Chesapeake Bay Modeling Laboratory Recommendation

Comment [ap1]: We should use a picture that is more relevant to modeling. I just wanted to see how it looked. -AP

Modeling Laboratory Action Team Report

Chesapeake Bay Program
A Watershed Partnership

Report Release Date: November, 2013

Cover photo provided by Chesapeake Bay Program.

Table of Contents

I. Executive Summary – Not submitted (will be completed after all other sections are turned in). Assigned to Mark Bennett

Comment [ap2]:

II. Background and Justification

Formation of the Modeling Laboratory Action Team

k

Comment [ap3]: Need a small intro here? -AP

National Research Council Recommendation

In 2011, The National Research Council of the National Academy of Sciences produced the report, "Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation." Among the many recommendations of the report was the specific recommendation to establish a Chesapeake Bay modeling laboratory.

"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."

In the report, the National Research Council highlighted advantages of establishing a Chesapeake Bay modeling laboratory, including integration of monitoring with modeling efforts, evaluating uncertainty in model simulations and assessing monitoring data needs, improving the predictive skill of the models, improving model credibility, incorporating multiple modeling approaches, emphasizing open-source models exercised cooperatively with the scientific community, and creating balance between the operational and research components necessary for continued improvement.

Management Board Memorandum

In response to the National Research Council recommendation, the Chesapeake Bay Program Management Board committed to proceeding forward with a more in-depth evaluation of establishing a Chesapeake Bay Modeling Laboratory (CBML). The Modeling Laboratory Action Team (MLAT) was charged with responsibility of developing a more definitive set of implementation options. Specific elements of the charge included:

1. evaluation of other existing modeling laboratories and adaptive management programs that encompass modeling, addressing how they function and how applicable their structure and mandate is to the Chesapeake Bay Program Partnership,
2. consideration of the range of options for what would constitute a Chesapeake Bay modeling laboratory, 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 Technical Advisory Committee and the jurisdictions' recommendations on modeling,
3. development of options and recommendations for actual institutional sponsorship and how the laboratory would function for carrying out mandates, and assessment of the possible range of financial investments and funding mechanisms required.

The appointed action team members are recognized for their expertise in modeling, monitoring data, and management decision making in order to represent multiple perspectives. The Chesapeake Bay Program Management Board will decide on what specific recommendations to put forward for deliberation and final decisions by the Principals' Staff Committee.

Chesapeake Bay Program Modeling Laboratory Action Team

MLAT first met in June 21st, 2012 and proceeded to have monthly meetings through September 2013 to determine the rationality and feasibility of a Chesapeake Bay Modeling Laboratory and to develop this report.

Modeling Laboratory Action Team Members:

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 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
Mark Bennett, U.S. Geological Survey
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
William Keeling, Virginia Department of Environmental Quality

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

Comment [ap4]: Do we need more details about the members than this? -AP

Comment [ap5]: Should we include Lewis, Gary, and Amanda in this section at all? If so, is "Support Team" the title we should use? -AP

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 Chesapeake Bay and its watershed to management scenarios and programmatic approaches. Over the past three decades, the modeling suite has grown from a steady-state Estuarine Model linked to a partial-year dynamic Watershed Model to an integrated set of models depicted below:

