".

"Establishing a Chesapeake Bay modeling laboratory would ensure that the CBP would have access to a suite of models that are state-of-the-art and could be used to build credibility with the scientific, engineering, and management communities."

The report highlighted many advantages of a Chesapeake Bay modeling laboratory, including:

- Integrating of monitoring with modeling efforts.
- Assessing monitoring data needs.
- Evaluating uncertainty in model simulations.
- Improving the predictive skill of the models.
- Improving model credibility.
- Incorporating multiple modeling approaches.
- Fostering open-source models exercised cooperatively with the scientific community.
- Creating balance between the operational and research components necessary for continued improvement.

Management Board Memorandum

1. The Chesapeake Bay Program (CBP) Management Board commissioned an in-depth evaluation of a Chesapeake Bay Modeling Laboratory (CBML). The Modeling Laboratory Action Team (MLAT) was charged with developing a definitive set of implementation options. Specific elements of the charge included: Evaluating other existing modeling laboratories and adaptive management programs that encompass modeling to document how those programs function and how applicable their structures and mandates are to the CBP Partnership.
2. Considering the range of options for structuring a CBML, a virtual laboratory, or responsive program reorganization that is capable of carrying out the functions outlined by the National Research Council committee and addressing the series of existing Scientific and Technical Advisory Committee and the jurisdictions' recommendations on modeling.
3. Developing options and recommendations for institutional sponsorship and laboratory functions and assessing the possible financial investments and funding mechanisms.

The appointed action team members provide multiple perspectives through recognized expertise in modeling, monitoring, and management decision making. The CBP Management Board will decide on the specific MLAT recommendations to advance to the Principals' Staff Committee for final decisions. For additional information please see the Management Board Memorandum.

Chesapeake Bay Program Modeling Laboratory Action Team

MLAT first met on June 21st, 2012 and met monthly through September, 2013. Meetings would address the group's goals, expectations and responsibilities, including the development of this report. For additional information please see the MLAT webpage.

Modeling Laboratory Action Team Members:

Mark Bennett, U.S. Geological Survey, Chair

Amy Guise, U.S. Army Corps of Engineers
Claire Welty, University of Maryland, Baltimore County
David Montali, West Virginia Department of Environmental Protection
Dominic Di Toro, University of Delaware
Donald Weller, Smithsonian Environmental Research Center
Heather Cisar, U.S. Army Corps of Engineers
Howard Townsend, National Oceanic and Atmospheric Administration Chesapeake Bay Office
Kevin Sellner, Chesapeake Research Consortium
Larry Band, University of North Carolina
Lee Currey, Maryland Department of the Environment
Marjorie Friedrichs, Virginia Institute of Marine Science
Raleigh Hood, University of Maryland Center for Environmental Science
Rick Luettich, University of North Carolina
Theo Dillaha, Virginia Polytechnic Institute and State University
Theodore Tesler, Pennsylvania Department of Environmental Protection
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Support Team:

Gary Shenk, Environmental Protection Agency at Chesapeake Bay Program Office
Lewis Linker, Environmental Protection Agency at Chesapeake Bay Program Office
Amanda Pruzinsky, Chesapeake Research Consortium at Chesapeake Bay Program Office

III. Justification of a Chesapeake Bay Modeling Laboratory

In addition to the NRC-NAS report, numerous external and internal reviews of CBP have suggested the need to improve the science behind the CBP modeling activities.

STAC Recommendations and Discussions

Over the past two years, STAC (the Chesapeake Bay Program's Scientific and Technical Advisory Committee) has repeatedly discussed a Chesapeake Bay Modeling Laboratory (CBML) and STAC support for establishing a CBML has been nearly unanimous: STAC agrees with the NRC review committee that the establishment of a modeling laboratory should be a high priority for CBP and that the laboratory would yield the advantages suggested by the NRC panel. The laboratory would also enhance capabilities to compare multiple models for the watershed and estuary, and to integrate knowledge from multiple models into decision making and regulation. STAC has repeatedly recommended that CBP should develop and employ multiple models. Support for the modeling laboratory and multiple modeling has also been documented through many communications from STAC to the Management Board (see Appendix A).

CBP Goal Implementation Team List of Modeling Needs

As CBP approaches the 2017 Midpoint Assessment, the Goal Implementation Teams (GITs) are prioritizing possible modeling changes needed. A short list of "high" and "low" priorities was selected by the CBP GITs from a comprehensive list of needs (an initial list of 431 modeling needs identified by the Water Quality GIT). The Modeling Workgroup and/or Modeling Team are the lead or supporting partners on seven of the eight "high" priorities and 11 of the 18 "low" priorities (see Appendix B). The "high" priority items are items that must be completed for the Midpoint Assessment and "low" priority issues should be addressed, but cannot take precedence over the "high" priorities. It will be challenging for the existing Modeling Workgroup and Modeling Team to address all of these issues given time constraints and the operational needs of the partnership. However, additional resources to establish a modeling laboratory would create a new entity that could advance the management-identified research priorities of CBP. The current research priorities of CBP's modeling team include, but are not limited to, climate change, lag times, BMP effectiveness, load impacts from spatial distributions of BMPs on the landscape, filter feeders, and shallow water.

Components of Existing Chesapeake Bay Program Modeling Efforts

The CBP partnership has developed and applied multiple generations of linked environmental models to evaluate the response of the Chesapeake Bay watershed, airshed, and tidal Bay to management actions aimed at restoration of the resource. Over the past three decades, the modeling suite has grown from a steady-state Estuarine Model linked to a dynamic Watershed Model into an integrated system of models (Figure 1):

