Achieving Nutrient and Sediment Reduction Goals in the Chesapeake Bay: An Evaluation of Program Strategies and Implementation

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ACHIEVING NUTRIENT AND SEDIMENT REDUCTION GOALS IN THE CHESAPEAKE BAY

An Evaluation of Program Strategies and Implementation

Committee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality

Water Science and Technology Board

Division on Earth and Life Studies

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BAY PROGRAM IMPLEMENTATION FOR NUTRIENT REDUCTION TO IMPROVE WATER QUALITY

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Preface

The Chesapeake Bay Program (CBP), a partnership among the U.S. Environmental Protection Agency, the six watershed states, and the District of Columbia, is working at federal, state, and local levels to restore the Chesapeake Bay ecosystem. In 1987, the CBP partners committed to reduce "controllable" phosphorus and nitrogen loadings to the Bay's main stem by 40 percent by 2000. The CBP's initial goals were modified in 1992, which led to a variety of actions directed at point and nonpoint sources of nutrient and sediment loading to the tributaries of the Bay. Unfortunately, progress has been limited and the nutrient and sediment reduction goals have not yet been attained.

During the years since the 1987 agreement, water pollution management under the Clean Water Act (CWA) shifted toward more quantitative assessments of water quality impairments. The CWA requires states and tribes to identify and maintain lists of water bodies that do not meet water quality standards and to develop total maximum daily loads (TMDLs) that the water bodies can receive and still comply with water quality standards. In 2000, the CBP partners signed an agreement that provided an alternative to developing a TMDL based on the expectation that actions would be taken that would result in the attainment of water quality standards within a 10-year period of time. However, a reevaluation in 2007 of nutrient and sediment target loads revealed that insufficient progress had been made toward improving water quality and meeting the intent of the 2000 agreement was unlikely. In response, the CBP and the federal government launched a new era of accountability, accompanied by more aggressive approaches to controlling nutrient and sediment pollution in the Bay watershed, including the development of a TMDL for the Bay, watershed implementation plans, and a two-year milestone strategy (described in more detail in Chapter 1).

In 2009, the EPA requested that the National Research Council (NRC) evaluate and provide advice on the CBP nutrient reduction program and strategy. The EPA specifically directed the NRC to evaluate the tracking of best management practice implementation, tracking and accounting efforts, the two-year milestone strategy, and the states' and federal agencies' adaptive management strategies, and to suggest improvements to these strategies that might better attain the CBP goals (see Box S-1). The committee has not been charged to review the TMDL or the models used to develop it. To carry out this work, the NRC appointed a multidisciplinary committee of experts to provide advice to the EPA, the six states in the Chesapeake Bay watershed, the District of Columbia, other federal agencies, and other interested parties.

Our committee is indebted to many individuals for their contributions of information and resources. Specifically, we appreciate the efforts of our committee's EPA technical liaisons—Julie Winters and Rich Batiuk—who assisted the committee with numerous requests for information and with utilizing the vast resources of agency expertise when needed. The committee also owes a debt of gratitude to the many individuals who educated our committee through their presentations at the open sessions of the committee's meetings.

The committee has been fortunate to have the support and collaboration of an excellent NRC staff. Stephanie Johnson, study director, has been an extraordinary source of information and advice and has contributed significantly to this report. Michael Stoever, research associate, has provided superb support during and between meetings and has also been instrumental in producing the report. I speak for the entire committee in expressing our profound respect and gratitude.

This report was reviewed in draft form by individuals chosen for their breadth of perspectives and technical expertise in accordance with the procedures approved by the National Academies' Report Review Committee. The purpose of this independent review was to provide candid and critical comments to assist the institution in ensuring that its published report is scientifically credible and that it meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The reviewer comments and draft manuscript remain confidential to protect the deliberative process. We thank the following reviewers for their helpful suggestions, all of which were considered and many of which were wholly or partly incorporated into the final report: Donald F. Boesch, University of Maryland; Mark B. David, University of Illinois; Theo A. Dillaha, Virginia Polytechnic Institute and State University; Joseph H. Harrison, Washington State University; Carlton

H. Hershner, Jr., Virginia Institute of Marine Science; David H. Moreau, University of North Carolina; Sujoy B. Roy, Tetra Tech Inc.; Thomas R. Schueler, Center for Watershed Protection; Kathleen Segerson, University of Connecticut; and Thomas W. Simpson, Water Stewardship Inc.

Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by David A. Dzombak, Carnegie Melon University, and Ken W. Potter, University of Wisconsin. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments received full consideration. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

Kenneth H. Reckhow, Chair
Committee on the Evaluation of
Chesapeake Bay Program Implementation for
Nutrient Reduction to Improve Water Quality

Contents

Summary

The Chesapeake Bay (Figure S-1) is North America's largest and most biologically diverse estuary, as well as an important commercial and recreational resource. However, excessive amounts of nitrogen, phosphorus, and sediment from human activities and land development (e.g., agriculture, urban and suburban runoff, wastewater discharge, air pollution) have disrupted the ecosystem, causing harmful algae blooms, degraded habitats, and diminished populations of many species of fish and shellfish. In 1983, the Chesapeake Bay Program (CBP) was established, based on a cooperative partnership among the U.S. Environmental Protection Agency (EPA), the state of Maryland, the commonwealths of Pennsylvania and Virginia, and the District of Columbia, to address the extent, complexity, and sources of pollutants entering the Bay. By 2002, the states of Delaware, New York, and West Virginia committed to the CBP's water quality goals by signing a Memorandum of Understanding.

In 2008, the CBP launched a series of initiatives to increase the transparency of the program and heighten its accountability, and in 2009 an executive order[1] injected new energy into the Chesapeake Bay restoration. By 2010, a total maximum daily load (TMDL) was established by the EPA that determined the limits (maximum loads) on the amount of nitrogen, phosphorus, and sediment from point and nonpoint sources that would be necessary to attain adopted water quality standards in the Bay, and each of the Bay jurisdictions (i.e., the six states and the District of Columbia) developed watershed implementation plans outlining the pollutant control

[1]Executive Order 13508.

FIGURE S-1 The Chesapeake Bay and its watershed.
SOURCE: CBP (2008). Available at http://www.chesapeakebay.net/maps.aspx?menuitem=16825.

measures that would be implemented by 2025 to reach the TMDL. In addition, as part of the effort to improve the pace of progress and increase accountability in the Bay restoration, a two-year milestone strategy was introduced aimed at reducing overall pollution in the Bay by focusing on incremental, short-term commitments from each of the Bay jurisdictions.

The National Research Council (NRC) established the Committee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality in 2009 in response to a request from the EPA and with funding from EPA Virginia, Maryland, Pennsylvania, and the District of Columbia. The committee was charged to assess the framework used by the states and the CBP for tracking nutrient and sediment control practices that are implemented in the Chesapeake Bay watershed and to evaluate the two-year milestone strategy. The committee was also charged to assess existing adaptive management strategies and to recommend improvements that could help the CBP to meet its nutrient and sediment reduction goals (see Box S-1).

BOX S-1
Statement of Task

The Water Science and Technology Board appointed a committee to undertake an evaluation of the Chesapeake Bay Program's nutrient reduction program. Specifically, the committee was to address the following questions:

Evaluation Theme I: Tracking and Accountability

1. Does tracking for implementation of nutrient and sediment point and nonpoint source pollution (including air) best management practices appear to be reliable, accurate, and consistent?
2. What tracking and accounting efforts and systems appear to be working, and not working, within each state (i.e., the six states in the watershed and DC), including federal program implementation and funding? How can the system be strategically improved to address the gaps?
3. How do these gaps and inconsistencies appear to impact reported program results?

Evaluation Theme II: Milestones

4. Is the two-year milestone strategy, and its level of implementation, likely to result in achieving the CBP nutrient and sediment reduction goals for this milestone period?
5. Have each of the states (i.e., the six states in the watershed and DC) and the federal agencies developed appropriate adaptive management strategies to ensure that CBP nutrient and sediment reduction goals will be met?
6. What improvements can be made to the development, implementation, and accounting of the strategies to ensure achieving the goals?

TRACKING AND ACCOUNTING

The term "tracking," as applied in the CBP, describes approaches to document the implementation of urban and agricultural nutrient and sediment reduction practices (also called best management practices, or BMPs) and treatment technology upgrades as well as the basic associated practice characteristics. The term "accounting" describes the process of analyzing and reporting the practice information and estimating the resulting load reductions. **Accurate tracking of BMPs is of paramount importance because the CBP relies upon the resulting data to estimate current and future nutrient and sediment loads to the Bay.** However, many Bay jurisdictions and localities are struggling with limited resources, complex and rapidly changing data reporting mechanisms, data privacy constraints, and quality assurance/quality control needs. Verifying the continued functioning and effectiveness of historical activities presents a significant challenge. Although state tracking and accounting programs are unlikely to be identical, the CBP has recently made strides toward common reporting goals and data requirements.

The current accounting of BMPs is not consistent across the Bay jurisdictions. Additionally, given that some source-sector BMPs are not tracked in all jurisdictions, the current accounting cannot on the whole be viewed as accurate. Although the Bay jurisdictions have a good understanding of point-source (i.e., wastewater) discharges, numerous issues affect the accuracy, reliability, and consistency of BMP reporting to the CBP. Only five of the seven Bay jurisdictions conduct any level of field verification of agricultural practices, and there are known problems with double counting that agencies are working to resolve. Only one Bay jurisdiction specifies a lifespan for practices recorded in the database, and few jurisdictions have mechanisms to identify and remove from the database practices that are no longer functioning or even in place. Current tracking systems do not account for agricultural practices that are not cost-shared by a government agency. Given these limitations, current accounting can be considered, at best, an estimate.

The committee was unable to determine the reliability and accuracy of the BMP data reported by the Bay jurisdictions. Independent (third-party) auditing of the tracking and accounting at state and local levels would be necessary to ensure the reliability and accuracy of the data reported.

The committee was not able to quantify the magnitude or the likely direction of the error introduced by BMP reporting issues. On the one hand, there is under-counting of BMPs because the jurisdictions do not currently report non-cost-shared (or voluntary) practices, although the model calibration may include the effects of some of these practices. On the other hand, there is over-counting of BMPs because few states account for the loss of BMPs when they are no longer properly maintained, functioning, or in place. Furthermore, there are errors introduced by site-level variability in BMP effectiveness, insufficient data on the location of BMPs, and discrepancies between state and CBP definitions of BMP management.

A consolidated regional BMP program to account for voluntary practices and increase geo-referencing of BMPs presents opportunities to improve the tracking and accounting process. A regional BMP program with incentives for participation as well as penalties for lack of participation has been used effectively in Florida to increase participation and improve data quality. Geo-referencing enables managers and modelers to identify the parcel-level location of BMPs, which would aid in inspecting, tracking, and assigning proper delivery ratios and BMP efficiencies, thereby improving the accuracy of the modeled estimates of nutrient and sediment loads delivered to the Bay.

Targeted monitoring programs in representative urban and agricultural watersheds and subwatersheds would provide valuable data to refine BMP efficiency estimates, particularly at the watershed scale, and thereby improve Watershed Model predictions. Current BMP load reduction efficiency estimates used in the Watershed Model are reasonable estimates of the short- to intermediate-term reduction efficiencies of newly installed BMPs at the field scale and gross representations of the same at the watershed scale. These estimates contain significant uncertainties caused by site-specific factors, practice design, extent of maintenance, and challenges in scaling up the data from the plot or field scale. Pilot studies in several sub-watersheds should be conducted to quantify BMP performance, particularly for the most common practices with the greatest uncertainty in their efficiency estimates. The CBP has recently implemented a review process to refine BMP efficiencies used in the Watershed Model based on emerging research findings.

Additional guidance from the EPA on the optimal extent of field verification of practices in relation to expected benefits would improve tracking and accounting of both cost-shared and voluntary practices. Field verification is costly, and several states have questioned its value given the resource constraints that limit BMP implementation. Although independent random, or probabilistic verification programs increase public confidence that reported data are accurate and reliable, attention should be given to developing ways to optimize field verification efforts that enhance the reliability of the BMP data sets, perhaps through the combined use of remote sensing data, written surveys, phone calls, and in-person visits.

Electronic tracking and data transfer systems are likely to improve the quality of reporting and reduce the jurisdictions' tracking and accounting burden but may currently be contributing to delayed assessments of implementation progress. Despite the concerns in tracking and accounting noted above, a great deal of information is available, and a plausible and collective effort seems to be under way to resolve some of the hindrances to data access, collection, and standardization. However, because implementation data are now reported electronically, several jurisdictions noted that the data are less accessible for assessments of statewide progress. Some Bay jurisdictions have mechanisms in place to compile progress updates as needed, but others have to wait approximately 9 months after the end of the reporting period for a summary of BMP implementation progress from the CBP. The recently launched tracking and accountability system for the TMDL (BayTAS) and ChesapeakeStat, which documents each jurisdiction's progress in a publicly accessible website, should incorporate mechanisms for more timely reporting and consolidation of federal and state data submissions.

TWO-YEAR MILESTONES

To accelerate Bay restoration efforts and increase accountability, the CBP introduced two-year milestones in May 2009. In the past, Bay recovery goals involved decadal increments and did not identify particular strategies for achieving the necessary pollution reductions. Thus, the prior strategy was considered "a ladder without rungs" (CBP, 2009b). The two-year milestone strategy requires Bay jurisdictions to meet short-term implementation goals for nutrient and sediment reduction. The CBP envisioned that through a series of two-year milestone periods with routine assessments of the pace of progress by 2025 the Bay jurisdictions could implement all of the nutrient and sediment control practices needed for a restored Bay, although actual Bay water quality response and recovery might lag behind the 2025 implementation target.

The two-year milestone strategy commits the states to tangible, near-term implementation goals and improves accountability and, therefore, represents an improvement upon past CBP long-term strategies. However, the strategy, in and of itself, does not guarantee that implementation goals will be met, and consequences for nonattainment remain unclear. The two-year timeframes should encourage frequent reevaluations and adjustments for Bay jurisdictions that fall short of their intended implementation goals. However, without timely updates and synthesis of statewide progress from the CBP, some states lack the information necessary to make appropriate mid-course corrections.

CBP jurisdictions reported mixed progress toward their first two-year milestone goals. However, data were insufficient to meaningfully evaluate implementation or anticipated load reduction progress relative to the goals. The jurisdictions reported numerous efforts to control urban and agricultural nutrient and sediment loads, although they experienced greater successes in implementation of some practices than others. Without associated load reduction estimates for the implemented practices, the committee was unable to evaluate how implementation shortfalls in some areas or greater than expected progress in others affect the likelihood that the Bay jurisdictions will meet their overall nutrient load reduction goals.

The first two-year milestone goals will likely be the easiest to achieve. Not surprisingly, the states are investing in the "low-hanging fruit"—the least expensive or most cost-effective among the nutrient reduction options—for the first accounting period. Large gains have been made with advanced treatment technologies applied to large publicly-owned wastewater treatment facilities, which to date have been relatively cost-effective per pound of nutrient removed compared to land-based BMPs. Additionally, states are working to document practices implemented prior to the current milestone period but not yet credited in the Watershed Model. Available water quality improvement options during subsequent milestone periods will likely become less cost-effective. It is possible that nonstandard control strategies, especially those that do not require high capital investments (see Chapter 5), may need to be considered.

ADAPTIVE MANAGEMENT

Since 2008, the CBP has advocated for the use of adaptive management at both the state and federal levels as a way to enhance overall management of the program and to strengthen scientific support for decision making. The committee examined the partners' efforts to implement adaptive management and the potential barriers to and possible successful applications of adaptive management for nutrient and sediment reduction in the Bay watershed.

Neither the EPA nor the Bay jurisdictions exhibit a clear understanding of adaptive management and how it might be applied in pursuit of water quality goals. Reviewing activities, assessing progress toward goals, and adopting contingencies were cited as examples of adaptive management. However, effective adaptive management involves deliberate management experiments, a carefully planned monitoring program, assessment of the results, and a process by which management decisions are modified based on new knowledge. Learning is an explicit benefit of adaptive management that is used to improve future decision making. The committee did not find convincing evidence that the CBP partners had incorporated adaptive management principles into their nutrient and sediment reduction programs. Instead, the current two-year milestone strategy approach is best characterized as an evolutionary (or trial and error) process of adaptation in which learning is serendipitous rather than an explicit objective. In the trial and error process, when failures occur, jurisdictions have limited capacity to understand why, and contingencies represent the next thing to try rather than a deliberate adaptation.

Successful application of adaptive management in the CBP requires

careful assessment of uncertainties relevant to decision making, but the EPA and Bay jurisdictions have not fully analyzed uncertainties inherent in nutrient and sediment reduction efforts and water quality outcomes. Each CBP goal brings with it uncertainties, not all of which can or should be addressed through adaptive management. Therefore, the EPA and Bay jurisdictions should carefully and realistically analyze uncertainties associated with potential actions to determine which are candidates for adaptive management. Bay jurisdictions may be more successful using adaptive management for a limited number of components or for programs in smaller basins, where effects of management actions can be isolated and well-designed monitoring and evaluation can be undertaken to clearly quantify outcomes.

Targeted monitoring efforts by the states and the CBP will be required to support adaptive management. Monitoring plans need to be tailored to the specific adaptive management strategies being implemented. Presently, CBP and jurisdictional monitoring programs have not been designed to effectively support adaptive management. In addition, adaptive management will require better integration of monitoring and modeling activities. Excessive reliance on models in lieu of monitoring can magnify rather than reduce uncertainties.

Additional federal actions are needed to fully support adaptive management in the CBP. The federal accountability framework being promoted through the TMDL and the threatened consequences for failure will dampen the Bay jurisdictions' enthusiasm for adaptive management. To support adaptive management, the EPA should modify its accountability framework and offer explicit language indicating that carefully designed management experiments with appropriate monitoring, evaluation, and adaptive actions are acceptable, and that failures resulting from genuine adaptive management efforts will not be penalized. If the Bay jurisdictions perceive that the costs of failure are too high, then they may not be willing to pursue the benefits that adaptive management can offer. Additionally, federal guidance and training to the states on effective adaptive management strategies at the local or state level are needed. One or more examples of adaptive management designed and implemented at the federal level, perhaps on federal land, would be helpful to the states as they seek acceptable and effective management options.

Without sufficient flexibility of the regulatory and organizational structure within which CBP nutrient and sediment reduction efforts are undertaken, adaptive management may be problematic. Depending upon how Clean Water Act (CWA) language and TMDL rules are interpreted, opportunities for certain types of adaptations may be limited. Truly embracing adaptive management requires recognition that the TMDL, load allocations, and possibly even water quality standards might need to be modified based on what is learned through adaptive management. However, the jurisdictions may find that the formal processes required under the CWA to modify load allocations, TMDLs, or water quality standards constrain or even preclude using adaptive management. Successful application of adaptive management in the CBP will require greater regulatory flexibility. Approaching the TMDL as a process, not an endpoint, and facilitating adaptive implementation of the TMDL is one way to provide that flexibility.

STRATEGIES FOR MEETING THE GOALS

Reaching the long-term CBP nutrient and sediment reduction goals will require substantial commitment from each of the Bay jurisdictions and likely some level of sacrifice from those who live and work in the watershed. Jurisdictions are required not only to significantly reduce current loads, but they will need to take additional actions to address future growth and development over the next 15 years. Additionally, the Bay partners will need to adapt to future changes (e.g., climate change, changing agricultural practices) that may further impact water quality and ecosystem responses to planned implementation strategies. To reach the long-term load reduction goals, Bay jurisdictions and the federal government will need to prepare for the challenges ahead and consider a wide range of possible strategies, including some that are receiving little, if any, consideration today.

Success in meeting CBP goals will require careful attention to the consequences of future population levels, development patterns, agricultural production systems, and changing climate dynamics in the Bay watershed. Nutrient and sediment management efforts are taking place in the context of a quickly changing landscape and uncertain outcomes that could significantly affect the strategies needed to attain the TMDL goals. For example, an increase in the concentration of livestock or dairy animals near processing and distribution centers would mean a greater concentration of manure nutrients in these areas than has existed in the past. Additionally, Bay jurisdictions may need to adjust future milestone efforts to larger than anticipated population and more intensive land-use development scenarios, as well as climate change influences. Further and continued study of future scenarios is warranted to help Bay partners adapt to a changing future.

Helping the public understand lag times and uncertainties associated with water quality improvements and developing program strategies to account for them are vital to sustaining public support for the program, especially if near-term Bay response does not meet expectations. Although the science and policy communities generally recognize the uncertainties inherent in water quality modeling, load projections, and practice effectiveness and expect that water quality successes will lag implementation, the same may not be true of the broader public. If the public expects visible, tangible evidence of local and Bay water quality improvements in fairly short order, they will almost certainly become frustrated. In the absence of a concerted effort to engage Bay residents in a conversation about the dynamics of the Bay and how and when improvements can be expected, CBP partners should anticipate and be prepared to respond to an impatient or disillusioned public. By developing small watershed-scale monitoring efforts that highlight local-scale improvements and associated time lags in water quality as they occur, the CBP can better understand and inform the public about anticipated responses to, and expectations for, nutrient control measures.

The committee identified potential strategies that could be used by the CBP partners to help meet their long-term goals for nutrient and sediment reduction and ultimately Bay recovery. The committee did not attempt to identify every possible strategy that could be implemented but instead focused on approaches that are not being implemented to their full potential or that may have substantial, unrealized potential in the Bay watershed. Because many of these strategies have policy or societal implications that could not be fully evaluated by the committee, the strategies are not prioritized but are offered to encourage further consideration and exploration among the CBP partners and stakeholders. Examples include:

Agricultural Strategies

- **Improved and innovative manure management.** Possible strategies include expanded concentrated animal feeding operation (CAFO) permitting programs, guidelines and/or regulations to control the timing and rates of manure application, innovative manure application methods, transport of manure to watersheds with the nutrient carrying capacity to accept it, alternative uses (e.g., bioenergy production), animal nutrition management to reduce nutrient loading, and limits on the extent of animal operations based on the nutrient carrying capacity of the watershed.
- **Incentive-based approaches and alternative regulatory models**. Several approaches have been used successfully elsewhere to increase the use of agricultural BMPs for the purpose of improving water quality. Florida developed a voluntary, incentive-based BMP program that provides regulatory relief in exchange for BMP implementation, maintenance, and reporting. Denmark's nutrient management program provides an alternative model that couples agricultural regulatory requirements with incentives and has resulted in large reductions in nutrient surpluses. The Chesapeake Bay Program could facilitate an analysis of the costs and potential effectiveness of various incentive-based and regulatory alternatives.

Urban Strategies

- **Regulatory models that address stormwater, growth and development, and residential fertilizer use.** Watershed-based permitting for urban stormwater can lead to cost savings if a consortium of permittees chooses to organize to distribute pollutant load allocations and contribute to monitoring and tracking efforts in their local or regional watersheds. Restrictions on nitrogen and phosphorus residential fertilizer application are cost-effective methods of nutrient load management in urban and suburban areas. Communities could also adopt regulations to restrict land-use changes that would increase nutrient loads from stormwater runoff or cap wastewater treatment plant discharges at current levels, requiring offsets for any future increases.
- **Enhanced individual responsibility.** Enhancing individual responsibilities, either through education and incentives or through regulations, can also contribute to the success of Bay restoration and to water quality improvements. Examples of actions that individuals can take to improve water quality include increasing application of low-impact design and residential stormwater controls, changing residential landscape management, maintaining and upgrading septic systems, and changing diets.

Cross-cutting Strategies

- **Additional air pollution controls.** Although the Chesapeake Bay has realized substantial benefits from the Clean Air Act, the atmosphere remains a major source of nitrogen entering the Bay. More stringent controls on nitrogen emissions from all sources, including NO_x and agricultural ammonia emissions, will benefit both the Bay and the people who reside in its watershed.

Innovative funding models will be needed to address the expected costs of meeting Bay water quality goals. Targeting agricultural BMP cost-share programs is not always politically popular, but it can produce greater reductions at lower cost than will distributing resources broadly with little attention to water quality impacts. Although nutrient trading among point and nonpoint sources is often cited as a mechanism to reach nutrient reduction goals at lower cost, its potential for reducing costs is limited. Stormwater utilities offer a viable funding mechanism to support stormwater management efforts of municipalities. Funding for monitoring will also be needed, and successful regional monitoring cooperatives in other parts of the United States may be useful models.

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 CBP relies heavily on models for setting goals and evaluating nutrient control strategies; thus, the models are essential management tools that merit substantial investment to ensure that they can fulfill present and future needs. Currently, only a few technical professionals are fully knowledgeable of the details of the models and their development. The models are not widely used outside the CBP and, therefore, are unfamiliar to the broader scientific community. Credibility of the models is essential if the CBP goals and strategies are to be accepted and have widespread support. A Chesapeake Bay modeling laboratory would bring together academic scientists and engineers with CBP modelers to examine various competing models with similar objectives and work to enhance the quality of the simulations. An important component of the work of a modeling laboratory would be the integration of monitoring with modeling efforts. Joint research investigations focused on evaluating the success of the Bay recovery strategies could be centered in the laboratory, such as studies on the role of lag times in the observed pollutant loads and Bay responses. A close association with a research university would bring both critical review and new ideas. A laboratory could also facilitate improvements to the models to support the 2017 reevaluation of the TMDL and the WIPs.

* * *

Recovery of the Chesapeake Bay from excessive nutrient and sediment loads will require profound changes in the Bay watershed. These changes include a greater awareness of each watershed inhabitant's contribution to the Bay nutrient load, extensive adoption of urban and agricultural nutrient control practices, and widespread willingness to balance the cost of restoration programs with the quality of life values provided by the Bay and its land uses. The CBP has taken important steps toward improving the pace of implementation and accountability, including implementing the two-year milestone strategy. However, opportunities exist to improve upon the current tracking and accounting strategies, provide support for effective applications of adaptive management, and enhance the credibility of modeling strategies. To reach the long-term goals, Bay partners will likely need to consider innovative strategies, including some that are receiving little attention today. Meanwhile, given that nutrient legacy effects in the watershed will significantly delay the Bay's full water quality response to land-based BMPs, the CBP should help the public understand lag times and uncertainties and develop program strategies to better quantify them.

1

Introduction

The Chesapeake Bay is North America's largest and most biologically diverse estuary, home to thousands of species of plants and animals (CBP, 2000) as well as an important commercial and recreational resource. The Chesapeake Bay serves as a key economic driver in the mid-Atlantic region, and the Chesapeake Bay Foundation (2010) valued its worth at over one trillion dollars to the watershed's economy. The Bay's ecosystem has been affected by human influences since early settlements, but these influences became known and more pronounced during the 20th century. Today, almost 17 million people live within the Bay's 64,000 square mile (166,000 square kilometer) watershed in six states—Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia—as well as the District of Columbia (Figure 1-1; CBP, 2010a). Excess amounts of nitrogen, phosphorus, and sediment from human activities and land development, including agriculture, urban and suburban runoff, wastewater discharge, and air pollution, are sent to the Bay (CBP, 2010a). These pollutants and other chemical and physical alterations have disrupted the ecosystem, causing degraded habitats and harmful algal blooms that impact the survival of fish, shellfish, and other aquatic life.

The Chesapeake Bay was among the first of the major U.S. estuaries where concerted efforts were made to understand the causes and consequences of changing ecosystem conditions. During the mid-1970s, a young U.S. Environmental Protection Agency (EPA) led the first comprehensive and detailed attempt to understand the Bay's condition and what would be necessary to restore it to its former condition. That 7-year research effort culminated in the report, *Chesapeake Bay: A Framework for Action* (EPA,

FIGURE 1-1 Chesapeake Bay Watershed.
SOURCE: CBP (2008). Available at http://www.chesapeakebay.net/maps.aspx?menuitem=16825.

1983a,b), which described the condition of the Bay's ecosystem, its change over time, and scientific evaluations of the Bay's functions in relation to its condition. The report established a framework for action to address some of the Bay's most significant problems. Expert panels assembled by the EPA recommended immediate attention to the cultural eutrophication caused by nutrient enrichment, which had caused a long-term decline in the Bay's health (EPA, 1983a,b).

In 1983, the Chesapeake Bay Program (CBP) was established, based on a cooperative partnership among the EPA, the state of Maryland, the commonwealths of Pennsylvania and Virginia, and the District of Columbia, to address the extent, complexity, and sources of pollutants entering the Bay (EPA, 1983a). By 2002, the states of Delaware, New York, and West Virginia committed to the CBP's water quality goals by signing a Memorandum of Understanding (CBP, 2002).

A key component of the restoration program focuses on improving the water quality in the Bay and its tidal tributaries. Water quality is evaluated according to three parameters that are linked to one or more of the Bay's habitats and faunal communities: dissolved oxygen, water clarity, and chlorophyll *a*. Criteria for these three water quality parameters serve as the basis for the current goals, spurring efforts to reduce nutrient and sediment loads. Excess nitrogen and phosphorus loads fuel the growth of algal blooms, which increase chlorophyll concentrations, reduce clarity, and contribute to hypoxia (or low dissolved oxygen levels). Hypoxia, in turn, impacts water quality and habitat, especially underwater grasses and associated aquatic life (reviewed in NRC, 2000). In addition to these direct responses to nutrient enrichment, indirect responses and nonlinear feedback mechanisms, such as increased turbidity associated with the decline of filter-feeding bivalves and underwater grasses, may play an important role in the Bay's degradation (Kemp et al., 2005). Other stressors such as chemical contaminants from air pollution, climate change, habitat destruction, and over-harvesting of fish and shellfish also stress the Bay and its living resources at great environmental, economic, and social costs to the populations that rely on a healthy ecosystem (CBP, 2010a).

In this introductory chapter, the sources and impacts of nitrogen, phosphorus, and sediment pollution in the Bay watershed are reviewed. A brief history of the CBP's efforts is presented to provide context for the major current initiatives, including the total maximum daily load (TMDL) and the two-year milestone strategy. Finally, the committee's task and approach are discussed.

NITROGEN, PHOSPHORUS, AND SEDIMENT IN THE CHESAPEAKE BAY WATERSHED

Since colonization by Europeans almost 400 years ago, the Chesapeake Bay and its watershed have undergone significant human-induced changes, such as deforestation and urban development. The watershed is still dominated by wooded and open space (69 percent of the watershed), but agricultural and developed land uses (22 and 7 percent, respectively) are significant and increasing (EPA, 2010a). Sedimentation from agricultural expansion and land-use conversions, runoff of fertilizers and animal wastes, and atmospheric deposition of nitrogen from fossil fuel combustion and agriculture have contributed to observed changes to the Bay (Brush, 2009; Cooper and Brush, 1991). By the mid-1980s, the Bay was receiving 7 times more nitrogen and 16 times more phosphorus than when English colonists arrived (Boynton et al., 1995).

This section briefly describes the specific sources of nitrogen, phosphorus, and sediments to the Bay and its watershed. These sources are internal (e.g., biological processes in soils, sediments, and the water column) and external (e.g., commodity imports, atmospheric deposition). On the whole for the Bay and its watershed, anthropogenic sources of both phosphorus and nitrogen are several-fold larger than natural sources (Boynton et al., 1995; reviewed in Rabalais et al., 2009).

Annual loads of nutrients and sediment vary widely with climatic conditions, with wet years leading to much higher loads (see Figure 1-2). Because this variability can create challenges for calculating source contributions, the pollutant source data presented in this section are largely based on model output. The data were produced by the CBP Phase 4.3 Watershed Model or the CBP Airshed Model (Box 1-1) and were presented in the *Bay Barometer* (CBP, 2010a). Recent watershed model updates provided new estimates, but the committee was unable to disassociate Phase 5.3 Watershed Model source load data to account for the specific contributions of atmospheric sources.[1] The Phase 4.3 Watershed Model data presented in this section represent loading averages based on simulations over 14 years of hydrologic record using land use, best management practices (BMPs), and point-source controls reflecting 2007 conditions.

Nitrogen

Imported fertilizer and commodities (e.g., grain), primarily from other regions in the United States, and atmospheric deposition are important external sources of nitrogen to the Bay watershed. Atmospheric deposition of oxidized reactive nitrogen (NO_y; the sum of nitric oxide [NO] and nitrogen dioxide [NO_2] [collectively termed NO_x] + all other oxidized nitrogen

[1]In many CBP reports, atmospheric deposition is frequently lumped into the source sector on which the nitrogen is deposited (i.e., nitrogen deposition on forested lands is considered a forest source). Thus, atmospheric deposition is reported as a much smaller fraction than the plots included in this chapter (e.g., Figure 1-3), which consider the original sources of the nutrients. Plots showing the actual sources were not available from the CBP Watershed Model Phase 5.3; therefore, these source data reflect model output from the earlier model, Phase 4.3. Comparison data to the latest model version are provided in subsequent footnotes.

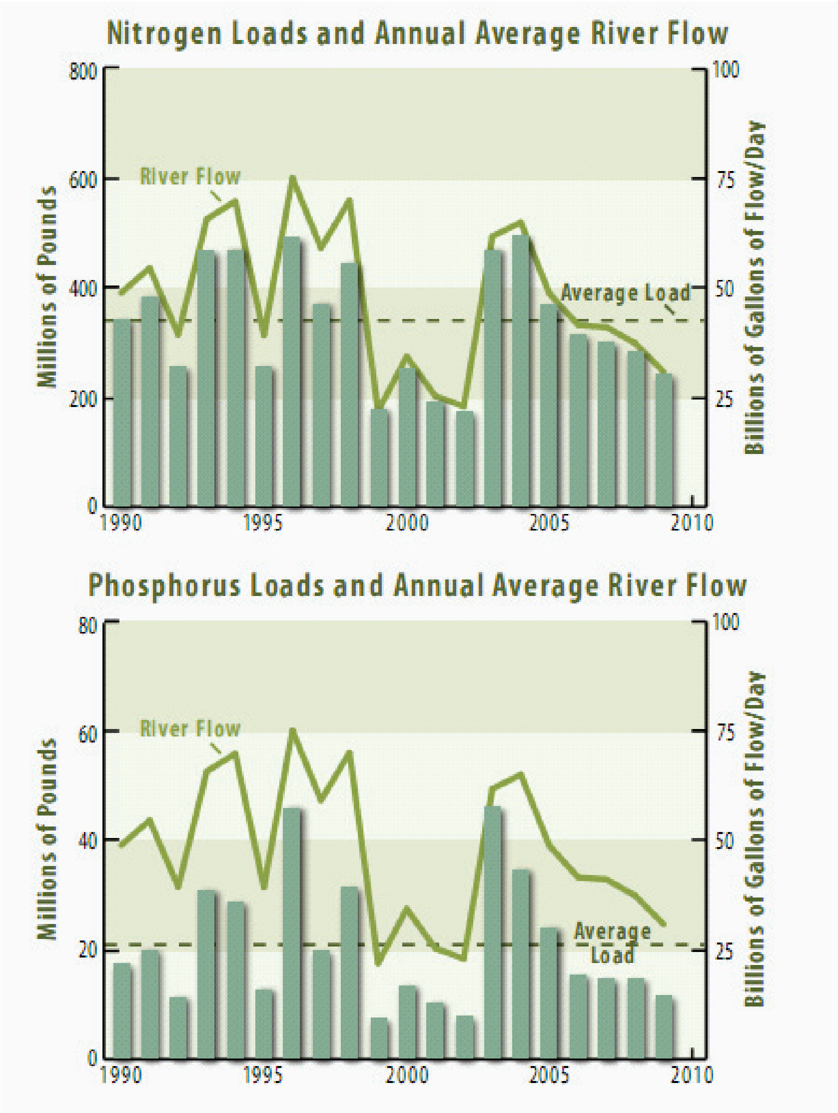

FIGURE 1-2 Nitrogen and phosphorus loading (millions of pounds) delivered to the Chesapeake Bay and total river flow (billions of gallons), 1990-2009. These loading estimates are based on direct measurements (i.e., monitoring in tributary rivers and point source discharges) supplemented by model estimates for ungaged portions of the watershed. The red lines indicate the 10-year average load targets for nitrogen and phosphorus (175 million pounds and 12.8 million pounds, respectively) established in EPA (2003).
SOURCE: CBP (2010a).