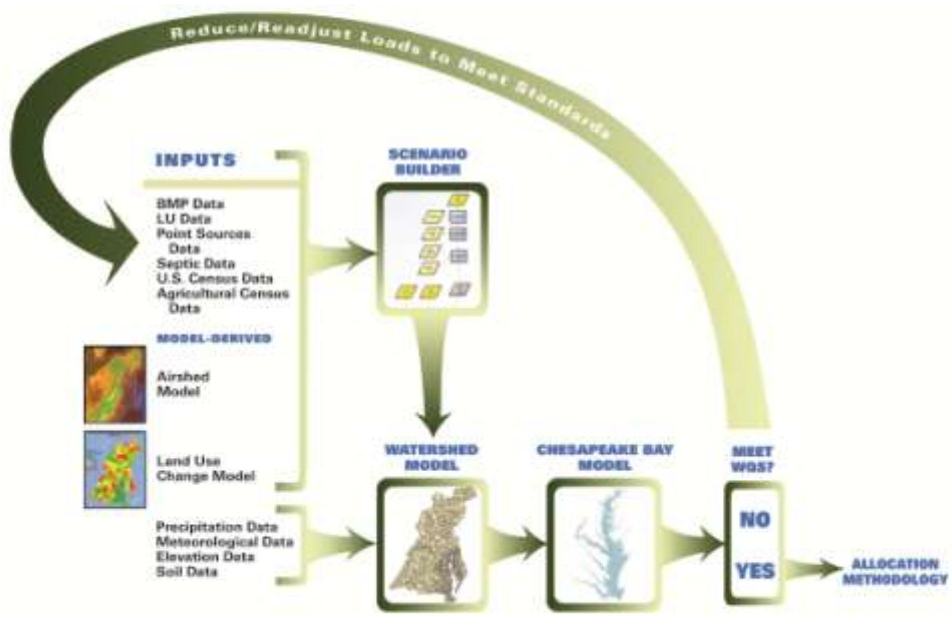

Figure 1.

The Chesapeake Bay Airshed Model provides estimates of nitrogen deposition change resulting from changes in emissions from utility, mobile, and industrial sources because of management actions or growth. The 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. A modeling lab 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 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 has considered these efforts as external to the modeling being considered for a modeling lab.

The MLAT has primarily discussed modeling lab 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 into the types and forms of data needed by Watershed Model preprocessors. Scenario Builder is primarily a model of agricultural behavior, estimating fertilizer and manure applications, among other factors, using data from a variety of sources, including crops and livestock populations. 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 is a combination of a hydrodynamic model and a water quality and living resources model of the Chesapeake Bay and its tidal tributaries. The Estuarine Model produces outputs of dissolved oxygen, chlorophyll, clarity, and submerged aquatic vegetation for water quality standards evaluation.

Comment [LB6]: Does Scenario Builder also use this information along with GIS information to build the model parameter files? -LB

Currently, Scenario Builder and the Watershed Model are developed and operated at the CBPO by a team consisting of federal employees, university research staff, and contract support. The Estuarine Model development is done by the U.S. Army Corps of Engineers. Operations are run by the Corps and at the CBPO by federal employees and university researchers.

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

Justification of a Chesapeake Bay Modeling Laboratory

In addition to the 2011 National Research Council (NRC) report, "Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation", numerous reviews of Chesapeake Bay Program, many of them internal, have suggested the need to improve the science behind the Chesapeake Bay Program modeling activities.

STAC Recommendations and Discussions

Over the past two years, STAC (the Chesapeake Bay Program's Scientific and Technical Advisory Committee) has had numerous extensive discussions regarding the idea of establishing a Chesapeake Bay Modeling Laboratory (CBML). In each case, STAC has been nearly unanimously positive: STAC agrees with the NRC review committee that the establishment of a modeling laboratory should be a high priority for the CBP. STAC believes that the modeling lab would yield the advantages suggested by the NRC-NAS panel. The modeling lab 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 the Bay Program should develop and employ multiple models strategies rather than relying on a single model for each system. Support for the modeling lab and multiple modeling has also been documented through many communications from STAC to the Management Board, submitted over the past year (see Appendix A).

Chesapeake Bay Program Goal Implementation Team list of modeling needs

As the Chesapeake Bay Program Partnership approaches the 2017 Midpoint Assessment, the Goal Implementation Teams (GITs) are discussing and deciding on priority issues. Currently, "high" and "low" priorities were voted on by the Chesapeake Bay Program Partnership from a much more comprehensive list of needs. Thus far, the Modeling Workgroup and/or Modeling Team are the lead or supporting partners on 7 of the 8 "high" priorities and 11 of the 18 "low" priorities (see Appendix B). The "high" priority items are items that must be completed before the Midpoint Assessment. The "low" priority issues are ongoing issues that will be addressed, but cannot take precedence over the "high" priorities. It will be difficult for the existing Modeling Team to address all of these issues, or even just the highest priorities, particularly when an item requires developing new data or algorithms that depart significantly from the existing modeling system. Establishing a Modeling Laboratory Action Team would create a new entity that could take on the research priorities related to Chesapeake Bay Program Partnership, which are often not able to be investigated fully or timely due to operational needs of the Partnership. These issues include, but are not limited to climate change, lag times, BMP effectiveness, filter feeders, and shallow water.

Barriers to Implementation within the Current Modeling Structure

For models to remain up to date, they must undergo periodic upgrades to incorporate the latest research and monitoring. The Estuarine Model has been successful in these upgrades partially because of the separation of operations and development. The U.S. Army Corps of Engineers (USACE) handles most of the development from a remote location while operations are primarily handled within the CBPO. Research relevant to the model development needs is paid for by USACE. This arrangement tends to insulate the developers from the daily press of 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. Between these major events, there is little need to run estuarine scenarios.