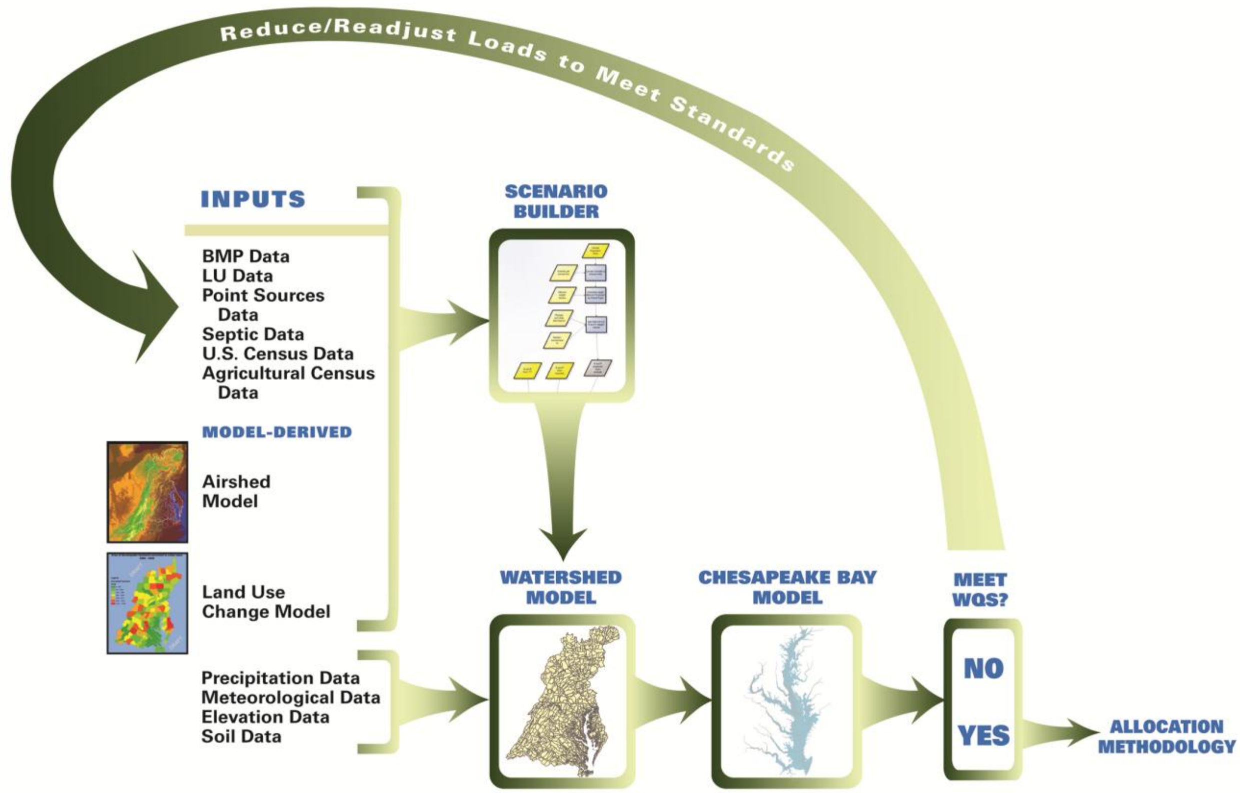

Figure 1. Chesapeake Bay Program Integrated Modeling System

The Chesapeake Bay Airshed Model estimates changes in nitrogen deposition resulting from changes in emissions from utility, mobile, and industrial sources due to management actions or growth. This Community Multi-scale Air Quality Model (CMAQ) model is an air quality model developed by the EPA and other partners to investigate policies for a wide range of environmental stressors. The complexity and scale of air deposition modeling leave it outside the scope of the CBP partnership to run or modify. A modeling laboratory would be unlikely to take on refinements to the Airshed Model, but would interact with the organizations supporting CMAQ.

Land use modeling provides estimates of historical, current, and future land uses. Land use estimation and modeling is performed at the Chesapeake Bay Program Office (CBPO) by a team of researchers associated with the USGS National Research Program. The MLAT considers these efforts to be external to the work that would be undertaken by a modeling laboratory.

The MLAT has primarily discussed modeling laboratory activities related to Scenario Builder, the Watershed Model, and the Estuarine Model. Scenario Builder is the input data base application for the Watershed Model, processing data from many sources to assemble much of the input data needed for the Watershed Model. Scenario Builder is primarily a model of agricultural behavior, and it estimates fertilizer and manure applications (and other factors) using data on crops and livestock populations, and other sources. The Watershed Model is a dynamic simulation of the water, nutrients, and sediment delivered to the tidal Bay from each land use type and region given a scenario of inputs from Scenario Builder. The Estuarine Model combines a hydrodynamic model with a water quality and living resources model of the Chesapeake Bay and its tidal tributaries. The Estuarine Model estimates dissolved oxygen, chlorophyll, clarity, and submerged aquatic vegetation for water quality standards evaluation.

Currently, Scenario Builder and the Watershed Model are developed and operated at CBPO by a team consisting of federal employees, university research staff funded through a contract, and other contract support. The Estuarine Model is developed by the U.S. Army Corps of Engineers (USACE), and run operationally by both the USACE and the CBPO Modeling Team.

These models are described more fully in the documentation for the Chesapeake TMDL: http://www.epa.gov/chesapeakebaytmdl/

Barriers to Implementation within the Current Modeling Structure

For models to remain up to date, they must be periodically upgraded to incorporate the latest research and monitoring. The Estuarine Model has been successfully upgraded partially because of the separation of model operations and model development. The USACE handles most of the development at their facility while operations are primarily handled within the CBPO. Research relevant to model development is funded by the USACE. This arrangement tends to insulate the developers from the daily pressure of CBPO business. The relationship is aided by the frequency of use. The Estuarine Model is exercised during a major decision-making period such as the months leading up to the 2003 goal-setting or the 2010 TMDL and has a constant analytical support role for activities, such as the Conowingo infill issue, James River Chlorophyll Model boundary, analysis of filter feeder influence on the Chesapeake water quality, support for shallow water multiple models, and ongoing requests for research support by investigators throughout the Chesapeake region.

The Scenario Builder and Watershed Model are also in constant use for many projects such as progress runs, milestones, and other partnership-requested scenarios related to scientific and policy questions and management decisions. In the current structure, one modeling team is responsible for research, development, and operations. The discussions in the MLAT have revealed that the CBPO modeling teams are focused on operations and operational development with little time or resources devoted to research or research-oriented development. The MLAT sees an urgent need for a CBML that emphasizes research and research-oriented development, but there must be very strong ties between the CBP, the CBPO Modeling Team, and the CBML to guide the CBML in creating products that are responsive to management needs.

An important difference between the Estuarine and Watershed Model governance arises from the different constituencies for the two systems. The Estuarine Model is governed primarily by the contractor, management, and academic communities at quarterly Modeling Workgroup meetings. This interaction provides sufficient guidance to the USACE on the partnership needs, which are important, but few and well defined. In contrast, Scenario Builder and Watershed Model development are governed by the Water Quality GIT, eight of its workgroups, approximately twenty BMP panels, and the Modeling Workgroup. This diverse and complex governance structure creates a barrier to research because the many constituents demand constant operations and development activity. Those demands also have potential to create a challenge for governance of a modeling laboratory.