BOX 1-1
Chesapeake Bay Models

The CBP relies upon models to forecast the effects of changing nitrogen, phosphorus, and sediment management in the Chesapeake Bay. The models also form the basis of the current total maximum daily load (TMDL) allocations. The models are of two types: (1) models that simulate the physical, chemical, and biological processes in the airshed (Chesapeake Bay Airshed Model), watershed (Chesapeake Bay Watershed Model), and estuary (Chesapeake Bay Water Quality and Sediment Transport Model [or Bay Model]) and (2) models that convert land-use practices and implementation of best management practices (BMPs) into predictions of nutrient and sediment loads under average hydrologic conditions (the Land Use Change Model and Scenario Builder).

The Bay Airshed Model combines a wet deposition regression model with a continental-scale air quality model called the Community Multiscale Air Quality (CMAQ) Model. The Airshed Model provides the quantity of nutrients deposited via rainfall and dry deposition to the watershed and the Bay's surface.

The Watershed Model is based on the Hydrologic Simulation Program-Fortran (HSPF) model. It receives the atmospheric and other nutrient inputs and stimulates the quantity of nutrients and sediment discharged to the tributaries and main stem Bay. It is a lumped-parameter model, which means that it is not able to represent spatial locations of specific land use categories in each of the many small watersheds in the overall Chesapeake Bay basin. Further, HSPF does not mathematically characterize the time dependency (lag) of the farm plot scale response to agricultural BMPs, nor does it consider lag times introduced by groundwater flow. In other words, an assumption in the HSPF model is that nutrient reductions due to BMP implementation are instantaneous load reductions as a simple fraction of the pre-BMP load.

The Bay Model combines a three-dimensional curvilinear hydrodynamic model (CH3D) with an eutrophication model (CE-QUAL-ICM) and computes the concentrations of nutrients and suspended sediment that result from the Watershed Model inputs, the quantity of phytoplankton that grow and decay, and the resulting water clarity and dissolved oxygen (DO) concentrations. In addition, the quantities of submerged aquatic vegetation (SAV) and water column (zooplankton) and benthic (deposit and filter feeding) organisms are also computed as well as specific simulations of oyster and menhaden populations. Modeled estimates of

DO, chlorophyll, and light attenuation are used to determine if Bay water quality standards for DO, chlorophyll *a*, and water clarity have been violated. The models of the watershed and estuary have been continuously developed and refined over a 25-year period (Table 1-1) (Linker et al., 2000, 2002, 2008).

The Land Use Change Model and Scenario Builder are used to construct input scenarios for the Watershed Model to analyze current loads and forecast future loads under various land-use conditions. The Land Use Change Model provides annual time series of land use in the watershed and forecasts the land-use changes expected through 2030. Scenario Builder converts the numerous BMPs, which have various pollution reduction efficiencies depending on type and location in the watershed, to a common currency of nitrogen and phosphorus load that will be generated by a given land use and estimates the area of soil available to be eroded. Loads are input to the Watershed Model to generate modeled estimates of loads delivered to the Bay (EPA, 2010a). The linkages between these models are illustrated in Figure 1-3.

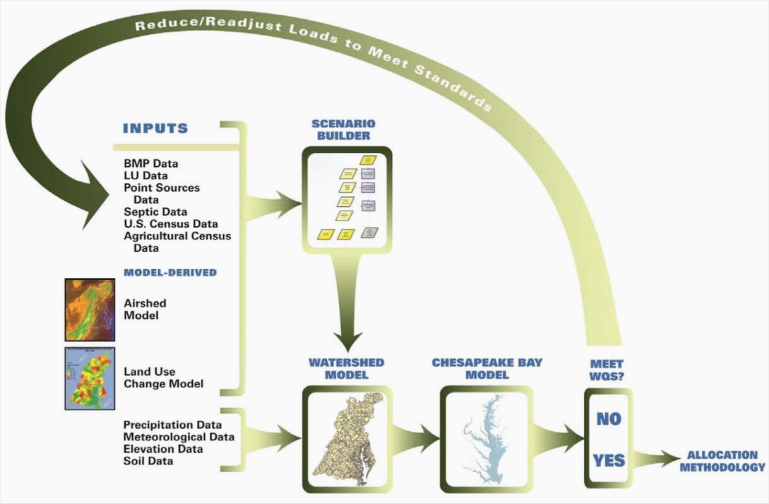

FIGURE 1-3 Key models used in the Chesapeake Bay Program.
SOURCE: EPA (2010a).

TABLE 1-1 Historical Development of the Watershed and Bay Models

Model Revisions	Watershed Model Characteristics	Bay Model Characteristics	Notable Advances	Period of Simulation	Management Decisions Supported
Phase 1 (1985)	Based on HSPF. Contained 5 land uses, 64 segments	Steady state	First coupling of watershed, hydrodynamic, and water quality models	4-month summer simulation only of 3 years (1965, 1984, and 1985)	General goal of 40% of controllable loads (CBP, 1987)
Phase 2 (1992)	Expanded agriculture simulation detail	Dynamic 4,000 grid cell model	First integrated sediment flux model; first inclusion of atmospheric deposition.	4 continuous years (1984-1987), hourly time step	Nutrient load reductions to achieve CBP (1987) goals
Phase 4.3 (2003)	9 land uses, 94 watershed segments	Dynamic 13,000 grid cell model	Integrated simulation of land and soil contaminant runoff processes; SAV, benthic deposit, and filter feeders models	14 continuous years (1985-1994), hourly time step	Expanded nutrient allocations
Phase 5.3 (2010)	25 land uses (time variable), 899 watershed segments	Dynamic 57,000 grid cell model	Enhanced segmentation, land uses, and mechanistic detail	21 continuous years (1985-2005)	TMDL

SOURCE: EPA (2010b); L. Linker, EPA, personal communication, 2011.

BOX 1-2
Forms of Atmospheric Nitrogen

Total oxidized reactive nitrogen, NO_y
$NO_y = NO + NO_2 + NO_3 + HNO_3 + N_2O_5 + HONO$
+ organic nitrates + particulate nitrates
Nitrogen oxides, NO_x
$NO_x = NO + NO_2$
Reduced inorganic nitrogen, NH_x
$NH_x = NH_3 + NH_4$
Unreactive nitrogen: N_2

compounds except N_2O) primarily results from combustion sources (see Box 1-2).

Atmospheric deposition of reduced inorganic nitrogen (NH_x; ammonia [NH_3] + aerosol ammonium [NH_4]; Box 1-2) primarily results from agricultural sources, such as manure. Sources internal to the watershed are primarily natural biological nitrogen fixation (e.g., soils) and cultivation-induced nitrogen fixation (e.g., soybeans).[2] For the Bay itself, the primary internal source is biological nitrogen fixation. Nitrogen that originates from sources internal and external to the watershed is delivered to the Bay waters by atmospheric deposition, direct discharges from wastewater treatment plants and stormwater systems, and groundwater and riverine inputs.

Once introduced into the watershed, the fate of nitrogen is dependent upon its source. A large fraction of the nitrogen from municipal and industrial wastewater point sources and urban runoff, which can be categorized either as a nonpoint source or regulated point source,[3] is rapidly trans-

[2]Nitrogen fixation is a natural process by which unreactive nitrogen (N_2) in the atmosphere is converted to biologically available ammonia by enzymatic reduction.

[3]The Clean Water Act (CWA) defines a point source of water pollution as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." Federal regulations require that all point sources meet discharge limitations provided for in National Pollutant Discharge Elimination System (NPDES) permits. More recently, stormwater runoff in urban areas meeting certain population density criteria or land use conditions has been defined as a regulated point source requiring an NPDES permit. Some urban and agricultural sources that are categorized as point sources under the CWA may be indistinguishable from unregulated nonpoint sources, both in terms of character and the management practices that may be effective in their control. The only difference is often size and whether a NPDES permit has been issued. To avoid confusion in this report, especially for readers who may

ported to the Bay. Of the nitrogen introduced into agricultural systems, most is used in the system and then lost to the atmosphere, discharged into an aquatic system, or stored in the soil. Less than 50 percent is actually incorporated into feed or food (Smil, 1999; Cassman et al., 2002). If nitrogen infiltrates into groundwater (e.g., from a septic system leach field or agricultural fertilizers), then it potentially could be stored for significant lengths of time (i.e., years to decades) before it is discharged to surface waters (Phillips and Lindsey, 2003; Lindsay et al., 2003; see Box 1-3).

Reactive nitrogen is lost from the watershed system by denitrification within the watershed and its waters and by export. Denitrification converts nitrate primarily to nitrogen gas (N_2), with smaller amounts of N_2O and NO produced. N_2 formation represents a conversion of reactive nitrogen to an unreactive nitrogen form and thus removes the nitrogen from interaction with the earth systems' processes for millions of years. N_2O and NO formation, however, represent the conversion of one type of reactive nitrogen to other types of reactive nitrogen, each with their own environmental impacts. The amount of NO formed by denitrification is small compared to the NO formed from fossil fuel combustion within the watershed. In contrast, denitrification forms the primary source of N_2O, a potent greenhouse gas, within the Bay and its watershed (Galloway et al., 2004, 2008). Overall, how much denitrification occurs in the Bay watershed remains the largest uncertainty of the nitrogen cycle.

Nitrogen is exported out of the watershed through three pathways: (1) atmospheric advection of the nitrogen emitted to the watershed's atmosphere, (2) hydrologic transport of nitrogen to the coastal ocean in the waters leaving the Bay, and (3) shipment from the watershed of nitrogen-containing commodities that are produced in the Bay (e.g., shellfish, fish) or its watershed (e.g., food, feed).

Estimates of Nitrogen Source Loads to the Bay

Approximately 400 million pounds (181 million kg) of nitrogen compounds emitted to the atmosphere are deposited on the Bay's watershed each year, with approximately 68 percent coming from NO_y and 32 percent from NH_x (R. Dennis, EPA, personal communication, 2011). Sources of atmospheric nitrogen are described in Box 1-4. Most of the deposited nitrogen is retained by forests or other vegetation and in other biological

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not be as familiar with federal regulatory programs, the terms "point" and "nonpoint" will be appropriately qualified as to origin, i.e., "municipal" and/or "industrial" point sources," "urban" and/or "agricultural" point or nonpoint sources. In many cases, it is expeditious to aggregate urban and agricultural point sources and nonpoint sources, in which case the terms "urban runoff" and "agricultural runoff" are used to incorporate the two but do not include discharges from municipal or industrial wastewater treatment facilities.

processes before it reaches the Bay. Of all the atmospheric nitrogen that is deposited on the watershed annually, the Watershed Model estimates that approximately 75 million pounds (34 million kg) actually reach the Bay's tidal waters, largely washed off impervious surfaces. Another 19 million pounds (8.6 million kg) are deposited directly on the Bay's tidal waters, for a total of approximately 94 million pounds (43 million kg) or 33 percent of the total nitrogen load to the Bay (CBP, 2010a; Figure 1-4). Of the nitrogen that enters the watershed, that which is not quickly discharged to the Bay or denitrified to N_2 is stored in the watershed in groundwater and can potentially be released to the Bay in the future (also called legacy nitrogen; see Box 1-3).

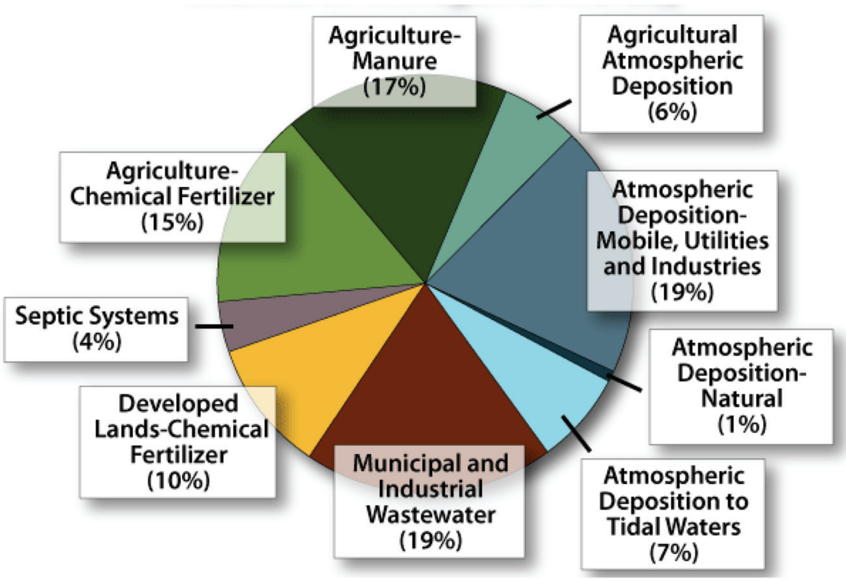


FIGURE 1-4 Sources of nitrogen to Chesapeake Bay.
NOTES: Based on model simulations using the Watershed Model Phase 4.3 and the Airshed Model, considering land use and pollution control measures in place as of 2007. The data reflects the average output when simulated over 14 years of hydrologic record and does not include loads from the ocean or tidal shoreline erosion. Atmospheric deposition loads are categorized by the source of the atmospheric nitrogen, except for the deposition directly to tidal waters, which includes all sources. For example, agricultural atmospheric deposition includes the atmospheric deposition that emanates from agricultural lands. Wastewater loads are based on measured discharges.
SOURCE: CBP (2010a).

BOX 1-3
Legacy Pollutants

Most nitrogen loads are contributed from large watershed areas and tend to be related to nitrogen applications used for land management (Heathwaite et al., 2000; Dale et al., 2010). Lag times between land-based BMP implementation and realization of nutrient reductions in the Bay are caused by the transport of nitrogen already present in groundwater. The lag time generally increases with stream order[1] or watershed size. Lindsay et al. (2003) estimated that groundwater residence times in the Chesapeake Bay range from zero to more than 50 years, with a median age of 10 years, depending upon the flowpath (Figure 1-5). Thus, the potential response times between land-based BMP implementation and significant resulting decreases in nutrient discharge from larger watersheds can vary widely based on watershed size, depth of water flowpaths, and relative contribution of groundwater to stream flow, which vary with physiographic provinces of the Bay Watershed. For instance, groundwater in the Coastal Plain contributes a larger proportion (>70 percent) of stream flow than does groundwater in the Appalachian Plateau and Mountain Provinces; therefore, nitrogen reductions from land-base BMPs in the Coastal Plain could be substantially masked for

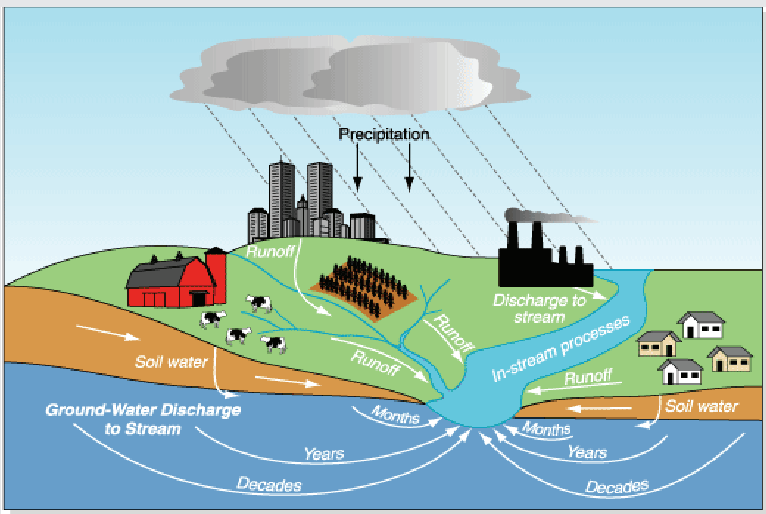
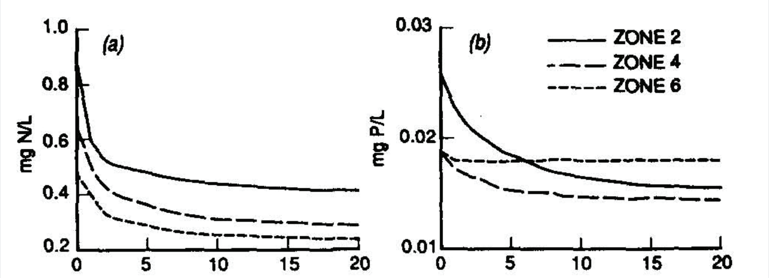


FIGURE 1-5 Age of groundwater draining to Chesapeake Bay.
SOURCE: Phillips and Lindsey (2003).

many years by the contributions of legacy groundwater nitrogen. Once delivered to the Bay, organic nitrogen in sediments can also create a lag time in water quality response, although organic nitrogen will be mineralized relatively quickly (with a half-life of a few years), after which legacy sediment nitrogen will not have a significant impact (Figure 1-6



Years Years

FIGURE 1-6 Modeled response of Bay water quality to an abrupt 50 percent reduction in all loadings to the Bay for Zone 2 (200-250 km from the mouth of the bay), Zone 4 (100-150 km), and Zone 6 (0-50km). *(a)* Surface total nitrogen, *(b)* Surface total phosphorus. These model runs do not consider the legacy effect of groundwater travel times on nitrogen concentrations, which can also be significant. Additionally, these simulations do not consider the effects of legacy phosphorus in watershed soils on loadings.
SOURCE: Cerco (1995).

Phosphorus from nonpoint and point sources can accumulate in soils and sediments, where it can remain sequestered and biologically inactive. Stored phosphorus in soil and sediments is referred to as *legacy* phosphorus. Phosphorus in Delmarva Peninsula soils has increased to levels nearly one order of magnitude greater than what is required for crop growth because of application of poultry litter (Buda et al., 2010). Accumulated phosphorus in the soil can remain for decades after phosphorus additions have ceased (Cox et al., 1981; Sharpley et al., 2009). Legacy phosphorus in stream and Bay sediments can be a source to the overlying water for a number of years after remedial actions have lowered the nutrient discharges. Legacy phosphorus can also be unpredictably released when hydrologic forces erode soils or resuspend sediments. These contributions often mask reductions in phosphorus

BOX 1-3 Continued

loads from BMP implementation. Watershed system structure can affect legacy phosphorus release rates with a slow release of phosphorus stored in soils and fluvial sediments and more rapid release along surface flowpaths where erosive and resuspension forces are stronger. Once sediments are delivered to the Bay, model estimates suggest that stored phosphorus can be a significant source for 5 to 10 years depending on the conditions in the overlying water and that overall response to an abrupt loading reduction reaches equilibrium after approximately 10 years (Figure 1-6; Cerco, 1995).

There are also legacy sediments in the Bay—sediments that have been deposited over many years. These solids compact over time and become less available for resuspension. Eventually they are buried by freshly deposited solids. To the extent that these processes take time, and that the legacy sediments participate in the quantity of solids that resuspend and settle, thereby contributing to the reduction in light penetration, there would also be a lag time associated with the response in bay water clarity to reductions in suspended solids delivered to the Bay.

[1]Stream order defines the size of a stream. First-order streams, also called headwater streams, are the smallest and generally form on steep slopes in the upper reaches of a watershed. As streams converge, they increase in size and order. In other words, as streams and watersheds get bigger, the path of rainwater through soils and geologic formations becomes more tortuous and, thus, longer (Gburek and Folmar, 1999; Lindsay et al., 2003).

Monitoring data supplemented with modeling in ungaged stream reaches showed an average annual nitrogen load of 338 million pounds (153 million kg) between 1990 and 2009 (see Figure 1-2). Phase 4.3 Watershed Model simulations using BMPs and point-source loading based on 2007 conditions estimated hat an average of 281 million pounds (127 million kg) of nitrogen were delivered annually to the Bay's tidal waters from all sources.[4] According to model estimates, the largest contributing sectors were atmospheric deposition from mobile and industrial sources (19 percent), municipal wastewater treatment plants and industrial facilities (19 percent), excess animal waste from agricultural areas (17 percent), and excess fertilizer from agricultural areas (15 percent) (Figure 1-4). Other

[4]For comparison, the CBP Watershed Model Phase 5.3 calculates that an average of 246 million pounds of nitrogen per year was delivered to the Bay based on 2009 land use scenarios when simulated over 21 years of hydrologic record (S. Ravi, CBPO, personal communication, 2011).

BOX 1-4
Sources of Atmospheric Nitrogen in the Chesapeake Bay Watershed

In 2002, poultry (including all poultry-related sources such as bedding or poultry houses, with the exception of manure), manure from all animals, and chemical fertilizer application were the major sources of reduced inorganic nitrogen (NH_x) deposited to the Bay watershed (Table 1-2). This deposition was from emission sources both within and outside of the watershed. By extrapolating model data from 2002, it was estimated that about 50 percent of the NH_x deposition resulted from emissions within the watershed, and about 50 percent resulted from emissions outside of the watershed, mostly from outside the airshed.

In 2002, mobile sources and power plants were the major sources of oxidized reactive nitrogen (NO_y) deposited to the watershed (Table 1-3). This deposition was from emission sources both within and outside of the watershed. By extrapolating model data from 1990 (Paerl et al., 2002), it was estimated that 38 percent of the NO_y deposition resulted from NO_x emissions within the watershed, and 62 percent resulted from NO_x emissions outside of the watershed, mostly within the airshed (Dennis, 1997; Paerl et al., 2002).

TABLE 1-2 Percentage of Total Reduced Nitrogen (NH_x) Deposition to the Chesapeake Bay Watershed and to the Chesapeake Bay by Source/Sector

Source/Sectors	Percent of Atm. Deposition to Watershed	Percent of Atm. Deposition to Bay
Poultry	22.0	22.5
Dairy	9.5	4.3
Beef	6.1	4.0
Swine	6.8	10.7
Other animals	2.2	1.7
Manure	21.1	16.6
Chemical fertilizer	14.4	16.1
On road mobile sources	9.8	14.2
Other non-agriculture	5.4	7.4
Canada	2.7	2.6
Total	100.0	100.1

BOX 1-4 Continued

TABLE 1-3 Percentage of Total Oxidized Reactive Nitrogen (NO_y) Deposition to the Chesapeake Bay Watershed and to the Chesapeake Bay by Source/Sector

Source/Sectors	Percent of Atm. Deposition to Watershed	Percent of Atm. Deposition to Bay
Power plants (EGUs)	25.5	23.0
Mobile sources (on road)	34.7	35.1
Industry	9.3	8.9
Off road; Construction; Marine	8.7	9.6
Residential and commercial	13.5	17.0
Other	8.2	6.5
Total	99.9	100.1

SOURCE: R. Dennis, EPA, personal communication, 2011.

significant sources include runoff from chemical fertilizers applied to urban/suburban lands, atmospheric nitrogen pollution derived from agricultural lands, and septic systems.

Phosphorus

Phosphorus occurs naturally in the soils and sediments of the Chesapeake Bay and its watershed, released slowly from mineral weathering and from decomposition of vegetation, with limited injection from the atmosphere. However, with growth in the human population and per-capita resource use, phosphorus has been introduced into the Bay watershed through the import of phosphorus fertilizer and of phosphorus-containing commodities, especially food and feed. According to CBP estimates, about 97 percent of the phosphorus now entering the watershed is from anthropogenic sources (CBP, 2010a; Figure 1-7).

Once introduced into the watershed for agriculture, phosphorus is either incorporated into agricultural products or lost to the environment during the food and feed production process. Unlike nitrogen, which can be converted to unreactive N_2 by denitrification, the only way to remove phosphorus from the system is through discharges to the coastal ocean or by export of phosphorus-containing commodities. With those two excep-

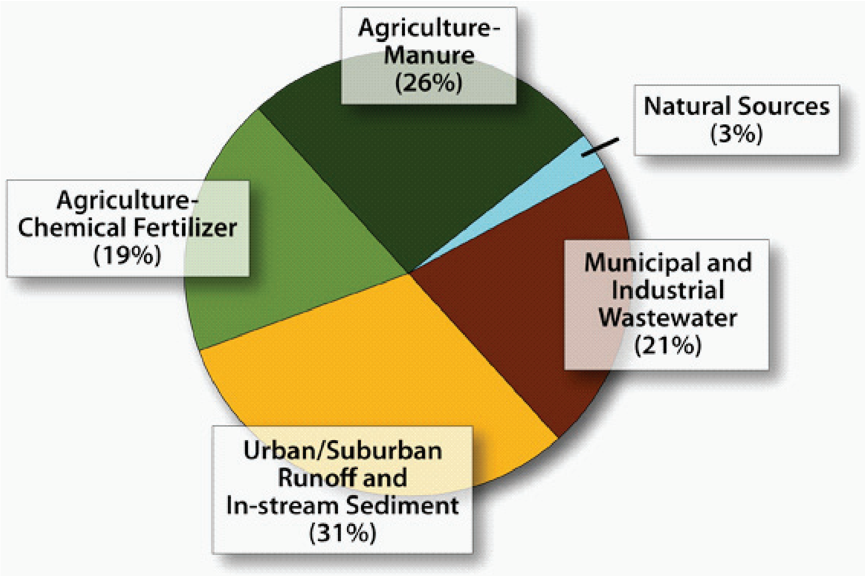


FIGURE 1-7 Sources of phosphorus to the Chesapeake Bay.
NOTES: Based on model simulations using the Watershed Model Phase 4.3, considering land use and pollution control measures in place as of 2007. The data reflects the average output when simulated over 14 years of hydrologic record. It does not include loads from the ocean or tidal shoreline erosion. Wastewater loads are based on measured discharges.
SOURCE: CBP (2010a).

tions, essentially all of the phosphorus introduced into the Bay watershed stays there. Because more phosphorus currently goes in than goes out, phosphorus is accumulating in the soils and sediments of the watershed and has the potential to be released to the Bay in the future (also called legacy phosphorus; see Box 1-3).

Estimates of Phosphorus Source Loads to the Bay

Between 1990 and 2009, the average annual phosphorus load based on direct measurements was estimated to be 21.0 million pounds (9.5 million kg) (Figure 1-2). Based on a 2007 source-loading scenario simulated over 14 years of hydrologic record using Watershed Model Version 4.3, an average of 18.2 million pounds per year (8.3 million kg/year) of phosphorus was estimated to be delivered to the Bay's tidal waters (Figure 1-7).[5] The largest contributing sectors included urban/suburban runoff (including in-stream sediment) (31 percent), excess animal waste from agricultural areas (26 percent), municipal wastewater treatment plants and industrial discharge (21 percent), and excess fertilizer from agricultural areas (19 percent).

Sediments

Sediment delivery to coastal waters by rivers and streams is a natural process created by the weathering of rocks and soil, but agricultural and urban/suburban activities have accelerated erosion and are now major contributors to sediment loads to the Bay (Figure 1-8). The average annual sediment load between 1990 and 2009 was estimated from direct measurements to be 8.0 billion pounds (3.6 billion kg) (CBP, 2010a). Based on a 2007 source-loading scenario simulated over 14 years of hydrologic record using Watershed Model Phase 4.3, an average of 9.6 billion pounds per year (4.4 billion kg) of sediment was estimated to be delivered to the Bay's tidal waters (CBP, 2010a).[6] Agricultural areas contribute approximately 60 percent of the total sediment load to the Bay, while "natural sources" (as classified by the CBP), such as forests, contribute 21 percent. Natural sources may include anthropogenic disturbances such as roads. Approximately 19 percent originates from urban and suburban runoff and sediment in stream channels from deposits that occurred during the conversion of forested areas to developed lands. Large reservoirs of sediment also exist behind dams in the watershed, such as the Conowingo Dam on the Susquehanna River. These dams currently trap a large quantity of sediment mobilized in the watershed, but sediment loads would increase substantially if, in the future, large dams are allowed to reach sediment storage capacity (Langland and Cronin, 2003).

Effects of Excess Nutrient and Sediment Loads to Coastal Waters

As with many estuaries throughout the world, one of the primary water quality challenges facing the Chesapeake Bay is cultural eutrophication—a

[5]For comparison, the CBP Watershed Model Phase 5.3 calculates that an average of 16.5 million pounds per year (7.5 million kg/yr) of phosphorus was delivered to the Bay based on 2009 land use scenarios when simulated over 21 years of hydrologic record (S. Ravi, CBPO, personal communication, 2011).

[6]For comparison, the CBP Watershed Model Phase 5.3 calculates that an average of 8.0 billion pounds per year (3.6 billion kg/yr) of sediment was delivered to the Bay based on 2009 land use scenarios when simulated over 21 years of hydrologic record (S. Ravi, CBPO, personal communication, 2011).

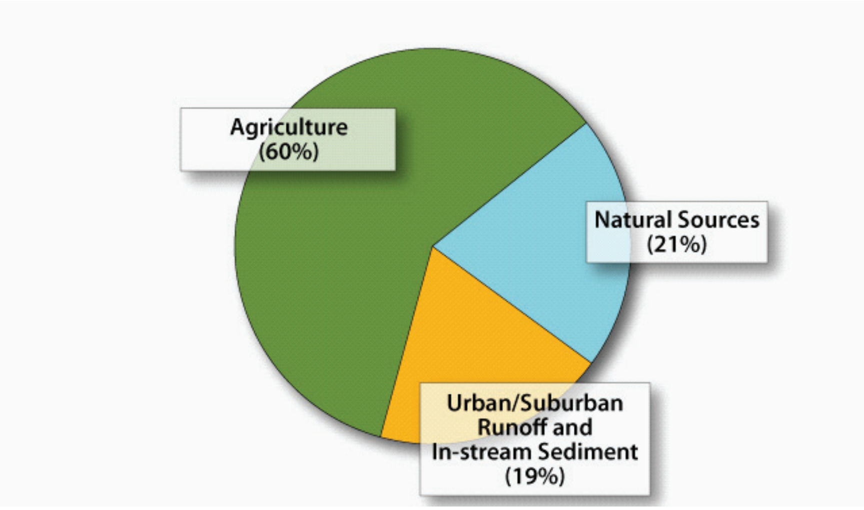


FIGURE 1-8 Sources of sediment to the Chesapeake Bay.
NOTES: The percentages are the currently available estimates and are based on model simulations using the Watershed Model Phase 4.3, considering land use and pollution control measures in place as of 2007. The data reflects the average output when simulated over 14 years of hydrologic record. Does not include loads from the ocean or tidal shoreline erosion.
SOURCE: CBP (2010a).

process by which human activities in the watershed and airshed lead to increased nutrient influxes to the water body, producing excess levels of nutrients that stimulate undesirable blooms of phytoplankton and macroalgae (Boesch et al., 2001; Cloern, 2001; Kemp et al., 2005; Bricker et al., 2007). Such blooms harm estuarine ecosystems in several ways. They reduce water clarity and block sunlight, reducing the size, quality, and viability of underwater grasses (also known as submerged aquatic vegetation [SAV]) and other aquatic habitats. Several bloom-forming phytoplankton species also produce toxins that can negatively affect the structure and function of aquatic food webs (Anderson et al., 2002) and pose health threats to wildlife and humans (Havens, 2008).

As phytoplankton and macroalgae die and decompose, dissolved oxygen is removed from the water column and bottom sediments. When the Bay is more strongly stratified in the summer, its bottom waters are not adequately replenished with dissolved oxygen to offset the effects of microbial decay under nutrient-enriched conditions. Because an adequate supply of dissolved oxygen is essential to the survival of aquatic organisms, such reductions can have substantial impacts on the local fauna. Fish and other highly mobile organisms can often disperse from areas with reduced dissolved oxygen levels, but they and the less mobile benthic infauna or early life stages of fish and shellfish can be physiologically stressed or killed by lengthy exposures to reduced dissolved oxygen that reaches hypoxic (< 2.0 mg/L) or anoxic (0 mg/L) levels (Gray et al., 2002).

Although phytoplankton and macroalgae require about 20 different nutrients and minerals to survive and reproduce (Reynolds, 2006), the macro-nutrients nitrogen and phosphorus tend to be the most important factors driving the eutrophication process in surface water bodies (NRC, 2000). In pristine environments the availability of nitrogen and/or phosphorus is usually low enough to limit algal growth rates. By adding large amounts of biologically available nitrogen or phosphorus to surface waters, human activities can reduce or eliminate these nutrient limitations and stimulate bloom development.

Nutrient loadings from nonpoint and point sources have resulted in hypoxic conditions in many of the world's vital water bodies (Rabalais et al., 2009). Diaz and Rosenberg (1995, 2008) note that no other environmental variable of such high ecological importance to global estuarine ecosystems has been altered so drastically in such a short period of time. In the Chesapeake Bay, data show that average volumes of hypoxic waters at mid-summer almost doubled from the time period 1950-1985 (an average of 4.5 km^3) to recent years, 1986-2007 (an average of more than 8 km^3) (Hagy et al., 2004; Rabalais et al., 2009). Such low levels of oxygen can lead to exclusion of fish and other biota from the water column (Courtant and Benson, 1990), and loss of prey biomass as a result of hypoxia can have extensive effects on fisheries (Diaz and Rosenberg, 2008).

Excess amounts of sediment in the water can prevent the attainment of water clarity criteria. Similar to the effects of excess planktonic algae, clay and silt particles suspended in the water column block sunlight from reaching underwater grasses , resulting in reduced extent of these productive aquatic meadows. Reduced extent or elimination of underwater grasses can affect juvenile fish, blue crabs, and other aquatic life needing the vegetation for shelter to survive. Nutrients and chemical contaminants can bind with sediments, allowing the pollutants to spread throughout the Bay and its local waterways. In addition, oysters and other bottom-dwelling species can lose necessary hard substrates for setting or be smothered when excess sediment settles to the bottom.

Based on these collective impacts, the Bay jurisdictions (i.e., the six states and the District of Columbia) have been charged with implementing restoration activities to reduce pollutant loadings to levels believed necessary to improve the health of the Chesapeake Bay ecosystem.

HISTORY OF CHESAPEAKE BAY PROGRAM RESTORATION EFFORTS: 1983-2008

Since its inception in 1983, the CBP has worked to understand and address the causes and effects of excess nitrogen, phosphorus, and sediment loadings to the Bay. Critical elements of the evolution of the CBP are outlined below and include: (1) developing measurable restoration and protection goals for the Bay's living resources and habitats, and identifying nitrogen, phosphorus, and sediment loading reduction goals necessary to obtain and sustain living resource goals; (2) adopting agreements among participating states and federal agencies to meet load reduction goals; (3) implementing efforts to meet agreements; and (4) measuring and reporting of results to date.

Development of Measurable Restoration and Protection Goals

The CBP is recognized internationally as having developed rigorous, research-based, natural resource goals and the numeric water quality and sediment targets needed to support those goals. The CBP has developed measurable goals for critical natural resources in the Bay, including underwater grasses, oysters, benthic organisms, and several fish species (Table 1-4). Although the CBP has developed many resource goals, this report will focus on those related to water quality targets and nutrient and sediment loadings.

Extensive research and monitoring have resulted in defined water quality targets to meet and maintain the natural resource goals. These goals have been revised and refined as additional information and data become available but are generally based on regulatory standards (e.g., dissolved oxygen criteria to meet the designated use), modeled cause-and-effect relationships (e.g., chlorophyll *a* concentration goals to meet water clarity goals), or historic values (e.g., underwater grass acreages representing the documented acreage found from the 1930s to present).

In 2003, the CBP established nitrogen and phosphorus cap loads for each major river basin and jurisdiction based on CBP model projections of attainment of dissolved oxygen water quality criteria. The CBP set long-term (10-year) average nitrogen and phosphorus load targets for the Bay at 175 and 12.8 million pounds (79 and 5.8 million kg) per year, respectively. The attainment of these cap loads was expected to eliminate summer hypoxia in the Bay's deeper waters and excessive algal blooms throughout the bay (EPA, 2003). The following section discusses these goals in more detail and also highlights agreements between the CBP partners.