By contrast, the Scenario Builder and Watershed Model are in constant use for various projects such as progress runs, milestones, and other partnership-requested scenarios related to scientific and policy questions. In the current structure, the same teams are charged with research, development, and operations. Given the immediacy of the partnership's demands for scenario analysis, operations takes priority with development being fit in when possible. There is no specific budget or staff designated for research and so existing research is used in development.

Comment [DEW7]: Not sure what this means

Are you trying to say that resources that might be used for research are instead applied to development so that no research is done?

Part of the difference between the Estuarine and Watershed Model governance is due to the different constituencies for the two systems. The Estuarine Model is governed primarily by the academic and management communities at the quarterly Modeling Workgroup meetings. This interaction is sufficient to provide guidance to USACE on the partnership needs, which are important, but few and well defined. By contrast, Scenario Builder and Watershed Model development are governed by the Water Quality Goal Implementation Team, eight of its workgroups, approximately twenty BMP panels, and the Modeling Workgroup. This diverse and complex model governance structure creates a barrier to research in that it demands constant operations and development activity. It would certainly also create a challenge for governance of a modeling research laboratory.

III. Review of existing modeling laboratories

A review of existing modeling laboratories provides context and different examples of successful established modeling laboratories. Existing modeling laboratories range from physical, dedicated buildings and staff, to fully virtual laboratories, to a blend of the physical and virtual labs. A good example of a physical modeling laboratory is the *National Center for Atmospheric Research* (NCAR), where widely used weather and climate change models are developed. A virtual modeling laboratory example is the successful Chesapeake Community Modeling Program, a consortium of different universities, agencies, and principal investigators effectively sharing modeling platforms, code, and expertise. A mixed form of physical and virtual modeling labs would be the community practice of developing the Community Multiscale Air Quality Model (CMAQ) which is the model used universally in the nation for air quality management. As a mixed form of modeling lab, a physical space and staff is dedicated to the development of the CMAQ model but a community of modeling practitioners in individual region centers is serviced virtually. The regional CMAQ centers are dedicated to the application of the model for multistate air quality management. Each of these three types of modeling laboratory formats will be discussed in more 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. A recommendation of the committee was to establish a national center for atmospheric research to be operated by a consortium of universities with support from the National Science Foundation.

The mission of NCAR was 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, 4) 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 National Science Foundation 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 dollars. 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 example of a dedicated modeling staff and building is the Geophysical Fluid Dynamics Lab (GFDL). Located on the Princeton University campus (Figure 3), the GFDL is a National Oceanic and Atmospheric Administration (NOAA) laboratory that develops and uses models and computer simulations to improve understanding and prediction of the behavior of the atmosphere and ocean, hurricane research and prediction, seasonal forecasting, and understanding and projecting 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 provided a major forward impulse to the world's research on modeling global climate change, and has played a significant role in the Intergovernmental Panel on Climate Change (IPCC) assessments, and the U.S. Global Change Research Program. The GFDL is a research laboratory within NOAA and 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, a general theme of the physical modeling laboratory examples is a focus on an area of science inquiry that has widespread application, such as climate and atmospheric science or the interaction of the oceans and atmosphere. A similar approach could be envisioned for the Chesapeake Modeling Laboratory, which could be both a resource addressing the Chesapeake watershed and estuary specifically, but also have general application to linked watershed and coastal systems everywhere. Upon adopting this approach, a physical Chesapeake Modeling Laboratory would provide a broader scientific and technical footing for the rapidly expanding field of simulating linked watershed and coastal systems, a research need of national and international scope. In this vision of a physical modeling laboratory, academic associations are important to allow a free flow of ideas among policy, management, and academic communities as well as joint research with faculty and laboratory scientists/engineers and joint appointments in academic departments. A modeling laboratory as a physical location would be a high cost/high value solution to a Chesapeake Modeling Laboratory which could provide a deeper and more far reaching base than a virtual association of collaborating individuals.

Virtual Modeling Laboratories

The Integrated Ocean Observing System (IOOS) Coastal and Ocean Modeling Testbed is an example of a virtual modeling lab. The IOOS has the goal of being a conduit among several federal operational and research communities which would allow the greater sharing of numerical models, observations, and software tools. The models developed through IOOS are used to elucidate, prioritize, and resolve federal operational coastal ocean issues through application and development of a range of existing and emerging coastal oceanic, hydrologic, and ecological models. The models provide information used to predict the fate of natural resources and resource management guidance. The general mission of the Coastal and Ocean Modeling Testbed (COMT) is to use targeted research and development to accelerate the transition of scientific and technical advances from the coastal and ocean modeling research community to improve operational ocean products and services used by decision makers, managers, and scientists. Support for IOOS is primarily through NOAA and had annual funding levels of between $4 million and $1 million over the last 4 years. Further information on IOOS-COMT can be found at: http://testbed.sura.org/.