IV. Review of existing modeling laboratories

A review of existing modeling laboratories provides context and examples of successful established institutions. Existing modeling laboratories range from physical structures with dedicated buildings and staff, to fully virtual laboratories, to laboratories that blend physical and virtual assets. A good example of a physical modeling laboratory is the *National Center for Atmospheric Research* (NCAR), which develops widely-used weather and climate change models. A virtual modeling laboratory example is the successful U.S. Integrated Ocean Observing System (IOOS), a consortium of different universities, agencies, and principal investigators effectively sharing modeling platforms, code, and expertise. A modeling laboratory that combines both physical and virtual assets supports the Community Multiscale Air Quality Model (CMAQ), the model widely used in the nation and internationally for air quality management. A physical space and staff develops CMAQ and virtually serves a community of regional centers, which apply the model for multistate air quality management. Each of these three types of modeling laboratory formats will be discussed in further detail below.

Physical Modeling Laboratories

The National Center for Atmospheric Research (NCAR) was established in 1956 by the National Academy of Sciences (NAS). The NAS convened a committee of distinguished scientists to investigate the state of the field and science of meteorology. The committee recommended that a national center for atmospheric research should be established and then operated by a consortium of universities with support from the National Science Foundation (NSF).

The mission of NCAR is to 1) attack the fundamental problems of the atmosphere on a scale commensurate with their global nature, 2) aggregate the large-scale research facilities necessary for such an attack, 3) provide a coordinated, interdisciplinary approach to these problems on a scale not possible in individual university departments, and 4) preserve the natural alliance between research and education, without unbalancing university departments. Today, NCAR and university scientists work together on research topics in atmospheric chemistry, climate, cloud physics and storms, weather hazards to aviation, and developing models capable of predicting the evolution of the climate system. The NCAR campus is located in Boulder, Colorado (Figure 2). Major funding for NCAR is provided by the NSF with significant additional support provided by other Federal agencies, as well as other national governments and the private sector. The total annual budget for NCAR is about $170 million. Further information on NCAR can be found at: http://ncar.ucar.edu/.

Figure 2. The National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

Another modeling laboratory with dedicated staff and building is the Geophysical Fluid Dynamics Laboratory (GFDL) on the Princeton University campus (Figure 3). The GFDL is a National Oceanic and Atmospheric Administration (NOAA) laboratory that develops and uses models to improve understanding and better predict of the behavior of the atmosphere, the ocean, hurricanes, weather, and climate change. The GFDL research concerns are: 1) predictability of weather on large and small scales, 2) structure, variability, predictability, stability, and sensitivity of global and regional climate, 3) structure, variability, and dynamics of the ocean over its many space and time scales, 4) interaction of the atmosphere and oceans, and how the atmosphere and oceans influence and are influenced by various trace constituents, and 5) Earth's atmospheric general circulation and fundamental understanding of natural climate variability and human influence on climate.

Since 1955, GFDL has contributed valuable information to the world's research on modeling of global climate change. GFDL has also played a significant role in the Intergovernmental Panel on Climate Change (IPCC) assessments, and the U.S. Global Change Research Program. The GFDL is entirely government funded. Its staff of 155 federal employees operates under an annual budget of about $20 million. Further information on GFDL can be found at: http://www.gfdl.noaa.gov/.

Figure 3. The Geophysical Fluid Dynamics Lab (GFDL) on the campus of Princeton University.

In summary, physical modeling laboratories generally focus on an area of science that has widespread application, such as climate and atmospheric science or the interaction of the oceans and atmosphere. Similarly, a Chesapeake Bay Modeling Laboratory could be both a resource addressing the Chesapeake watershed and estuary specifically and also have general application to linked watershed and coastal systems globally. A physical Chesapeake Bay Modeling Laboratory could provide a broader scientific and technical foundation for the rapidly expanding need to model and manage linked watershed and coastal systems. Academic associations would be important to allow a free flow of ideas among the policy, management, and academic communities, and laboratory scientists could have joint appointments in academic departments. A physical location would be a high cost and high value solution to a CBML.

Virtual Modeling Laboratories

The Integrated Ocean Observing System (IOOS) Coastal and Ocean Modeling Testbed (COMT) is a virtual modeling laboratory. IOOS seeks to be a conduit that promotes sharing of numerical models, observations, and software tools among several federal operational and research communities. The models developed through IOOS are used to elucidate, prioritize, and resolve federal operational coastal ocean issues by developing and applying a range of coastal oceanic, hydrologic, and ecological models to predict the fate of natural resources and resource management guidance. The COMT uses targeted research and development to accelerate the transition of scientific and technical advances from the modeling research community into operational products and services used by decision makers, managers, and scientists. Support for COMT is primarily through NOAA, and annual funding levels were between $1 million and $4 million over the last 4 years. Further information on IOOS-COMT can be found at: http://testbed.sura.org/.

Virtual laboratories are a low cost approach to a modeling laboratory. Freed from the capital and maintenance costs associated with a physical place and associated staff, virtual modeling communities are an effective option where cooperating agencies and institutions can rally around a unifying common cause for action. Virtual modeling laboratories are also flexible in their institutional and cooperative arraignments and have low startup costs.

Combined Physical and Virtual Modeling Laboratories

The Community Modeling and Analysis System (CMAS) combines physical and virtual assets to support key air quality models and associated tools for research and regulatory purposes to meet Clean Air Act requirements. The Community Multiscale Air Quality (CMAQ) Model is a CMAS model used by the CBP to estimate nitrogen deposition to the Chesapeake watershed and estuary. The CMAQ Model is developed by EPA staff in dedicated facilities at Research Triangle Park in North Carolina. CMAS interfaces with the broader air quality modeling community by providing an online help desk, a software and data clearing house, training, conference (such as the annual CMAQ Conference), software documentation, software-related research, model quality assurance, and reviews of the model and their associated utilities. In addition to CMAQ, CMAS supports a set of ancillary software for land surface emissions estimation (SMOKE), health benefits of air quality control (BenMAP), and other tools. While CMAS is only funded at a level of 2-3 full-time positions, it is important to note that this small budget is leveraged with a larger number of atmospheric scientists and engineers within the Institute for the Environment at the University of North Carolina working on CMAQ and related support software.

CMAS encourages standardizing open-source, advanced modeling systems that enable collaborative development and linking of models for meteorology, emissions, air quality, hydrology, and environmental and health effects. CMAS-supported models use a modular approach that facilitates rapid evolution of the technology to meet changing needs. CMAS tools provide centralized coordination of development and application efforts for the mutual benefit of scientists, model developers, modeling practitioners, and regulatory users. Generally CMAS "pushes" new developments of air quality modeling out to the user community which applies the air quality models in regional applications in many regional centers throughout the country.