TABLE 1-4. Chesapeake Bay Water Quality and Bay Resource Goals and Status as of 2009

Indicator	Metric	Goal	2008-2009 Status
Bay Ambient Water Quality			
Dissolved oxygen concentration	Varies by fish or shellfish species, season, and location in the Bay. Generally, higher levels of oxygen are needed in shallow waters during the spring, when aquatic animals spawn.	100% of the Bay and its tidal tributaries to meet applicable standards for dissolved oxygen	12% of the Bay and its tidal tributaries met standards for dissolved oxygen in 2007-2009
Water clarity	Adequate light to support underwater grasses during the growing season. Varies by location and depth.	100% of the Bay to meet guidelines for water clarity	26% of the Bay's tidal waters met or exceeded guidelines in 2009
Chlorophyll-*a* concentration	Varies by location and depth, and linked to water clarity goal	100% of the Bay's tidal waters to be below certain threshold concentrations of chlorophyll a that are acceptable to underwater grasses	29% of the Bay's tidal waters met or exceeded guidelines in 2009
Bay Resources			
Bay bottom habitat	Index of Biotic Integrity (IBI) is used to rate the health of bottom habitats on a scale of 1 (low) to 5 (high)	All IBI scores for Bay bottom habitat to be at least 3	56% of the Bay bottom habitats had an IBI score of at least 3 in 2009

Underwater grasses	Acres of underwater grasses	185,000 acres (74,900 hectares [ha]) of underwater grasses in the Bay by 2010, which represents the documented acreage found from the 1930s to present	85,899 acres (34,800 ha) in 2009, 46% of the Bay-wide goal
Phytoplankton	IBI is used to rate the health of phytoplankton on a scale of 1 (low) to 5 (high)	All IBI scores for phytoplankton health to be at least 3	54% of the Bay's waters met the phytoplankton goal in 2009
Oysters	Oyster biomass	Achieve at least a 10-fold increase in native oysters in the Bay by 2010, based on 1994 levels, which would equal 31.6 billion grams of oyster biomass	10% of goal achieved in 2008
Blue crab	Number of blue crabs in the bay	200 million blue crabs that are at least 1 year old in the Bay	112% of goal achieved in 2009
Striped bass	Female spawning stock biomass	Spawning stock biomass equal to the averages from 1960-1971, which is 82.7 million pounds (37.5 million kg) of the females	148% of goal achieved in 2008
American shad	Spawning stock biomass in major river systems	2 million fish in the Susquehanna River stock each year	27% of goal achieved in 2009
Menhaden	Percentage of cast and seine net hauls in which juvenile menhaden are caught	No goal defined, used to track trends	22% positive hauls in 2009

SOURCE: CBP (2010a).

Adoption of Agreements among Participating Jurisdictions and Government Agencies to Meet Load Reduction Goals (1983-2008)

In 1983, the governors of Maryland, Virginia, and Pennsylvania; the mayor of the District of Columbia; the EPA; and the chair of the Chesapeake Bay Commission, later named the Chesapeake Executive Council, signed the Chesapeake Bay Agreement, a pledge aimed at restoring the Bay and its ecosystem (EPA, 1983a). In 1987, the Executive Council signed a follow-up agreement to "reduce and control point and nonpoint sources of pollution to attain the water quality conditions necessary to support the living resources of the bay" and "plan for and manage the adverse environmental effects of human population growth and land development in the Chesapeake Bay watershed." In this agreement, the Executive Council set a specific goal of reducing the amount of nitrogen and phosphorus entering the Bay's main stem by at least 40 percent by the year 2000. The 40 percent nutrient reduction goal was to be measured against 1985 point and nonpoint source loads in an average rainfall year (CBP, 1987). The CBP interpreted the goal to mean a 40 percent reduction in "controllable" nutrients, which did not include atmospheric deposition and the contributions of non-signatory states (Ernst, 2003).

The 1987 agreement was amended in 1992 to include a tributary-specific focus aimed at rehabilitating the majority of fish spawning grounds and essential habitat, which are located in the tributaries (CBP, 1992). In 1993, the CBP committed to develop jurisdiction-specific tributary strategies to achieve the water quality requirements necessary to restore living resources in both the Bay's main stem and its tributaries and to attain the 40 percent nutrient reduction goal. The amendment also highlighted the difficulty of achieving the goals set by the Executive Council, noting that "achieving a 40 percent nutrient reduction goal, in at least some cases, challenges the limits of current point and nonpoint source control technologies" (CBP, 1992). The CBP admitted that mustering the political will to reduce nutrient loading and control population growth and urban sprawl across the watershed was a huge challenge.

By 2000, it was clear that the promised 40 percent reduction of the controllable loads of nitrogen and phosphorus had not been attained. However, during the years since the 1987 agreement, the landscape of water pollution management under the Clean Water Act (CWA) had shifted toward more quantitative assessments of water quality impairments and more quantitative management action. Under Section 303(d) of the CWA, states and tribes are required to identify and maintain lists of water bodies that do not meet adopted water quality standards (defined as nonattainment) and to assign priorities for the development of TMDLs. The TMDLs would identify the maximum amount of each pollutant from point and nonpoint sources that the water bodies could receive and still comply with water quality standards, including a margin of safety. Therefore, the states with jurisdiction over Bay segments that were not attaining dissolved oxygen and other numeric standards and criteria could be required to develop TMDLs to control pollutant loads consistent with their water quality standards.

The 2000 Chesapeake Bay Agreement provided an alternative to development of a TMDL, consistent with EPA regulations that allowed under TMDL priority "Category 4b" that a TMDL is not needed if other pollution control requirements are expected to result in the attainment of an applicable water quality standard in a reasonable period of time. The 2000 Agreement, signed again by the CBP partners, not yet including New York, West Virginia, or Delaware, acknowledged the difficulty of the management tasks facing them, including the management of nutrients. In the preamble, a concession to this difficulty stated,

> While the individual and collective accomplishments of our efforts have been significant, even greater effort will be required to address the enormous challenges that lie ahead. Increased population and development within the watershed have created ever-greater challenges for us in the Bay's restoration. These challenges are further complicated by the dynamic nature of the Bay and the ever-changing global ecosystem with which it interacts.

In the 2000 agreement, the CBP partners recommitted to achieving the 40 percent nutrient reduction goal set in 1987 until specific nitrogen and phosphorus cap loads for each major river basin and jurisdiction could be developed. The Bay partners also committed to correcting the Bay's nutrient- and sediment-related problems by 2010. The 2000 Agreement also reiterated the goal of improving water quality in the Bay and its tributaries "so that these waters may be removed from the impaired waters list prior to the time when regulatory mechanisms under Section 303(d) of the Clean Water Act would be applied" (CBP, 2000).

The nitrogen and phosphorus cap loads were determined in 2003 (EPA, 2003), as discussed in the previous section, and the CBP jurisdictions developed new tributary-specific strategies to achieve the cap loads. The Chesapeake Bay Tributary Strategies, released during 2004-2006, outlined partner-specific implementation activities within each tributary necessary to remove the Bay and tributaries from the impaired waters list (summarized in EPA, 2010a). In 2007, the CBP re-evaluated the nutrient and sediment cap loads and found that sufficient progress had not been made toward improving water quality (CBP, 2007a). These findings led to the development of the two-year milestone strategy, the federal Chesapeake Bay TMDL, and watershed implementation plans, described later in this chapter.

Implementation Efforts to Meet Agreements (1987-2008)

Between 1987 and 2008, the CBP, in coordination with its federal, state, and local partners, developed and implemented a set of management strategies aimed at reducing the amount of nutrients entering the Bay. Overall, the 2009 *Bay Barometer* stated that the CBP partnership has implemented 64 percent of the needed actions to reduce pollution, restore habitats, manage fisheries, protect watersheds, and foster stewardship (CBP, 2010a).

Nutrient and sediment management strategies can be divided into four main categories: activities to preserve and restore natural lands, activities to control pollution from agricultural lands, activities to control pollution in urban and suburban areas, and activities to control atmospheric pollution. Progress made in each of these categories is detailed below.

Activities to Preserve and Restore Natural Lands

Because of growing population and land development within the Bay watershed, the CBP focused on land preservation and protection in the thousands of small watersheds within the Bay region. Managing the effects of growth was especially critical because of the vast amount of land that drains into the relatively shallow Bay and the consequences of development and other uses of that land. The CBP strategy relied on three approaches: planting and reforesting streamside buffers, developing plans to better manage existing conditions and new development, and preserving lands and open space (CBP, 2010a).

In 2000, the CBP set a goal of restoring 2,010 miles of streamside forest buffers by 2010 (CBP, 2000), which was achieved 8 years ahead of schedule in 2002 (CBP, 2006). In 2003, the CBP expanded its goal, committing to restore 10,000 miles of riparian forest buffers by 2010 (CBP, 2006). As of August 2008, approximately 6,172 miles of forest buffers had been restored in Maryland, Pennsylvania, and the District of Columbia (CBP, 2010a). In addition, the 2007 Forest Conservation Initiative committed the CBP to accelerating forest restoration and conservation beyond 2010; the CBP agreed to restore 900 miles of forest buffer per year until 70 percent of all streambanks in the watershed have been buffered (CBP, 2007b).

The CBP also set a goal to develop and implement watershed management plans for two-thirds of the total watershed acreage in Maryland, Pennsylvania, Virginia, and the District of Columbia, or 22.7 million acres (9.2 million ha), by 2010. By the end of 2007, the cumulative number of acres in the watershed with plans was 13 million acres (5.3 million ha), putting the CBP at 57 percent of its goal with 3 years remaining (CBP, 2010a).[7]

[7]See also http:www.chesapeakebay.net/watershedmanagementplans.aspx.

The CBP has permanently preserved more than 7 million acres (2.8 million ha) in the states of Maryland, Pennsylvania, Virginia, and the District of Columbia, representing more than 20 percent of the land area in the Chesapeake Bay watershed (CBP, 2010a). In December 2007, the CBP set a goal to preserve an additional 695,000 acres (281,000 ha) of land by 2020 (CBP, 2007b).

Activities to Control Pollution from Agricultural Lands

The process undertaken by the CBP to reduce the amount of pollution entering the watershed has focused on implementing nutrient reduction practices on agricultural lands, which comprise about 22 percent of the land within the watershed (EPA, 2010a). The relative cost-effectiveness of agricultural nutrient reduction strategies led the CBP to target agricultural best management practices (BMPs) for more than half of the remaining nutrient reductions needed to meet restoration goals (CBP, 2010b).

Agricultural land uses, because of their reliance on nutrient-containing fertilizers and manures, constitute a significant portion of the nonpoint sources of nutrient loads to the Bay (Figures 1-4, 1-7, and 1-8). Agricultural land uses have a long history of BMPs aimed at conserving and protecting the soils on which agricultural commodities are produced and the water resources upon which the production of those commodities rely. These BMPs include activities such as the development and implementation of farm-specific nutrient management plans, the establishment and maintenance of vegetated buffers between agricultural fields and surface water bodies such as rivers, lakes, and streams, and implementation of conservation tillage programs. Many agricultural BMPs are non-structural and need to be practiced every year.

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) primarily develops the technical standards for these agricultural BMPs and provides some technical and financial assistance to farmers who wish to implement them. The USDA Farm Service Agency (FSA) administers additional funding to support conservation programs. From 2007 to 2010, funding from the NRCS and the FSA for the Environmental Quality Incentives Program (EQIP), the Wetlands Reserve Program (WRP), the Conservation Reserve Program (CRP), and the Wildlife Habitat Improvement Program (WHIP) in the Bay watershed totaled approximately $327 million (J. Winters, EPA, personal communication, 2010), which suggests that BMPs were established on significant agricultural acreage within the six Bay states. Five of the Bay states (Delaware, Maryland, Pennsylvania, Virginia, and West Virginia) have also authorized state-funded agricultural BMP cost-share programs. Despite significant investments in agricultural nutrient and sediment control practices, limited peer reviewed studies are available to rigorously document the water quality improvements from these practices at a watershed scale (see also Chapter 2).

Activities to Control Pollution in Urban and Suburban Areas

Structural BMPs designed to reduce nutrient loading from the watershed's urban and suburban areas have seen mixed success, in part because of the need to offset the effects of new growth. The CBP has had significant success in decreasing the amount of nutrients discharged from municipal and industrial wastewater treatment plants (WWTPs). More stringent permitting requirements, put in place in 2005, required the installation of a new generation of nutrient removal technology to further reduce nitrogen and phosphorus discharge. WWTP upgrades have accounted for a large portion of the estimated nutrient reductions in the watershed. As of 2009, 78 percent of the CBP's wastewater nitrogen reduction goals and 99 percent of its wastewater phosphorus reduction goals have been met (CBP, 2010a). Although the amount of nutrients discharged from WWTPs accounted for a large portion of the estimated nutrient reductions in the watershed, the watershed population continues to grow and with it so does the amount of wastewater to be treated (CBP, 2007a).

The CBP has had less success in addressing and limiting stormwater discharge from urban and suburban developed lands. The rapid rate of population growth and related residential and commercial development combined with the high cost and relatively low nutrient removal efficiencies of land-based BMPs have left the urban/suburban stormwater sector as the only one in the Bay watershed with still-increasing pollutant loads in the year 2009. Thus, "progress" can be deemed negative. Model estimates suggest that from 1985 to 2009, nitrogen loads from urban/suburban sectors (not including wastewater discharges) increased by 3 percent, phosphorus by 7 percent, and sediment by 4 percent (EPA, 2010a).

Many strategies have been proposed to promote infiltration and reduce the nutrient and sediment loads in urban and suburban areas, including low impact development (LID), alternative stormwater management techniques (e.g., narrower streets, use of pervious materials for driveways, rain gardens, sunken medians), higher density development with less reliance upon septic systems, and greater open space conservation (Boesch and Greer, 2003; NRC, 2008). BMP technologies for developed land are typically structural approaches applied to multiple point locations or across the landscape to remove dilute pollution distributed over many small source or catchment areas. This treatment is much less efficient than treatment of concentrated municipal and industrial discharges and, as a result, is usually much more costly per pound of pollutant removed. However, most urban BMPs are expected to perform for many years without major maintenance costs. Stormwater management practices are most effective when included in planning for new development. LID retrofits can also be introduced into existing developed areas, although land costs and availability and BMP installation present significant challenges. Unlike agricultural practices, urban BMPs are often required under state regulations or local permits and are rarely cost-shared. As with agricultural practices, limited information exists to reliably document the performance and long-term cost-effectiveness of urban BMPs, particularly at a watershed scale.

Activities to Control Atmospheric Pollution

The atmosphere is a significant source of nitrogen to the Bay and its watershed because of the deposition of oxidized reactive nitrogen (NO_y) and reduced nitrogen (NH_x) resulting from NO_x and NH_3 emissions in the Bay's airshed. The airshed for NO_y and NH_x is significantly larger than the watershed and extends west to the Ohio Valley and south to South Carolina (Figure 1-9).

The CBP has benefited from the designation of NO_2 as a regulated criteria pollutant by the EPA in 1970 and has therefore been a target for NO_x emission decreases for more than forty years. These actions have led to reductions in the deposition of nitrogen oxides to the Chesapeake Bay and its watershed based on national air pollution control efforts. More specifically, the Clean Air Act of 1970 and the Clean Air Act Amendments of 1990 have resulted in significant decreases in the emissions of NO_x in the United States. For example, in 1985, NO_x emissions were 16 billion pounds nitrogen per year (N/yr; 7.1 teragrams [Tg] N/yr). By 2008, they had decreased to 9.9 billion pounds N/yr (4.5 Tg N/yr), even though the U.S. population had increased by approximately 30 percent during the same period. As a consequence, the per capita NO_x emissions in 2008 were 16.5 tons (15 metric tons) N/yr, in contrast to 33 tons (30 metric tons) N/yr in 1985.

This decrease in national NO_x emissions has resulted in a decrease in NO_y deposition to the Bay and its watershed (Figure 1-10). An equivalent program for ammonia has not been implemented because the EPA has not listed ammonia as a criteria pollutant. As a consequence, NH_x deposition increased between 1994 and 2009, as illustrated in Figure 1-11. As of 2009, the CBP had met less than 10 percent of its total air deposition reduction implementation goal (CBP, 2010a).

Results to Date

The CBP monitors changes in nitrogen, phosphorus, and sediment concentrations and loadings to the Bay and observed changes in the Bay's

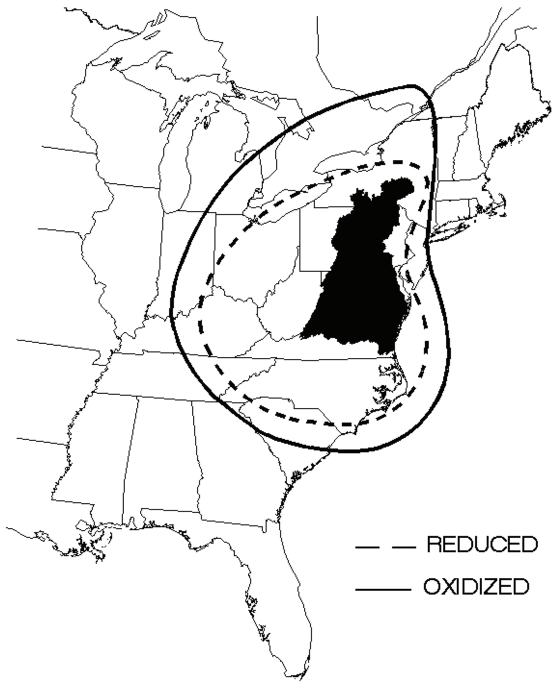
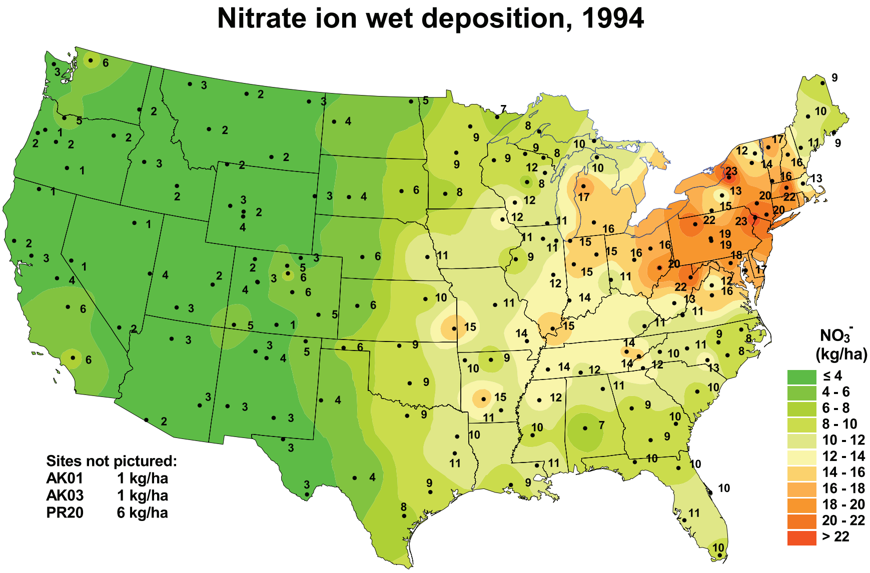


FIGURE 1-9 Chesapeake Bay watershed (shaded area) and reduced and oxidized nitrogen airshed.
SOURCE: EPA (2010a).

water quality and living resources and annually reports them in the *Bay Barometer* (CBP, 2009a, 2010a). The data are derived from the CBP's monitoring program to support assessment and evaluation of progress toward achieving Bay recovery. These data are also supplemented with modeling results to clarify trends amidst hydrologic variability.

Nutrient and Sediment Loading

From 1990 to 2009, the average annual nitrogen load reaching the Bay was estimated (based largely on direct measurements) to be 338 million pounds (153 million kg), which is 163 million pounds (74 million kg) higher than the 10-year average load target established in 2003 (Figure 1-2; EPA, 2003). The 1990-2009 average annual phosphorus load (also based on direct measurements) was estimated to be 21.0 million pounds (9.5 million kg), which is 8.2 million pounds (3.7 million kg) higher than the 10-year average load target (Figure 1-2). The 1990-2009 average annual sediment load was estimated from direct measurements to be 8.0 billion



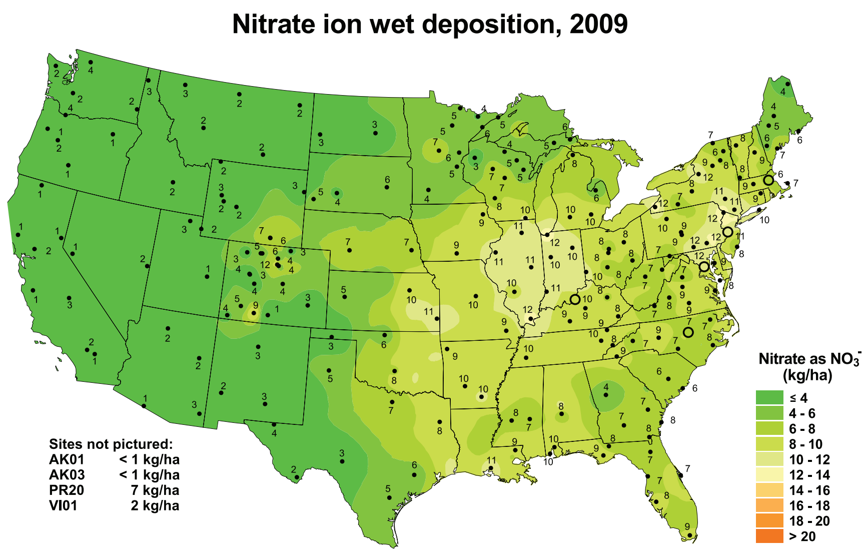


FIGURE 1-10 Nitrate ion wet deposition, 1994 and 2009.
SOURCE: National Atmospheric Deposition Program/National Trend Network. Available at http://nadp.uiuc.edu, accessed December 2010.

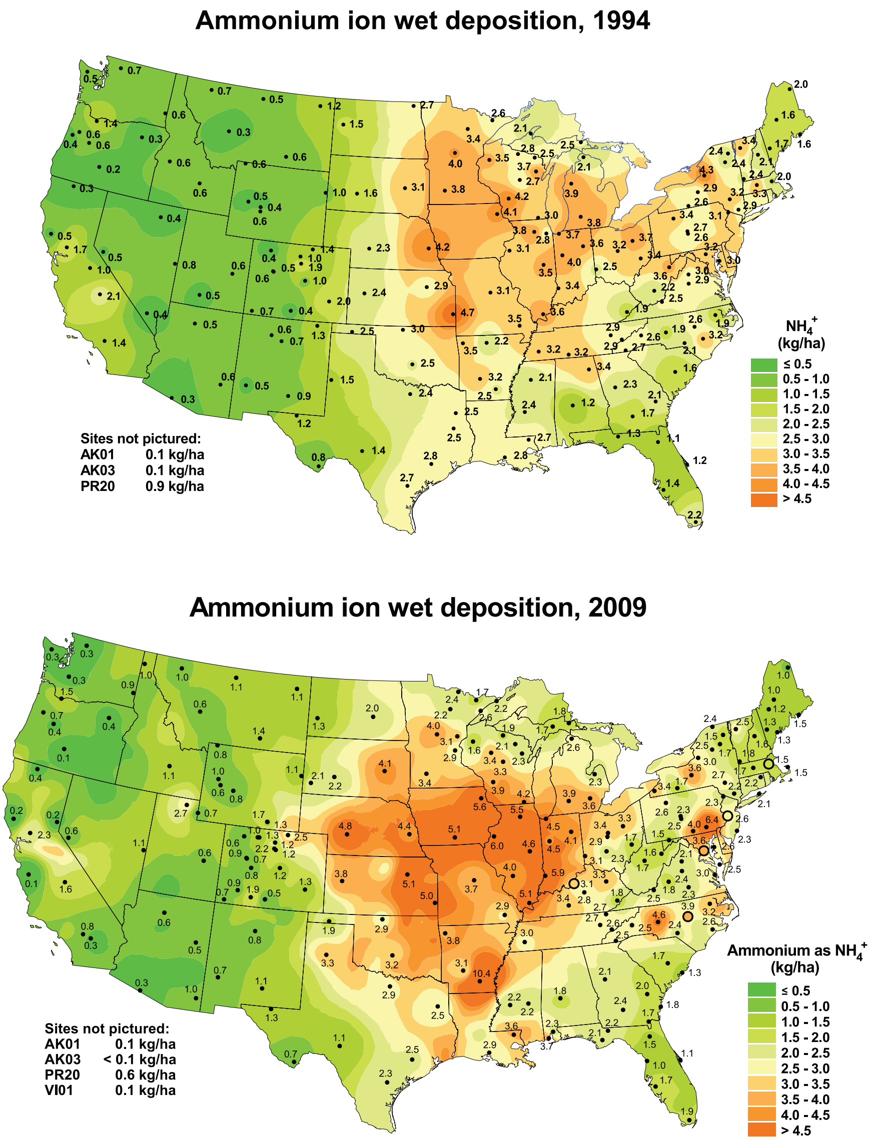


FIGURE 1-11 Ammonium ion wet deposition, 1994 and 2009.
SOURCE: National Atmospheric Deposition Program/National Trend Network. Available at http://nadp.uiuc.edu, accessed December 2010.

pounds (3.6 billion kg) (CBP, 2010a), or 1.55 billion pounds (700 million kg) higher than the TMDL (EPA, 2010a).[8] River flow strongly influences the nitrogen, phosphorus, and sediment loads to the Bay, sometimes confounding trends (CBP, 2010a).

Hirsch et al. (2010) presented trend analyses for nitrogen and phosphorus based on 31 years of monitoring data in the 9 large tributaries to the Chesapeake Bay. Surface water concentrations were analyzed using weighted regressions to flow-normalize flux measurements. Over the period of record, greater than 1 percent per year decreases in phosphorus and nitrogen (nitrate plus nitrite) flux were observed for the Patuxent River site (see Figure 1-12a), which is located downstream from wastewater treatment plants that were upgraded starting in the late 1980s. Since 2000, four sites (Patuxent, Potomac, Pamunkey, and Appomatox) showed greater than 1 percent per year decreases in nitrogen flux and only one site (Potomac) showed a similar decrease in phosphorus. Since 2000, greater than 1 percent increases per year in nitrogen and phosphorus flux were observed in two sites (James, Choptank) and five sites (James, Choptank, Susquehanna, Rappahannock, Pamunkey), respectively. Hirsch et al. (2010) analyzed the Choptank River trends in detail and observed that the steeper increase over time in low-flow stream concentrations (see Figure 1-12b) suggest that much of the increase in nitrogen results from increasing nitrate and nitrite in groundwater.

Average nutrient and sediment loads to the Chesapeake Bay from the Phase 5.3 Watershed Model (Figure 1-13a,b,c; Appendix A) show appreciable reductions between 1985 and 2009 when the land use scenarios for each year are modeled over 21 years of climate and hydrologic data, thereby controlling key parameters that affect nutrient and sediment loads. However, the model simulations show that significant reductions are still needed to meet the CBP goals. According to the model, BMPs implemented between 1985 and 2009 accomplished 62 percent of the nitrogen goal, 66 percent of the phosphorus goal, and 49 percent of the sediment goal, based on the TMDL.

Condition of the Bay's Resources

Despite expenditures of about $15 billion for restoration activities, reports of record-sized hypoxia zones in 2003 and 2005 raised public concerns about whether progress was really being made in the Chesapeake Bay (Boesch et al., 2007). The *Bay Barometer* (CBP, 2010a) reported: "Although there were improvements in some areas of the Bay's health in

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[8] The CBP did not set sediment-specific load targets in 2003 because of an incomplete understanding of sediment sources and their impacts to the Bay (EPA, 2003).

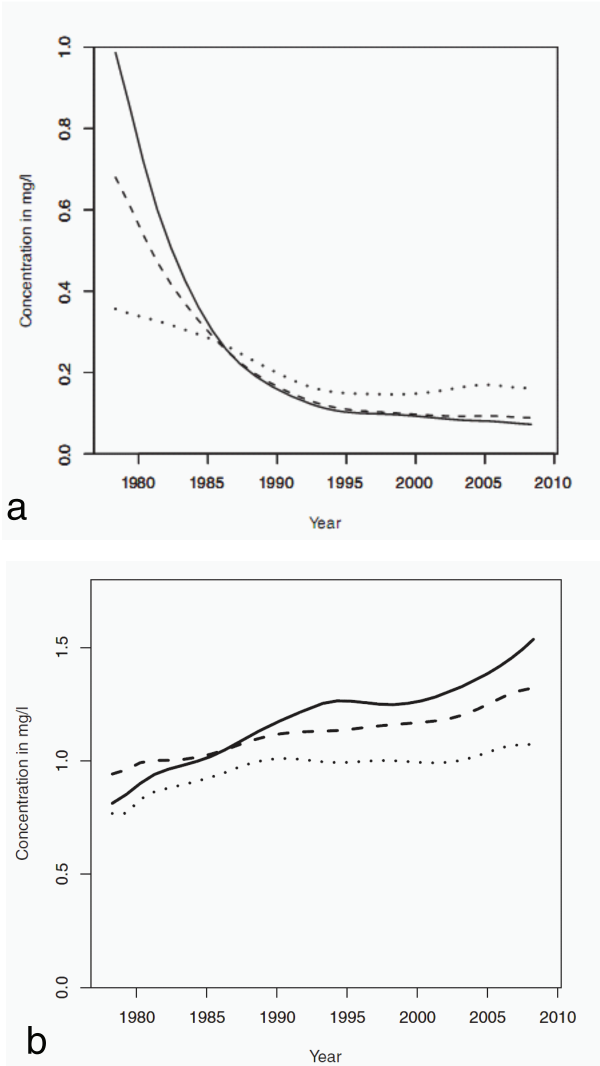


FIGURE 1-12 a) Estimated concentration of total phosphorus on May 1 each year on the Patuxent River near Bowie, Maryland, evaluated for discharge values of 180 cubic feet per second (cfs; or 5 m3/sec; solid), 320 cfs (9 m3/sec; dashed), and 1100 cfs (30 m3/sec; dotted) based on weighted regressions of monitoring data. b) Estimated concentration of dissolved nitrate plus nitrite on April 1 of each year in the Choptank River near Greensboro, Maryland, evaluated for discharge values of 53 cfs (1.5 m3/sec; solid line), 250 cfs (7 m3/sec; dashed line), and 490 cfs (14 m3/sec; dotted line).
SOURCE: Hirsch et al. (2010).

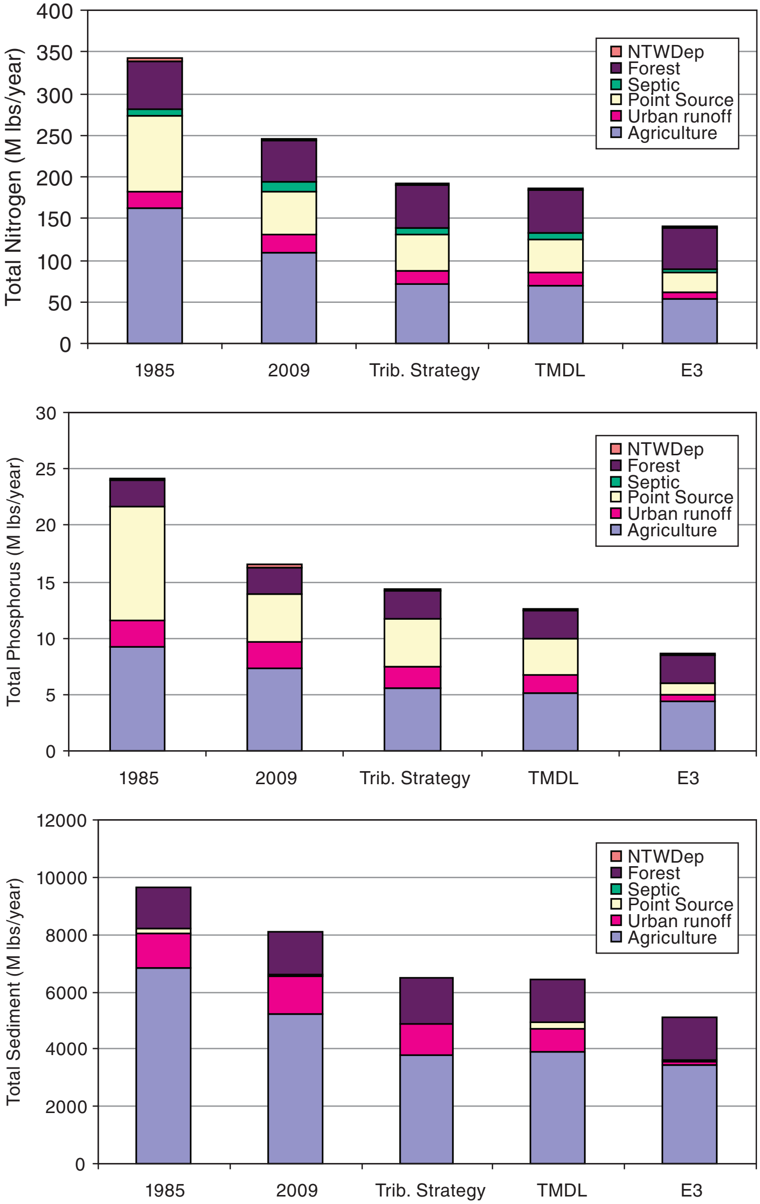
2009, the ecosystem remains in poor condition." The overall health of the Bay averaged 45 percent based on goals for water quality, habitats and lower food web, and fish and shellfish abundance, which represents a 6 percentage point improvement from 2008. Only 12 percent of the Bay and its tidal tributaries met applicable water quality criteria for dissolved oxygen between 2007-2009, a decrease of 5 percentage points from 2006-2008. An estimated 26 percent of tidal waters met or exceeded guidelines for water clarity, a 12 percentage point increase from 2008. Finally, underwater grasses covered 9,000 more acres (3,600 ha) of the Bay's shallows for a total of 85,900 acres (34,800 ha), which equals 46 percent of the Bay-wide goal (CBP, 2010a; Table 1-2).

Some improvements were noted. The index for the health of the Bay's bottom-dwelling species reached a record high of 56 percent of the goal, improving by approximately 15 percentage points Bay-wide. The adult blue crab population increased to 223 million in 2009, its highest level since 1993 (CBP, 2010a). The 2010 Bay-Wide Blue Crab Winter Dredge Survey indicated that blue crab populations continued to increase to an estimated 658 million, the highest population since 1997, as a result of recent multi-jurisdiction restrictions on harvests of female crab (MD DNR, 2010a).

In addition, there have been measured improvements in some subsections of the Bay and tidal rivers. Ruhl and Rybicki (2010) reported that, although efforts to restore the Bay are often viewed as failing, reduced in-situ nutrients, wastewater treatment effluent nitrogen, and total suspended solids were significantly correlated to increased abundance and diversity of underwater grasses in the Potomac River. Based on aerial observations of the Potomac River area over an 18-year period, Ruhl and Rybicki (2010) concluded that estimates of underwater grasses in the Potomac River recently approximate the historical extent.

In the Upper Patuxent River, improvements in wastewater treatment plants in the late 1980s and 1990s led to reductions of phosphorus and then nitrogen loads to the freshwater section of the river (Boynton et al., 2008; see Figure 1-12). In 1993, freshwater underwater grasses were first reported in the mainstem Upper Patuxent River and rapidly became established in the fringing shoals of the river (Orth et al., 2010).

Overall, despite concerted efforts by the Bay jurisdictions and numerous federal agencies, some improvements in localized measures of ecosystem health, and model estimates that total nitrogen and phosphorus loadings have been reduced since 1985 by about 29 percent and 32 percent, respectively, the CBP remains far from its goals. The Bay continues to have poor water quality, degraded habitats, and low populations of many species of fish and shellfish (CBP, 2010a; EPA, 2010a).


Total Nitrogen (M lbs/year)
400
350
300
250
200
150
100
50
0
1985
2009
Trib. Strategy
TMDL
E3
NTWDep
Forest
Septic
Point Source
Urban runoff
Agriculture
Total Phosphorus (M lbs/year)
30
25
20
15
10
5
0
Total Sediment (M lbs/year)
12000
10000
8000
6000
4000
2000
0

RECENT INITIATIVES (2008-2010)

Recognition that the CBP would again fail to meet its goals set in the 2000 Agreement (CBP, 2000), combined with a highly critical review by the Government Accountability Office (GAO, 2005), led to a renewed focus on accountability and tracking of progress in the restoration process. In its 2005 report, GAO stated:

> The Bay Program does not have a comprehensive, coordinated implementation strategy to better enable it to achieve the goals outlined in *Chesapeake 2000*. Although the program has adopted ten key commitments to focus partners' efforts and developed plans to achieve them, some of these plans are inconsistent with each other or are perceived as unachievable by program partners.