Another example of a virtual modeling laboratory is the Chesapeake Community Modeling Program (CCMP). The CCMP is a research community that has cooperatively built an open source system of watershed and estuary models specific to the Chesapeake Bay and its watershed. The goal of the CCMP is to develop a comprehensive model system consisting of interchangeable individual modules covering all aspects of hydrodynamics, ecosystem dynamics, trophic exchanges, and watershed interactions to move towards the next generation of linked watershed-estuary models. Support for the CCMP is primarily through Chesapeake Research Consortium (CRC) member institutions and the NOAA Chesapeake Bay Office. Further information on CCMP can be found at: http://ches.communitymodeling.org/

Virtual laboratories provide one of the least cost approaches to a modeling laboratory. Freed from the capital and maintenance costs cost 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 have the additional advantage of being flexible in their institutional and cooperative arraignments and have low startup costs.

Combined Physical and Virtual Modeling Laboratories

An example of a modeling laboratory that's a mix of the physical and virtual forms is the Community Modeling and Analysis System (CMAS) that supports key air quality models and their associated tools that are applied in the U.S. for research and regulatory purposes in order to meet Clean Air Act requirements. One of the models supported by CMAS is the Community Multiscale Air Quality (CMAQ) Model which is a key model used by the CBP for airshed modeling of nitrogen deposition of the Chesapeake watershed and tidal waters. While development of the CMAQ Model is with dedicated EPA staff and facilities at Research Triangle Park in North Carolina, CMAS functions as the outreach arm of the air quality modeling community and provides and online help desk, a software and data clearinghouse, model training, conferences such as the annual CMAQ Conference, software documentation, software related research, model quality assurance, and reviews of the model and their associated utilities. CMAS is associated with the University of North Carolina.

An advantage of CMAS is that encourages standardizing open-source, advanced modeling systems enabling more collaborative development and linking of models for meteorology, emissions, air quality, hydrology, and environmental and health effects. The CMAS-supported models use a modular approach with well-defined communications between modules, allowing developers to upgrade existing processes or add new ones, ensuring the rapid evolution of the technology to meet the changing needs of the environmental modeling community. Models-3, which includes CMAQ, was the first generation of air quality models to evolve out of the community modeling paradigm. With Models-3, there is a need for centralized coordination of development and application efforts for the mutual benefit of scientists, model developers, practitioners of modeling, and regulatory users of modeling results. 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.

IV. Chesapeake Bay Modeling Laboratory Proposal

The proposal developed by the MLAT for the establishment of the CBML is presented below.

Mission Statement

The purpose of the Modeling Laboratory is to improve watershed and estuarine modeling and to translate that modeling from research to practice. Achieving this goal will support the protection and restoration science that informs and guides management decisions in Chesapeake Bay Program Partnership. Some specific objections include:

- Accelerate the translation of research into operational models and utilities
- Facilitate testing and bench marking of appropriate models for Chesapeake Bay Program operations
- Allow rapid modification of models to improve predictive skill and foster adaptive management
- Maximize operational efficiency of the Chesapeake Bay Program Models
- Build credible open-source community modeling tools and data for stakeholders
- Develop tools that facilitate access to models and data for states, researchers, and other partners
- Provide a framework that would be responsive to input from major stakeholders

Vision

With the enhanced resources available from the modeling lab, Chesapeake Bay Program modeling activities will be more strongly based on the best available science

Comment [LB8]: Also facilitate and coordinate open source contributions to models, tools and data. -LB

Comment [DEW9]: This sounds like operations, not the research mission of the lab

Comment [DEW10]: This is very vague

What kind of response? What kind of input?

Guiding Principles

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

   a. *Clear budgeting between the three components*

   b. *These three 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 Chesapeake Bay Program Office*

These three elements of modeling within the Chesapeake Bay Program must be clearly addressed within the proposed Modeling Lab and the existing Modeling Team. It is essential that this be done not only from a budgeting perspective, but also a coordination and communication perspective. This will be done in guidance that would establish a Modeling Lab. The operations aspect of modeling within the CBP must remain connected to the CBPO, not be placed in the Modeling Lab; operations includes scenario runs to support the TMDL, WIPs, Milestones, etc.