The governance and operation of CMAS is through a contract from EPA's Atmospheric Modeling and Analysis Division. The base funding for CMAS supports a help desk, newsletters, notifications to model users, and some model development. Further information on CMAS can be found at: http://www.cmascenter.org.

V. Chesapeake Bay Modeling Laboratory Proposal

The proposal developed by the MLAT for the establishment of the CBML is presented below. Prior to considering options and making recommendations for a CBML, the team developed and agreed upon a Mission Statement, Vision and Guiding Principles, and the modeling functions that the CBML would need to accomplish.

Mission Statement

The purpose of the CBML is to improve watershed and estuarine modeling and to translate that modeling from research to practice. Achieving this goal will support protection and restoration science that informs and guides management decisions in the CBP. Specific objectives include:

- Accelerate the translation of research into operational models and utilities

- Facilitate testing and bench-marking of appropriate models for CBP operations
- Allow rapid modification of models to improve predictive skill and foster adaptive management
- Develop modeling approaches that maximize operational efficiency of the CBP models
- Build credible open-source community modeling tools and data
- Develop tools that facilitate access to models and data for states, researchers, and other partners
- Provide a framework that improves communication and is responsive to input from major stakeholders about the development of models, tools, and data

Vision

With the enhanced resources available from the Modeling Laboratory, CBP modeling activities will be more strongly based on the best available science.

Guiding Principles

1) Research, development, and operations must all be addressed

  a. *Clear budgeting between the different components*

  b. *These components do not necessarily need to be physically located in the same place, but must have regular communication*

  c. *Operations need to be connected to the CBPO*

These elements of modeling within the CBP must be clearly addressed within the proposed Modeling Laboratory and the existing Modeling Team. Budgeting, coordination, and communication must all be considered through a formal guidance document that would establish the Modeling Laboratory.

2) Sustainable dedicated core funding

The modeling laboratory should be funded from a line item in a budget, not from grants. Stable, sustained core funding is essential to the success of the laboratory and continued excellence in the models used for the bay's restoration.

3) Research and development is management focused

Research and development in the modeling laboratory must be responsive to the management needs identified by the CBP, primarily the list of improvements requested by the GITs and recommendations from advisory panels, such as STAC, while also exploring new frameworks and paradigms to develop improved operational models.

4) Research must be of publishable quality and should be peer reviewed

Operational models and results used for program activities should be peer reviewed and results should be of publishable quality. Peer review of published materials is important for model credibility and justifiable application of the model for management. Time must be allocated to ensure external access to model code, data, documentation, and publication.

5) Formal methods to track and openly distribute model input data and products of the data (with meta data meeting accepted standards) must be included

A clear process for documenting the origins of model input data is critical for more widespread access to researchers, partner staffs, and others who wish to utilize the Chesapeake Bay Program models. Clear documentation and metadata for the input data is part of the peer review process and is necessary for others to replicate results.

6) Consider both regional and local issues across the watershed and estuary

The models being used by the CBP are designed to help understand the impacts of actions that are often being taken at the local level. Model design must incorporate the flexibility to cover an area as large as the Chesapeake Bay and its watershed, but still provide information and potentially small scale models that help guide implementation of practices at the local level.

7) Supports development of open-source, modular code

Generically, open source refers to a program in which the source code is available to the general public for use and/or modification free of charge. The Modeling Laboratory should encourage and facilitate an open source community to make it easier for modelers and researchers anywhere to utilize the CBP models and potentially improve components through their own expertise and insights.

8) Transparency and communication should be considered in development and operations

a. *Timely model documentation*

b. *Introductory operations documentation, programs, and training*

Ensuring that adequate avenues of communication exist between the CBML and the CBP partners (GITs and Workgroups) will be essential for a successful laboratory. Timely documentation of models as they are calibrated and developed is important for communicating to the CBP partners and to other modelers who may wish to utilize components of the CBP models. Training for researchers or other model users is provided by many existing modeling laboratories.

9) Support co-development of a suite of models to support Chesapeake Bay modeling needs

The CBML should broaden the community of modelers who are contributing to CBP models. Increased access to the research community should improve the modeling capability of the program as a whole, exemplified through community model development in CMAQ, ROMS (Regional Ocean Modeling System), POM (Princeton Ocean Model), and FVCOM (Finite Volume Coastal Ocean Model). Co-development should include support of multiple models and open-source code, development of stable code with release updates that include documentation, and benchmarking and testing of unit and combined modules.

10) Transferability

Transferable models can be applied to other systems beyond the one for which they were originally developed. Transferability can increase the value of a model, expand the communities of developers and users, and broaden the base of financial support for further model development.

11) Regional focus with the ability to expand

The focus of the CBML will be the Chesapeake Bay watershed and estuary. Models or sub-models developed by the CBML should be applicable to other watersheds and estuaries, in order to contribute more broadly to the science of estuarine and watershed modeling.

Chesapeake Bay Modeling Laboratory Essential Functions

MLAT has identified four essential functions of models for the CBP: operations, operational development, research-oriented development, and research. When properly integrated, these four functions will provide models with the highest possible scientific credibility and high confidence from managers and stakeholders. Furthermore, model operations will be agile enough to quickly respond to requests for scenarios.

Operations: Model operations are defined here as the rapid and automated development of scenarios. The CBP Partnership currently undertakes 100-200 Scenario Builder and Watershed Model runs per year and a lesser number of land use change model and estuarine model scenarios. These scenarios support the TMDL, the Watershed Implementation Plans (WIPs), Progress runs, Milestones, *ad hoc* questions from partners, and collaborations with university, state, or federal partners. Many of the person-hours involved in these scenarios are in the communication with partners about appropriate inputs and interpretation of the output.

Operational Development: The modeling teams at the CBPO perform a significant amount of programming and development work that supports the ability of the CBPO to efficiently run scenarios and to quickly respond to decisions made by the partnership. These demands are generally met by enhancing the current models to incorporate new information, to run more efficiently, or to be calibrated more effectively. A few examples may be useful.

1. The Scenario Builder and Watershed Model teams are frequently asked to incorporate new types of BMPs. This can often be accomplished with little additional programming.

2. The partnership may also wish to investigate different algorithms for estimating manure application to cropland. This type of task involves modest software development or modification.

3. The Watershed Model is really an interconnected system of small model runs with complex dependencies. Certain scenario-intensive tasks such as climate change investigations require

a different parallel mode structure than a typical single scenario for optimal performance. Development and maintenance of multiple parallel methods is a significant task.

4. The partnership co-develops the automated calibration method for the Watershed Model through the Modeling Workgroup. Modifications to the calibration method can require extensive code modification.