In addition, the GAO questioned the effectiveness and credibility of the CBP's annual progress reports, which had not clearly distinguished monitoring results from model projections. To address these concerns, the CBP developed the Chesapeake Action Plan (CAP), which was intended to enhance coordination and engagement among CBP partners, increase the CBP's transparency, and heighten the CBP's accountability (CBP, 2008).

The Obama administration injected new energy into Bay restoration efforts. On May 12, 2009, President Obama released an executive order directing the federal government to lead restoration efforts and the EPA

FIGURE 1-13 Average annual (a) total nitrogen loading, (b) total phosphorus loading, and (c) total sediment loading (in million lbs/yr) delivered to Chesapeake Bay as estimated in five scenarios of the Phase 5.3 Watershed Model (see Table 1-1).
SOURCE: S. Ravi, CBPO, personal communication, 2011.
NOTES: The scenarios are modeled using the same hydrologic conditions (1985-2005) and changing land use, point source, and BMP conditions. The scenarios include 1985 baseline conditions, 2009 progress, the tributary strategy (TS) goals based on the cap loads set in 2003, total maximum daily load (TMDL), and maximum feasible reduction (E3) scenarios. The E3 scenario is a "what if" scenario of watershed conditions with theoretical maximum levels of managed controls on load sources ("everything, by everyone, everywhere"), with no cost and few physical limitations to implementing BMPs for point and nonpoint sources. Source sectors include agriculture, urban runoff, point sources (including wastewater), septic systems, forested lands, and non-tidal waters atmospheric deposition (NTW Dep). Note that in these bar graphs, atmospheric deposition is considered separately only when it falls directly on non-tidal waters; otherwise, the source is attributed to the land-use type on which the deposition falls. The data are also provided in Appendix A.

to coordinate efforts with several federal agencies, in collaboration with state governments, to reduce pollutants flowing into the Bay (Executive Order 13508). In response, by November 2009, federal CBP partners had completed reports that outlined a new state and federal accountability framework and actions to reduce pollution and improve compliance (DOD, 2009; DOI, 2009; DOI and DOC, 2009a,b,c; EPA, 2009; USDA, 2009).

Chesapeake Bay Total Maximum Daily Load (TMDL)

A TMDL, or total maximum daily load, is defined as the maximum allowable load of a pollutant that a water body can receive while still meeting its water quality standard. Under President Obama's executive order, the EPA Administrator was charged with developing a management plan to address the negative consequences of nutrient and sediment loading into the Chesapeake Bay. Under the lead of EPA Region III, a multistate TMDL analysis was conducted. The Bay jurisdictions produced watershed implementation plans (WIPs) in support of the TMDL. The EPA established the final TMDL in December 2010.

The EPA established the Chesapeake Bay TMDL in response to a number of existing authorities, including the CWA, several judicial consent decrees, a settlement agreement resolving litigation brought by the Chesapeake Bay Foundation, the 2000 Agreement, and Executive Order 13508. The TMDL's executive summary identifies the effort as "…a 'pollution diet' that will compel sweeping actions to restore the Chesapeake Bay and its vast network of streams, creeks and rivers" (EPA, 2010a). Further, the TMDL addresses three pollutants—nitrogen, phosphorus, and sediment—related to dissolved oxygen and water clarity standards necessary to restore the Bay ecosystem. The TMDL articulates the following expectation: "The TMDL is designed to ensure that all pollution control measures to fully restore the Bay and its tidal rivers are in place by 2025, with 60 percent of the actions completed by 2017" (EPA, 2010a).

The TMDL stipulates Bay watershed load limits of 185.9 million pounds (85.3 million kg) of nitrogen, 12.5 million pounds (5.67 million kg) of phosphorus, and 6.45 billion pounds (2.93 billion kg) of sediment per year based on average hydrologic conditions during the 1985-2005 period. These loads represent a 24 percent reduction in nitrogen and phosphorus and a 20 percent reduction in sediment from the model-simulated loads based on 2009 land use conditions (EPA, 2010a). These loads are allocated among the seven Bay jurisdictions. The overall TMDL nutrient and sediment reduction goals reflect relatively small modifications to the cap load goals set in 2003 (EPA, 2003). The TMDL supports the CBP's goal of removing the Bay from the EPA's list of impaired waters.

The Bay TMDL covers a larger area than any other U.S. TMDL.

Although EPA lists over 4,700 nutrient TMDLs nationwide that have been established since October 1995, relatively few address estuaries.[9] However, the Chesapeake Bay TMDL is within the range of reductions (by percentage) for several other estuaries, including the nutrient TMDL for New York and Connecticut's Long Island Sound (58.5 percent reduction in nitrogen discharges from the adjusted 1990 baseline load; NYS DEC and CT DEP, 2000), the Caloosahatchee Estuary in Florida (23 percent reduction in total nitrogen loading; Bailey et al., 2009) and Newport Bay in California (50 percent reduction from current nutrient and sediment loadings; EPA, 2002).

Watershed implementation plans (WIPs), developed by the seven Bay jurisdictions, define how and when they will meet their nitrogen, phosphorus, and sediment load allocations. The EPA will evaluate WIP implementation and the Bay jurisdictions' progress toward meeting their two-year milestones (described in the next section). If implementation progress is insufficient, the EPA can take appropriate "backstop measures" to ensure compliance with the TMDL. Backstop measures can include targeted enforcement actions on regulated sources, expansion of requirements to obtain discharge permits for currently unregulated sources, or additional reductions from federally permitted sources of pollution (e.g., wastewater treatment plants, large animal operations, municipal stormwater systems) (EPA, 2010a).

The Bay jurisdictions will submit draft Phase II WIPs that provide local area nutrient allocations on a smaller scale by December 2011. Phase II WIPs are expected to include roles for local governments and municipalities, especially for managing nutrient loading from urban and suburban areas (EPA, 2010a).

Two-Year Milestones

To accelerate progress and increase accountability in the Bay restoration, the CBP introduced a two-year milestone strategy for nutrient load reductions in May 2009. In the past, Bay recovery goals involved decadal increments and did not identify specific strategies for achieving the necessary pollution reductions. The prior decadal goals were characterized as "ladder[s] without rungs" (CBP, 2009b). In addition, elected officials were not held accountable for attaining the goals because the timeframes for achieving them often extended beyond their terms of office. As a result, progress was sluggish, and major goals were not met (CBP, 2009b). The two-year milestone program introduced a revised strategy aimed at reducing overall pollution in the Bay by focusing on short-term, incremental implementation goals. The CBP envisioned that through a series of two-

[9] See http://www.epa.gov/waters/ir/index.html.

year milestone periods with routine assessments of the pace of progress, by 2025 the Bay jurisdictions could implement all of the nutrient and sediment control practices needed for a restored Bay, although actual Bay water quality response and recovery likely will lag behind the 2025 implementation target.

The two-year milestone strategy required each Bay jurisdiction to commit to an initial suite of actions in the first milestone period to be completed by December 31, 2011. The jurisdictions identified specific actions, including application of land-based BMPs and wastewater treatment facility upgrades, anticipated to keep them on track to meet the long-term implementation goals by 2025. Each Bay jurisdiction also identified contingency actions that could be taken if some of the primary nutrient reduction practices could not be implemented in this timeframe. The CBP aims ultimately to reduce nitrogen and phosphorus loading in the watershed by 15.8 million pounds (7.2 million kg) and 1.1 million pounds (500 thousand kg), respectively, by actions completed during the first milestone (CBP, 2009b). If all proposed actions are implemented, the first milestone actions are anticipated to ultimately provide about 21 percent of the nitrogen load reduction and 22 percent of the phosphorus load reduction needed to meet the Tributary Strategy cap loads (Table 1-5). See Box 1-5 for a Bay-wide summary of the first milestone actions. Reductions for nitrogen and phosphorus in the first milestone period are shown by sector in Figure 1-14.

No sediment milestone was set for the first milestone period (2009-2011) because of uncertainties in the overall sediment target at the time, although sediment milestones are expected to be added for the next two-year milestone (2012-2013). Many of the two-year milestone measures to control nutrient loading, however, will also significantly reduce sediment loading.

The Bay jurisdictions are currently developing strategies for the second milestone period. Through tracking and accounting mechanisms (see Chapter 2), the CBP will assess each Bay jurisdiction's implementation progress toward the two-year milestones. Given lags between land-based BMP implementation and nutrient and sediment reduction in the Bay (see Box 1-3), the CBP primarily assesses progress toward the two-year milestone goals by tracking implementation of practices rather than monitoring nutrient loads in streams.

Integrating Two-Year Milestones, Watershed Implementation Plans, and the TMDL for Chesapeake Bay

Although the two-year milestones were originally conceived as steps toward meeting the cap load goals, they are now being used as measures of incremental progress toward meeting the TMDL WIP goals for 2017

TABLE 1-5 Estimated Contribution of the First Milestone Toward Reductions to Meet Tributary Strategy Cap Loads

	Model-estimated Average Load based on 2008 Progress Run (million pounds per year)	Tributary Strategy Cap to Meet Water Quality Standards (million pounds per year)	Reduction Required by 2025 (million pounds per year)	2009-2011 Estimated Milestone Reduction (million pounds per year)	Percentage of Load Reduction to meet Tributary Strategy Cap Loads Targeted in First Milestone
Nitrogen	258.5	183.1	75.4	15.8	21.0
Phosphorus	17.8	12.8	5.0	1.1	22.1
Sediment	9,500	8,293	1,207	NA	NA

NOTES: All load estimates, including the Tributary Strategy cap loads, were developed based on Phase 4.3 of the Chesapeake Bay Watershed Model. The TMDL (EPA, 2010a) was developed using Phase 5.3, and therefore, for consistency, the overarching goals are presented in terms of the Tributary Strategy goals. The original milestone commitments would need to be simulated using the Phase 5.3 Watershed Model to calculate the percentage of the TMDL to be accomplished by the first milestone.
SOURCES: CBP (2009b); K. Antos, CBPO, personal communication, 2011.

BOX 1-5
Best Management Practices to Be Implemented in First Milestone Period (2009-2011) across the Chesapeake Bay Watershed

The following best management practices represent the sum of total activities to be implemented under the first milestone period in the Chesapeake Bay watershed.

Agriculture

Nutrient Management	1,082,251 acres
Conservation Tillage	306,991 acres
Cover Crops	652,152 acres/year
Pasture Grazing BMPs	168,800 acres
Streamside Forest Buffers	39,110 acres
Streamside Grass Buffers	14,910 acres
Forest Harvesting Practices	125 acres
Wetland Restoration	3,809 acres
Land Retirement	81,676 acres
Tree Planting	27,965 acres
Carbon Sequestration/Alternative Crops	25,740 acres
Conservation Plans/SCWQP	584,648 acres
Animal Waste Management Systems	1,016 systems
Mortality Composters	22 systems
Water Control Structures	25,000 acres
Horse Pasture Management	300 acres
Non-Urban Stream Restoration	232,088 feet
Poultry Phytase	19,626 fewer pounds P

and 2025. The milestones are intended to improve accountability and allow for adjustments if needed. These issues are discussed in more detail in Chapter 3.

A summary of how the two-year milestone strategy is incorporated into the existing Bay restoration goals and TMDL accountability framework is depicted in Figure 1-15. In the two-year milestones, Bay jurisdictions identify practices to be implemented during every 2 year period until 2025. WIPs present cumulative practice implementation goals for 2017 (Phase 1) and 2025 (Phase 2).The TMDL defines the total load reductions (nitrogen, phosphorus, and sediment) necessary to meet water quality criteria. The ultimate goal is to meet the ecological endpoints associated with a fully restored Bay (extent of underwater grasses, fisheries abundance, and diver-

Manure Transport	131,503 net tons
Dairy Precision Feeding and/or Forage Management	291,203 pounds N 51,264 pounds P
Heavy Use Poultry Area Concrete Pads	400 farms
Livestock and Poultry Waste Structures	198 structures
Dairy and Poultry Manure Incorporation Technology	5,000 acres
Wastewater	
1,887,350 pounds nitrogen reduced	
201,500 pounds phosphorus reduced	
Urban/Suburban	
Urban Stormwater Management	148,740 acres
Tree Planting	30 acres
Urban Stream Restoration	18,656 feet
Erosion and Sediment Control	62,731 acres
Nutrient Management	133,000 acres
Wetland Restoration	350 acres
Abandoned Mine Reclamation	2,219 acres
Dirt and Gravel Road Erosion	124,913 feet
Septic Improvements	27,125 systems
Air	
Heavy Truck Anti-Idling Rule	9.78M hours reduced
NO_x Reductions	56,000 tons
Maryland Healthy Air Act	305,882 fewer pounds N/year

SOURCE: CBP (2009b).

sity and other natural resource goals), as defined by the CBP (see Table 1-2). The EPA will review progress toward these two-year milestones, in the context of the TMDL, and will evaluate whether sufficient actions are being planned and undertaken to achieve the necessary pollution reductions (EPA, 2010a).

STATEMENT OF COMMITTEE TASK AND REPORT OVERVIEW

In 2009, the NRC's Committee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality was formed to undertake an evaluation of the CBP's nutrient reduction program and to respond to the GAO (2005) recommendation for indepen-

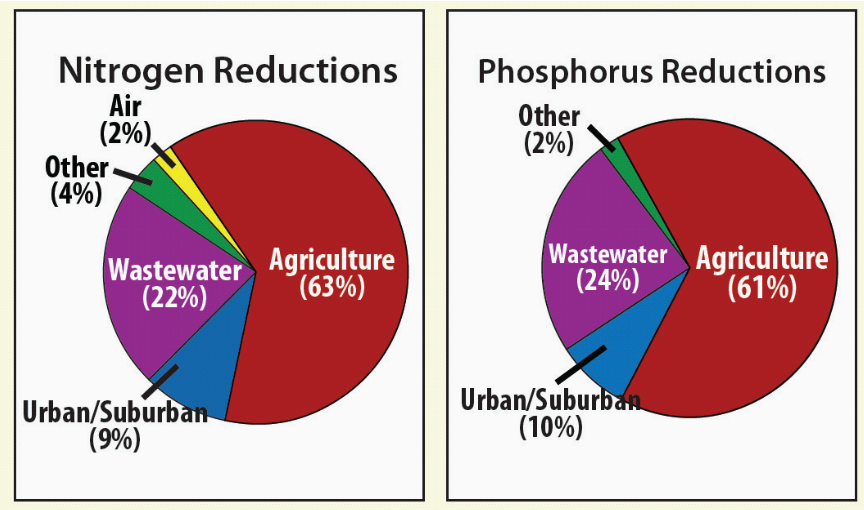


FIGURE 1-14 Percentage of nutrient reductions planned in the first milestone period from agriculture, wastewater, urban/suburban, air, and other sectors.
SOURCE: CBP (2009b).

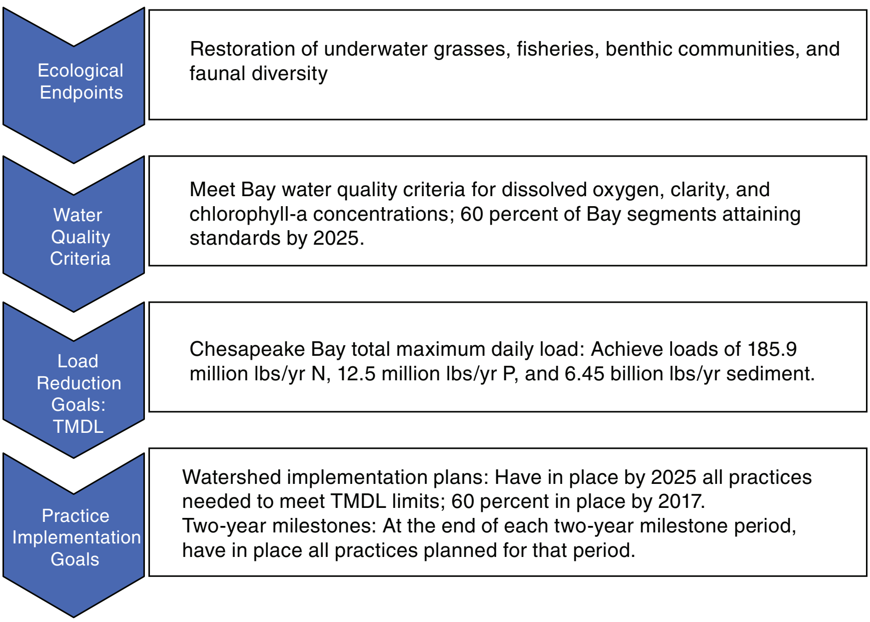


FIGURE 1-15 Integration of the goals and strategies used in the CBP, including two-year milestones and the TMDL accountability framework.

dent review to enhance the credibility and objectivity of its reports. This study was sponsored by the EPA, with additional funding support from the states of Virginia, Maryland, Pennsylvania, and the District of Columbia. The committee was specifically tasked to address the following questions, broken down into two themes:

> *Evaluation Theme I: Tracking and Accountability*
>
> 1. Does tracking for implementation of nutrient and sediment point and nonpoint source pollution (including air) best management practices appear to be reliable, accurate, and consistent?
>
> 2. What tracking and accounting efforts and systems appear to be working, and not working, within each state (i.e., the six states in the watershed and DC), including federal program implementation and funding? How can the system be strategically improved to address the gaps?
>
> 3. How do these gaps and inconsistencies appear to impact reported program results?
>
> *Evaluation Theme II: Milestones*
>
> 4. Is the two-year milestone strategy, and its level of implementation, likely to result in achieving the CBP nutrient and sediment reduction goals for this milestone period?
>
> 5. Have each of the states (i.e., the six states in the watershed and DC) and the federal agencies developed appropriate adaptive management strategies to ensure that CBP nutrient and sediment reduction goals will be met?
>
> 6. What improvements can be made to the development, implementation, and accounting of the strategies to ensure achieving the goals?

It is important to note, as discussed further in Chapter 2, that the committee charge (particularly Task 4) focuses on implementation of strategies during the two-year milestone period, rather than on actual water quality improvement during this period. Realistically, interannual variability and delayed responses preclude the determination of conclusive relationships between action and water quality improvement for such a short increment of time. Additionally, because there are no milestones for sediment during the first reporting period, which the committee was tasked to analyze, the committee places greater emphasis on issues affecting nutrient loads, although sediment issues are included throughout and have been more recently quantified in the 2010 TMDL.

Although most of the tasks are narrowly focused, the committee took a broad view in its interpretation of Task 6 on what improvements can be made to the development, implementation, and accounting of the strategies to ensure achieving the goals. The committee considered "the goals" to include the long-term nutrient and sediment reduction goals and subsequent recovery of the Bay ecosystem, not just the first two-year milestone goals. In addition, the committee considered both practices and policies that could improve the likelihood of achieving the goals, because the feasibility of implementing specific practices is often affected by broader policy decisions.

The committee's conclusions and recommendations are based on a review of relevant technical literature, briefings, and discussions at its four meetings and the experience and knowledge of the committee members in their fields of expertise. Following this brief introduction, the statement of task is addressed in four subsequent chapters of this report:

- In Chapter 2, the committee assesses the tracking and accounting for BMPs and infrastructure upgrades for nutrient and sediment control and identifies key issues facing the Bay jurisdictions and the CBP (Tasks 1, 2, and 3). The committee also identifies ways to improve tracking and accounting procedures.
- In Chapter 3, the committee evaluates the two-year milestone strategy and, based on the information presented, discusses the likelihood of achieving the nutrient reduction goals for the first milestone period (Task 4).
- In Chapter 4, the committee assesses the CBP's adaptive management approaches (Task 5), and identifies the challenges to and opportunities for using adaptive management to meet nutrient and sediment reduction goals.
- In Chapter 5, the committee describes overarching issues affecting achievement of the nutrient reduction goals (Task 6), and discusses improvements that, if implemented, could enhance the likelihood of achieving the program goals.

2

Tracking and Accounting

The term "tracking," as applied in the Chesapeake Bay Program (CBP), describes approaches to document the implementation of nutrient and sediment reduction practices and treatment technology upgrades and the basic associated practice characteristics needed to estimate resulting changes in nutrient and sediment loads. The term "accounting" describes the process of analyzing and reporting the practice information and quantifying the estimated load reductions. Reliable tracking and accounting of point and nonpoint nutrient reduction efforts are essential for program managers and policy makers to determine if current strategies are sufficient or if new strategies are necessary to meet established milestones. In addition, accurate and transparent tracking and accounting are key to maintaining public confidence that funds for Bay restoration are being wisely invested and that CBP partners are fulfilling their commitments to reduce nutrient and sediment loads.

By examining the strengths and weaknesses of current jurisdictional tracking and accounting practices, the committee provides insights into their reliability, accuracy, and consistency. In this chapter, the committee reviews and critiques the tracking and accounting practices for nutrient and sediment reduction efforts in the Chesapeake Bay.

TRACKING AND ACCOUNTING FRAMEWORKS

Diverse activities have been implemented within the Bay watershed to reduce nutrient and sediment loads, and many more are planned for the years ahead. The six states and the District of Columbia (i.e., the Bay jurisdictions) have developed separate and distinct strategies within their regulatory and nonregulatory programs to identify, quantify, and attempt to control point and nonpoint sources of nutrients. In addition, state and federal agencies fund wastewater infrastructure improvements through the federal Clean Water Act State Revolving Funds and other programs designed to improve land management and reduce nutrient and sediment pollution. Finally, there are voluntary efforts that are not cost-shared by any particular state or federal agency. Ideally, tracking and accounting in the Bay watershed would account for all of these activities consistently and accurately, without duplication, and in a centralized framework.

The Bay jurisdictions bear the primary responsibility for tracking nutrient and sediment control efforts and reporting them to the CBP. Through a variety of state and local agencies, each jurisdiction compiles information about the nutrient and sediment control practices implemented in the Bay watershed to address point and nonpoint sources of pollution. The CBP has approved more than 60 agricultural and urban best management practices (BMPs) for credit in the Chesapeake Bay Watershed Model (see Appendix B) and has used a peer-review process to assign pollutant load-reduction effectiveness estimates to each BMP.

Any practice approved by the CBP and implemented since 1985 is included in the tracking and accounting of nutrient and sediment reduction strategies. In 1987, the CBP partners agreed to specific goals for pollution control (see Chapter 1), including a goal to reduce nitrogen and phosphorus discharges by 40 percent below 1985 levels by the year 2000. All nutrient reduction that has taken place since 1985 is, therefore, credited toward the achievement of those CBP goals and tracked in the Watershed Model.

All of the Bay jurisdictions report annually to the U.S. Environmental Protection Agency (EPA) data concerning compliance with National Pollutant Discharge Elimination System (NPDES) permits associated with point-source discharges, including for entities such as wastewater treatment plants and urban and suburban Municipal Separate Storm Sewer Systems (MS4s). All Bay jurisdictions have been delegated authority from the EPA to implement the NPDES program and, therefore, assume that regulatory responsibility. As part of that responsibility, the Bay jurisdictions check the quality and completeness of permit compliance and monitoring data in accordance with EPA-approved quality assurance plans and programmatic requirements before submitting the data to the CBP for incorporation into the Chesapeake Bay Model and tracking and accounting systems. Data from NPDES compliance monitoring are used in the tracking and accounting of significant wastewater treatment facilities. However, water quality monitoring is largely not part of the tracking and accounting process for nonpoint-source pollution control measures.

National permitting programs do not exist for nonpoint sources of pollution, which include general agricultural and forestry land uses, stormwater runoff from small communities that do not exceed population thresholds, and stormwater runoff from undeveloped native forested uplands and wetlands, including both privately and publically owned properties. Because national data collecting and reporting standards do not exist for nonpoint sources, individual Bay jurisdictions and the CBP have faced many challenges in their efforts to accurately account for the implementation of nutrient reduction practices. Activities can be especially difficult to track when BMPs are implemented on a voluntary basis rather than under a more formal governmental program.

Each of the Bay jurisdictions submits data to the CBP at least annually on the nonpoint source nutrient and sediment pollution control programs implemented in the watershed. In past years, the CBP struggled to handle the wide variety of data formats and spent a large amount of staff time incorporating these data into the Chesapeake Bay Model. However, since 2003, the CBP and Bay jurisdictions have devoted substantial efforts and resources to standardize data formats and develop approaches for electronic submission of both permit compliance and BMP data. The EPA provided grants to Virginia, Pennsylvania, and Maryland to develop templates for submitting nonpoint source and stormwater BMP data to a statewide database, which would then facilitate transferral to the CBP via the National Environmental Information Exchange Network (NEIEN) schema (see Figure 2-1). Data can be submitted using one or more of the following types of information to identify BMP locations: (1) latitude and longitude, (2) watershed code, (3) county name, or (4) national hydrography dataset (stream reach) codes. Data are then translated for use in the Watershed Model and related tools (see Figure 1-3) to assess progress toward program goals, based on nitrogen, phosphorus, and sediment load reduction efficiencies assigned to each practice. The usefulness of the NEIEN-exchanged data is highly dependent on the quality of the data entered into the system. NEIEN was completed in late 2010, and by December 2010 all agencies were required to submit their BMP implementation data through NEIEN (B. Burch, EPA CBPO, personal communication, 2010).

Tracking changes in atmospheric deposition of nitrogen to the Bay watershed is the responsibility of the EPA, which uses data from several national monitoring networks. These networks provide a good estimate of wet deposition of nitrate and ammonium, a fair estimate of dry deposition of nitric acid, nitrate, and ammonium, and poor estimates of ammonia dry deposition (see Box 2-1 for details).

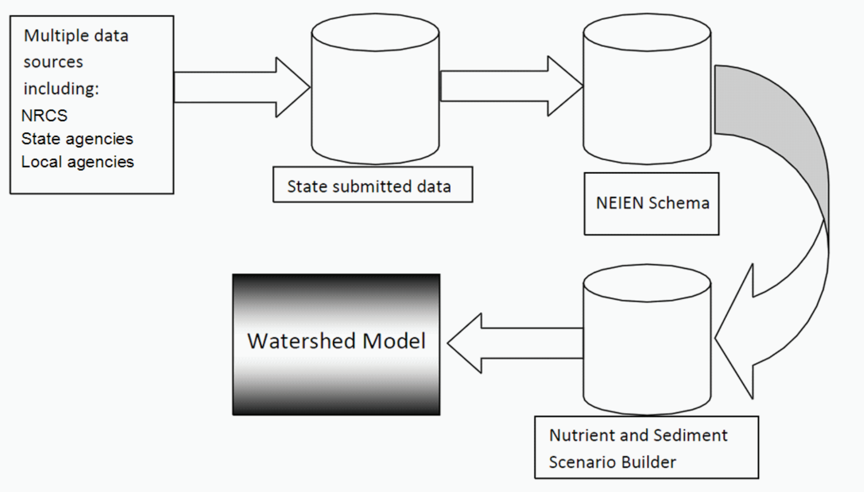


FIGURE 2-1 Role of NEIEN in data transmission to the Watershed Model.
SOURCE: Modified from Devereux (2009).

ASSESSMENT OF TRACKING AND ACCOUNTING

The committee was tasked to evaluate whether the tracking for implementation of nutrient and sediment control BMPs appears to be reliable, accurate, and consistent and to assess what is working and not working in each Bay jurisdiction and at the federal level (Tasks 1 and 2, Box S-1). To complete these tasks, the committee reviewed two main sources of information from each of the Bay jurisdictions: (1) a committee-generated questionnaire submitted to each of the Bay jurisdictions and the EPA and (2) relevant information submitted in the draft (September 1, 2010) and final (November 29, 2010) watershed implementation plans (WIPs). In this section, the committee provides a general assessment of tracking and accounting efforts and identifies key issues that affect multiple states. Jurisdiction-specific strengths and weaknesses in tracking and accounting are discussed briefly at the end of the section, summarized in Table 2-1, and detailed in Appendix C.

Jurisdiction-wide Issues in Tracking and Accounting

In general, the Bay jurisdictions responded that they have a good understanding of wastewater discharges and state cost-shared BMP data. However, key issues affecting the reliability, accuracy, and consistency of

BOX 2-1
Tracking Nitrogen Deposition in the Bay Watershed

Tracking of nitrogen deposition is dependent upon measurements for specific locations and calibration/validation of models for regional assessments. A complete understanding of nitrogen loadings from the atmosphere requires information on the wet deposition of nitrate, ammonium, and organic nitrogen and on dry deposition of the gases nitric acid and ammonia and the aerosols nitrate and ammonium.

The most intensive coverage for atmospheric nitrogen loadings exists for wet deposition of nitrate and ammonium through the National Trends Network of the National Atmospheric Deposition Program (NADP); within the Chesapeake Bay watersheds, there are 16 sites, 5 of which have been in place since 1987. There is no systematic program to determine the deposition of organic nitrogen to the Bay watershed, which probably leads to underestimates of nitrogen deposition by up to 25 percent (Neff et al., 2002).

The next most detailed coverage is provided by the Clean Air Status and Trends Network (CASTNET) program, established in 1991, which measures the concentrations of nitric acid, ammonium, and nitrate and then uses the Multi-Layer Model (MLM) to estimate the dry deposition flux. Within the Chesapeake Bay watershed, there are six measurement sites across three states—in Maryland (BEL116, BWR139), Pennsylvania (ARE128, PSU106), and Virginia (PED108, SHN418), with starting dates from 1991 to 1995.

Estimates of the dry deposition of ammonia, an important source of nitrogen loadings to the Bay watershed, are not made within CASTNET. A new program, the Ammonia Monitoring Network (AMON), was initiated in 2010 as part of the NADP to provide this information. Unfortunately, only three sites (PA00, MD08, and MD99) are in the Bay watershed.

In summary, monitoring data exist to provide good estimates of wet deposition and fair estimates of dry deposition of nitric acid, nitrate, and ammonium; however, understanding of ammonia dry deposition is poor and deposition estimates are, therefore, weak. Importantly, funding for the NADP and CASTNET sites has declined in real terms, leading to a reduction in the number of sites. Static funding over the past decade, combined with increasing operational and maintenance costs, means further loss of sites is likely. A decline in monitoring sites and funding seriously limits the ability to understand and track changes in atmospheric nitrogen loadings in response to management actions.

TABLE 2-1 Summary of Tracking and Verification Efforts for Land-based BMPs by Bay Jurisdiction

Jurisdiction	Who Collects Information for Nonpoint Source BMPs? (federal agencies not included)	Verification Process
Delaware	Multiple agencies, including: • Dept. of Natural Resources and Environmental Control • Dept. of Agriculture • local government agencies for stormwater BMPs	Field verifications are completed by each of the partner agencies. Aerial photography is used to verify the establishment of new agricultural BMPs annually. Cost-share reporting data is used to verify practice implementation. Stormwater BMPs field verified.
District of Columbia	Dept. of the Environment (DOE)	DOE conducts maintenance inspections of all stormwater management facilities. Inspections of wetland mitigation projects and recent tree plantings are also conducted.
Maryland	Multiple agencies including: • Dept. of Agriculture • Dept. of Environment (MDE) • Dept. of Natural Resources • Dept. of Planning • local government agencies Data compiled by MDE.	Field verification for all sectors. See Appendix C for details.
New York	The Upper Susquehanna Coalition (USC) collects and reports all nonpoint source data.	USC field checks agricultural and wetland-related practices. Only field verified practices are reported. Frequency of verification not reported.

Process for Removing BMPs from the Database When Expired or Not Functioning?	Processes to Protect Against Double Counting?	Point Locations Provided?	Underreported Practices
NO	YES for ag. BMPs In development for stormwater BMPs	SOME (mostly in development)	• Non-cost-shared practices • Stormwater and septic practices where databases are lacking
No information provided. However, permitted facilities have maintenance plans.	YES, through Plan Review Database	YES, for most practices	• Street sweeping • Practices on private lands with no permit • Forest conservation
YES	YES for ag BMPs In development for stormwater BMPs	YES, for most practices	• Stream restoration • Septic upgrades funded by local govt. • Innovative BMPs not yet approved by the CBP
No information provided	No information provided	YES for ag. practices	Urban and septic practices are generally not reported

Continued

TABLE 2-1 Continued

Jurisdiction	Who Collects Information for Nonpoint Source BMPs? (federal agencies not included)	Verification Process
Pennsylvania	Dept. of Environmental Protection tracks and collects BMP data for most sectors, with assistance from other agencies, including: • Bureau of Forestry • State Conservation Districts • Department of Agriculture • Infrastructure Investment Authority (PennVest)	Verification and quality assurance of implemented agricultural BMPs are considered to be the responsibility of the federal and state agencies and the nongovernmental organizations providing the information. It is beyond the capacity or responsibility of PA's Water Planning Office to complete such tasks. No information is provided about state agency-level verification. Construction-related stormwater BMPs are permitted and verified.
Virginia	Many agencies including: • Dept. of Health • Dept. of Environmental Quality • Dept. of Forestry • Dept. of Conservation and Recreation • Dept. of Agriculture and Consumer Services	Permitted CAFOs currently inspected annually, after 7/1/2011 on a risk-based inspection schedule at least once every 5 years Inspections on land-disturbing activities for stormwater pollution prevention Up to 5% installed agricultural BMPs annually BMPs that are also alternative onsite sewage systems inspected at least annually.
West Virginia	Dept. of Environmental Protection tracks and collects BMP data for most sectors, with assistance from: • Dept. of Agriculture • Conservation Agency	No current field verification process in place, although WV plans to develop verification protocols for stormwater and agricultural BMPs.

NOTE: This table summarizes the more detailed data provided by each Bay jurisdiction on tracking and accounting (see Appendix C).

Process for Removing BMPs from the Database When Expired or Not Functioning?	Processes to Protect Against Double Counting?	Point Locations Provided?	Underreported Practices
No information provided	NO (No additional processes beyond those used by all states to track BMPs by funding sources)	NO	• Cover crops • No-till cultivation • Manure storage • Stream fencing • Rotational grazing • Precision feeding • Septic tank hook-ups to central sewer No tracking of construction-related stormwater BMPs (an estimate of practices is instead provided)
No practice life reported, but BMPs can be removed if found on random inspections to be insufficient	YES for ag BMPs	YES for cost-shared ag. practices (others in development)	Septic systems connections Non-cost shared practices Urban stormwater BMPs over past 20 years Practices not approved by CBP
No information provided	YES	YES for stormwater practices	Non-cost-shared practices Practices missed because of poor tracking

BMP tracking and accounting data include: (1) data privacy restrictions, (2) the challenge of accounting for voluntary practices, (3) limitations in staff resources for data management and quality assurance/quality control (QA/QC), (4) limitations in staff resources for field verification of practices, and (5) uncertainty in BMP load reduction effectiveness.

Data Privacy Restrictions

Much information regarding agricultural point and nonpoint source nutrient and sediment reduction activities within the Bay watershed resides within the U.S. Department of Agriculture (USDA), but privacy requirements associated with Section 1619 of the 2008 Farm Bill create challenges for accurately tracking agricultural BMPs. Under Farm Bill privacy requirements, federal and state agencies may not publicly release the addresses (or location data) for Farm Service Agency (FSA) or National Resources Conservation Service (NRCS) grant recipients. To comply with these privacy restrictions, these data previously have been submitted to the CBP aggregated at the county level, which reduces the spatial accuracy of calculated nutrient and sediment loads in the Watershed Model. However, a recent data sharing project between the U.S. Geological Survey (USGS), the FSA, and the NRCS in all Bay states allows the USGS to receive the point location data in confidence and aggregate these data at a watershed scale (hydrologic unit code [HUC] 8 or 11), for improved BMP location attributes in the Watershed Model, before submitting these data to the CBP. Aggregated data that do not divulge individual landowner information is not confidential.