Comment [DEW11]: This text is mostly redundant with the bullets above. Need to weed through it and all the text below to reduce such redundancy.

2) Sustainable dedicated core funding

Funding for the Modeling Lab should be established from a line item in a budget, not from grants. Stable, core funding is essential to the success of the lab.

3) Research and development is management focused

The research and development that would be done by the Modeling Lab needs to be responsive to the needs identified by the CBPO, primarily the list of improvements requested by the GITs.

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

Research and development done by the Modeling Lab must be documented and published in a peer reviewed process. Peer review of published materials is important from the model credibility perspective. Time must be budgeted to allow this to happen.

Operational models and results used for program activities should be peer reviewed and results should be of publishable quality.

Comment [BMR12]: Seems like this should replace the previous bullet

5) Formal methods to track and openly distribute model input data and products of the data (with meta data according to current standards)

A clear process and documentation of the origin of model input data is critical for more widespread access to researchers and others who wish to utilize the Chesapeake Bay Program models. Clear documentation and meta data associated with input data is also part of the peer review process so that others may replicate results

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

The models being used by the CBPO 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 that helps guide implementation of practices at the local level.

7) Supports development of open-source and modular code

Comment [LB13]: Just public domain or are we encouraging and facilitating an open source community? -LB

Generically, open source refers to a program in which the source code is available to the general public for use and/or modification from its original design free of charge. Open source and modular code make it easier for researchers in any location to utilize the Chesapeake Bay Program models and potentially improve components through their own research

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

a. Timely modeling documentation

b. Communication includes introductory operations documentation, programs, and training

Ensuring adequate avenues of communication exist between the CBML and the CBP partners (GITS and Workgroups) will be an essential component for a successful lab. Timely documentation of models as they are calibrated and developed is important from the aspect of not only communicating to the CBP partners, but also to other modelers who may wish to utilize components of the models being developed by the CBP. Training for those that wish to use the models (researchers or others that simply want to run the models) being developed at the CBPO or the CBML is an element seen in many of theexisting modeling labs that were reviewed.

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

The CBML is envisioned as a means to increase the community of modelers who are contributing to all of the models being utilized by the CBP. Increased access to the research community should result in an improvement in the modeling capability of the program as a whole.

10) Transferability

Transferability is a process whereby the specifics of a research situation are compared to the specifics of other environments or situations. If there are enough similarities between the two situations, the model being developed in one location can be applied to the other environments or situations. Transferability is a key component in modeling where a model verified with data in one location or over one time period is expanded to other like locations or time periods.

11) Regional focus with the ability to expand

The focus of the CBML will be the Chesapeake Bay watershed and it's receiving waters. Models or sub-models that are developed by the CBML may have broad application to other watersheds and estuarine areas. Ultimately is that thought that the CBML will contribute in a broader way to the science of estuarine and watershed modeling.

Sound, science-based modeling is impossible without quality monitoring data for model development, calibration, and validation. The CBML will be responsible for periodic reviews of CBP monitoring programs to insure that they are based on the best available science and that the collected data meets data quality and information objectives. The CBML will be responsible for redesigning monitoring systems that do not meet data quality and information objectives.

Comment [BMR14]: Adding this as a guiding principle will require some discussion during our next conference call, as it adds a significant component to the responsibilities of the CBML

Comment [DEW15]: This is an important function, but I'm not sure it belongs in the modeling lab.

The modeling lab should certainly weigh in on whether monitoring programs produce the data needed to parameterize, calibrate, and validate the models; but this statement is much broader than that.

- Clarification of Guiding Principle #9:
  "Support co-development of Chesapeake Bay models"
    - Support of multiple models
    - Support of open-source and modular
        - Stable code with released updates that include documentation
        - Make the updated code open-source before making it operational, which includes others in the testing
    - Benchmarking and testing of unit and combined modules
    - Development of a Chesapeake Bay Modeling System

Comment [ap16]: Comments from 03/26/2013 MLAT Meeting, which should be incorporated into the guiding principles. -AP

Modeling Laboratory Framework

k

Elements of Research, Development, and Operations relative to a proposed Chesapeake Bay Modeling Laboratory

Restoration of the Chesapeake Bay and its watershed will call for the implementation of management practices requiring tremendous public and private investments. Prudent and effective decision making will need to be informed by models with the highest possible scientific backing and by models receiving a high degree of confidence from managers and stakeholders. Further, the model operations must be agile enough to quickly respond to requests for scenarios. To provide those involved with the restoration effort with the highest degree of responsiveness and confidence, the Modeling Lab Action Team (MLAT) has identified the following four essential functions of models for the Chesapeake Bay Program.