5. Linkages among models require development and maintenance as models change or as scenarios alter sources of loads.

6. The CBPO is frequently requested to provide inputs to other models. This requires a method to link the geography and data types.

The proposed CBML would be involved in operational development in partnership with the CBPO. Its key operational development responsibility would involve verification of model changes to ensure that the model is performing as intended and in accordance with research results.

Research-Oriented Development: To answer research questions, new models can be developed or old models can be modified to add new processes. This type of model development consists of conceptual modeling, code development, testing, and model validation. To become a part of the CBP modeling suite, an input to the suite, or a stand-alone model to answer a separable management question, the developed model must be implementable with available data and computing resources at a spatial scale relevant to management. Care must be taken to adequately represent the scientific knowledge while producing a model that is appropriate to its intended purpose. However, new model development will be explored for which available data may not be adequate, but can contribute to guidance on new measurement and monitoring. The proposed CBML would oversee these development activities.

Research: Managers, modelers, academics, and other partners frequently ask questions that the current CBPO suite of models are not ideally equipped to answer. Two recent examples from the STAC are how to incorporate lag times in the modeling and decision process and how to describe and integrate the effects of the spatial placement of land use within a watershed. When such questions are raised about the watershed, there is no current mechanism to obtain answers for watershed-related questions other than waiting for the scientific community to take on these tasks independently. Historically, the Estuarine Model development has been informed by directed research sponsored by the USACE with occasional topic-specific code development (e.g., sediment dynamics) sponsored by the EPA. The CBML should also investigate new modeling paradigms and frameworks, in addition to research on the current Watershed Model framework.

Linkages among functions

To provide the greatest management effectiveness, the four functions of CBP modeling must be tightly linked to each other for management. The closest linkages are needed between neighboring functions (operations and operational development, between operational development and research-oriented development, and between research-oriented development and research). However, the governance structure must provide an overarching framework to coordinate efforts among all the functions.

***Operations and operational development*:** Coordinating scenario development requires working closely with the partnership and often requires quick adjustments of modeling software in order to incorporate a new BMP or reporting mechanism. Those who run scenarios have a working knowledge of operational bottlenecks and can effectively coordinate requirements to the system developers. The coupling between these two functions has been very tight. Scenario Builder operators and developers have weekly meetings. Watershed and Estuarine Model operators and developers are often the same people. The close linkage has allowed for effective two-way communication between operational development and operations.

***Research-oriented development and research*:** Management-relevant research questions can be addressed with models if the questions can be effectively represented with model code, calibrated parameters, and measurements. Active communication will be necessary to ensure that these conditions are met.

***Operational development and research-oriented development*:** To be useful for management, an operational model will generally need to be implemented for the entire Chesapeake system. This may create issues related to run time, data availability, and software compatibility when research-oriented models are up-scaling for operational use. Research developers may also be concerned that the essential features of the model are not being scaled correctly. Effective communication between these two types of developers will facilitate the movement of models from the research phase to operations.

Overall linkage: The CBML governance structure should provide a clear set of short- and long-term priorities, so that each researcher and developer understands how their contribution fits into the CBML plan for eventual use in management decisions, ensuring that each member of the operations and operational development teams anticipates future capabilities.

Governance of a Chesapeake Bay Modeling Laboratory

Modeling Laboratory Board of Directors (propose modified Modeling Workgroup constitute this Board)

A governing body or Board of Directors would be appointed by the Management Board. Appointees must have both the technical expertise and the authority to make the technical decisions related to modeling at CBP. The Board would have ability to decide on activities and budgeting of the CBML. The Board would determine the work elements related to research, research-oriented development, and operational development that would be incorporated into an annual work plan of the CBML. The Board would prioritize input from the GITs and the Workgroups and work interactively with the CBML to determine the scope of each annual work plan. This Modeling Laboratory Board (ML Board) would periodically brief the Principal Staff Committee and Management Board on CBML activities and direction. The MLAT proposes that a modified Modeling Workgroup constitute this Board, with the Board consisting of both voting and non-voting members. The final make-up of the ML Board would be decided by the Management Board.

Recommended Actions to Create a Chesapeake Bay Modeling Laboratory

Recommendation #1: MLAT reached consensus on a recommendation that a Chesapeake Bay Modeling Laboratory be established to take on research, research-oriented development, and some operational development of CBP models. A modeling laboratory is a critical component in addressing the significant issues brought up by the NRC/NAS report and STAC recommendations. Resources at a modeling laboratory would help close an existing gap in research and model development at the CBP and improve integration of knowledge, expertise, and development skills of the academic community into the modeling program. Increased resources at a modeling laboratory are necessary to take on numerous model improvements and model-related analysis (see Appendix B for a condensed list, from 431 total suggestions) that have been requested by the GITs and their workgroups.

Recommendation #2: The state representatives on MLAT strongly recommended that the Modeling Laboratory should also assemble and calibrate the operational models. Under this recommendation, the existing Modeling Team at the CBPO office would be incorporated into the Modeling Lab.

Recommendation #3: A Modeling Laboratory Board of Directors appointed by the Management Board should be created from a re-constituted Modeling Workgroup. The appointees must have <u>both</u> the technical expertise and the authority to make the technical decisions related to modeling at the CBP. The ML Board would have ability to decide on the activities and budgeting of the CBML. The ML Board would determine the work elements related to research, research-oriented development, and operational development that would be incorporated into an annual work plan of the CBML.

Funding a Chesapeake Bay Modeling Laboratory

A laboratory that pursues management-identified priorities must be maintained for the long-term, to insure continuous revision of the existing models and the development of new code or complementary models that would expand modeling capacities into new areas that cannot be addressed with the current CBP Modeling Team or its resources. Expanded, sustained funding is needed to ensure the essential modeling functions. Without sustained funding, new and emerging issues requiring substantial model revision will not be incorporated, thereby jeopardizing the model as a credible tool for simulating local/regional water quality and projecting future scenarios through an increasing population, changing land use, and climate change.

The CBML will require approximately $1.5M annually to meet research objectives that have been identified for improving the CBP modeling system, and $0.5M annually for enhancing the operational component. This would be new funding above the funding that the CBP and its partners currently use to support the modeling effort. Offered through a Request for Services (RFS) or Request for Proposals (RFP), the funds would support a permanent/core staff and modeling expertise for management-specific modeling needs.