This data sharing project has the potential to fill many of the information gaps about distribution of Farm Bill–funded BMPs implemented across the landscape. Additional opportunities to access aggregated data that do not violate the confidentiality provision of the Farm Bill could be used by the CBP. For example, records of nutrient management plans developed under Farm Bill programs could be compiled and reported in such a way that Bay jurisdiction administrators would at least know how many agricultural acres in each watershed county were being managed under an NRCS-developed or NRCS-approved nutrient management plan. However, some nutrient management plans are developed by state-certified plan writers. Because these plans are paid for by the land owners, they are proprietary. Thus, important nutrient management information may not be available to the USDA-USGS data sharing effort and to the CBP.

Non-cost-shared (Voluntary) Practices

Every Bay jurisdiction reports that there is little to no accounting for the implementation of BMPs that are installed without the support of federal or state cost-shared programs, sometimes called "voluntary practices." Many agricultural and other BMPs are voluntarily implemented because of their inherent benefits to landowners. For example, significant acreage is farmed within no-till and other conservation tillage practices without regard to the CBP because they are good agronomic practices that permit double cropping and increase economic returns. The underreporting of non-cost-shared practices also affects the accounting of suburban and urban practices (e.g., stream restoration efforts by nonprofit organizations, non-cost-shared sewer line hook-ups). See Table 2-1 for examples of practices described by each jurisdiction as underreported.

Pennsylvania recently conducted several regional studies to document this data gap, focusing on key subsets of agricultural conservation practices. A pilot study that surveyed 17 percent of the farmland in Bradford County in northeastern Pennsylvania reported that up to 88 percent of the nutrient-control practices being used were not reported to the CBP because they were not cost-shared (PA DEP, 2010; see Table 2-2). However, the study did not attempt to quantify the effect of this under-reporting on the county's (or the state's) reported nutrient or sediment loads. The Pennsylvania study suggests that key practices may be significantly under-reported in some areas. Overall, available data are insufficient for the committee to assess the implications of non-cost-shared practices for accuracy of current BMP reporting in the various states or to evaluate the relative magnitude of this error against other potential accounting errors.

Maryland has recently implemented an aggressive inventory strategy to track and verify non-cost-shared practices and in 2009 launched the Conservation Tracker database, which can be used to track both cost-shared and non-cost-shared BMPs (MDE et al., 2010). However, as of fall 2010,

TABLE 2-2 Surveyed Agricultural BMPs in Bradford County, Pennsylvania

Practice	Data Reported	Percent Not Cost-Shared
No till	6,039 acres	85
Cover crop	3,335 acres	74
Manure storage	81 units	43
Stream fencing	79 farms/339 acres	51
Rotational grazing	74 farms/4,679 acres	88

SOURCE: PA DEP (2010).

Conservation Tracker was only being used to track cost-shared practices (MD DNR, 2010b). In November 2010, Virginia outlined a multi-phased strategy to collect, store, and report non-cost-shared agricultural and forestry BMP data, although it acknowledged that better accounting for non-cost-shared practices alone would not enable the state to reach its milestone goals (VA DNR, 2010). Delaware developed a BMP survey form through a pilot study in the Choptank River watershed that could be used in the future to collect data on non-cost-shared practices (DE DNREC, 2010).

If voluntary BMP implementation is not significant in a particular state, then federal or state cost-shared practice information will by necessity have to suffice. However, if states find that non-cost-shared practices significantly affect their total loads, then rigorous state-level programs would be of value to facilitate data collection, verification, and quality control and to assess progress towards management goals. President Obama's 2009 Executive Order 13508 pledged: "By July 2012, mechanisms for tracking and reporting of voluntary conservation practices and other best management practices installed on agricultural lands will be developed and implemented." As of early 2011, the CBP partners, with USDA and state leadership, were still considering how they will implement non-cost-shared BMP tracking while ensuring that data meet CBP expectations for reliability, accuracy, and verification. The EPA has explained its expectations for non-cost-shared BMP data, including procedures to prevent double counting, to allow for field verification, and to ensure that the datasets are updated over time to reflect land conversions or maintenance failures (EPA, 2010c,d; K. Shenk, CBP, personal communication, 2011). The CBP will also need to consider that current models have been calibrated with many of these uncounted practices in place. Therefore, if these non-cost-shared practices are eventually added to the model even though they were in place during the model calibration period, their load reductions may effectively be double counted.

Data Management

Currently, CBP data management and quality control efforts are staff- and resource-intensive endeavors, especially as the program transitions to electronic BMP reporting. Tracking BMP data from multiple data sources requires rigorous QA/QC efforts, and weaknesses in state-level programs combined with resource limitations will contribute to reduced accuracy and reliability. For example, double counting can occur when a specific BMP receives both state and federal funding. USDA privacy restrictions may also limit the capacity to cross-check state- and federally funded BMPs and other conservation efforts to minimize double counting. Other errors that affect data quality include incorrect entry of BMP data from stormwater permit reporting or failure by states to remove from the database BMPs that are no longer in operation, perhaps because they have exceeded their reasonable lifespan or because the land use has changed since the BMP was implemented.

Of the seven Bay jurisdictions, only Maryland, the District of Columbia, Virginia, and Delaware reported specific practices to reduce double counting, and those practices were sometimes limited only to certain sectors (see Appendix C). Additionally, only Maryland reported that BMPs were assigned specific lifespans, after which those BMPs would be removed from the database. Many states expressed optimism that electronic reporting via NEIEN would significantly reduce double counting of cost-shared BMPs. NEIEN, however, may simply transfer this problem from the states to the CBP if the cost-share data are not first screened for double-counting at the state level prior to electronic submissions. Cost-share privacy issues would need to be addressed to fully resolve this problem as each BMP would require a unique identifier such as a specific location to facilitate cross-checking of activities between state and federal databases.

In addition to improving data quality, electronic submissions of local and state BMP data should also significantly reduce the data management burden on state staff, particularly for those states that previously had to compile data from paper files. Nevertheless, there appears to be unequal progress toward improving data management among the Bay jurisdictions. Those jurisdictions with greater resources can devote more attention to data management and electronic data submissions. Those with greater resources are also more likely to invest in training for local agency staff on how to manage data effectively and accurately and how to use available tools for nutrient accounting.

Resources not only affect the staffing levels for data management and QA/QC, they also affect the ability to record precise locations of practices (i.e., geo-referencing), which is under way in some states (see Table 2-1). The precise location of a BMP within a watershed (e.g., distance from a stream) will affect its performance; thus, geo-referencing BMPs is critical to improving the Watershed Model's predictions of nutrient load reductions (Djojic et al, 2002). States with limited resources would, understandably, prefer to spend available funding on BMP implementation rather than on tracking and accounting efforts, perhaps sacrificing some level of reporting accuracy for greater load reductions in the long run.

Field Verification

The extent of field verification of urban and agricultural nutrient and sediment BMPs varies widely with state resources. Field verification ensures that the BMP implementation data are reliable and accurate and that the installed practices meet the definitions and design standards used by the

CBP to estimate efficiency and performance. However, the necessary staff and travel expenses make field verification extremely costly. Field inspections ideally should occur when BMPs are actually performing (e.g., during or shortly after rain events). Timing field inspections in this way would significantly improve the reliability of verification results. Virginia, the District of Columbia, Maryland, and New York reported that they have programs in place to field verify BMP implementation and maintenance. However, at most, these programs field verify approximately 8-10 percent of agricultural BMPs per year; most programs verify far fewer or do not report the number of verified sites. Details on these verification programs are provided in Appendix C. Because of staffing and financial limitations, adequate state or federal funding to visit every participating landowner to verify recordkeeping and other implementation-related data seems unlikely. Also, in many cases, agencies charged with implementing BMPs are the same as those conducting the tracking and accounting, sometimes leading to a perception of a biased verification system. Random verification programs by agencies/personnel independent of those advising installation help to build confidence that reported data are accurate and reliable and can be sized to available resources.

Ultimately, a reasonable balance of implementation and verification is necessary to optimize resources while maintaining the CBP's credibility. The EPA has indicated that jurisdications will need to develop programs to verify that BMPs are properly designed, installed or implemented, and maintained to get full credit in the Watershed Model (EPA, 2010c). Additional EPA guidance on the extent of verification in relation to expected benefits would be useful. As a surrogate for field verification, grower and developer survey questionnaires could be mailed to gauge participation, followed by some percentage of field visits to confirm the reliability of the survey data. For example, available trends in county-level fertilizer sales data could be used to gauge the extent of nutrient management related BMP implementation. Remote sensing also might offer lower cost verification of some practices. Early verification is important to determine whether practices have been implemented according to recommended standards, but some level of periodic verification is also needed to determine whether practices are still in place and are being maintained properly. Developing ways to optimize field verification efforts will ultimately enhance the reliability of the BMP data sets, perhaps through some combination of remote sensing data, written surveys, phone calls, and site visits.

BMP Efficiencies

Data on BMP implementation are converted into load reductions by the Watershed Model using load reduction efficiencies established by the

Water Quality Goal Implementation Team (WQGIT) of the CBP. Thus, load reduction efficiencies are critical components of both goal-setting and implementation progress accounting.

The efficiencies of municipal and industrial wastewater nutrient control technologies are well understood because of the high level of process control at centralized wastewater treatment facilities. In addition, NPDES permitting requires monitoring at centralized treatment facilities, so results of management actions accurately reflect nutrient and sediment load reductions in the field.

In contrast, the BMP efficiencies for diffuse sources, such as suburban, urban, and agricultural nonpoint sources, are less predictable and vary widely with local site conditions. Many factors affect the pollutant removal efficiency of BMPs and create challenges for establishing BMP efficiencies for the Watershed Model. Field monitoring of BMPs on a comprehensive basis is neither practical nor affordable.

Performance of BMPs in the field may vary with age and level of maintenance. The lack of adequate maintenance and life-cycle replacement can reduce intrinsic pollutant removal design capabilities and negatively affect performance. BMP efficiency can also change as treatment systems age; those systems that rely on natural biological features may improve with maturity but act as a sink during the growing season and a source of nutrients during the non-growing season even after they mature. Technology-based BMPs (e.g., storm drain filter inserts) may lose effectiveness with time due to clogging and general wear and tear.

BMP efficiency is also a function of location and site conditions, which vary widely. BMP efficiency is heavily influenced by rainfall amount, intensity, and duration; soil type and slope; land use; and proximity to the receiving water body. Implementation, operation, and maintenance of agricultural BMPs also may vary widely from the NRCS Conservation Practice Standard. For instance, cover crops can vary by type of crop used, extent of ground cover achieved, whether manure is applied, and whether the cover crop is harvested, plowed in, or left as protective cover on the field, each of which affects the overall practice efficiency. Thus, as noted previously, it is important to verify that the installed practices meet the definitions used by the CBP to establish efficiency estimates.

BMP efficiency in a field situation can be difficult to study because of the costs and challenges associated with monitoring, especially when pollutant loading is driven by weather events that can be erratically distributed in time and space. As a result, BMP efficiencies are often derived from limited research or small-scale, intensive, field-monitoring studies in which they may perform better than they would in aggregate in larger applications, particularly at the watershed scale. Thus, estimates of load reduction efficiencies are subject to a high degree of uncertainty.

Concerns about the accuracy of BMP load reduction efficiencies used in the Watershed Model led to a detailed review of currently available science for both urban and agricultural practices (Simpson and Weammert, 2009). The EPA (2010e) also provided extensive land management guidance that is applicable to federal and non-federal lands and that addresses agriculture, urban and suburban areas, forestry, riparian areas, decentralized wastewater treatment systems, and hydromodification. Simpson and Weammert (2009) and the EPA (2010e) provide detailed assessments of BMP applications and efficiencies, including offsets for land use changes. A review of the Simpson and Weammert (2009) efficiencies acknowledges a predictably high degree of spatial and temporal variability and uncertainty depending on hydrogeomorphic region, land use, and to a certain extent type of BMP (Table 2-3). Because of the variety of factors affecting BMP efficiency, including maintenance and longevity effects, Simpson and Weammert (2009) were conservative in their efficiency estimates.

The committee did not undertake a separate detailed review of BMP load reduction efficiencies, although the original documentation by Simpson and Weammert (2009) and the EPA (2010e) were thoroughly peer-reviewed prior to publication. In addition, BMP efficiencies have been the subject of numerous studies, especially by the Center for Watershed Protection

TABLE 2-3 Range in Load Reduction Efficiency (percent decrease) Estimates for Select Best Management Practices implemented in the Chesapeake Bay Watershed

Best Management Practice	Total N	Total P	Sediment
Conservation plans	3–8	5-15	8-25
Conservation tillage	8	22	30
Forest buffer	19-65	30-45	48-60
Grass buffer	13-46	30-45	40-60
Wetland creation and restoration	7-25	12-50	15
Cover crops			
Coastal plains/ Piedmont—crystalline	11-45	0-15	0-20
Mesozoic lowlands/Ridge and Valley—siliciclastic	9-34	0-15	0-20
Ammonia emission reduction	15-60	NA	NA
Dairy feed management	24	25	0
Mortality composting	40	10	0

SOURCE: Adapted from Simpson and Weammert (2009).

(CWP), the Water Environment Research Foundation (WERF), and the EPA.[1] Although unable to review and assess the technical aspects of BMPs and their efficiencies, the committee endorses the approach taken by the CBP to develop research-based BMP efficiencies and concludes that the general approach and associated conservative assumptions are reasonable given currently available science.

Despite this endorsement, the committee acknowledges the need to continuously assess and improve upon the current understanding of BMP efficiencies. Therefore, targeted monitoring programs in representative urban and agricultural streams are needed to evaluate associated water quality changes over time and to validate or improve model predictions, particularly at the watershed scale.

As new field research becomes available, BMP efficiencies for the Watershed Model should be updated. The CBP WQGIT recently developed a protocol by which estimates of BMP efficiencies can be revised or additional BMPs can be accepted for use in the Watershed Model (CBP WQGIT, 2010). This protocol provides an adaptive approach to reducing the high levels of uncertainty in estimates of BMP efficiencies. The protocol requires a six-person panel composed of experts in water quality and experts in the proposed BMP to work with the relevant source-sector workgroup to develop a report that includes:

- Detailed definition of the land use or practice,
- Estimates of recommended nitrogen, phosphorus, and sediment loading or efficiency, and justification for the selected efficiency estimates,
- Locations in the watershed and land uses to which the BMP is applicable,
- Conditions under which the BMP works and does not work,
- Temporal performance,
- Useful life and effectiveness over time, and
- Operation and maintenance requirements (and impacts of neglect).

The relevant source sector workgroups, the Watershed Technical Workgroup, and the WQGIT review the panel's recommendations before the BMP is adopted for use in the Watershed Model. This strategy appears to be a reasonable, consensus-based mechanism to assign pollutant removal efficiencies to new practices not currently represented in the model (e.g., low-impact design, state-of-the-art stormwater controls) and update BMP efficiencies or offsets from land-use conversions with new data, while main-

[1]For details and references, see CWP—http://cwp.org/; WERF— http://www.werf.org//AM/Template.cfm?Section=Home; and EPA water programs—http://www.epa.gov/owow_keep/nps/chesbay502/downloads.html.

taining rigorous review standards. Past experience, however, has shown that credited BMP efficiencies have more commonly been decreased rather than increased in the light of new field information.

What Is Working and Not Working in Each Jurisdiction and in the Federal Agencies

As previously described, the Bay jurisdictions' tracking and accounting approaches vary substantially. Programmatic components are summarized in Table 2-1, and full details are provided in Appendix C. Ideally, each Bay jurisdiction would have a clear organizational framework for BMP reporting, geo-located data for accurate conversion of the data into the Watershed Model, a rigorous QA/QC process that includes some level of field verification, a process for removing BMPs when they have expired or are not functioning, processes to prevent double counting, and few unreported practices. In reality, most jurisdictions are still working through these challenges, and there are significant disparities between the human and financial resources applied to tracking and accounting across the states. All of the Bay jurisdictions are working to improve their practices, but resources remain the primary limiting factor.

BMP Reporting and Transparency

All Bay jurisdictions have identified an organizational reporting structure for tracking and accounting among various state and local agencies, although the complexity of these structures varies widely. The District of Columbia reports all data through a single agency, which simplifies data collection, quality control, and reporting, but most states have more complex multi-agency reporting responsibilities. Some Bay jurisdictions suggested communication would improve if each jurisdiction and the CBP had a single point of contact for tracking and reporting issues.

Most Bay jurisdictions report BMP implementation on an annual basis to the CBP (on December 31, for the prior July-June period), and all jurisdictions are required to submit these data through NEIEN. Although the recent conversion to the NEIEN schema promises to improve data management, the system appears to have made the data less accessible to some jurisdictions. Whereas, previously, states compiled their BMP data from multiple agencies on an annual basis, now many state and local agencies submit their data separately. Thus, a jurisdiction may now only see its overall annual progress update after it has been compiled by the CBP, unless it has procedures in place to separately compile the data. Because of the time it takes for the CBP to compile the data and run the models to convert the BMP data into load reductions, significant delays (currently a minimum of

9 months) occur between BMP implementation and progress assessments, which hinder the application of adaptive management (see Chapter 4). Only Maryland reports its implementation progress more frequently via its own BayStat website, which it uses to make frequent adjustments to its BMP program to ensure achievement of its milestone goals.[2]

In January 2011, the CBP launched a new tracking and accounting system (Bay TMDL Tracking and Accounting System [BayTAS]) to track all of the Bay jurisdictions' progress toward meeting the TMDL requirements. BayTAS will be used to track progress for both point and nonpoint sources using geographic information system (GIS) technologies and the Watershed Model, and data will be displayed by state, segment, or facility on the CBP's new ChesapeakeStat website.[3] Among the questions the EPA expects to answer with BayTAS are:

- What is the status of BMP practice implementation and programmatic activities?
- What is the status of two-year milestone achievement?
- Are point source wasteload allocations being achieved? Are nonpoint source load allocations being achieved?
- Are states on target to achieve the Bay TMDL?

Because the forum is publicly accessible, BayTAS also improves the transparency of implementation data (P. Rana, EPA, personal communication, 2011). It remains unclear whether the system could be used for more frequent reporting by Bay jurisdictions to provide them with a tool to assess their progress toward the two-year milestones.

All Bay jurisdictions reported challenges in counting and reporting voluntary practices, as discussed earlier in the chapter. Only Maryland has developed a process to report voluntary practices, although it has not yet been implemented. Virginia and Delaware are actively developing and other states are considering such a process. Some jurisdictions also mentioned that they do not report some practices because of insufficient databases (e.g., septic system upgrades or hook-ups, stormwater practices) or challenges in converting the data into the format expected by the CBP (e.g., street sweeping). The EPA is working to overlay wastewater service areas to identify those areas served by septic systems in Phase 5.3 of the Watershed Model.

[2] See http://www.baystat.maryland.gov/.
[3] See http://stat.chesapeakebay.net/.

Geo-referencing

Three Bay jurisdictions geo-reference all or most BMPs that are tracked (i.e., New York, Maryland, District of Columbia); three states provide point locations for at least some BMPs (Virginia, West Virginia, Delaware; see Appendix C for details). Pennsylvania does not provide point locations for BMPs but instead reports them by county. Those locations that are not geo-referenced are typically reported by county, although some are reported by watershed or stream reach. Even Bay jurisdictions that collect location data for all new practices face challenges in siting historical BMPs that remain in the database. If BMPs are reported by county, then the EPA must make assumptions regarding the locations of these practices within specific watersheds. Proximity of the land use and BMPs to a water body is one of the major factors that affect the delivery of pollutants (Djojic et al., 2002). Thus, without accurate geo-location of urban and agricultural BMPs, there will be errors in accounting for BMP impacts on pollutant loads.

Quality Assurance and Quality Control

Field verification of agricultural BMPs is limited for some Bay jurisdictions (e.g., West Virginia, Pennsylvania), while other jurisdictions have implemented structured field verification programs (e.g., Virginia verifies up to 5 percent of agricultural BMPs annually, Maryland verifies 7-8 percent of agricultural BMPs annually, and New York verifies all reported practices). Most states reported some level of field verification for permitted stormwater management practices.

QA/QC of BMP data varies across the states. Maryland, the District of Columbia, Virginia, West Virginia, and Delaware reported specific strategies in their WIPs to reduce double counting of BMPs (DDOE, 2010; DE DNREC, 2010; MDE et al., 2010). Virginia reported that privacy agreements have only recently allowed its agencies to examine FSA or NRCS data to check for double counting in a manner that is consistent with Farm Bill privacy-related restrictions. Only Maryland and Virginia reported processes to remove BMPs when they are no longer functioning or have expired. As a result, "legacy" BMPs and double-counted BMPs from some jurisdictions will result in overestimating the extent of nutrient load reductions.

Despite inconsistencies in philosophy and approach, a great deal of information is available, and good faith efforts are under way to resolve some of the hindrances to data access, collection, and standardization (see Appendix C). The Bay jurisdictions are not likely to modify their respective programs to bring them into perfect alignment, but they are developing their own tailored programs based on their own circumstances and priorities. Although statewide programs are unlikely to be identical to one another in process or in fiscal and personnel allocations, the CBP has recently made strides toward common reporting goals and data requirements, in part because of the WIP process. The Bay jurisdictions are adapting to these data quality expectations, and some jurisdictions are much closer to meeting these expectations than others. However, electronic data management, new databases, and data transfer schema should ultimately reduce the BMP tracking and accounting burden for all jurisdictions.

How Do Gaps and Inconsistencies in Tracking Affect Reported Program Results?

As described above, the current tracking and accounting of BMPs is not consistent across the Bay jurisdictions. The committee was also tasked to evaluate the accuracy and reliability of the BMP tracking data and assess how gaps and inconsistencies appear to impact reported program results (Tasks 1 and 3, Box S-1). Thus, the committee attempted to estimate the extent of error in the BMP implementation data. On the one hand, the CBP could under-count BMP implementation rates and levels because state-reported data do not include non-cost-shared practices. Given that at least some of these practices were in place when the model was calibrated, the extent of error that these uncounted practices introduce into the overall simulations is unclear. Even recent pilot studies to quantify these differences at a county scale (e.g., Table 2-2) did not extrapolate the findings to nutrient load estimates. On the other hand, the model could over-count BMP implementation rates and levels, because few states account for the loss of BMPs when they are no longer in place or no longer effective or for known double-counting problems. State quality assurance project plans (QAPPs) generally do not specify procedures to evaluate differences between quantities of activities reported to the CBP and actual on-the-ground implementation, despite the EPA's request that jurisdictions include such information in the QAPPs (J. Winters, EPA, personal communication, 2010).

The nonuniformity of BMP efficiencies can lead to inaccuracies in Watershed Model simulations. Any error in accounting for the areal extent of implemented BMPs will have direct impact on the load simulations. Such errors can cause either under- or over-estimation of loads by the Watershed Model. Furthermore, there are several discrepancies between a state's and CBP's definitions of BMP management that affect the accuracy of the calculated nutrient load reductions. For example, states allow application of manure to cover crops, while the CBP definition for cover crops assumes no manure is applied.[4]

[4]No manure is applied except on commodity cover crops after March 1.

BOX 2-2
Florida Agricultural Nonpoint Source Best Management Practices Summary

The Florida agricultural BMP program was formalized in state law with the passage of the Watershed Restoration Act (WRA) (Ch. 403.067 F.S.) in 1999. The WRA is Florida's blueprint for development and implementation of TMDL provisions of the Clean Water Act primarily focused on achieving nutrient load reductions to impaired water bodies. Implementation of a TMDL through adoption of a Basin Management Action Plan requires agricultural landowners to either implement BMPs or monitor water quality. The WRA charges the Florida Department of Agriculture and Consumer Services (FDACS) with the responsibility for agricultural BMP development.

The WRA mandates that agricultural BMPs be: (1) based on sound science (generally using University of Florida expertise); (2) adopted by administrative rule into the Florida Administrative Code; (3) verified as effective by the Florida Department of Environmental Protection initially using best professional judgment followed by water quality monitoring; and (4) revised accordingly, with revisions implemented by participating landowners, if BMPs are found ineffective in meeting water quality goals. All FDACS BMP programs mandate the implementation of nutrient management plans.

The WRA also requires that FDACS develop and adopt by Rule a formal procedure for agricultural landowners to enroll their lands in the BMP program. This procedure requires landowners to submit name and contact information, land parcel tax identification number(s), crops be-

Based on the information provided, the overall accounting of BMPs in the Bay watershed cannot be viewed as accurate. However, the committee was not able to determine the magnitude or the likely direction of the overall reporting error (that is, whether the actual load reductions of currently implemented practices are likely to be greater or less than the current modeled output based on the practices counted). Some of these errors will likely cancel each other out, but there is substantial room for improvement. Additionally, the committee was unable to determine whether the actual data reported by each jurisdiction are reliable and accurate. The only way to truly assess the reliability and accuracy of the reported data would be through independent (third-party) auditing of the tracking and reporting at state and local levels.

ing produced, and specific BMPs being implemented. Landowners who enroll in the BMP program and implement all applicable BMPs receive a "presumption of compliance" with nutrient water quality standards and become eligible for state cost-share funding. Eighty-three percent (1.5 million acres) of statewide irrigated agricultural acreage is enrolled. An additional 6.6 million acres of nonirrigated land is also enrolled. The current total of 8.1 million acres will expand dramatically over the next year as the focus for enrollment will be on the largest agricultural land use in Florida: improved and unimproved pasture land for beef cattle production. FDACS BMP programs now cover forestry, citrus, vegetables and row crops, sod, containerized nurseries, specialty crops (tropical fruit, blueberries, pecans, etc.), and beef cattle. BMP programs are under development for the equine and field-grown nursery industries.

FDACS has also developed a quality assurance program to follow up with enrolled landowners to verify that they are implementing the BMPs identified on their submitted documentation. On a statewide basis, the quality assurance program consists of grower surveys and site visits to verify survey results for a fraction of the respondents. In high-priority watersheds (the Suwannee River and Lake Okeechobee Basins) participating landowners are visited in greater proportion and frequency.

Since the inception of the program, Florida has spent $75.5 million on developing, implementing, and evaluating agricultural BMPs. This state money has leveraged in excess of $200 million in USDA/NRCS Environmental Quality Incentives Program (EQIP) funding over the same period of time. FDACS estimates that landowners have contributed at least $60 million in capital costs, not including long-term operation and maintenance.

HOW CAN THE TRACKING SYSTEM BE STRATEGICALLY IMPROVED?

Although many programs are actively in place to improve the tracking and accounting system, in this section the committee proposes additional strategies that could improve BMP tracking in the CBP.

A Consolidated Chesapeake Bay Region Agricultural BMP Program

All Bay jurisdictions lack the ability to reliably and consistently document agricultural nonpoint source BMPs that are implemented without the assistance of federal or state cost-share programs. These shortcomings could be overcome by the development and implementation of BMP programs similar to those that exist elsewhere in the nation whereby agricultural producers report voluntary conservation practices that would otherwise be unaccounted for (see Florida example in Box 2-2).

The establishment of a regional BMP program, perhaps coordinated by an independent organization or alliance of organizations (e.g., the American Farm Bureau Federation, the National Association of Conservation Districts) with close coordination with the Bay jurisdictions' respective Departments of Agriculture, would lay the foundation for a more formal program to track and account for voluntary BMPs. This BMP program could include record keeping and reporting requirements, including reporting of geo-locations for BMP data. Verification of BMP implementation could occur through random field inspections of a percentage of program participants. The BMP efficiencies could be assessed through representative site water quality monitoring coupled with watershed or sub-watershed-scale monitoring, which would serve to document a range of nutrient load reduction estimates for prioritized conservation practices. Initially, financial and human resources for this program could be focused on the regions of each state that are within the Bay watershed, although state TMDL initiatives would likely benefit from such programs implemented statewide.

Coupling cost-share eligibility (for those states that allocate cost-share funds) to BMP program participation is an effective mechanism to entice landowners to participate. Structured properly, a state program can also leverage USDA cost-share funds and further reduce landowner costs for BMP implementation. Reducing property taxes for participating agricultural landowners would likely be an effective incentive, although local governments would suffer lost revenues. Finally, disincentives are possible tools, such as requiring parcel-scale water quality monitoring if landowners choose not to implement BMPs. Providing agricultural producers who implement, report, and maintain BMPs with a presumption of compliance with water quality standards has proven to be a powerful incentive for landowners in Florida and has contributed to successful long-term operation and maintenance of implemented BMPs (Box 2-2). USDA has recently begun discussions with EPA and Bay jurisdictions about developing a similar such program in the Chesapeake Bay, where farmers would agree to implement certain practices in exchange for presumptive compliance with regulations (A. Mills, USDA, personal communication, 2011).

Expanded Geo-location Data

Although some states are working toward geo-referencing all BMPs, most states are far from this goal. Geo-referencing will improve the tracking of implemented BMPs with time, allowing easier quality control checks for double counting and improving the accuracy of siting in the Watershed

Model, thereby improving the accuracy of the modeled loads. Once accurately geo-located, the information can be used in increasingly finer scale models. Geo-referenced data can also help to assign proper pollutant delivery ratios in the Watershed Model and to prioritize BMP inspections based on the proximity of BMP implementation to the receiving water body, as described by Djojic et al. (2002).

CONCLUSIONS AND RECOMMENDATIONS

Accurate tracking of BMPs is of paramount importance because the CBP relies upon the resulting data to estimate current and future nutrient and sediment loads to the Bay. However, many Bay jurisdictions and localities are struggling with limited resources, complex and rapidly changing data reporting mechanisms, data privacy constraints, and QA/QC needs. Verifying the continued functioning and effectiveness of historical activities presents a significant challenge. Although state tracking and accounting programs are unlikely to be identical, the CBP has recently made strides toward common reporting goals and data requirements through the watershed implementation plan (WIP) process, the NEIEN, and the recent launch of BayTAS.

The current accounting of BMPs is not consistent across the Bay jurisdictions. Additionally, given that some source-sector BMPs are not tracked in all jurisdictions, the current accounting cannot on the whole be viewed as accurate. Although the Bay jurisdictions have a good understanding of point-source (i.e., wastewater) discharges, numerous issues affect the accuracy, reliability, and consistency of BMP reporting to the CBP. Only five of the seven Bay jurisdictions conduct any level of field verification of agricultural practices, and there are known problems with double counting that agencies are working to resolve. Only one Bay jurisdiction specifies a lifespan for practices recorded in the database, and few jurisdictions have mechanisms to identify and remove from the database practices that are no longer functioning or even in place. Current tracking systems do not account for agricultural practices that are not cost-shared by a government agency. Given these limitations, current accounting can be considered, at best, an estimate.

The committee was unable to determine the reliability and accuracy of the BMP data reported by the Bay jurisdictions. Independent (third-party) auditing of the tracking and accounting at state and local levels would be necessary to ensure the reliability and accuracy of the data reported.

The committee was not able to quantify the magnitude or the likely direction of the error introduced by BMP reporting issues. On the one hand, there is under-counting of BMPs because the jurisdictions do not currently report non-cost-shared practices, although the model calibration may include the effects of some of these practices. On the other hand, there is over-counting of BMPs because few states account for the loss of BMPs when they are no longer properly maintained, functioning, or in place. Furthermore, there are errors introduced by site-level variability in BMP effectiveness, insufficient data on the location of BMPs, and discrepancies between state and CBP definitions of BMP management.

A consolidated regional BMP program to account for voluntary practices and increase geo-referencing of BMPs presents opportunities to improve the tracking and accounting process. A regional BMP program with incentives for participation as well as penalties for lack of participation has been effectively used in Florida to increase participation and improve data quality. Geo-referencing enables managers and modelers to identify the parcel-level location of BMPs, which would aid in inspecting, tracking, and assigning proper delivery ratios and BMP efficiencies, thereby improving the accuracy of the modeled estimates of nutrient and sediment loads delivered to the Bay.

Targeted monitoring programs in representative urban and agricultural watersheds and subwatersheds would provide valuable data to refine BMP efficiency estimates, particularly at the watershed scale, and thereby improve Watershed Model predictions. Current BMP load reduction efficiency estimates used in the Watershed Model are reasonable estimates of the short- to intermediate-term reduction efficiencies of newly installed BMPs at the field scale and gross representations of the same at the watershed scale. These estimates contain significant uncertainties caused by site-specific factors, practice design, extent of maintenance, and challenges in scaling up the data from the plot or field scale. Pilot studies in several subwatersheds should be conducted to quantify BMP performance, particularly for the most common practices with the greatest uncertainty in their efficiency estimates. The CBP has recently implemented a review process to refine BMP efficiencies used in the Watershed Model based on emerging research findings.

Additional guidance from the EPA on the optimal extent of field verification of practices in relation to expected benefits would improve tracking and accounting of both cost-shared and voluntary practices. Field verification is costly, and several states have questioned its value given the resource constraints that limit BMP implementation. Although independent random or probabilistic verification programs increase public confidence that reported data are accurate and reliable, attention should be given to developing ways to optimize field verification efforts that enhance the reliability of the BMP data sets, perhaps through the combined use of remote sensing data, written surveys, phone calls, and in-person visits.

Electronic tracking and data transfer systems are likely to improve the quality of reporting and reduce the jurisdictions' tracking and account-

ing burden but may currently be contributing to delayed assessments of implementation progress. Despite the concerns in tracking and accounting noted above, a great deal of information is available, and a plausible and collective effort seems to be under way to resolve some of the hindrances to data access, collection, and standardization. However, because implementation data are now reported electronically, several jurisdictions noted that the data are less accessible for assessments of statewide progress. Some Bay jurisdictions have mechanisms in place to compile progress updates as needed, but others have to wait approximately 9 months after the end of the reporting period for a summary of BMP implementation progress from the CBP. The recently launched tracking and accountability system for the TMDL (BayTAS) and ChesapeakeStat, which documents each jurisdiction's progress in a publicly accessible website, should incorporate mechanisms for more timely reporting and consolidation of federal and state data submissions.

3

Assessment of the Two-Year Milestones

As discussed in Chapter 1, the two-year milestone strategy was adopted in May 2009 to provide tangible short-term nutrient and sediment reduction goals for each of the Bay jurisdictions. The jurisdictions adopted aggressive goals for nitrogen and phosphorus load reductions for the first milestone period (through December 2011). The committee was tasked to assess whether the two-year milestone strategy and its level of implementation were "likely to result in achieving the nutrient and sediment reduction goals for this milestone period" (Task 4, Box S-1).

CONTEXT FOR THE COMMITTEE'S ANALYSIS

The central purpose of this chapter is twofold: (1) an evaluation of the two-year milestone strategy and (2) an assessment of its level of implementation. Both parts contribute toward assessing whether the Chesapeake Bay Program (CBP) nutrient and sediment reduction goals for this milestone period are likely to be achieved. However, clarification of the committee's interpretation of what it means to achieve the nutrient and sediment reduction goals (Task 4) is a first step. The committee is *not* addressing whether the Chesapeake Bay's water quality will improve during this milestone period, because actual nutrient and sediment deliveries and the Bay's response are affected by lag times, legacy nutrients, and precipitation quantity, duration, and intensity. The full benefits of land-based nutrient reduction strategies will likely take decades to be seen in the Bay's main stem (see Box 1-3).

One could also interpret Task 4 as asking whether the two-year milestone practices, if implemented, would result in the promised load reductions. That is, are the nutrient and sediment load reduction efficiencies, which are assigned to each of the best management practices (BMPs) and used by the Watershed Model to predict load reductions, reasonably accurate? However, as noted in Chapter 2, a comprehensive review of BMP efficiencies was beyond the task and time available for the committee. (See Chapter 2 for additional discussion of BMP efficiencies.)

Based on discussions with U.S. Environmental Protection Agency (EPA) staff, the committee interpreted this task as asking: (1) Is the two-year milestone strategy appropriate to address the Bay's excess nutrient and sediment loads, and (2) are treatment technologies and land-based BMP practices being implemented as promised in the original two-year milestones, such that the jurisdictions are on track to meet their modeled load reduction goals? These questions, and the data available to address them, are examined separately in the sections that follow.