Operations: Model operations are defined here as the rapid and automated development of scenarios. The Chesapeake Bay Program (CBP) Partnership currently runs 100-200 Scenario Builder and Watershed Model runs per year with a lesser number of land use change model and estuarine model scenarios. These scenarios support the TMDL, the 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. MLAT does not believe that these activities should be included in the portfolio of the proposed CBML.

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 generally are not to develop new models, but to enhance the abilities of 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 a minimum of additional programming.
2. The partnership may also wish to investigate different algorithms for estimating manure application to cropland. This type of task involves software development or modification.
3. The Watershed Model is a vast 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 change sources of loads.

Comment [ap17]: Need small summary/intro here? -AP

Comment [DEW18]: This is very well said and could be moved back to the earlier section on

Justification of a Chesapeake Bay Modeling Laboratory 8

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 insure that the model is performing as intended and in accordance with research results.

Research-Oriented Development: New models can be developed or old models can be modified to add new processes to the CBP modeling suite or to answer research questions. 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 during the development process to adequately represent the scientific knowledge while producing a model that is appropriate to its intended purpose. 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 Scientific and Technical Advisory Committee (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 within a watershed. These questions are raised, but there is no current mechanism to get answers for watershed-related questions other than waiting for the scientific community to take these tasks independently. Historically, the Estuarine Model development has been informed by directed research sponsored by the US Army Corps of Engineers.

The discussions in the MLAT have revealed that the CBPO modeling teams are focused on operations and operational development with little time or resources developed to research or research-oriented development. Additionally, the MLAT feels that it is important that operations and operational development stay within the CBPO so that the current responsiveness to the partnership can be maintained. The MLAT sees an urgent need for a separate Chesapeake Bay Modeling Lab (CBML) that focuses on research and research-oriented development. It is clear that there must be very strong ties between the CBP, the CBPO modeling teams, and the CBML to guide the CBML in creating products that are responsive to management needs.

Comment [DEW19]: This material seems like basid background that should be presented before getting in the Mission, Vision, and Plan for the ML.

Perhaps it could be combined with the info on the current model system on p 11 to create a Background section

The proposed CBML would oversee modeling oriented research development activities.

Linkages between functions

To provide the greatest management effectiveness, the four functions of CBP modeling must be tightly linked to each other and also to management. The closest linkages would need to be formed between neighboring functions as listed above. That is, between 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 between the functions to coordinate efforts.

***Operations and operational development*:** The coordination of scenario data gathering includes working closely with the partnership, which often results in quick adjustments that need to be made to the 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 historically 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 where possibilities are fed from operational development to operations and requirements are returned.

***Research-oriented development and research*:** To maximize the effectiveness of research, it must be tailored to answer specific questions generated by the development of the research models. Specifically, the research must be able to parameterize the relationship between measurable variables in order to be incorporated successfully in models. Active communication will be necessary to ensure that research questions are relevant to any developed models and that the models developed appropriately replicate the research.

***Operational development and research-oriented development*:** To be useful for management, a research-scale model will generally need to be implemented at the Chesapeake Bay scale. This may create issues related to run time, data availability, and software compatibility. Up-scaling may also create concern on the research side 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 the operations phase.

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

Recommended functions of a Chesapeake Bay Modeling Laboratory

MLAT reached consensus on a recommendation that a Chesapeake Bay Modeling Lab be established to take on research, research-oriented development, and some operational development aspects of the Chesapeake Bay Program models. A modeling lab would be a critical component in addressing the significant issues brought up by the NRC/NAS report and previous STAC reports. Resources at a modeling lab would help close an existing gap in research and model development at the Chesapeake Bay Program and improve integration of the academic community into the modeling program. Increased resources at a modeling lab are needed to take on a long list of model improvements and model related analysis that have been requested by the GITs and their workgroups.

An additional option was put forth where-by assembly and calibration of the model also would be moved to a group outside of the Modeling Team at the CBPO. Under this option, the final assembled and calibrated model would be provided to the partnership as a turn-key product. This recommendation was not supported by all of the MLAT members. Some of the jurisdiction believe that this option would improve the credibility of the model and help reduce confusion about when versions of the model are “locked down” for use in allocation and scenario development. On the other hand, scientists on the panel

Comment [LB20]: Management needs and barriers? -LB

Comment [DEW21]: This seems circular. Need a clearer statement about research modeling.