Sustained funding would ideally be provided through a multi-year line item adopted in the U.S. Congress, but recent Congressional lethargy and the austere economic constraints on the federal budget indicate that other options must be pursued. Redirecting the current CBP modeling budget of $2.5M annually is not possible, because all of those funds are needed simply to meet the partner demands for routine operations, including 1) scenario runs via Scenario Builder, CAST, the Watershed Model, and the CBP hydrodynamic-WQ model and 2) BMP revisions derived from expert panel recommendations. Multi-agency support is possible. The Executive Order and Federal Strategy provide a foundation for a multifederal agency commitment. State, or partner, contributions are also possible, particularly if some of the partners seek and obtain a modeling laboratory with acceptable independence from EPA for its governance, calibration, and expanded academic participation. However, both federal and state contributions must be sustained because there is no practical way to set up and run a laboratory for a year or two, see it collapse due to fiscal cutbacks, and then expect it to be quickly reassembled and function once funding returns. The modeling laboratory must become as permanent a part of the CBP infrastructure as are the Modeling Team, Management Board, advisory committees, and Goal Implementation Teams.

Process for Establishing Chesapeake Bay Modeling Laboratory

Once sustained funding is secured for the Modeling Laboratory, there are several mechanisms that could be explored for establishing the research and development laboratory to assist in advancing research and development of management-identified modeling priorities. First, by-laws for governance, decisions, identification of management priorities, and a schedule for delivering model code from the modeling laboratory would be adopted. Procedures for activities and oversight by the governance board would be drafted, reviewed by the CBP partners, and codified to specifically define the decision processes for operations and activities of the Board and the laboratory. This would include allocations of specific amounts for research and operations not to be less than $2.0M annually

Second, the MLAT recommends that the governance Board work with the funding organization to develop a Request for Proposals/Request for Services (RFP/RFS) that outlines tasks that would be completed in the modeling laboratory. MLAT envisions a request that would seek proposal submissions addressing two or three specific functions in a modeling laboratory. The successful request from an applicant/organization for a CBP Modeling Laboratory would include:

1) Permanent/core staff: A director, a half-time administrative assistant, and permanent, full-time staff modelers. All decisions in the laboratory would be the director's responsibilities and he/she would be the primary contact with the ML Board and Water Quality GIT. The administrative assistant would provide secretarial help and some writing assistance to the director. The full-time staff would 1) provide CBP data and model code and output to model experts and 2) transition newly developed model or model code, documentation, and calibration/verification data back to the CBP. These individuals would communicate with CBP operational modeling staff and the ML Board on all aspects of model calibration, with documented, scheduled calls, meetings, and electronic correspondence to insure two-way communication between the modeling laboratory and the CBP model operations team. However, final decisions on 'next steps' in any of the staff's activities would be in the director's purview.
2) Modeling expertise for management-specific modeling needs: Each year, the ML Board with input from the Water Quality GIT and other Bay Program GITs (see Governance Section above) would determine management-specific modeling priorities for exploration in the modeling laboratory. To address these priorities, the lead organization of the laboratory must have documented access to broad modeling expertise, allowing inclusion of modelers in many disciplines (such as, local to regional hydrology, physical processes impacted by land cover and use, biogeochemistry of soils and water, biology, and fisheries). Those proposing to serve as the CBP Modeling Laboratory must therefore identify expertise across many modeling areas, through

letters of agreement from model experts in the submitted proposal accompanied by extended *curricula vita* outlining models or model code previously developed (and implemented) by each model expert.

Selection of the organization to host the Modeling Laboratory would require rigorous, non-conflicted peer review. Unbiased review would be assured through inclusion of technically skilled modelers (federal and academic), science experts, and two types of representatives of the management community, those familiar with regional commitments to 1) load reductions and land uses and 2) use of models in jurisdiction decision-making. The format of the modeling lab would ultimately be determined through the selection process, but would probably be a combination of physical lab and virtual lab; with a core staff in one location, and other needed expertise available in other locations.

A long-term (5 year) cooperative agreement, with annual review of progress, would be the most appropriate mechanism for the award, because this funding option enables active communication and cooperation between the ML Board, GITs, and the modeling laboratory organization in delivering collaboratively-defined and executed models or model code. Multiple iterations and alterations in models, modeling laboratory activities, and responses with the CBP partners can be discussed and implemented, with flexibility across years for use of research funds for continued model refinement. A long term award would also enable repeated adjustments for calibrations in response to partner needs and requests should the modeling laboratory be assigned model calibration as part of its mission. Another mechanism could be a contract, but that would be a binding, inflexible option with specific deliverables and dates, all communication mechanisms defined and scheduled, and required data and model code archives and access stipulated. Although attractive for fixed delivery of code or model, iterative adjustments in code or a model or extended refinements in model calibrations could easily exceed allocated funds, potentially jeopardizing delivery of useful, implementable code or model to the partnership unless a specific number of modeling laboratory iterations or calibrations were defined (this is a serious concern and funding for calibration and delivery of the 'gold standard' CBP model (Recommendation #2 above) must be distinct from the sustained funding for models of new topic areas). A grant is a third funding option, but a grant is not recommended for the Chesapeake Bay Modeling Laboratory. A grant leaves all decisions to the grantee, with the initial negotiated award the only restrictions on the modeling laboratory activities. If the initial negotiated award does not cover all possible contingencies for modeling and deliverables, the partnership has limited recourse in receipt of model code or models that it the CBP modeling team or the ML Board believes are inadequate or nor responsive to the management need.

Based on input from Bay Program GITs and each year's modeling laboratory output, and if needed, technical insights from an external peer review (e.g., STAC), the governance board would recommend continued support for the modeling laboratory organization as well as identification of additional management-specific modeling needs for new model or model code development. The modeling laboratory director would seek expertise from the larger modeling laboratory to meet the management need, using relevant peer review that his/her organization implements to insure competency in model development by the new model experts. These comments would be kept on record for ML Board review on criteria used in the selection of the experts. These processes would be repeated each year through the duration of the award, if functional code and calibrated models (if selected as a laboratory responsibility) have been delivered to the CBP operational modeling team. If delivered code or calibrations are deemed inadequate, supported by additional technical review, the agreement can be voided and a new RFP/RFS issued for more responsive, functioning laboratory deliverables.

Appendix A: STAC Report Recommendations

The Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) agrees with the NRC review committee that the establishment of a modeling laboratory should be a high priority for CBP and that the laboratory would yield the advantages suggested by the NRC panel. STAC has also repeatedly recommended that CBP should develop and employ multiple models. Support for the modeling laboratory and multiple modeling has been documented through many communications from STAC to the Management Board. Information and links are provided below.