THE TWO-YEAR MILESTONE STRATEGY

The two-year milestone strategy adopted by the CBP Executive Council simply breaks the overall implementation goals for nutrient and sediment reduction into two-year increments, with the goal of having all actions in place by 2025. At the time they were adopted, the milestones were targeted toward the tributary strategy goals, but since that time, the total maximum daily load (TMDL) has replaced the tributary strategy goals. Starting in 2011, the milestones will be set with the objective of implementing by 2025 all nutrient and sediment reduction practices (including wastewater treatment and BMPs for regulated and unregulated stormwater and nonpoint sources) needed to reach the TMDL and implementing 60 percent of the practices by 2017 (see Chapter 1). The CBP adopted a longer increment for the first milestone (roughly 3 years), although the additional time in no way slows the pace of progress expected for this period. As noted in Chapter 1 (see Table 1-5), the first milestone goals represent approximately 21-22 percent of the nitrogen and phosphorus reductions needed to reach the loading goals—a sizeable first increment. As envisioned by this strategy, the success of implementation strategies would be evaluated by the CBP every 2 years, making each jurisdiction and its elected and appointed officials more accountable for successes and shortfalls. The two-year milestone strategy is dependent on tracking and accounting processes to produce reliable implementation data (see Chapter 2).

The overall impact of wastewater treatment upgrades and newly-implemented BMPs can be significantly reduced if additional controls are not specifically included to offset development and population growth. In the two-year milestone strategy launched in 2009, each Bay jurisdiction approached adaptation to growth with varying degrees of rigor. Maryland ultimately revised its goal to include additional practices to offset the growth that occurs over the first milestone (H. Stewart, MD DNR, personal communication, 2010; see Appendix D). Delaware stated that it developed a tool (the Nutrient Budget Protocol) to evaluate changes in loading due to land-use changes and that it would manage these increases adaptively going forward (J. Volk, DE DNREC, personal communication, 2010). However, most Bay jurisdictions simply noted that their permitted wastewater loads provided room for additional growth above actual current loads or noted that regulations required stormwater BMPs for new development. However, managing for growth appears to be better addressed in the watershed implementation plans (WIPs) created by each of the Bay jurisdictions. In the WIPs each of the Bay jurisdictions explicitly addresses how it will offset growth effects while continuing to reduce nutrient and sediment loads.

Overall, the committee endorses the two-year milestone approach as an improvement over the previous strategy of setting long-term (~10-year) goals. The prior strategy was only marginally effective, in part because the time frame exceeded the terms of most elected officials who were responsible for achieving the state-level goals. In general, the two-year milestone strategy should improve accountability and encourage reevaluations and adjustments for Bay jurisdictions that are not achieving their goals (see Chapter 4). However, it remains unclear whether the jurisdictions will face consequences for failing to achieve the two-year milestones, and if so, how severe the consequences will be. In the original documentation of the two-year milestones, consequences for nonattainment were not mentioned (CBP, 2009b), and meeting public expectations appeared to be the primary incentive for jurisdictions to achieve the milestone goals. Under the TMDL process, the EPA has stated that consequences could be applied at any point if a jurisdiction is failing to meet its expected progress (EPA, 2010a), and the two-year milestones could certainly be used as benchmarks for such assessments.

Meeting the milestones, however, is not likely to result in immediate improvement in water quality or the Bay's condition. Although wastewater treatment facility upgrades will result in rapid reductions in nutrient loads to receiving waters, given groundwater lag times (Phillips and Lindsey, 2003) and legacy nutrients associated with landscape nutrient sources, the benefits of land-based BMPs can have response times on the order of years to decades. Traditional monitoring of Bay water quality parameters may cause the public to doubt the value of the milestone effort if Bay responses are slow or even nonexistent. Therefore, targeted monitoring programs are needed, particularly at a small watershed level, to highlight local-scale improvements in water quality as they occur and to better understand the time lags of system responses to nutrient control measures. These issues are discussed further in Chapter 5.

IMPLEMENTATION PROGRESS IN THE BAY JURISDICTIONS

The second part of Task 4 asks whether the jurisdictions are implementing the nutrient and sediment reduction practices as promised, such that they are on track to meet their modeled load reduction goals for the first milestone. To answer this question, information on implementation progress for a substantial portion of the first milestone period and associated anticipated load reductions (generated from model runs and wastewater treatment plant discharge reports) would be needed. Unfortunately, modeled 2010 progress data were not available in time for the committee's review. The Bay jurisdictions are required to report their BMP implementation data to the CBP on December 31, for the previous July 1-June 30 period. As of February 2011, when the committee was finalizing its report, the CBP was still compiling the July 1, 2009 to June 30, 2010 data, which were submitted via the new National Environmental Information Exchange Network (NEIEN) (see Chapter 2). The CBP was not able to complete the milestone progress model runs using the reported 2010 data within the time constraints of the committee's study schedule.

In lieu of model-generated nutrient and sediment load estimates for the time elapsed in the first milestone, the committee requested BMP implementation data directly from the Bay jurisdictions in an attempt to gauge progress based solely on the percentage of practices implemented versus the percentage of the milestone elapsed. It is worth noting that the committee received inconsistent information on the official start date of the first milestone period (July 2008, January 2009, or July 2009) and its duration (2.5 years, 3 years, or 3.5 years) from the EPA and the Bay jurisdictions. The original milestone publication (CBP, 2009b) generally cited the first milestone as a 3-year period, ending on December 31, 2011; thus, for the purpose of this analysis, the committee assumed a 3-year milestone period. However, the final decision about what to credit toward the first milestone may still be unfolding, especially in light of the fact that the annual reporting periods (July to June) do not coincide with the January to December milestone period.

The committee requested data from July 1, 2009 to June 30, 2010 (or later), because this was the first full year of data reported after the two-year milestone strategy was announced in May 2009 and would certainly be counted toward the first milestone period. Maryland, Virginia, West Virginia, and the District of Columbia were able to produce a compiled tally of BMP implementation for this period, although Virginia noted that this required significant additional effort to compile the data from the information submitted through NEIEN. Two states, Pennsylvania and Delaware, no longer compiled practice information once electronic data reporting was required, and they were only able to provide BMP implementation data for July 2008 to June 2009. New York did not provide any BMP implementation data in response to the committee's request. No nitrogen and phosphorus load reduction estimates were available from any of the jurisdictions associated with the reported implementation progress for 2009-2010. All reported BMP implementation data are provided in Appendix D.

Given the limited available data, the question of whether the level of implementation will result in achieving the first milestone goals cannot be answered. BMP implementation data alone provide a general sense of whether the jurisdiction is making progress, but associated model runs are needed to evaluate how implementation shortfalls in some areas or greater than expected progress in others affect the overall anticipated nutrient reduction. Simply surveying the percentages of proposed practices actually implemented (as is reported in Appendix D) has only limited value, because the individual practice implementation targets identified vary in size and nutrient removal efficiency. Additionally, the effect of individual BMPs on the overall load removal to the Bay varies with practice location in the watershed and proximity to surface waters. For example, West Virginia reported that during July 2009 through June 2010, it achieved 4 percent of its wetland restoration goal (0.2 out of 5 acres drained) but 138 percent of its cover crops acreage goal (2,071 acres out of 1,500 acres). However, it would be a mistake to conclude that West Virginia has therefore accomplished 71 percent of its nutrient reduction goal. Achieving a modest percentage of a large and efficient nutrient control project may achieve greater progress than achieving 100 percent of a very modest project. Thus, any evaluation of the implementation data provided must, by necessity, only be qualitative and not quantitative.

The committee's qualitative analysis of the pace of practice implementation was, in most cases, limited to progress in a single year out of a (assumed) three-year milestone period. All jurisdictions that responded outlined numerous efforts to control urban and agricultural nutrient and sediment loads. However, they reported mixed progress on their original milestone implementation goals, with greater successes in implementation of some practices than others over the reporting period (see also Appendix D):

- Virginia reported substantial progress in the implementation of some practices over a 12-month period (or 33 percent of the milestone period), such as continuous no-till (118 percent of the goal) and cover crops (78 percent of the goal). Progress lagged in other areas (e.g., forest buffers [12 percent of the goal], agricultural stream restoration [0 percent of the goal], stormwater management BMPs [12 percent of the goal]). To meet its milestone load reduction goals, Virginia will need to implement significantly more practices than it originally proposed to address a 990,000-pound nitrogen shortfall in its milestone implementation commitments that was identified by the CBP (CBP, 2009a).

- Maryland reported substantial progress in some areas (e.g., cover crops [152 percent of goal], stream protection with fencing [94 percent of the goal]) over a 21-month period (or 58 percent of the milestone period), and limited progress in others (e.g., precision agriculture [0 percent of the goal], septic hookups [5 percent of the goal]; see Appendix D).
- West Virginia reported that over a 12-month period (or 33 percent of the milestone period), it exceeded its first milestone goals for cover crops (138 percent of the goal), animal waste management systems (209 percent of the goal), and forest buffers (365 percent of goal), but it is lagging behind the expected pace of progress in a few areas, mostly for BMPs with small implementation goals (e.g., grass buffers, urban filtering systems).
- Although the District of Columbia is making progress on implementing urban BMPs, the bulk of its load reductions are anticipated to come with upgraded nutrient removal technology at the Blue Plains wastewater treatment plant, which will not be completed until 2015. Therefore, the District does not expect to reach the first milestone for nitrogen in 2011, although it had already reached its milestone for phosphorus prior to 2009.

Two states, Pennsylvania and Delaware, submitted data for July 2008 to June 2009, which largely reflect the pace of implementation prior to the announcement of the two-year milestone strategy. Although this period may ultimately be credited toward the first milestone, these data are not comparable to the 2009-2010 data, because the milestone strategy encouraged states to increase their implementation rates above that of prior years. Thus, the committee primarily considered this earlier data as evidence of baseline implementation progress. Substantial implementation progress in 2008 could suggest that a state is well poised to continue that rate throughout the first milestone period. Minimal implementation progress in 2008 would suggest the need for greater implementation progress from 2009-2011 to reach its milestone goals. However, a slow or fast pace of progress in 2008 cannot be considered indicative of whether a state will achieve its first milestone goal.

- Pennsylvania's baseline implementation progress (July 2008-June 2009) appeared generally consistent with the pace needed to meet its first milestone, assuming the pace is maintained throughout the first milestone period. However, like other states, Pennsylvania reported successes in some areas (e.g., erosion and sediment control, enhanced nutrient management) and limited progress in others (e.g., stream restoration, off-stream watering).

- Delaware's reported baseline implementation progress (July 2008-June 2009) showed substantial implementation progress in some agricultural practices (e.g., cover crops [89 percent of the first milestone goal], forest buffers [82 percent of the goal]). However, it appears that implementation of many additional nutrient control practices would be needed to address the large shortfall in the original milestone (264,000 pounds of nitrogen, nearly 6,000 pounds of phosphorus) that was identified by the CBP (CBP, 2009a).

At least one state reported that it was working to better account for existing BMPs and was making additional progress toward its milestone by identifying BMPs that had not previously been reported. This raises an interesting issue regarding tracking and accounting. Each jurisdiction needs to be given appropriate credit for practices that are in place. However, implementation progress reported for the first milestone period may overestimate the actual new reduction in nutrient load if jurisdictions are working to meet their milestones by reporting practices that have actually been in place for many years, particularly those practices that were in place when the model was calibrated. This also means that a trajectory for future progress cannot be predicted based on what is accomplished for the first milestone. The committee is not able to estimate the magnitude of this effect, but the effect is likely to decline over time as future milestone accomplishments reflect work actually done during the milestone period and the pace of actual new implementations becomes more evident.

OTHER ISSUES

Bay jurisdictions have raised the concern that the recent evolution of the Watershed Model (from Phase 4.3 to Phase 5.3) will confound interpretation of two-year milestone progress. The original milestone goals were developed using the Phase 4.3 model, while the TMDL and WIPs have been assessed with the latest version. The CBP is currently resolving how to manage this issue, either by using the retired model to assess the load reductions from the 2010 implementation data or by generating new load estimates for the original milestone scenarios using the Phase 5.3 model. Either way, there may be some unexpected results, but this should not significantly hinder the interpretation of whether the states are keeping pace with implementation of their load reduction projects and actions.

One of the committee's largest concerns with the current milestone strategy relates to the time frames for BMP reporting efforts, discussed in Chapter 2. In December 2010, states submitted their July 2009-June 2010 implementation data via NEIEN for the first time. With this new reporting system, some states no longer compiled the implementation data in a single report because the federal, state, and local agencies directly transferred the data to the CBP via the NEIEN schema. Although the intent of NEIEN is to reduce the workload associated with data transfer, improve accuracy, reduce double counting, and provide reporting consistency among the CBP jurisdictions, the process appears to have added delays to some states' assessments of their own implementation progress. If most states are unable to evaluate their own progress on a frequent (at least semi-annual) basis, especially for more uncertain stormwater and nonpoint source BMP applications, their capacity to improve the pace of their implementation progress through mid-course corrections and by adopting contingencies during the two-year milestones is greatly limited. Additionally, even if the jurisdictions were to compile their own implementation progress in parallel to the NEIEN submissions, most jurisdictions (with the exception of Maryland) lack the modeling capability to estimate load reductions associated with practice implementation. More frequent opportunities for reporting and feedback on implementation progress (included associated load reductions) via the Bay TMDL Tracking and Accounting System (BayTAS) and ChesapeakeStat[1] are needed to enable jurisdictions to evaluate their successes toward their two-year milestone goals and work to address their shortfalls in a timely way (see Chapter 4 on adaptive management).

CONCLUSIONS

The two-year milestone strategy commits the states to tangible, near-term implementation goals and improves accountability and, therefore, represents an improvement upon past CBP long-term strategies. However, the strategy, in and of itself, does not guarantee that implementation goals will be met, and consequences for nonattainment remain unclear. The two-year timeframes should encourage frequent reevaluations and adjustments for Bay jurisdictions that fall short of their intended implementation goals. However, without timely updates and synthesis of statewide progress from the CBP, many states lack the information necessary to make appropriate mid-course corrections.

CBP jurisdictions reported mixed progress toward their first two-year milestone goals. However, data were insufficient to meaningfully evaluate implementation or anticipated load reduction progress relative to the goals. The jurisdictions reported numerous efforts to control urban and agricultural nutrient and sediment loads, although they experienced greater suc-

[1]ChesapeakeStat is a website designed to display TMDL progress. See http://stat.chesapeakebay.net/.

cesses in implementation of some practices than others. Without associated load reduction estimates for the implemented practices, the committee was unable to evaluate how implementation shortfalls in some areas or greater than expected progress in others affect the likelihood that the Bay jurisdictions will meet their overall nutrient load reduction goals.

The first two-year milestone goals will likely be the easiest to achieve. Not surprisingly, the states are investing in the "low-hanging fruit"—the least expensive or most cost-effective among the nutrient reduction options—for the first accounting period. Large gains have been made with advanced treatment technologies applied to large publicly-owned wastewater treatment facilities (see Figure 1-13a), which to date, have been relatively cost-effective per pound of nutrient removed compared to land-based BMPs. Additionally, states are working to document practices implemented prior to the current milestone period but not yet credited in the Watershed Model. Available water quality improvement options during subsequent milestone periods will likely become less cost-effective. It is possible that nonstandard control strategies, especially those that do not require high capital investments (see Chapter 5), may need to be considered.

4

Adaptive Management

Since 2008, Chesapeake Bay Program (CBP) partners have embraced adaptive management as a way to enhance overall management of the program (EPA, 2008a) and to strengthen scientific support for decision making (EPA, 2008a; DOI and DOC, 2009c). The *Strategy for Protecting and Restoring the Chesapeake Bay Watershed* (FLC, 2010b) promotes adaptive management to coordinate science and decision-support activities. This emphasis on adaptive management crosses all facets of the CBP and federal and state initiatives for protecting and restoring the Chesapeake Bay. This chapter provides an overview of how the CBP and federal partners have framed adaptive management generally and then turns to the application of adaptive management to nutrient and sediment reduction programs to meet water quality goals. In subsequent sections the committee reviews CBP partner efforts to implement adaptive management and discusses potential barriers to and possible successful applications of adaptive management for nutrient and sediment reduction in the Bay watershed.

THE CHESAPEAKE BAY PROGRAM FOCUS ON ADAPTIVE MANAGEMENT

In a 2005 report, the Government Accounting Office (GAO) recommended that the Chesapeake Bay Program Office (CBPO) develop a coordinated implementation strategy and establish a means to better target its limited resources to ensure program effectiveness. In the Chesapeake Action Plan (CAP; EPA, 2008a), a report to Congress demonstrating implementation of the GAO recommendations, the U.S. Environmental Protection

Agency (EPA) presented the intent to institute adaptive management as a way to enhance overall management of the CBP. The EPA concluded that the CBP possessed many essential components of adaptive management but "lacked a single set of strategies for achieving program goals, a comprehensive activity plan, and a framework to organize these parts into a cohesive whole." In the CAP, the EPA proposed to fill these gaps by adopting a "five stage model of adaptive management" based on adaptation of the Kaplan and Norton (2008) closed-loop management system (Figure 4-1). This approach is intended to establish "strong relationships between strategy and operations" (EPA, 2008a) and foster "continual improvement of both Bay implementation activities and CBP's organizational performance" (EPA, 2008a). "The cycle of active strategy development, planning, implementation, and evaluation is being applied to all areas of CBP activity, so that the organization itself, not only individual partners or partners engaged in on-the-ground implementation, will learn and change based on the outputs of the adaptive management process" (EPA, 2008a).

Adaptive management in the CBP is further emphasized in documents responding to President Obama's 2009 Executive Order 13508. Specifically,

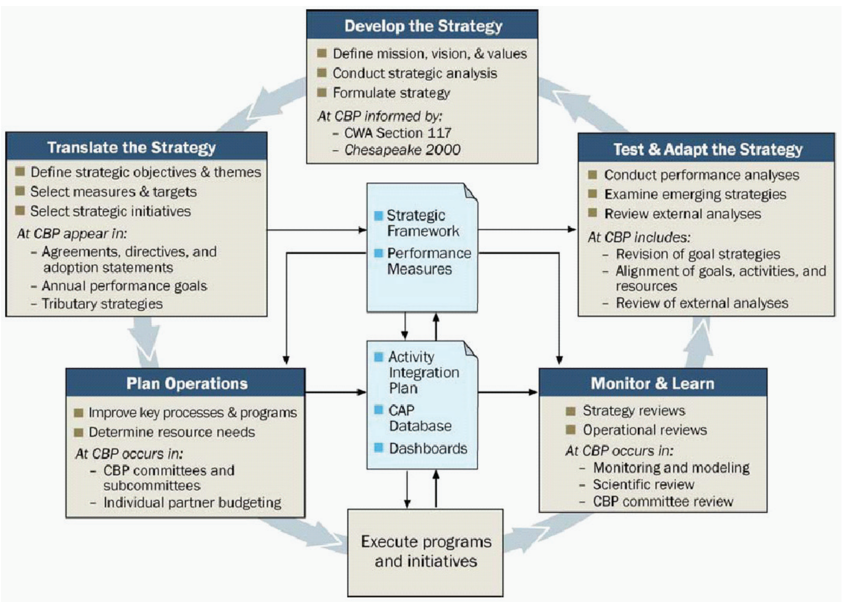


FIGURE 4-1 The Chesapeake Bay Program adaptation of the Kaplan and Norton closed loop management system.
SOURCE: EPA (2008a).

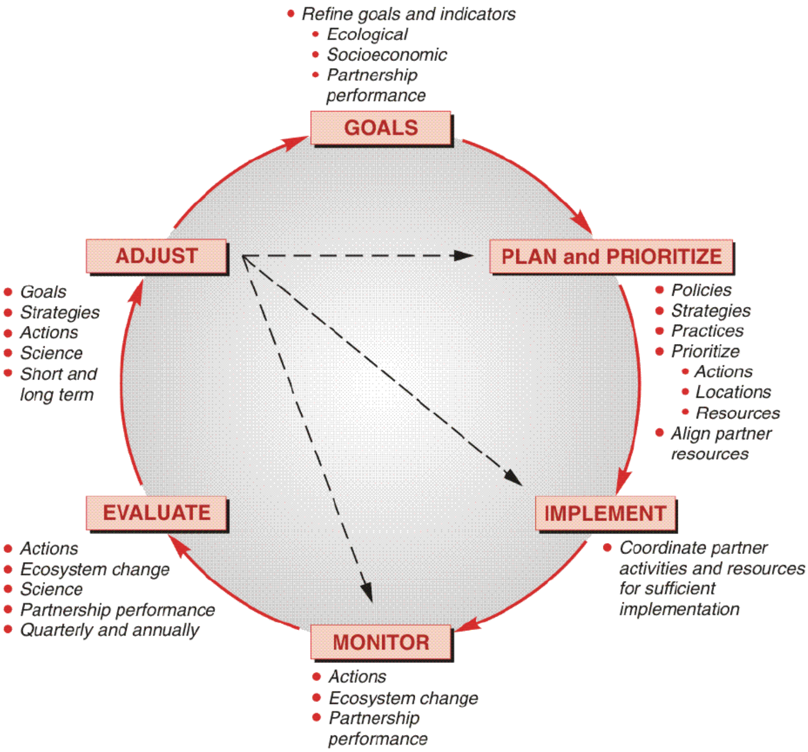


FIGURE 4-2 Proposed adaptive ecosystem management framework.
SOURCE: DOI and DOC (2009c).

Section 202(f) of the Executive Order required specific agencies to submit reports that make recommendations for "strengthen[ing] scientific support for decision making to restore the Chesapeake Bay and its watershed, including expanded environmental research and monitoring and observing systems."

In response, the Section 202(f) report proposed that the CBP further employ adaptive ecosystem management to complement the adaptive management process described in the CAP (DOI and DOC, 2009c). The Section 202(f) report recommends an adaptive ecosystem management framework (Figure 4-2) based on approaches presented by Williams et al. (2009) and Levin et al. (2009). Section 203 of the Executive Order calls upon federal agencies to develop a strategy for protecting and restoring the Chesapeake Bay, including a process for implementing adaptive management principles with periodic evaluation of protection and restoration activities. The final strategy, called the *Strategy for Protecting and Restoring the Chesapeake Bay Watershed* (FLC, 2010b), promoted "ecosystem-based, adaptive management through enhanced coordination of science and decision-support activities" and presented the adaptive management framework depicted in Figure 4-2.

These two adaptive management frameworks apply to all Chesapeake Bay protection and restoration goals: restoring clean water, recovering habitat, sustaining fish and wildlife, conserving land, and increasing public access. However, for the purposes of this report, discussion of adaptive management is bounded by the committee's task, that is, to evaluate whether each of the Bay jurisdictions (i.e., the six states in the Bay watershed and the District of Columbia) and the federal agencies developed appropriate adaptive management strategies to ensure that CBP nutrient and sediment reduction goals will be met.

OVERVIEW OF ADAPTIVE MANAGEMENT

Definitions of adaptive management and descriptions of adaptive management efforts abound in the literature. Excellent overviews can be found in NRC (2004) and Stankey et al. (2005). The term "adaptive management" surfaced from research on improving environmental assessment and management described by Holling (1978). Gregory et al. (2006) describe the general goal of adaptive management as improving "managers' knowledge about a set of well-defined ecological objectives through the implementation of carefully designed, quasi-experimental management interventions and monitoring programs." This focus on improving knowledge, which may slow ecosystem improvements in the short run in an effort to make them more effective in the long run, sets adaptive management apart from other environmental management efforts.

Adaptive management arose from the recognition that uncertainty is inherent in natural systems, yet management actions generally cannot be delayed until knowledge is complete and uncertainties resolved. At its heart, adaptive management reflects the understanding that many ecosystem management decisions must be made in scenarios that are characterized by uncertainty. Additionally, adaptive management acknowledges that "managed resources will always change as a result of human intervention, that surprises are inevitable, and that new uncertainties will emerge" (Gunderson, 1999) and embraces the notion that, if management decisions are framed as experiments, learning can occur when the results are carefully monitored and evaluated.

Adaptive management's experimental, learning-focused approach is offered as an effective strategy for reducing uncertainties. Sometimes referred to as "learning while doing," adaptive management learning derives from deliberate formal processes of inquiry (Stankey et al., 2005), replacing evolutionary learning by trial and error with learning by careful tests (Walters, 1997; Box 4-1). What does this mean in practice? In his discussion of the use of adaptive management in Coastal Louisiana and the Chesapeake Bay, Boesch (2006) lays out the charge:

> Under adaptive management, practitioners must be explicit about what they expect and they must collect and analyze information so that expectations can be compared with actuality. They must periodically correct errors, improve their imperfect understanding, and change actions and plans. The coupling among explicit expectations (from modeling), comparisons with actuality (through monitoring), and changed actions and plans is the essence of adaptive management.

There is no recipe of steps or building blocks that will immediately constitute an adaptive management program (NRC, 2004), but discussions of adaptive management expansively describe various procedural components (see Box 4-2). Consider the stylized adaptive management process

BOX 4-1
Trial and Error, Passive Adaptive Management, and Active Adaptive Management

Management can be structured as an adaptive process in three ways: evolutionary (or trial and error), passive adaptive, and active adaptive. With an evolutionary process, early management choices are essentially haphazard, and experience illustrates which subset of choices gives better results. This information is used to frame subsequent decisions that, it is hoped, lead to improved results. In contrast, passive and active adaptive management incorporate definition of management objectives, deliberate monitoring, effective evaluation and reflection, appropriate communication among all project participants, and formal mechanisms for incorporating learning into planning and management. Passive adaptive management uses available historical data to construct a single best hypothesis and implements a single policy or practice to test it. Active adaptive management uses available data to structure a range of alternative hypotheses and designs management experiments to test them that reflect an acceptable balance between expected short-term ecosystem response and long-term learning about which alternative (if any) is correct.

SOURCES: Walters and Holling (1990); Schreiber et al. (2004); Allan and Curtis (2005); Gregory et al. (2006).

BOX 4-2
Key Elements of Adaptive Management Identified in Theory and Practice

1. Management objectives that are regularly revisited and accordingly revised.
   a. Agreement among scientists, managers, and stakeholders on goals and modes of progress.
   b. Agreement on key research questions or lines of inquiry to be pursued.
   c. Iterative process to review (and revise if appropriate) key questions, paths of inquiry, and programmatic objectives.

2. A model(s) of the system being managed.
   a. Clear understanding of model assumptions and limits so that model results are not equated with reality.

3. A range of management choices.
   a. Evaluation, at the outset, of the likelihood that each alternative will achieve management objective, generate new information, or foreclose future choices.
   b. Exploration of potential for implementing two or more actions simultaneously to help discriminate among competing models.

4. Monitoring and evaluation of outcomes.
   a. A monitoring and evaluation plan developed as part of initial program design and not added ad hoc after implementation.

illustrated in Figure 4-3, which emphasizes key elements of adaptive management identified by the NRC (2004) as applied to water quality management. Once the water quality goal is established (Step 1 in Figure 4-3), existing interdisciplinary experience and scientific information is integrated into models to clarify the management problem; enhance communication among scientists, managers, and other stakeholders; and screen management options (Walters, 1997). Through this planning process (Step 2 in Figure 4-3), scientists, managers, and stakeholders, in consultation, explore uncertainties that affect related management decisions. These uncertainties could be associated with the natural system that is the target of management or the social system within which management is to occur.

Collectively, scientists, managers, and stakeholders select one or more management options to be tested through carefully designed experiments

b. A mechanism for comparing outcomes of management decisions.
c. Focus on significant and detectable indicators of progress toward management objectives.
d. A mechanism to help distinguish between natural changes and changes caused by management actions.

5. A mechanism(s) for incorporating learning into future decisions.
   a. A plan for how new information will be incorporated as part of the initial program design.
   b. Political will to act upon new information.
   c. Flexibility to adjust operations in light of new information or shifting conditions and preferences.

6. A collaborative structure for stakeholder participation and learning.
   a. Stakeholder involvement in initial decision to apply adaptive management.
   b. Formal process for involving stakeholders in setting objectives.
   c. Formal process for incorporating stakeholder knowledge into process and for stakeholder learning from new information.
   d. Stakeholder flexibility and willingness to compromise.

SOURCE: NRC (2004).

(Step 2 in Figure 4-3), using either active or passive adaptive management (see Box 4-1). The experiments involve the formulation of hypotheses about the outcomes of particular management strategies. Testing the hypotheses requires that management actions be purposefully implemented in such a way that their effects can be measured (Schreiber et al., 2004). Rather than trying all management alternatives, sequentially or simultaneously, adaptive management focuses on one or a few alternatives, implements them, and deliberately monitors outcomes in a way that enables evaluation of the alternatives tested. The choice of alternative(s) to be tested is based on the likelihood of reducing key uncertainties, model results and other sources of knowledge, stakeholder input and response, resource constraints, and temporal considerations.

Monitoring starts with the development of a monitoring plan that

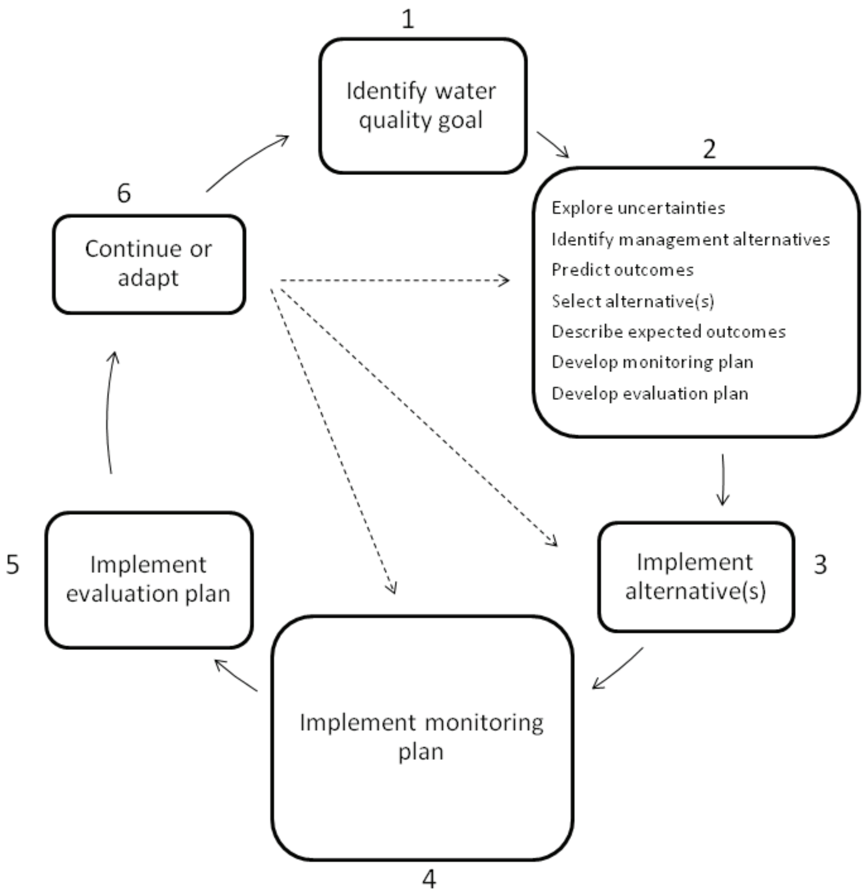


FIGURE 4-3 Stylized adaptive management strategy, with the size of the box proportional to the amount of effort required. Steps 2 (planning) and 4 (monitoring) typically require the greatest attention for successful adaptive management.

describes how the assumptions and hypotheses embodied in the experiments will be tested (Figure 4-3, Step 2). Monitoring requires more than assessing status and, as asserted by Lee (1999), information gathering alone is not monitoring. A monitoring plan should be designed not only to test whether expected outcomes are realized but also to understand why or why not (Halbert, 1993). Monitoring and evaluation processes should enable scientists and managers to answer questions such as:

- How and when will expected outcomes be identified?
- If the expected outcome is observed, then how can we be sure it was because of the management implemented?
- If the expected outcome is observed, then what should be done next?
- If the expected outcome is not observed, then why not? What should be done next?

The monitoring process typically requires an assessment of baseline conditions in addition to monitoring responses to the management action over time (Williams et al., 2009). The monitoring design must be scaled to the questions at hand and account for the impacts of routine variability (e.g., precipitation, stream flow). Box 4-3 presents an example of monitoring and evaluation in Tampa Bay and how the results are used to refine management efforts in an adaptive management context.

Implementation of the management practices is undertaken only after extensive attention has been paid to the experiments' design, monitoring, and evaluation. This is represented in Figure 4-3, which illustrates where emphasis in adaptive management differs from traditional evolutionary (trial and error) learning through the relatively larger boxes for Steps 2, 4, and 5. Often, adaptive management efforts are stymied by traditional funding approaches and programmatic cultures that focus on implementation rather than on monitoring. In addition, progress evaluations often emphasize reports on implementation activity, rather than on the value of new knowledge and how it has been used to improve decision making (Allan and Curtis, 2005).

EVALUATION OF ADAPTIVE MANAGEMENT STRATEGIES IN THE CHESAPEAKE BAY PROGRAM

The committee is charged with evaluating whether the CBP partners have developed appropriate adaptive management strategies to ensure that the program's nutrient and sediment reduction goals will be met. Challenges in addressing this question arise from the fact that there are many definitions and descriptions of adaptive management in the literature. The National Research Council report *Adaptive Management for Water Resources Project Planning* (NRC, 2004) describes the problem:

> There are many dimensions of adaptive management, and the ambiguities inherent in adaptive management can result in policymakers, managers, and stakeholders developing unique definitions and expectations. The term is complex and multidisciplinary… adaptive management is an evolving theory and practice….

BOX 4-3
Adaptive Management in Tampa Bay

The Tampa Bay water quality management program is a collaborative, flexible, multi-disciplinary effort that has evolved in response to changes in technology, data availability, and scientific understanding. To address the inherent uncertainties and complexities of Bay responses to changing pollutant loads and other environmental conditions, the program has adopted an adaptive management (Holling, 1978; Lee, 1993) approach. The adaptive nutrient management strategy used in Tampa Bay incorporates periodic evaluations of water quality and seagrass management goals and annual evaluations of water quality monitoring data to redirect management actions on an as-needed basis (Greening and Elfring, 2002).

Because of the importance of seagrass as a biological resource in Tampa Bay, the Tampa Bay Estuary Program (TBEP) and its partners have adopted numerical targets for water clarity levels (expressed as annual mean Secchi depth), chlorophyll a concentrations, and nitrogen loading to help meet seagrass acreage restoration goals for the Bay (Greening and Janicki, 2006). To ensure consistency with the adaptive management approach, the effectiveness of the adopted nitrogen management strategy is assessed annually by evaluating chlorophyll a concentrations and water clarity levels measured in each Bay segment during the previous calendar year and comparing those values to the segment-specific targets (Greening and Janicki, 2006). A decision matrix approach (Janicki et. al., 2000; Sherwood, 2009) is used to determine the level of management response that is appropriate in years when water quality targets are not met.

The continual monitoring of water quality and seagrass in Tampa Bay allows managers to assess progress toward meeting established goals. An important component of this effort is the routine comparison

Kai Lee has been quoted as saying, "Adaptive management has proven difficult to understand because it's so easy to understand approximately" (Halbert, 1993). Definitional problems appear to be a challenge for the CBP. A review of the federal *2011 Action Plan* (FLC, 2010a) for implementing the *Strategy for Protecting and Restoring the Chesapeake Bay Watershed* (FLC, 2010b), the Chesapeake Bay total maximum daily load (TMDL; EPA, 2010a), and the Bay jurisdictions' watershed implementation plans (WIPs) indicates that the Bay partners have not established a clear understanding of what adaptive management means.

The *2011 Action Plan* for protecting and restoring the Bay watershed suggests that using adaptive management "will provide science to improve of mean annual chlorophyll *a* concentrations and light attenuation to desired targets. TBEP has developed a tracking process to determine if water quality targets are being achieved. The process to track status of chlorophyll *a* concentration and light attenuation involves two steps. The first step uses a decision framework to evaluate differences in mean annual ambient conditions from established targets. The second step incorporates results of the decision framework into a decision matrix, leading to possible outcomes dependent upon magnitude and duration of events in excess of the established target (Janicki et al., 2000, Greening and Janicki, 2006). When outcomes for both chlorophyll *a* concentration and light attenuation are good (i.e., when both targets are being met), no management response is required. When differences from the targets exist for either chlorophyll *a* concentration or light attenuation or both, conditions are intermediate and may result in some type of management response. When conditions are problematic, such that there are relatively large, longer-term differences from either or both targets, stronger management responses may be warranted. The recommended management actions resulting from the decision matrix are classified by color into three categories for presentation to the Tampa Bay resource management community (see Sherwood, 2009).