Comment [DEW22]: I don’t think this statement is correct. Models often contain parameters that cannot be tied to measurements. That’s one reason we have to calibrate.

Comment [DEW23]: I disagree with this statement. Many research questions could be answered usefully without always considering the entire system.

thought that confusion over model versioning and “lock down” were administrative problems, not issues in modeling science, and that this option would derail the research mission of the lab as envisioned in the NRC-NAS report. Costs for this option were not determined. Some CBPO personnel costs could be reduced, but it is expected that this option would require additional funds.

Governance of a Chesapeake Bay Modeling Laboratory

Modeling Lab Board of Directors (Propose modified Modeling Workgroup constitute this Board)

Governing body or Board of Directors appointed by the Management Board. Appointees must have both 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 day to day 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 workplan of the CBML. The ML Board would prioritize input received from the GITs and the Workgroups and work interactively with the CBML to determine the eventual scope of each annual workplan. This Modeling Lab Board (ML Board) would from time to time brief the Principle Staff Committee, and Management Board on ML activities and direction.

Comment [BMR24]: Do we wish to recommend the make-up of the Governance Board?

Funding a Chesapeake Bay Modeling Laboratory

Existing funding for Chesapeake Bay Program modeling

Proposed funding for the Chesapeake Bay Modeling Laboratory

Proposed additional funding – Although, the funding section is complete, it should be noted that it is different than the assigned sections under the outline

Comment [ap25]: -AP

A laboratory that pursues management-identified priorities must be maintained for the long-term, to insure continuous revision of the current models as well as development of new code or complementary models to expand the partnership's modeling capacities into new areas that cannot be addressed with the current CBP operations team. As noted elsewhere, modeling operations in the CBP are in place to run scenarios for the jurisdictions as each partner plans its land use changes to meet the allocated loads in the Bay-wide TMDL. The team may also make minor adjustments to the models, derived from input on BMPs through its expert panels but beyond these two functions, the team is committed to strict delivery schedules for most years, thereby prohibiting substantial model modifications for major issues (e.g., climate change, loads associated with the spatial arrangement of BMPs on the landscape, land use change and aquatic habitat linkages, interfacing land use change with living resource stocks and production, etc.) that now face the jurisdictions in meeting their load reductions.

Comment [LB26]: Is this the new laboratory or the current operational group? -LB

Comment [DEW27]: Suggest deleting this redundant material

It is envisioned that sustained funding will ensure these ML functions, and without it, substantial model revision to include new and emerging issues will not occur, and thereby jeopardize reasonable model projections of the effects of required land use changes on local/regional WQ.

The ML will require approximately $1.5M annually to meet its objectives of responsive and quality modeling for improving the CBP modeling system. Should additional monitoring be needed to inform the desired model improvements, additional revenues would need to be identified, to be administered through the CBP or the ML, but neither should draw down the core funding for management-specific research and development in the ML to address modeling needs. Offered through a Request for Services (RFS) or Request for Proposals (RFP), the funds would support a ML director, a staff member as liaison to the CBP and its modeling team, one technical staff for data management, and a secretarial assistant. The remainder of the funding would support, through RFPs for specific management needs, teams of modelers to develop, test, calibrate/validate, and transfer compatible code to the CBP for use in its modeling framework. This might be teams of 3 modelers per management topic, up to 4 teams per fiscal year.

Comment [DT28]: Is this a real number based on a detailed budget or just a place holder?

Comment [DEW29]: This point seems distracting here. Maybe it should be deleted.

Comment [LB30]: Show a breakdown in an appendix. –LB

Comment [DT31]: I agree that we need detailed budget and think it should also be summarized here with some sort of breakdown with respects to personnel (how many person years/year), operations, etc. Still vague to me whether we are talking brick and mortar or virtual lab. Also, when we do the budget, I would expect that we should include a cost-share component to show that the researchers/universities/agencies will be contributing substantively to the effort.

Sustained funding would ideally be provided through a multi-year line item adopted in the U.S. Congress, but considering recent Congressional lethargy and the austere economic constraints within the Federal budget, other options must be pursued. Redirecting the current CBP modeling budget of $2.5M annually is not possible, as all of those funds are needed simply to meet the partner demands for routine operations that include 1) scenario runs via Scenario Builder, CAST, Watershed Model, and the CBP hydrodynamic-WQ model and 2) BMP revisions derived from expert panel recommendations. Multi-agency support, both Federal and state is possible, with the Executive Order and Federal Strategy a foundation for such a multi-Federal agency commitment. State, or partner, contributions are potentially possible, particularly if some of the partners seek and obtain a ML with acceptable independence from EPA for its governance, calibration, and expanded academic participation. However, for both contributions, funding must be sustained as there is no practical way to set up and run a ML for the duration of 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 ML must become as permanent part of the CBP infrastructure as the modeling team, management board, the advisory committees, and goal implementation teams.