June 2011 Quarterly Meeting: Dr. Ken Reckhow summarized the findings of a recently released National Research Council's (NRC) report entitled, "Achieving nutrient and sediment reduction goals in the Chesapeake Bay: an evaluation of program strategies and implementation". According to Reckhow, the report suggests that the establishment of a Chesapeake Bay Modeling Laboratory would bring together a suite of state-of-the-art models, which would "…help build credibility with the scientific, engineering, and management communities". This was "…envisioned as a place to bring academics and CBP modelers together to bring new ideas and critical review…" and would also encourage the use of multiple "…competing models". Following the presentation, STAC members agreed that the CBP should consider creating a modeling laboratory (STAC Minutes June7-8, 2011).

June 2011 STAC-sponsored Chesapeake Bay Hydrodynamic Modeling Workshop: Dr. Raleigh Hood (UMCES) facilitated a discussion of the NRC recommendation for establishing a Chesapeake Bay Modeling Laboratory. Most attendees were very supportive of the idea (Chesapeake Bay Hydrodynamic Modeling Workshop Report, June 9-10, 2011).

July 2012: STAC sent the CBP Acting Director (Mr. James Edwards) correspondence describing the recommendations of the STAC-sponsored Chesapeake Bay Hydrodynamic Modeling Workshop, specifically highlighting the recommendation for establishing a Modeling Laboratory to enable the implementation of multiple open-source community models, and comparing the relative skill of these models (STAC_letter_July_2011.pdf).

September 2011 Quarterly Meeting: Dr. Marjy Friedrichs (VIMS) presented the final Hydrodynamic Modeling Workshop recommendations to STAC, which included the recommendation to form a Chesapeake Bay Modeling Laboratory in order to enable the use of multiple open-source community models. STAC members fully supported these recommendations (September 2011 STAC QM Minutes.pdf).

October 2011: A letter was formally submitted by STAC on the "Future of CBP Modeling" to the CBP Director (Mr. Nick DiPasquale), again recommending that the EPA help support the comparison of multiple hydrodynamic/water quality models in order to help establish confidence bounds on the existing CBP model simulations. STAC pointed out that this would help address the NRC recommendation for establishing a Modeling Laboratory by fulfilling the report's encouragement for community participation in future CBP model development and application (STAC_letter_Oct_2011.pdf).

October 2011: The STAC formally submitted the Chesapeake Bay Hydrodynamic Workshop Report to the CBP Management Board.

December 2011 Quarterly Meeting: Dr. Kevin Sellner (CRC) facilitated a discussion on recent updates from the CBP modeling workgroup regarding plans for the implementation of a new shallow-water hydrodynamic model. The STAC recommended that any future modeling choices should be made only after considering multiple models, ensemble modeling, skill assessment, and peer review to determine the most appropriate model or suite of models. The STAC also recommended that, following the NRC recommendations for the establishment of a Chesapeake Bay Modeling Laboratory, the CBP incorporate the larger scientific community in its modeling decisions to ensure that all modeling options are considered (http://www.chesapeake.org/stac/minutes/203_December%20QM%20Minutes%20-%20Approved.pdf).

January 2012: The STAC formally submitted a letter to the CBP Director (Mr. Nick DiPasquale) highlighting the details of a proposed multiple model intercomparison project that would assist the CBP in addressing the NRC recommendations (STAC letter Jan 2012.pdf).

February 2012: The STAC received a formal response from DiPasquale addressing the recommendations of STAC and the NRC regarding the use of multiple models within the CBP and the development of a Chesapeake Bay Modeling Laboratory. The letter stated that there was "…broad agreement by EPA and the Management Board with the recommendations of the Hydrodynamic Model Workshop…" and that "…we expect to begin this Bay Program-wide consideration of the role of multiple models in April 2012." Specifically, the letter requested a STAC-sponsored workshop to outline the details regarding a prototype multiple model intercomparison project, and discuss how multiple models could be used in a regulatory environment (http://www.chesapeake.org/pubs/267_NickDiPasquale2012.pdf).

March 2012 Quarterly Meeting: Mr. Gary Shenk (CBP EPA) discussed the Management Board response to the STAC recommendations, and proposed a workshop to investigate how to incorporate multiple management models into the Chesapeake Bay's modeling suite (http://www.chesapeake.org/stac/minutes/200_March%202012%20QM%20Minutes%20-%20Approved.pdf).

April 2012: The first M3.1 workshop was held, chaired by Dr. Marjy Friedrichs. The attendees strongly encouraged development of multiple shallow water models for informing the CBP's commitment to implementing a highly resolved modeling scheme for the shallow littoral zones of the bay's shoreline, for ultimately, inclusion of valued living resources (submersed grasses, oysters) in the CBP model. A demonstration project was proposed to offer the national modeling community the opportunity to provide useful shallow mater model options for the CBP management community (http://www.chesapeake.org/pubs/291_Pyke2012.pdf).

October 2012: The M3.1 Workshop report was submitted recommending a shallow water demonstration project to inform the CBP on the utility of multiple models to meet CBP modeling priorities (http://www.chesapeake.org/pubs/291_Pyke2012.pdf).

February 2013: A M3.2 workshop was held, convened by Dr. Don Weller (SERC). A report is in preparation but the overall consensus is that the CBP should move forward with multiple models/modules, as case studies and strong legal support suggest likely benefits of these activities for the CBP.

Appendix B: CBPO WQGIT Modeling Priorities

As CBP approaches the 2017 Midpoint Assessment, the Goal Implementation Teams (GITs) are prioritizing possible modeling changes needed. Below is a short list, description, and link to the work-plans of "high" and "low" priorities needs that the Modeling Workgroup and/or Modeling Team are the lead or supporting partners on. The "high" priority items are items that must be completed for the Midpoint Assessment and "low" priority issues should be addressed, but cannot take precedence over the "high" priorities. It will be challenging for the existing Modeling Workgroup and Modeling Team to address all of these issues given time constraints and the operational needs of the partnership. However, additional resources to establish a modeling laboratory would create a new entity that could advance the management-identified research priorities of CBP.

High priorities:

1. *Model data processing:* The evaluation of existing model data processing and the identification and prioritization of improved processing methods to support enhanced analyses and decisions.

2. *Modeling baseline/input data assumptions:* Provide access to improved baseline/input data and assumptions which are incorporated into functional models that operate collaboratively.

3. *Revise watershed modeling system structure:* Investigate, evaluate, and possibly transition to an all PQUAL model, to enhance decision support and to improve transparency, accuracy, and confidence. The benefits of a PQUAL Model is that the calibration would be simple, fast, and precise. The Watershed Model run times would be shorter, and sensitivity to inputs would be explicitly specified, which provides clarity.