Addressing uncertainty is a necessary component in any management strategy. The use of the decision matrix for adaptive management has proven to be an effective and easily communicated tool to address management actions in a timely way and has provided a mechanism for detecting and responding to uncertainty, if it arises. For example, if seagrass cover stopped expanding before reaching the target acreage, although nutrient loading and water clarity targets continued to be met, then a new round of technical investigations would be initiated.

the efficiency and accountability of federal actions to restore water quality, habitat, fish and wildlife, and conserve lands" (FLC, 2010a). The *2011 Action Plan* also commits the Federal Leadership Committee of the Chesapeake Bay (FLC) to institute adaptive management in support of implementation and accountability by establishing "a regular cycle for reviewing activities, progress against goals and timelines outlined in the strategy" (FLC, 2010a). Unfortunately, merely reviewing activities and progress regularly will not provide the learning offered by adaptive management and is unlikely to improve the efficiency or accountability of federal actions to restore water quality or achieve other goals. Adaptive management is not mentioned at all in the *2011 Action Plan* section on restoring clean water (FLC, 2010a).

Section 10 of the Chesapeake Bay TMDL (EPA, 2010a), which addresses implementation and adaptive management, highlights several eventualities that might result in modifications of the TMDL, including changes in legal and regulatory authorities, updates to the model, and updates of Bay jurisdictions' WIPs. Adaptive management is specifically mentioned only in the context of climate change: "EPA has committed to take an adaptive management approach to the Bay TMDL and incorporate new scientific understanding of the effects of climate change into the Bay TMDL" during the 2017 mid-course assessment (EPA, 2010a). However, modification of the TMDL mid-course is not, by itself, adaptive management.

Several Bay jurisdictions refer to adaptive management in their WIPs, and some of the jurisdictions refer to what could be gained from implementing adaptive management. However, the WIPs do not provide descriptions of adaptive management strategies. In a few cases, jurisdictions refer to the two-year milestones and listed contingencies as an adaptive management strategy. The milestones and contingencies could be an important part of an adaptive management strategy but, as is explored in the next sections of this chapter, they do not themselves constitute adaptive management. In a few cases, plans to implement practices or programs, monitor results, and modify activities are described (e.g., Pennsylvania's targeted watershed approach [PA DEP, 2010]), which are key elements of adaptive management. Whether management implementation is designed with learning in mind and whether the monitoring and evaluation plans provide learning to support management changes is unclear from the WIPs.

In sum, although many of the CBP partners think they are implementing adaptive management, the committee did not find evidence of any formal adaptive management efforts for nutrient and sediment reduction. In the following sections, the committee analyzes federal agency and Bay jurisdiction documents to evaluate whether the CBP partners have key elements in place that would support the development of effective adaptive management strategies (i.e., identification of goals, exploration of uncertainties, development of management experiments, and monitoring and evaluation). Potential barriers to and opportunities for adaptive management are also discussed.

Identification of Goals

Clear goals have been set for the water quality programs in the Chesapeake Bay. The overarching and ecological goal shown at the top of Figure 1-15 and detailed in Table 1-4 is to restore biological integrity in the Bay. The second goal, which contributes to the capacity to accomplish the ecological goal, is to meet water quality criteria in the Bay and its tidal tributaries (FLC, 2010b). An interim goal is to meet water quality criteria in 60 percent of Bay segments by 2025, but the CBP does not dictate which Bay segments should be addressed first.

The CBP has also set in the TMDL a load reduction goal of achieving annual load targets under average hydrologic conditions of 185.9 million pounds per year nitrogen, 12.5 million pounds per year phosphorus, and 6.45 billion pounds per year sediment (EPA, 2010a). The load reduction goal is to be met by implementation of wastewater treatment plant upgrades and best management practices (BMPs), outlined in the WIPs, that will reduce the discharge of nitrogen, phosphorus, and sediment to the Bay and tidal tributaries. The WIPs describe the BMP implementation goals of each Bay jurisdiction and will soon be expanded to provide detail at the county scale. The fourth goal (Figure 1-15), then, is to have in place by 2025 all practices needed to meet the load targets, with 60 percent of practices in place by 2017 (FLC, 2010b). Finally, short-term goals are set for the BMPs that are to be implemented during each two-year milestone period, reflecting an incremental process toward meeting the BMP implementation goals.

Exploration of Uncertainties

CBP partners have not undertaken sufficient analysis of the uncertainties inherent in water quality management. In federal documents, issues of uncertainty largely are minimized or passed off to nonfederal partners to address as part of their WIPs and program design and implementation. For example, in section 5 of the Chesapeake Bay TMDL, modeling uncertainties are minimized: "Although models have some inherent uncertainty, the amount of data and resources taken to develop, calibrate, and verify the accuracy of each of the Bay models, minimized the uncertainty of the suite of Bay models" (EPA, 2010a). Section 6 of the TMDL describes the use of margins of safety to account for any uncertainties in the supporting data and models. Again, however, especially for nitrogen and phosphorus, those uncertainties are minimized; the TMDL describes "state-of-the-science models, with several key models in their fourth or fifth generation of management applications" (EPA, 2010a) and concludes that "use of those sophisticated models to develop the Bay TMDL, combined with application of specific conservative assumptions, significantly increases EPA's confidence that the model's predictions of standards attainment are correct" (EPA, 2010a). In Appendix S of the TMDL, the EPA presses the Bay jurisdictions to deal with uncertainties about BMP effectiveness, monitoring, reporting, and accounting for unregulated nonpoint sources when calculating credits in offset programs for new or increased loads.

Some WIPs refer to uncertainties about funding, effectiveness of specific management practices, incompatible datasets, future land-use changes, and the quality of the EPA's models. However, the WIPs do not describe whether, or how, the Bay jurisdictions would seek to reduce these uncertainties through adaptive management. In a few instances, WIPs propose actions that should reveal new information, that is, opportunities to reduce uncertainty. However, the WIPs do not describe the Bay jurisdictions' expectations for what could be learned and how water quality management could be improved as a result of the new information.

The 2001 NRC report *Assessing the TMDL Approach to Water Quality Management* describes two significant sources of uncertainty in water quality management: epistemic and aleatory uncertainty. *Epistemic uncertainty* results from insufficient information to estimate probabilities of responses to management actions. NRC (2001) states:

> Epistemic uncertainty…is a by-product of our reliance on models that relate sources of pollution to human health and biological responses. We are limited by incomplete conceptual understanding of the systems under study, by models that are necessarily simplified representations of the complexity of the natural and socioeconomic systems, as well as by limited data for testing hypotheses and/or simulating the systems. …For example, at present there is scientific uncertainty about the parameters that can represent the fate and transfer of pollutants through watersheds and waterbodies. *It is plausible to argue that more complete data and more work on model development can reduce epistemic uncertainty* [emphasis added].

Aleatory uncertainty results from the inherent variability in natural processes and, by definition, cannot be reduced (Pielke, 2007). NRC describes the aleatory uncertainty affecting water quality programs: "Not only are waterbodies, watersheds, and their inhabitants characterized by randomness, but they are also open systems in which we cannot know in advance what the boundaries of possible biological outcomes will be..." (NRC, 2001).

The committee identified specific sources of uncertainty that challenge management strategies to reduce nutrient and sediment loads and improve water quality in the Bay. Epistemic uncertainties arise from incomplete knowledge about:

- **The CBP models.** Even after years of application, testing, and validation, questions remain about uncertainty in the modeled loading estimates, which are influenced by multiple factors, including the models' assumptions, equations, parameters, and initial and boundary conditions (Box 4-4).

BOX 4-4
Estimation of Prediction Uncertainty for the Chesapeake Bay Model

An estimate of error in the predictions from the Chesapeake Bay Model quantifies the confidence that scientists have in their forecasts of Bay response to nutrient load reductions. This, in turn, is likely to influence stakeholder opinions of nutrient control strategies, as well as support the need for adaptive management. Unfortunately, the complexity of the Chesapeake Bay Model prevents a thorough assessment of model prediction uncertainty.

An alternative that partially captures prediction error for the model is to use a summary measure of the difference between model predictions and actual observations. This approach generally is not used, in part because the number of prediction-observation comparisons tends to be limited (because of datasets of limited size). Because most of the observations are used in the model calibration exercise, this comparison may be strongly biased toward a lower error estimate. However, because there are many historic water quality observations for the Chesapeake Bay, it may be possible to run a calibrated model to predict key water quality variables (e.g., chlorophyll *a* and dissolved oxygen) and compare these against observations for noncalibration years. This comparison can yield an approximation of model prediction error.

- **Ecological processes in the Bay and tributaries.** Designated uses reflected in water quality standards are based upon "a combination of natural factors, historical records, physical features, hydrology, bathymetry, and other scientific considerations" (EPA, 2010a). However, expectations about desired endpoints in coastal ecosystem restoration efforts may be frustrated by the occurrence of baseline shifts and regime shifts in ecosystems (Duarte et al., 2009). The trajectory that the Bay and its tributaries will follow in recovery is uncertain.
- **Water quality impacts of reduced nutrient and sediment loads.** Bay responses to nutrient enrichment are complicated by a range of ecological feedback mechanisms. Questions about interactions among organisms and biogeochemical processes and their effects on ecological and water quality responses to nutrients are unresolved (Kemp et al., 2005).
- **Realization of anticipated nutrient and sediment load reductions.** Extensive, comprehensive efforts have produced estimates of effectiveness for BMPs to be used in planning and implementation. Yet, variability in

site-specific conditions, BMP designs, implementation and maintenance of practices, scale of implementation, combined practices, and lag times between implementation and full performance are recognized as factors that introduce uncertainty into effectiveness estimates (Simpson and Weammert, 2009; see also Chapter 2).

- **Willingness and ability to implement nutrient and sediment controls.** The responses of individuals, firms, communities, and governmental bodies to initiatives intended to increase the use of point and nonpoint source controls depend upon the incentives and opportunity sets that drive and constrain decisions. Considerable research has been undertaken to explain, for example, why and when farmers adopt conservation practices. However, the absence of any clear universally significant factors affecting conservation behavior across locations and practice types suggests that the effectiveness of policy tools such as financial or technical assistance will depend upon particulars of location, farmers, and farm operations (Knowler and Bradshaw, 2007).
- **Political will and multijurisdictional cooperation.** Several Bay jurisdictions have balked at the requirement to develop and seek EPA approval of a WIP. Bay jurisdictions have expressed concerns about the costs of plan implementation, the EPA's reliance on model results as the basis for major policy decisions, and the distribution of costs and benefits of water quality improvements. Additionally, the distribution of responsibilities among federal, state, and local governments will make reaching agreements about sharing costs challenging. Adoption of the two-year milestone approach was intended to overcome uncertainties associated with electoral cycles and leadership changes, but elections will continue to introduce new questions about commitment to Bay priorities.

Climate change and its impacts introduce aleatory uncertainty, especially over the long run. Unanticipated droughts or flooding can make nutrient and sediment reduction practices appear more effective or can undermine practice implementation.

Even though the CBP partners face many uncertainties, programmatic structures, program timeframes, regulatory requirements, and available budgets likely prevent experimentation to respond to them all. As a result, the CBP will benefit from careful consideration of what uncertainties can be most effectively and usefully addressed through adaptive management. If uncertainty is very low or nonexistent, then adaptive management is simply not needed, because the outcomes can be projected with confidence. If uncertainty is high, then adaptive management may be inappropriate because of difficulties with separating the effects of management actions from external influences (Gregory et al., 2006). In addition, there may be significant uncertainties that currently prevent identification of appropriate management interventions, called "decision-critical uncertainties" in NRC (2007). The committee has not identified any decision-critical uncertainties that suggest that ongoing nutrient and sediment reduction strategies are inappropriate. Instead, there are numerous uncertainties that are relevant to decision making, as listed above, for which the dimensions of uncertainty are understood and for which experiments can be designed to better inform future water quality management decisions.

Designing Management Experiments

Uncertainties are reduced through learning about what works, what doesn't, and why. This learning comes from carefully designed management experiments and deliberate monitoring and evaluation. Some example initiatives described in the WIPs can be used to illustrate how specific management actions could be framed as management experiments in the context of adaptive management.

Testing the Effectiveness of New BMPs

In its WIP (DDOE, 2010), the District of Columbia proposes to incorporate low impact development (LID) techniques into any new or reconstructed Water and Sewer Authority facilities as demonstrations. Monitoring at those sites would indicate the effectiveness of the LID techniques at reducing runoff that reaches combined sewer overflows (CSOs) or surface water. What if this proposal were framed as a management experiment with specific plans for what is to be learned and how the new knowledge is to be used? Uncertainties about the effectiveness of LID techniques would be explored. Specific predicted runoff reductions could be articulated and a plan designed to monitor for those outcomes. A plan for how to respond to a different outcome from what is expected, that is, to adapt, would also be needed. To enhance learning and further reduce uncertainty through an adaptive approach, a series of locations could be identified where different LID techniques could be tested and the different outcomes compared to evaluate which techniques are preferred in what types of situations.

Testing the Effectiveness of Incentive Programs

As another example, West Virginia describes the addition of soil nitrogen testing and cornstalk nitrate testing to the components supported by cover crop incentive payments (WV WIPDT, 2010). Even with the nitrogen availability benefits observed with cover crops, farmers will often add additional nitrogen to insure crop yields. Covering the costs of these additional BMP components allows farmers to test for whether additional nitrogen is needed, which reduces the risks of purchasing and over applying unneeded nitrogen fertilizer. Framing this change in incentive programs as a management experiment could address a series of questions: Does the modification of the cover crop incentive program change farmers' willingness to adopt cover crops? Do supplemental nitrogen applications differ depending upon whether farmers plant cover crops independently or because of the incentive program? What can be learned from the monitored nitrogen balances about nitrogen retained in the corn and cover crop and nitrogen lost (to air or water) in fields where the additional components are used and fields where they are not? Framing specific questions about adoption rates and/or BMP efficiency, designing a monitoring and evaluation program to answer those questions, and modifying the BMP design or the incentive program, if indicated, in response to what is learned represent elements of adaptive management.

Testing the Effectiveness of Watershed Overlay Permits

Pennsylvania describes the potential use of a Municipal Stormwater Separate Storm Sewer System (MS4) watershed overlay permit in Lancaster County that would establish a protocol with specific tools to assist municipalities in meeting MS4 permit requirements. Described as an iterative and adaptive approach, the protocol would assist municipalities with meeting MS4 permit responsibilities and would identify other opportunities for BMP installation and load reductions, and other prospects for nutrient, sediment, and stormwater credits. The WIP (PA DEP, 2010) asserts that this approach will allow the Department of Environmental Protection to gather data, monitor effectiveness, and evaluate implementation and load reduction successes. The WIP does not indicate exactly how the overlay permit would work and how areas included under the overlay permit would differ from those that are not. However, such a management alternative could be a component of an adaptive management strategy. In an experimental context, the opportunity exists to compare outcomes in overlay permit areas with outcomes in similar but non-overlay areas to evaluate the effectiveness of the approach for increasing implementation of practices.

Monitoring and Evaluation

When management decisions are framed as tests under adaptive management, monitoring provides the results of the tests. In this section the committee discusses aspects of monitoring and evaluation needed to support adaptive management in the CBP.

In most cases, the WIPs address monitoring in terms of assessing compliance with permits, checking for practice implementation progress, and

BOX 4-5
Long-term Monitoring to Assess Response to BMPs in the Lake Erie Watershed

The importance of long-term monitoring for assessing watershed response to conservation management is demonstrated by the Lake Erie Agricultural Systems for Environmental Quality (LEASEQ) Project (Richards et al., 2002b, 2009). Phosphorus loads in two Ohio watersheds (Maumee and Sandusky River Watersheds) with major tributaries to Lake Erie have been monitored since 1975 to determine the effect of BMPs (e.g., conservation tillage and nutrient management planning in predominantly row-crop agriculture) on water quality. Monitoring showed an 8 percent average increase in flow since 1975, while mean annual flow-weighted concentrations of suspended sediment, total phosphorus, and dissolved phosphorus decreased 23, 44, and 86 percent, respectively (Richards et al., 2002a). Since 1995, annual flow-weighted concentrations of dissolved phosphorus have increased, while particulate (and total phosphorus) have continued to decline (Baker and Richards, 2009). The trend of increasing dissolved phosphorus and decreasing total phosphorus may be attributed to a combination of several factors: a change in rainfall distribution pattern; a buildup of phosphorus at the soil surface with no-till cropping; and increased applications of fertilizer and manure, without incorporation in the fall and winter. An adaptive process in the LEASEQ might have avoided recent dissolved phosphorus increases through quicker response to perceived impacts of soil phosphorus build-up at the surface.

This project showed water quality changes (both positive and negative) in response to management changes at a watershed scale, and it may offer lessons for the Chesapeake Bay Watershed. Specifically, BMPs such as incorporation of applied phosphorus in no-till crops, use of winter cover crops on conventionally tilled fields, and a transition from fall to spring application of phosphorus could potentially reduce phosphorus loss from agricultural land in the watershed. However, consistent monitoring, evaluation of data collected, and changes in management are necessary to avoid unexpected negative impacts of practices.

collecting ambient water quality samples. These kinds of activities do not, in and of themselves, provide evidence that the technology upgrades or implemented BMPs are having the intended effects (Box 4-5). In the agricultural BMP implementation context, external financial or weather-related pressures on farmers may complicate efforts to gauge the effectiveness of BMP incentive programs.

Similarly, as noted by the CBP's Science and Technical Advisory Committee (STAC) in its report on small watershed monitoring designs:

> To interpret the effects of the conservation practices on nutrient discharges, watershed monitoring alone is not sufficient. It will be necessary to collect detailed data on the practices and other agricultural activities that affect nutrient discharges, including: areas, spatial distribution, and types of agricultural lands (croplands, pastures, etc.); fertilizer application rates; livestock populations; and the locations of riparian buffers and wetlands. (Weller et al., 2010)

Weller et al. (2010) provided extensive recommendations for appropriate monitoring strategies. These included focusing on smaller watersheds (4-15 mi^2 or 10-40 km^2) within larger areas of high nutrient and sediment discharges for the greatest impacts and making long-term commitments (5 to more than 10 years) to maintain conservation practices and assemble spatially explicit data on conservation practices and watershed monitoring. The report also offered suggestions for improving the cost-effectiveness of monitoring efforts.

Monitoring is costly, and prioritization of monitoring efforts is essential. The STAC conducted a review of the CBP monitoring program objectives and priorities and how well monitoring provides information to assess progress toward goals and to improve decision making in the CBP (STAC, 2009). The report noted that the CBP has a long and rich history of monitoring which has served some objectives quite well. However, the STAC also noted that the monitoring program has evolved reactively, is spread across many fronts, and lacks clear prioritization or reassessment. Although no monitoring program could effectively address the enormous range of management endpoints represented in the CBP goals, the STAC concluded that "continuing operation of the monitoring effort in a status quo condition is unacceptable" (STAC, 2010). As a result of its review (and the associated series of workshops held in 2008), the STAC recommended that the CBP focus monitoring efforts toward two objectives—the delisting of tidal segments of the Bay and determining the effectiveness of management actions—and concluded that appropriate monitoring information needed to address these issues could be obtained (STAC, 2010). However, the STAC also noted that balance between the monitoring efforts related to each objective would be required, as resources dedicated to monitoring for progress toward one objective would not be available for use for the other. Senior managers participating in the workshops identified their priorities for new monitoring as follows:

1. What is the effectiveness of management actions, most specifically those implemented in the upper portions of the watershed,
2. Where can we demonstrate early signals of trajectories, and
3. If we can't demonstrate success, then how do we determine the reasons for failure?

With expected outcomes of management actions made explicit and monitoring focused on these questions, the CBP would be better prepared to undertake adaptive management and to address at least some uncertainties, although additional focused monitoring programs would undoubtedly be needed. Adaptive management in the CBP will also require better integration of monitoring and modeling activities so that new information obtained about the effectiveness of management actions is reflected in modeled projections of broader nutrient load reductions. Two STAC reports (STAC, 1997, 2005) provide detailed discussion on and suggested approaches for improving the integration of modeling and monitoring.

Potential Barriers to and Opportunities for Adaptive Management in the CBP

Adaptive management has been applied to a range of ecosystem management problems with varying degrees of success, and many reasons have been suggested for why some applications of adaptive management have been more successful than others (Halbert, 1993; Lee, 1993; McLain and Lee, 1996; Walters, 1997; Gregory and Failing, 2002). Several barriers to successful adaptive management in the Chesapeake Bay exist, but opportunities to overcome the barriers also exist in some cases.

Time and Resource Intensity

Adaptive management requires considerable time and effort in advance of actual practice implementation for planning the management experiment and monitoring and evaluating outcomes. These intense resource needs are problematic for the use of adaptive management in the Chesapeake Bay watershed because resources are limited and stakeholders (and taxpayers) are anxious for evidence of improvement. Bay jurisdictions wrote their WIPs within a short time window with the objective of describing how load reduction goals will be met. Not surprisingly, Bay jurisdictions are likely to focus their efforts in the two-year milestones on meeting implementation goals and to pass on the chance to learn why particular BMPs were or were not implemented or whether the implemented BMPs are having the desired effect. Bay jurisdictions are most likely to experience successful adaptive management if they focus on a very limited number of management initiatives, rather than on their full programs, because not all initiatives warrant the type and level of planning and monitoring involved in adaptive management.

Regulatory Inflexibility

Absent sufficient flexibility in institutional structures, successful adaptive management is unlikely (Gunderson, 1999). Political and legal rigidities and narrow interpretations of management agencies' legal mandates are among examples of inflexibilities that limit opportunities for adaptive management (NRC, 2004; Stankey et al., 2005). Potential inflexibilities introduced by language in the Clean Water Act (CWA) and in regulations directing the TMDL implementation process may constrain adaptive management in the CBP. For example, Shabman et al. (2007) noted that obstacles to adaptive management can be found in how the current National Pollutant Discharge Elimination System (NPDES) process is applied under a TMDL. Once waste load allocations (WLAs) are incorporated into NPDES permits, anti-backsliding requirements generally prevent changes to the permits, even if new learning suggests that the initial TMDL or the WLAs should be changed. Anti-backsliding refers to the CWA requirement that NPDES permits not be reissued, renewed, or modified to contain less stringent effluent limitations than the previous permit (Thorme, 2001).

On the other hand, philosophical foundations for adaptive approaches in the CWA may make adaptive approaches to TMDL implementation feasible (Freedman et al., 2004). Shabman et al. (2007) examined opportunities for the use of adaptive management (or adaptive implementation, AI) within a TMDL framework.

> AI begins with installation of certain controls to move the watershed in the direction of reducing pollutant loads, while also providing information on their effectiveness in improving water quality at different geographic and time scales. With new knowledge, the original watershed analysis, water quality analyses, and models can be revised to update the estimates of current and future pollutant loads and the resulting water quality in the impaired water body. The new information is used to revise and modify the implementation plan of the original TMDL. If a [water quality standard] WQS assessment is added to this mix, then AI expands the concept of "learning while doing" to the assignment of appropriate WQS to the waterbody. This reassessment of the implementation strategy distinguishes AI from SI (standard or current implementation). (Shabman et al. 2007)

However, Shabman et al. (2007) noted that accommodations for adaptive implementation in the NPDES permitting process may be needed because AI could involve modification of the TMDL or the WLA over time. Successful application of adaptive management in the CBP will require greater regulatory flexibility. Freedman et al. (2004) explored opportunities for greater flexibility and suggested approaching a TMDL as a process, not an endpoint.

The EPA has defined adaptive implementation of TMDLs as "an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities" (EPA, 2006). However, in its guidance on adaptive implementation, the EPA only goes so far in embracing adaptation: "In most cases adaptive implementation is not anticipated to lead to the re-opening of a TMDL. Instead, it is a tool used to improve implementation strategies" (EPA, 2006). The EPA does suggest, however, that new scientific understanding of the effects of climate change might be incorporated into the TMDL during the mid-course assessment (EPA, 2010a).

Embracing Uncertainty

Framing programs in terms of adaptive management requires explicit admission that the management effort is experimental. The Bay jurisdictions are likely hesitant to report planned experiments to the EPA and indeed have little or no experience with designing such experiments. Further, federal requirements of reasonable assurance that Bay jurisdictions will meet nutrient and sediment load reductions remove any impetus for learning from experiments. Bay jurisdictions are forced to present WIPs that minimize uncertainty and offer assurances in ways that rule out learning with adaptive management.

Acceptability of Failure

The EPA has adopted an accountability framework as part of the renewed efforts reflected in the Executive Order and accompanying strategy (FLC, 2010b), with expected actions (e.g., Phase I, II, and III WIPs; two-year milestones; BMP implementation to meet the TMDL) and potential consequences for the failure to meet expectations. This accountability framework poses challenges for the development of adaptive management strategies by the Bay jurisdictions. The regulatory structure and threat of consequences makes admitting to uncertainties and the possibility of failure, undertaking management experiments, and proposing plans for adapting based on new information gained difficult propositions. Figure 4-4 depicts EPA's accountability framework and, with a dead-end at the consequences box, illustrates the way in which the framework makes adaptive management unlikely.

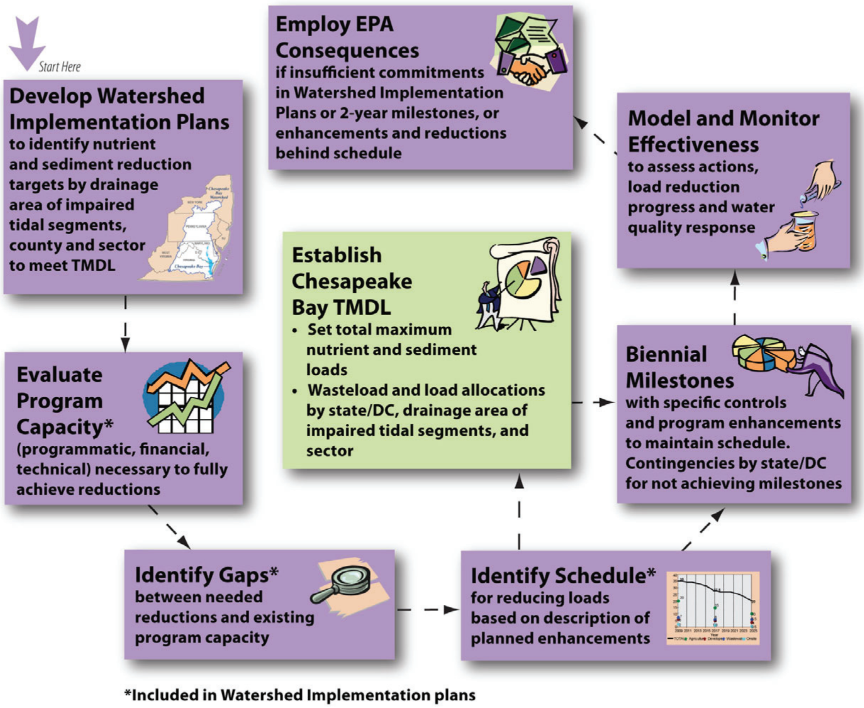


FIGURE 4-4 EPA's state accountability framework.
SOURCE: EPA (2009).

An alternative way to frame the EPA's accountability initiative that is more compatible with adaptive management is to base the threat of consequences on the failure of the Bay jurisdictions to propose management alternatives based on sound expectations, to adequately monitor and evaluate outcomes to understand the effectiveness of alternatives, and to adapt management strategies according to the results of the evaluation. Yet another way to frame the EPA's accountability initiative that is less prejudicial against adaptive management is to base the threat of consequences on the failure of Bay jurisdictions to authorize and appropriate sufficient resources for management agencies to undertake planned management activities, including adaptive management, and the failure of management agencies to allocate those resources effectively. For the EPA, the levying of consequences could be viewed as a part of an evaluative process such as that described in Figure 4-5. The consequences are viewed as an incentive to continue water quality improvement efforts. Ongoing monitoring of water

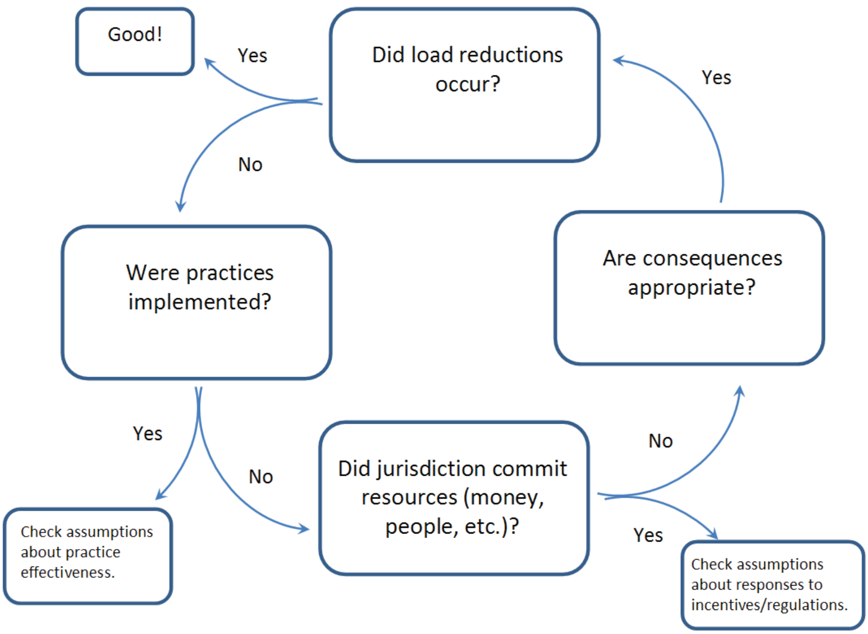


FIGURE 4-5 A process that could be used by the EPA to evaluate the need for consequences that is more compatible with adaptive management.

quality and Bay jurisdictions' programmatic components provides feedback on the effectiveness of the consequences levied.

CONCLUSIONS AND RECOMMENDATIONS

Neither the EPA nor the Bay jurisdictions exhibit a clear understanding of adaptive management and how it might be applied in pursuit of water quality goals. Reviewing activities, assessing progress toward goals, and adopting contingencies were cited as examples of adaptive management. However, effective adaptive management involves deliberate management experiments, a carefully planned monitoring program, assessment of the results, and a process by which management decisions are modified based on new knowledge. Learning is an explicit benefit of adaptive management that is used to improve future decision making. The committee did not find convincing evidence that the CBP partners had incorporated adaptive management principles into their nutrient and sediment reduction programs. Instead, the current two-year milestone strategy approach is best characterized as an evolutionary (or trial and error) process of adaptation in which learning is serendipitous rather than an explicit objective. In the trial and error process, when failures occur, jurisdictions have limited capacity to understand why, and contingencies represent the next thing to try rather than a deliberate adaptation.

Successful application of adaptive management in the CBP requires careful assessment of uncertainties relevant to decision making, but the EPA and Bay jurisdictions have not fully analyzed uncertainties inherent in nutrient and sediment reduction efforts and water quality outcomes. Each CBP goal brings with it uncertainties, not all of which can or should be addressed through adaptive management. Therefore, the EPA and Bay jurisdictions should carefully and realistically analyze uncertainties associated with potential actions to determine which are candidates for adaptive management. Bay jurisdictions may be more successful using adaptive management for a limited number of components or for programs in smaller basins, where effects of management actions can be isolated and well-designed monitoring and evaluation can be undertaken to clearly quantify outcomes.

Targeted monitoring efforts by the states and the CBP will be required to support adaptive management. Monitoring plans need to be tailored to the specific adaptive management strategies being implemented. Presently, CBP and jurisdictional monitoring programs have not been designed to effectively support adaptive management. In addition, adaptive management will require better integration of monitoring and modeling activities. Excessive reliance on models in lieu of monitoring can magnify rather than reduce uncertainties.

Additional federal actions are needed to fully support adaptive management in the CBP. The federal accountability framework being promoted through the TMDL and the threatened consequences for failure will dampen the Bay jurisdictions' enthusiasm for adaptive management. To support adaptive management, the EPA should modify its accountability framework and offer explicit language indicating that carefully designed management experiments with appropriate monitoring, evaluation, and adaptive actions are acceptable, and that failures resulting from genuine adaptive management efforts will not be penalized. If the Bay jurisdictions perceive that the costs of failure are too high, then they may not be willing to pursue the benefits that adaptive management can offer. Additionally, federal guidance and training to the states on effective adaptive management strategies at the local or state level are needed. One or more examples of adaptive management designed and implemented at the federal level, perhaps on federal land, would be helpful to the states as they seek acceptable and effective management options.

Without sufficient flexibility of the regulatory and organizational structure within which CBP nutrient and sediment reduction efforts are under-

taken, adaptive management may be problematic. Depending upon how CWA language and TMDL rules are interpreted, opportunities for certain types of adaptations may be limited. Truly embracing adaptive management requires recognition that the TMDL, load allocations, and possibly even water quality standards might need to be modified based on what is learned through adaptive management. However, the jurisdictions may find that the formal processes required under the CWA to modify load allocations, TMDLs, or water quality standards constrain or even preclude using adaptive management. Successful application of adaptive management in the CBP will require greater regulatory flexibility. Approaching the TMDL as a process, not an endpoint, and facilitating adaptive implementation of the TMDL is one way to provide that flexibility (Freedman et al., 2004).

5

Strategies for Meeting the Goals

The Chesapeake Bay estuary is one of the nation's unique and valuable environmental resources. Preservation of this important ecosystem and proper evaluation and maintenance of its water quality are high priorities for the federal government, the Bay jurisdictions, and their citizens. As discussed in Chapter 1, the Chesapeake Bay Program (CBP) has established water quality goals for the Bay to address the adverse effects caused by nitrogen, phosphorus, and sediment loading from human activities and land development in the watershed. The primary sources of these pollutants include animal and crop agriculture, urban and suburban runoff, wastewater discharge via wastewater treatment plants and septic systems, and air pollution (see Chapter 1).

Bay jurisdictions have developed broad watershed implementation plans (WIPs) to implement practices by 2025 that will ultimately reduce nutrient and sediment loads by the amount necessary to attain the Bay water quality criteria. Reaching these goals will not be easy, however, and will require substantial commitment and, likely, some level of sacrifice from all who live and work in the Bay watershed. Jurisdictions will not only have to make significant reductions in current loads, but they will need to make additional cuts to address future growth and development over the next 15 years. Implementation strategies for the near-term have been developed for the first of the two-year year milestone periods, and detailed strategies through 2017 are in development through the Phase II WIP process. To reach the long-term load reduction goals, Bay jurisdictions and the federal government will need to consider a wide range of strategies, including some that are receiving little, if any, consideration today. Additionally, Bay partners will need to adapt to future changes (e.g., climate change) that may impact the response of the Bay to reduced loads.

In this chapter, the committee takes a broad view of its task to discuss improvements in the development and implementation of strategies to meet the sediment and nutrient reduction goals (Task 6, see Box S-1). The chapter covers two main topics. First, the committee discusses future challenges in implementing effective remediation actions, including adapting to future changes in the drivers of Bay degradation and adapting to factors, such as climate change, which may alter the mechanisms of Bay recovery. Additionally, the committee discusses the costs associated with nutrient and sediment management actions and the challenge of maintaining political and public will. Second, the committee presents a range of strategies that could be used to help the CBP meet its restoration goals. These strategies encompass a wide range of topics, including practices, policies, funding strategies, and programmatic science management changes that have promise for improving the likelihood of attaining overall restoration goals.

CHALLENGES

Several cross-cutting issues could affect the pace and likelihood of achieving CBP goals. These challenges include expanding pressures on the Bay, such as population growth and development, changes in agriculture, and climate change. Additional challenges discussed in this section include costs and political and public will.