Process for Establishing Chesapeake Bay Modeling Laboratory

Once sustained funding is secured for a 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 (see Governance Section above). Procedures for activities and oversight by the governance board would be drafted, reviewed by the CBP partners, and codified, specifically defining the decision processes for operations and activities of the board and the laboratory. This would include allocations of specific amounts for research and development not to be less than $1.5M annually. If the modeling laboratory is also to provide calibrated models to the partnership, additional resources would be required for the production and distribution of fixed, operational, not-to-be modified models to the partnership.

Comment [DEW32]: Deleted this undefined jargon phrase

Comment [LB33]: Calibration no longer done by operational team. Use formal version control such as GIT. -LB

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. It is envisioned that there will be a request that would seek proposal submissions that include two or three specific functions in a modeling laboratory. The successful applicant/organization for a CBP Modeling Laboratory would include:

1) Permanent/core staff: A director, a half-time administrative assistant, and one permanent, full-time staff modeler. All decisions in the laboratory would be in the director's responsibilities and he/she would be the primary contact with the governance board, Modeling Workgroup, and Water Quality GIT. The administrative assistant would provide secretarial help and some writing assistance to the director. The full-time staff would provide 1) CBP data and model code and output to model experts and 2) undertake transition of the developed model or model code, documentation, and calibration/verification data back to the CBP. If the modeling laboratory is also to routinely provide calibrated, fixed models to the partnership, two additional permanent, full-time staff are required with sole responsibility to insure delivery of calibrated watershed and hydrodynamic-water quality models, respectively. These might be current EPA or sub-contractor members of the CBP modeling team shifted to the direct supervision by the modeling laboratory director, an increasingly feasible possibility as funding reductions for EPA are projected for the future (N. DiPasquale, comments to STAC 6/11/13). These individuals would communicate with CBP operational modeling staff and the governance 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.

Comment [LB34]: So modeling laboratory works on existing codes? -LB

Comment [DEW35]: This seems much less than the manpower (oops, personpower) that provides the current calibrated models

2) Modeling expertise for management-specific modeling needs: Each year, the Modeling Workgroup and Water Quality Goal Implementation Team (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, e.g., for the atmosphere, local to regional hydrology, processes embedded in 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 Model Laboratory would require rigorous, non-conflicted peer review. Unbiased review would be assured through inclusion of technically skilled modelers, natural and social science experts, and two types of representatives of the management community, those familiar with regional commitments to 1) load reductions and land uses to insure those reductions and living resource restoration, harvest, or sustainability for tidal and non-tidal waters and 2) use of models in jurisdiction decision-making.

Comment [DEW36]: Only if there will be social science modeling

A long-term (5 yr) cooperative agreement, with annual review of progress, would be the most appropriate mechanism for the award, as this funding option enables active communication and cooperation between the governance board, Modeling Workgroup, Water Quality GIT, 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; it also would 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, 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. Finally, a grant is a third funding option, 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, through the CBP modeling team or the governance board, believes are inadequate or non-specific to the management need.

Based on input from the Modeling Workgroup and Water Quality GIT on 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 governance 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.

References

National Research Council. *Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation*. Washington, DC: The National Academies Press, 2011.

Management Board Memorandum

http://www.chesapeakebay.net/channel_files/17880/(attachment_iii.b)_memo_mb_to_psc_ie_recommendations_final_11-3-2011.pdf

Modeling Laboratory Action Team

http://www.chesapeakebay.net/groups/group/modeling_lab_action_team

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:

Comment [DT37]: This would be scientifically a step backward in my opinion if done for all constituents. We would be giving up better science for the convenience of quicker model runs.

Comment [DT38]: This is certainly desirable but I don't think it can be done with HSPF. To accomplish this, a new model is needed and to do that, the CBML is needed.

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. 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 Mid-Point 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, including boundary condition support, model data needs support, and other ancillary technical support as requested.

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: The STAC formally submitted a letter 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).

Comment [DT39]: Avoid beginning a sentence with an acronym or an abbreviation.

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 Nick 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: First M3.1 workshop 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: M3.1 Workshop report 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: M3.2 workshop 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.