4. *Revisit Watershed Model calibration methods:* Revisit Watershed Model calibration methods with the goal of improving local watershed results, including revisiting regional factors. The workplan also includes activities to extend the simulation period and to revise the Airshed and WQSTMs.

5. *Midpoint Assessment and Phase III WIP Schedule:* Actions on the schedule will include soliciting and prioritizing input from the Partnership, gathering data and conducting analyses to address midpoint assessment priorities, incorporating findings into the Chesapeake Bay Program modeling tools, as appropriate, reviewing results, developing Watershed Implementation Plans

(WIPs) and milestones, and modifying the Bay TMDL, as necessary. The schedule will include approximate dates as well as recommended timeframes for completing actions. The schedule will be an appendix of the Midpoint Assessment Guiding Principles, and will be subject to change as the midpoint assessment progresses.

6. *Trapping capacity behind dams, esp. Susquehanna, and greater capture of local impoundments and reservoirs:* There are three primary objectives: (1) develop and assess options for addressing increased amounts of sediment and nutrients from the Lower Susquehanna Reservoirs, (2) better characterize trapping of sediment in reservoirs, and (3) develop an approach to simulate effect of impoundments in the Bay watershed.

7. *Improved modeling accuracy of land use characteristics, phosphorus, and sediment:* Improve characterization of urban land use with differentiating loading rates. Assess the model's accuracy by running small scale simulations for headwater areas with relatively uniform land use (all urban or all agriculture) to verify loadings based on input parameters. Improve the model's depiction of explicit stream erosion: after a watershed reaches a certain impervious threshold, much of the sediment and phosphorus may be coming from stream erosion versus land surface wash off, especially in low density dominated areas. Improve the model's depiction of local hydrologic networks by distinguishing connected from non-connected areas, and incorporating proximity to watercourses. This would help improve regionalization factors that currently display large variability between segments.

Low priorities:

1. *Improve communication about the role of forests in attenuating the nutrient loads to Bay tidal water from air deposition, esp. of nitrogen compounds:* In the experience of Forestry Workgroup (FWG) members, the way in which the Chesapeake Bay Program presents nutrient loads can lead to the misunderstanding that forests themselves are a large source of nutrients, rather than air deposition onto forest lands, which the forest "controls" to a large extent. The only nutrient loads to the Bay attributed to forests are caused by air deposition, and the forest ecosystem reduces (attenuates) these loads substantially, thus preventing a large percentage from reaching the Bay. The Program's information about air pollution as a source of nutrients, presented on the Chesapeake Bay website, fails to mention the important role that land use and resulting attenuation play in reducing air deposition loads to the Bay. Continuing loss of forest lands and their attenuating capacity, especially conversion to developed land, would increase the volume of delivered nutrient loads from air deposition.

2. *Review and refine modeled assumptions about forests:* Currently, 1% of "forest" land cover in the Chesapeake Bay Watershed Model is assumed to be harvested annually. Some states have regulatory programs around forest harvesting and document acres of forests harvested and BMPs applied on those acres for any given year. Thus far, Virginia and West Virginia have been working with the Modeling Team to report actual forest harvested acres to the model, and Delaware has similar information. Other jurisdictions that are unable to report actual acres of forest harvest could continue to use or refine the 1% harvest assumption based on best available data. Two complementary tasks will be pursued by the Forestry Workgroup in 2013-2014: 1) The Workgroup will continue to develop the Verification Protocol for Forest Harvest BMPs,

examining current and proposed future methods for tracking and verifying these BMPs in each jurisdiction. And 2) the Workgroup will convene an Expert Panel to review the efficiency rate assigned to Forest Harvest BMPs. This Expert Panel will also recommend what the literature says about loading rates resulting from harvested forest, and also about loading rates for the proposed new land cover layer "true forest".

3. *Enhanced use and explanation of monitoring data for the TMDL Midpoint Assessment:* The Chesapeake Bay Program (CBP) will enhance the use of monitoring information as part of the Midpoint Assessment to assess attainment of water-quality standards in the Bay, water quality responses in the watershed, and relationships to actions being implemented for *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment* (Bay TMDL). The CBP partners have endorsed (PSC, May 2012) an integrated approach that includes three primary pieces of information to assess progress toward water-quality standards: (1) reporting of water-quality practices, (2) trends of nitrogen, phosphorus, and sediment in the watershed, and (3) attainment of dissolved oxygen, chlorophyll-a, and water clarity/SAV standards.

4. *Establishment and update of BMP definition and efficiencies:* The reevaluation of prioritized approved BMPs, and the evaluation and establishment of new BMPs to improve their definitions and associated effectiveness values through the partnership approved BMP protocol process.

5. *Accurate representation of federal land boundaries and land uses within those boundaries:* Improve the accuracy of federal land boundaries and land use information informing the Phase 6 suite of models.

6. *Determine delivery factor changes impact on jurisdictions' trading and offset programs:* When delivery factors in the Chesapeake Bay Watershed model change, trading and offset program that rely on these delivery factors will need to change, at a minimum, credit calculation methodology.

7. *Influence of climate change on Water Quality Standards and Bay TMDL:* The airshed, watershed, and Water Quality and Sediment Transport models will be used to examine the impact of climate change on projected water quality. Current efforts are to frame an initial future climate-change scenario based on estimated 2050 conditions.

8. *Effects of Conowingo infill on Chesapeake Bay Water Quality Standards:* The Modeling Workgroup will work with the US Army Corps of Engineers (USACE) Lower Susquehanna River Watershed Assessment (LSRWA) study and the Scientific, Technical Assessment, and Reporting (STAR) workplan for the assessment of trapping capacity behind dams, especially the Conowingo, as well as greater representation of local impoundments and reservoirs throughout the Phase 6 Watershed Model domain.

9. *Influence of oyster filter feeders on water quality, with increased aquaculture and sanctuary development:* The oyster model will be revised as necessary to incorporate aquaculture operations and additional oyster biomass brought about by restoration activities including sanctuaries. Current and projected data on biomass distribution and abundance will be mapped

onto the current computational grid and various combinations of restoration and load reductions will be examined.

10. *Refinement of shallow water simulation for improved assessment of open water DO and SAV/clarity standards:* The employment and rigorous comparison of different models applied to shallow-water systems by different teams is proposed as an initial step towards the development of multiple management models, which would contribute to the research and development of shallow-water modeling.

11. *Refined assessment of James River chlorophyll:* The Modeling Workgroup is working closely with the principal investigators of the James River Chlorophyll Model and is providing assistance as requested on an as-needed basis. Assistance includes technical assistance as requested, via provision of boundary condition support, model data needs support, and other ancillary technical support as requested.