Shifting Drivers of Bay Water Quality and Ecosystem Response

The Chesapeake Bay's ecological integrity and, hence, economic and social value has deteriorated because the ability to prevent excess nutrients and sediment from being discharged into the Bay has not kept pace with the generation of nutrients and sediment from rapid population growth and intensification of agricultural operations. These activities, combined with new economic challenges and impacts of climate change, will continue to challenge Bay restoration efforts. The success of an enhanced focus on water quality in the Bay will be, to a large extent, dependent upon the degree to which current plans (e.g., the total maximum daily load [TMDL]) and future efforts anticipate and respond to these challenges. This section of the report discusses trends in activities that are driving water quality problems in the Bay and the role that additional stressors may play in the ability of the CBP to meet future challenges.

Urban Issues: Population Growth and Development

In 2007, the U.S. Environmental Protection Agency (EPA) Inspector General concluded that new development in the Chesapeake Bay watershed had increased nutrient and sediment loads at rates faster than urban restoration efforts had reduced them (EPA OIG, 2007). This conclusion was reinforced by the CBP *2009 Bay Barometer* report, which stated that pollution from urban and suburban areas continues to hinder the effectiveness of restoration efforts (CBP, 2010a). Phase 5.3 Watershed Model outputs estimate that total nitrogen loads from urban runoff and septic systems grew by 7.7 percent between 1985 and 2009; total phosphorus loads from urban runoff grew by 5.8 percent and sediment loads by 4.0 percent (see Appendix A). Urban and suburban sources of nutrients and sediment remain the only categories that continue to increase in modeled scenarios.

Population growth, development, and wastewater management combine to produce the observed impacts of urban and suburban development on water quality. The population of the Chesapeake Bay watershed grew from 8.1 million in 1950 to almost 16 million in 2000 (Claggett, 2007). Population growth estimates suggest that by 2030 the population will exceed 19 million (EPA OIG, 2007).

Distribution and patterns of population growth and development across the landscape have a major effect on water quality. Low-density, land-extensive residential development has combined with land-extensive development for other purposes (e.g., business, government), with connecting networks of impervious roadways and parking lots. More recently characterized as sprawl, this development pattern means that the rate at which open space is converted to support population growth outpaces population growth rates. Between 1990 and 2000, the watershed population increased by 8 percent, but the amount of land converted to development more than doubled. Based on projected population growth and the rate of growth in land development, the area of developed land could increase by more than 60 percent by 2030 (Boesch and Greer, 2003).

Sprawl development brings with it significant increases in the amount of impervious surface area, which channels water, nutrients, and sediment to waterways and minimizes the potential for landscapes to absorb them (Claggett, 2007). Between 1990 and 2000 impervious surface area in the Bay watershed increased by 41 percent (Claggett, 2007), and a 2006 study reported that impervious surface accounted for 18 percent of all urban lands in the Bay watershed (Tilley and Slonecker, 2006). Research suggests that stream water quality can be impaired when impervious cover in a watershed exceeds 5-6 percent (Couch and Hamilton, 2002).

Population growth and development patterns directly influence nutrient loading from wastewater. Wastewater treatment plants (WWTPs) collect and treat wastewater from 75 percent of the households in the watershed, and technology upgrades have substantially reduced nutrient loadings from wastewater to the Bay (see Figures 1-12 and 1-13). However, private septic systems continue to present a challenge. The 2003 Chesapeake Futures report noted that approximately 25 percent of the housing units in the watershed were served by septic systems, contributing an estimated 33 million pounds of nitrogen per year to the watershed. Advanced nitrogen-removing septic designs exist, but they generally are not required for new development (Boesch and Greer, 2003). According to figures produced by the CBP, each new person added in homes built on septic systems results in about 3.6 pounds of nitrogen entering the local stream. By contrast, for homes connected to a state-of-the-art wastewater treatment plant, each new person adds only 1.6 pounds of nitrogen (Blankenship, 2006). For more than 50 years, residential development trends in the United States have been toward larger homes on larger lots at greater distance from urban centers with heavy reliance on septic systems for wastewater management.

If population, land development, and reliance on private septic systems continue to grow, the challenges of reducing nutrients and sediment entering the Bay will continue to grow. Simply managing development that comes with population growth may not be sufficient to meet water quality goals. Tom Horton (conservationist) has argued that attention to restricting population growth may be needed:

> Our environmental impacts are the sum of how many of us there are, and how much each of us demands of the air, water and land. That is our total environmental 'footprint'. Common sense tells us we can help the Chesapeake Bay and the planet by reducing either per capita impacts, or the number of capitas. It also tells us that if one side of the footprint equation keeps increasing, we will gain that much less from just working the other side (Horton, 2008).

Agricultural Issues: Changes in Animal and Crop Agriculture

Agriculture is an integral component of the culture, heritage, and economy of the Bay watershed, and as of 2003, agriculture accounted for 13 percent of the region's gross domestic product (GDP). However, agriculture's share of GDP has steadily declined over the past decades (Boesch and Greer, 2003). Between 2002 and 2007, cropland and farmland acres declined by 10 percent and almost 15 percent, respectively. Furthermore, the type of agriculture being practiced is shifting. Even though the total amount of nutrients and sediment entering the Bay and its tributaries from agricultural sources has decreased since 1985, the agriculture sector has been responsible for a smaller portion of reductions than have point sources, especially municipal wastewater treatment plants. This imbalance can be explained by the fact that reduction efforts by agriculture tend to be voluntary and incentive-based, whereas efforts by point sources are dictated by regulation.

Changes in Animal Agriculture. In 2007, there were 16.8 million people living in the Bay Watershed along with 2.4 million cattle, 1.2 million hogs, and 222 million chickens (U.S. Census of Agriculture, 2007).[1] The waste generated by these populations contributed 40 percent of the total nitrogen load to the Bay watershed: 23 percent of the total from human sewage (i.e., septic systems and municipal and industrial wastewater) and 17 percent from animal manure (see Figure 1-6). Although projections for future changes in human population are readily available,[2] projections for changes in the animal population are not. However, based on current trends, the number of animal production operations (including dairy) is predicted to decrease as a result of continuing industry consolidation within the Bay watershed. Yet, the number of animals per operation is predicted to continue to increase to meet growing demand, especially from a growing regional market (Mark Dubin, University of Maryland, personal communication, 2010). With fewer but larger operations, the total number of animals may well be maintained or even increased. However, the species mix may change. Over the period of 2002 to 2007, cattle, sheep, and swine populations decreased, while the numbers of chickens, horses, and goats increased. Of these, the most notable was the increase in chickens. At this point, formal projections for changes in animal populations are not available from the CBP (Mark Dubin, University of Maryland, personal communication, 2010). If the trend towards increased livestock concentration continues, more animal production operations will be classified as point sources, which will bring them under NPDES regulatory requirements and presumably reduce contributions to nutrient loads.

Agricultural Production and Land-Use Changes. Shifts in agricultural production and land use often occur because of external pressures, and these changes have implications for nutrient management in the Bay watershed. For instance, the drive for biofuel production to provide a greater share of consumed energy, often required by law,[3] could lead to increased nutrient loading from agricultural lands. Between 2005 and 2010, corn acreage in

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[1]Note that the 2007 Census of Agriculture numbers reported are for mid-atlantic subwatersheds that drain to the Bay. The human population is from the CBP, available at http://www.chesapeakebay.net/status_population.aspx?menuitem=19794.

[2]See http://www.chesapeakebay.net/populationgrowth.aspx?menuitem=14669.

[3] For example, the American Recovery and Reinvestment Act of 2009 required 12.5 billion gallons of biofuel (primarily ethanol) be mixed with gasoline by 2012.

Bay watershed states increased by 11 percent, mostly on land removed from soybean production, the Conservation Reserve Program, and pastureland (USDA National Agricultural Statistics Service, 2010). The potential for nitrogen and phosphorus loss from corn production is greater than most other land uses (see Box 5-1).

Additionally, the incorporation of dry distiller's grain (DDG), a by-product of ethanol production, into beef and dairy cattle rations could erode progress in managing nitrogen and particularly phosphorus in animal feed (to reduce nutrients in manure). Using DDGs as a feed ration alternative is likely to increase because of its ready availability and low cost relative to corn grain prices. However, the phosphorus content of DDGs (0.8-0.9 percent phosphorus) is about three times that of corn, which makes it dif-

BOX 5-1
Shifting Nutrient Loads from Agricultural Land Use Changes

Corn is an inherently inefficient nitrogen user; 40 to 60 percent of nitrogen applied generally is not taken up by the crop, and nitrogen loads to downstream aquatic ecosystems from corn-dominated landscapes are typically 25 to 45 lb nitrogen ac^{-1} yr^{-1} (Balkcom et al., 2003; Randall et al., 2003). Nitrogen losses to aquatic systems from soybeans average 18-35 lbs nitrogen ac^{-1} yr^{-1} (CBP, 2006). Similarly, average phosphorus losses in runoff from corn (3-18 lbs ac^{-1} yr^{-1}) tend to be greater than from soybeans (1-10 lbs ac^{-1} yr^{1}) (Carpenter et al., 1998; Kimmell et al., 2001; Sharpley and Rekolainen, 1997). The loss of phosphorus from perennials and hay crops (0.2-1 lb ac^{-1} yr^{-1}) is generally less than from annuals because runoff volumes are lower and crop phosphorus requirements are smaller, so smaller amounts of fertilizer or manure are applied (Sharpley et al., 2001; Smith et al., 1992). Further, water-quality model simulations of converting Conservation Reserve Program acreage or perennial grasses to cropland confirm that delivered nitrogen and phosphorus loads increase by more than double the percentage land area converted (Mankin et al., 1999, 2003). Assuming fertilizer application rates remained constant, the estimated 0.25 million acre increase in corn acreage (0.1 million ha) over the past five years in the Chesapeake Bay Watershed is projected to have increased annual nutrient loads by 5 million lbs nitrogen and 2 million lbs phosphorus (Table 5.1).

ficult to use such materials at more than 15 percent of animal feed rations without exceeding dietary phosphorus recommendations (Lawrence, 2006; NRC, 2000). The inclusion of DDGs in rations exceeding recommended rates will increase the phosphorus content of manure (Baxter et al., 2003; Maguire et al., 2004; Wu et al., 2001) and, if the manure is land-applied, increase the potential for phosphorus loss in runoff (Ebeling et al., 2002; Maguire et al., 2007; Sharpley et al., 2005).

Climate Change

Climate change is likely to affect the Bay's response to nutrient and sediment management controls. However, uncertainty exists in predicting

TABLE 5-1 Estimated Increase in Nutrient Export in Farm Runoff from Growing an Additional 0.25 Million Acres of Corn in the Chesapeake Bay Watershed

		Nitrogen Export in Runoff		Phosphorus Export in Runoff	
Acreage Shift to Support Ethanol	Land Area (10^3 ac)	Average (lbs ac^{-1})	Change (10^3 lbs)	Average (lbs ac^{-1})	Change (10^3 lbs)
New corn acres	250	35	+8,750	11	+2,750
Converted from soybeans[a]	110	27	–2,970	6	–660
Converted from CRP land[a]	12	4	–48	0.2	–2
Converted from idle, pasture or hay land[a]	125	5	-625	0.6	–75
Estimated increased nutrient export in runoff[b]			+5,107		+2,013

[a]Nutrient export of nitrogen and phosphorus if land had remained in soybeans, Conservation Reserve Program, idle, pasture, or hay land.

[b]Increase in nitrogen and phosphorus export in runoff estimated as that occurring from additional corn acres minus the runoff that would have occurred from the original land use prior to conversion to corn.

SOURCE: Adapted from Simpson et al. (2008).

BOX 5-2
Historical Climate Changes and the Effect on Hypoxia

The relationship between spring nitrate loading from the Susquehanna River (a proxy for total nitrogen loading to the Bay) and the resulting summer time anoxic water was examined by Hagy et al. (2004) and is shown in Figure 5-1. There appears to be a change in the anoxia's response to nitrogen loading. The anoxia that developed during the latter years (1980-2001) was significantly greater than that which developed during the early years (1950-1979) for the same winter-spring loading. For example, a January-May loading of 20 gigagrams (Gg), resulted in an anoxic volume of approximately 1 km^3 in the early years and perhaps 3 km^3 in the latter years. There is significant scatter in these data, and the loading and anoxic volume estimates in the early years are less reliable than those subsequent to 1985 when more intensive monitoring became available.

This striking result has generated a number of hypotheses, including the idea that a "regime shift" has occurred in the biology (Petersen et al., 2008). More mechanistic hypotheses have been advanced, but all are associated with changes that are related to climate variation. Suspected mechanisms include wind direction (Scully, 2010a,b); increase in water temperature, decrease in oyster abundance and associated filtration capacity, and less efficient nitrification-denitrification (Kemp et al., 2009); and decreased mixing of waters and increases in early summer stratification (Murphy et al., 2011). In particular, Murphy et al. (2011) have suggested that the decreased mixing of waters and increased early-summer stratification may relate to both an observed shift in the predominant wind direction over the Bay (Scully, 2010a) and to observed increases of Bay salinity levels, which have in turn been related to sea level rise (Hilton et al., 2008).

climate change effects on the forcing functions to the Bay (e.g., magnitudes and timing of rainfall and runoff, range and patterns of temperature variation, influence of storm activity) and how the Bay's physical, chemical, and biological systems will respond. Nevertheless, attempts have been made to quantify the possibilities, using models and professional judgment.

Najjar et al. (2010) published a comprehensive examination of the potential responses of the Bay to climate change and concluded that "likely changes" include increases in precipitation amount and intensity, salinity variability, harmful algae, hypoxia, and coastal flooding. Annual mean temperatures in the Bay Watershed are projected to increase by 1°C during

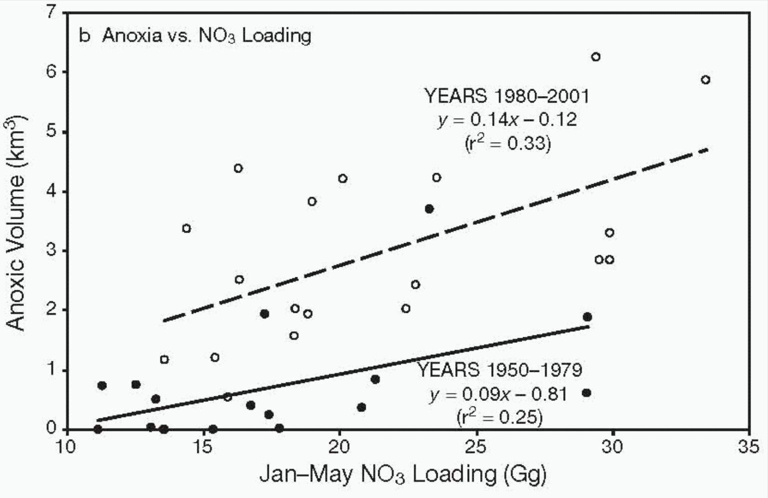

FIGURE 5-1 Midsummer volume of anoxic bottom water vs. winter-spring nitrate loading from Susquehanna River for earlier years (1950-1979, solid line, filled circles) and for later years (1980-2001, dashed line, open circles).
SOURCE: Kemp et al. (2005), modified from Hagy et al. (2004).

the next 30 years and perhaps by 7°C by the end of this century. Najjar et al. (2010) concluded: "Climate change alone will cause the Bay to function very differently in the future." Such changes include altered interactions among trophic levels and a reduction in eelgrass, the dominant species of underwater grasses in the Bay. Even small changes in water temperature are projected to have significant impacts on fishery resources. Climate changes during the past 50 years also appear to be affecting the extent of Bay hypoxia that can be detected in observational data (Box 5-2). Climatic variations can dramatically change the Bay's response to nutrient management actions. To avert overly optimistic expectations, and the associated disappointment from achieving less than forecasted results, a systematic investigation should be initiated. Coupling the currently available models, validated by hindcasting historical data, with the available climate change scenarios would be a first step.

Costs

Meeting the overall cost of Bay management is a key challenge facing the CBP. In October 2004, the CBP's Blue Ribbon Finance Panel considered the entire 64,000 square mile watershed and estimated total water quality restoration costs at $28 billion (or $32 billion in 2010 dollars).[4] This is equivalent to approximately $1,900 (in 2010 dollars) for each of the 16.8 million residents in the Bay watershed. The recent release of the watershed implementation plans (WIPs) has generated additional concerns about the costs of implementation (EPA, 2010f). For example, Maryland estimates costs to residents, businesses, and taxpayers of meeting the goals of its Phase I WIP at $13-15 billion (MDE et al., 2010). Virginia estimates costs in that state of implementing its Phase I WIP will exceed $7 billion (VA DNR, 2010). Undoubtedly, the costs reported in these and other documents are rough estimates at best, but their magnitude is indicative of the financial challenges posed.

Costs beyond those included in financial calculations are also possible. For example, restrictions on land-use changes and limits on growth could be manifested over time in higher housing costs. Efforts to reduce airborne nutrient sources could raise the cost of energy generation or transportation. Lifestyle changes also may be required, such as restrictions on residential and commercial landscaping (e.g., restricted fertilizer applications) and greater reliance on public transportation. However, such lifestyle changes could offer economic benefits, such as reduced day-to-day cost of living for individuals and reduced emissions of greenhouse gases. Also, many BMPs may offer broader benefits than just those targeted; for example, reducing stormwater runoff volume to protect water quality may reduce flood damages.

The costs of nutrient and sediment reduction are unlikely to be evenly distributed. Even if nutrient and sediment reductions are distributed across the Bay jurisdictions based upon their relative contributions, the shares of the overall cost borne by any jurisdiction's residents, businesses, and taxpayers are likely to vary depending upon the specific sources within the jurisdiction's boundaries and the location of the jurisdiction within the watershed. Much of the public cost will be absorbed by taxpayers as local governments deal with upgrades to wastewater treatment plants and

[4] See http://archive.chesapeakebay.net/blueribbon.htm.

stormwater management, and higher taxes and fees are always contentious. Distribution of costs across regulated and unregulated sources will differ. All states have indicated that they will rely upon federal funds to cover a substantial portion of implementation costs. In light of other federal budgetary pressures, sufficient federal assistance is unlikely.

Costs to Agriculture

The costs to agriculture of implementing BMPs to further reduce nutrients and sediments will be a function of the mix of land management requirements adopted by states, financial assistance from federal, state, and local governments, and the financial benefits that may offset some or all of the costs incurred by farmers' groups. A substantial body of research indicates that many agricultural practices that reduce nutrient and sediment loss from farms can offer economic benefits and sometimes provide competitive gains at the farm level (NRC, 2010). However, some practices may impose significant on-farm costs that are not recovered. Agricultural producers are not able to set the prices they receive for their products and, as a result, are not able to make adjustments to cover additional costs of implementing BMPs. Farmers groups have questioned whether agriculture can bear the costs of additional BMPs (American Farm Bureau, 2010).

Estimates of costs to agriculture vary widely, and how the relative on-farm costs and benefits of individual BMPs are accounted for in these estimates is not clear. In 2005, the CBP estimated the cost of implementing agricultural portions of Bay cleanup strategies at about $700 million a year, with only $188 million in conservation funding provided each year by the 2008 Farm Bill (Blankenship, 2008). More recent estimates suggest that the costs to agriculture could be even higher, and the future availability of federal and state subsidies is uncertain. Without doubt, the costs of reducing agricultural sources of nutrients and sediment will be very high. Deciding how and among whom the costs will be distributed represents a substantial challenge.

Costs in Urban Areas

Efforts to control nutrients and sediments in the Bay watershed have had, and will continue to have, significant effects on the way municipalities and industries manage their land, wastewater, development, and redevelopment. The seven Bay jurisdictions have identified ambitious plans necessary to meeting the wasteload and load allocations required by the TMDL (EPA, 2010a). Although they do not fully articulate the potential sector-specific costs associated with TMDL compliance, together with information from the 2008 Clean Watersheds Needs Survey (EPA, 2010g) they provide enough information to indicate that costs to enhance wastewater facilities and control stormwater and nonpoint source runoff from urban areas will be in the billions of dollars. The Bay jurisdictions cite nearly $70 billion in existing wastewater and stormwater management needs (including state needs for facilities located outside the Bay watershed) to meet the goals of the Clean Water Act (EPA, 2010g). For the five jurisdictions reporting this information, meeting the 2011 milestone goals, alone, will require federal, state and local funds totaling more than $2 billion to address urban point and nonpoint sources (CBP, 2009b).

The Chesapeake Bay WIPs identified costs of urban stormwater BMPs (including retrofitting and low impact design [LID]) ranging from just a few thousand dollars per impervious cover acre treated to as much as $200,000 per acre. Implementing stormwater BMPs on existing development is typically costly because of constraints such as the lack of space to install BMPs and the often-prohibitive cost of purchasing land for BMP installation. (See Box 5-3 for an example.) By contrast, installing stormwater management practices at the time of new development is more cost-effective, and with proper planning LID may even include some cost savings over conventional development (Schueler et al., 2007; Schueler, 2009). With public

BOX 5-3
A Connecticut Example of Urban Stormwater Management Costs

In 2007, Connecticut issued the first TMDL based on impervious cover that provides a surrogate approach for addressing a multitude of pollution problems related to development, including nutrients and suspended solids (CT DEP, 2007). The TMDL impaired watershed is dominated by the University of Connecticut campus, which provided an excellent opportunity, primarily within one land ownership entity, to develop a management plan that incorporates state-of-the-art LID retrofit technologies (Center for Watershed Protection and Horsley Witten Group, 2010). The analysis determined that actions could be taken to mitigate the effect of impervious cover and meet water quality standards, but at a substantial cost. High priority ("top 10") actions would address 30 acres of impervious cover at a cost of $1.35 million, or about $45,000 per acre of impervious cover. A full retrofit scenario addressing nearly 61 acres of impervious cover would cost $5.8 million or about $95,000 per acre of impervious cover. Both are in the range of costs estimated in the WIPs and are substantial.

acceptance, some LID practices such as pervious pavers, naturalistic landscaping, and broader open space can add value to a development. In any case, requiring all developers to abide by the same restrictions prevents any imposition of competitive disadvantage, a primary concern of many (Fuss and O'Neill, 2010a).

Public Support and Political Will for Attaining Goals

Despite the importance that watershed residents place upon Bay water quality and all of the ecosystem and economic benefits that are expected to result from improved water quality, questions remain about watershed residents' willingness to bear the expected costs of reducing nutrient and sediment loads to the Bay and its tributaries. For one thing, the benefits of reducing nutrient and sediment loads are not evenly distributed across the watershed. Of the seven jurisdictions that lie within the watershed, only Maryland and Virginia directly border the Bay's mainstem. As a result, residents of the other states may question why they should finance programs designed to help water quality in the Bay itself.

Residents of Delaware, New York, Pennsylvania, West Virginia, and the District of Columbia likely are more concerned about water quality within their own boundaries than for downstream water bodies including the Chesapeake Bay. New York, Pennsylvania, and West Virginia also have significant land area that falls outside the Bay Watershed, which means that water quality programs in those states must balance efforts between the Bay watershed and other watersheds.

Residents' willingness to invest in environmental protection and resource conservation is demonstrated by recent resident-supported bond initiatives in New York, Pennsylvania, and Virginia. New York's 1996 initiative, which passed by 57 to 43 percent, provides for bonds to fund clean water and clean air programs. Pennsylvania voters passed bond initiatives in 2004 (63 to 37 percent) to support water and wastewater infrastructure improvements, in 2005 (61 to 39 percent) to support land conservation, and in 2008 (62 to 38 percent) to support water and sewer improvements. Virginia voters approved bond initiatives in 1992 (67 to 33 percent) and 2002 (69 to 31 percent) to support investments in parks and recreational facilities, including land acquisition and capital improvements.[5]

Likewise, state legislatures have made funds available for nutrient reduction programs. For example, Maryland's legislature voted in 2004 to levy fees on each household served by a wastewater treatment plant and each household served by an on-site septic system; the funds are used to

[5]Election results from the Trust for Public Land's LandVote database are available at http://www.tpl.org/tier3_cd.cfm?content_item_id=12010&folder_id=2386.

support upgrades for wastewater treatment facilities and septic systems in order to reduce nutrient discharges (Marx, 2004). Virginia's legislature voted in 2007 to sell bonds to fund nutrient removal technologies at wastewater treatment plants (Code of Virginia § 10.1-1186.01.).

Whether public support for additional investments in Bay improvements will continue is an open question. State and federal economic climates have forced citizens and their elected officials into recurrent rounds of fiscal belt-tightening. High unemployment combined with tight state budgets may well leave state residents focused on priorities other than water quality in the Chesapeake Bay in particular and environmental concerns generally. Historically, public concerns about environmental quality have not always been accompanied by public willingness to bear the costs of achieving environmental improvement and protection (Gillroy and Shapiro, 1986), especially when economic health is tenuous (Franzen and Meyer, 2010). However, economic and environmental initiatives can be coupled. The American Recovery and Reinvestment Act of 2009 provided $105 billion for infrastructure improvements, including $4 billion nationally for Clean Water State Revolving Funds and an additional $2 billion for Drinking Water State Revolving Funds.

The CBP's success hangs on political will as much as individual citizen willingness to shoulder the financial burden. Questions about whether such political will exists are widespread (Pegg, 2004; Thompson, 2004; Ernst, 2006; The Monitor's View, 2009; Wood, 2010). Political scientist and author Howard Ernst has described the "political dead zone," in which elected officials profess concern about the Bay but fail to make the hard decisions necessary to achieve real improvement. Polluting industries continue to pollute, and the environmental community lacks the influence needed to advocate successfully for the Bay (Ernst, 2009).

Elected officials are generally hesitant to implement environmental policies that are perceived to challenge economic development, even if the policies promise environmental improvement. When specific business sectors or communities expect that costs of environmental policies will affect them disproportionately, they see a direct benefit from lobbying elected officials and voicing their opposition. Challenges to the Chesapeake Bay TMDL have been heated (e.g., Agricultural Nutrient Policy Council, 2010; American Farm Bureau, 2010; ESA Policy News, 2010; Harper, 2010; Stuart, 2010). In contrast, environmental benefits will be diffuse and enjoyed by a broad cross-section of the population. Such beneficiaries are less likely to become directly involved in lobbying efforts because they know they will benefit from environmental policies even if they do not actively lobby for them. The EPA received more than 14,000 comments on the draft TMDL. More than 13,000 of those comments originated from mass mail campaigns organized by more than 20 environmental groups. Of the remainder, the most detailed individual responses were from those voicing opposition to or some degree of reservation about the plan (Blankenship, 2010).

Compliance with the water quality criteria (e.g., for dissolved oxygen) is the measuring stick for success of the TMDL, but Bay area citizens may require more visible, tangible evidence of water quality improvement. Because of lag times between the implementation of land-based nutrient and sediment control practices and improvement in Chesapeake Bay water quality (see Box 1-3), many BMPs undertaken for the first milestone may not result in observable improvements in the Bay until much later. Likewise, the research and regulatory communities working on Bay issues may be aware of the uncertainties inherent in the load projections and Bay system dynamics that could result in outcomes that differ from those anticipated (see Chapter 4). However, absent sufficient articulation and explanation of those uncertainties, members of the public less schooled in the scientific elements may fail to understand or accept less than absolute, observable improvements. If these lags and uncertainties aren't adequately explained, CBP partners will need to anticipate and be prepared to respond to the potential ramifications of an impatient or disillusioned public. Concerns that non-experts will be unable or unwilling to adjust their expectations based on a better understanding of uncertainties or time lags are likely unfounded. Propst et al. (2000) presented research evidence that individuals who lack knowledge of technical scientific issues can quickly learn about their critical features and choose policy options similar to those chosen by scientists and are likely to ask the right questions and find novel solutions.

If public and political support wanes in the face of high costs and time lags between BMP implementation and water quality improvement, a jurisdiction could formally question the feasibility of meeting water quality goals by requesting a use attainability analysis (UAA). A UAA is an assessment of the factors affecting the likely attainment of designated uses of a water body. A jurisdiction may request that a designated use be changed if it can be shown, through a UAA, that current designated use is precluded by physical, chemical or biological factors or that the stringency of controls needed would result in "substantial and widespread economic and social impact" (EPA, 2010i). Changing the designated use would result in the establishment of new water quality criteria, which could reduce both the efforts required to meet water quality goals and the costs of those efforts. Thus, if a jurisdiction is concerned about its ability to garner financial resources needed to address costs resulting from federal requirements for compliance with water quality criteria, it could assert public and political will by working to change designated use and reduce pollution control pressures.

STRATEGIES FOR IMPROVEMENT

Previous sections of this chapter presented a number of challenges the CBP could face in its efforts toward the CBP's long-term nutrient and sediment reduction goals. In this section, the committee identifies strategies that could be used to help the CBP meets its goals. The committee did not attempt to identify every possible strategy that could be implemented but instead focused on approaches that are not being implemented to their full potential, or in some cases have substantial potential but are not being widely discussed. This section includes practices and policies for reducing agricultural and urban pollutant loads and air pollution strategies followed by a discussion of possible funding strategies. Because many of these strategies have policy or societal implications, the strategies are not prioritized but are offered to encourage further consideration and exploration among the CBP partners and stakeholders. Finally, the committee discusses the importance of modeling and monitoring to help meet the goals and recommends the formation of a Chesapeake Bay modeling laboratory as a strategy to improve the scientific and modeling support for the CBP.

Agricultural Strategies

Several strategies exist to improve nutrient management on agricultural land. Key strategies that could be used in the Bay watershed include, but are not limited to, improving management of animal agriculture and manure use and developing new incentive- and regulatory-based programs targeted at improved agricultural nutrient management.

Strategies for Improved Animal Agriculture and Manure Management

Intensive animal feeding operations (i.e., dairy, poultry, swine) are common locally significant sources of nutrient enrichment to surface water and groundwater. The potential for phosphorus and nitrogen surplus on farms dominated by concentrated animal feeding operations (CAFOs)[6] can be much greater than on farms with cropping systems or integrated crop and

[6]An animal feeding operation (AFO) is a facility that confines animals for more than 45 days in an area that does not produce vegetation during the growing season. CAFOs are AFOs that meet specific size and surface water discharge criteria or that have been designated on a case-by-case basis as significant contributors of pollutants by the state or local permitting authority (see http://www.epa.gov/npdes/pubs/sector_table.pdf, and http://www.epa.gov/region07/water/cafo/).

livestock operations.[7] Nutrient inputs to CAFOs are dominated by feed, and often nutrients in feed exceed the amount that can cycle through a feed-crop production system for removal from the farm. Research has shown that only about 30 percent of nitrogen and phosphorus in feed is utilized by the animal, with the remaining excreted in manure (Poulson, 2000; Valk et al., 2000). As a result, in most CAFOs, animal feed is the primary source of on-farm nutrient excess.

Based on U.S. agricultural census surveys of livestock numbers over the past 15 years, a steady increase in the amounts of nitrogen and phosphorus accumulating in livestock operations exceeding crop requirements at the farm level has been described (Kellogg et al., 2000). Unless crop and livestock operations are combined or enter into contractual arrangements to optimize nutrient management, innovative approaches—beyond typical nonpoint BMPs expected of agriculture—will be needed to reduce or eliminate the nutrient imbalances. In this section, strategies for animal nutrition and manure management are discussed separately.

Animal Nutrition Management. Sustainable nutrient management in animal agriculture begins with sound feed decisions (i.e., nutrient concentrations in animal feed that match dietary recommended levels). Ebeling et al. (2002) showed that increasing the phosphorus concentration in the diet of dairy cattle doubled the potential for phosphorus export in runoff from land-applied manures, even with similar overall phosphorus application rates. This difference was likely due to a greater proportion of manure phosphorus being water soluble in manure with a high-phosphorus diet compared to a low-phosphorus diet. Similar trends have been observed in beef cattle, pigs, and poultry (Kleinman et al., 2002, 2005). Implementing a carefully planned diet tailored to meet the specific nitrogen and phosphorus requirements of animals in each phase of their growth will minimize nutrient loss to the environment in feces, urine, and gases. Reducing nitrogen and phosphorus in animal feed presents a promising nutrient management opportunity that can effect lasting reductions in nitrogen and phosphorus loads to the environment.

A reduction in the quantity of nitrogen and phosphorus excreted by livestock can also be accomplished by supplementing livestock diets with enzymes to enhance digestion (Keshavarz and Austic, 2004; Knowlton et al., 2002). Enzymes, such as phytase, can be added to feed to increase the efficiency of grain phosphorus absorption by pigs and poultry. Such

[7]Annual surpluses of nitrogen and phosphorus were reported for grain-poultry farms in Delaware (Sims, 1997) and grain-dairy farms in New York (Klausner et al., 1998). These surpluses can vary from 105 to 1170 lbs N ac^{-1} yr^{-1} and from 23 to 1000 lbs P ac^{-1} yr^{-1} (Bacon et al., 1990; Lanyon, 2000).

enzymes reduce the need for phosphorus supplements in feed and potentially reduce the total phosphorus content in manure. Corn hybrids are also available that contain a lower percentage of indigestible phosphorus so that phosphorus availability to nonruminants is two to three times higher than from normal corn. Pigs and chickens fed "low-phytic-acid" corn excreted less phosphorus in manure than those fed conventional corn varieties (Ertl et al., 1998).

There are many opportunities through the use of conventional breeding and genetic engineering to improve the digestibility, nutrient utilization, and need for mineral additives in feed, as well as the digestive process of the animal (Abberton et al., 2008; McSweeney et al., 1999; Tabe et al., 1993). For example, a genetically enhanced line of Yorkshire pigs has been developed with the capability of digesting plant phosphorus more efficiently than conventional Yorkshire pigs (Forsberg et al., 2003). The salivary glands of these pigs produce the enzyme phytase, which in the acidic environment of the stomach, degrades indigestible phytate in the feed that accounts for 50 to 75 percent of grain phosphorus. Thus, there is no need to supplement the diet with either mineral phosphate or commercially produced phytase, and there is less phosphorus in the manure. Nevertheless, the public's acceptance of and willingness to use genetically modified products remains to be seen.

CAFO and Manure Management. Only Maryland, Delaware, and New York currently require specific comprehensive nutrient management plans as a part of statewide CAFO permitting programs. Making these programs consistent across all states and including smaller animal production operations, which in aggregation can be locally significant sources of nutrients to surface and groundwater, would enhance nutrient management in the Bay watershed. Interestingly, the TMDL backstop allocations proposed for CAFOs throughout the watershed appear to assume that all animal feeding operations, regardless of size, are subject to the same nutrient management requirements as CAFOs. Changes in CAFO requirements at a national, rather than regional, level would avoid putting producers in the Bay watershed at a competitive disadvantage.

Manure is a valuable resource for improving soil structure and increasing vegetative cover, thereby reducing runoff and erosion potential (Risse et al., 2006). However, manures have historically been applied at rates designed to meet crop nitrogen requirements, providing at least twice as much phosphorus as crops need and resulting in the buildup of soil phosphorus above levels required for crop production. EPA (2010e) recommends that manure or fertilizer not be applied to any soil in the Chesapeake Bay watershed with a "phosphorus saturation" value above 20 percent. Manure applications in excess of crop nitrogen or phosphorus needs, causes a concomitant increase in the potential for nitrogen and phosphorus loss via surface and groundwater flows and nitrogen gas emissions within the Bay Watershed (Kovzelove et al., 2010; Sutton and Cox, 2010). In the case of nitrogen emissions to the atmosphere, not only is N_2O a global concern, but the ammonia and NO_x emissions are a concern for nitrogen deposition back to the Bay and its watershed, and to downwind regions.

Transport of manure from nutrient-surplus to nutrient-deficit areas can address imbalances as long as the nutrients are appropriately applied on receiving lands to avoid potential losses to water and air. Manure transport out of the Bay watershed is of long-term benefit and is occurring through subsidized initiatives of poultry integrators, with poultry litter that is dried, ground, and compacted into small, less bulky pellets (pelletized litter). However, wet and heavy manures are not being transported more than a few miles from where they are produced because of cost and technical difficulties. Wider adoption of manure transport that links producers with buyers of manures for crop fertilization will greatly enhance the sustainability of animal operations over a larger geographic area. In attempts to address this, the Natural Resources Conservation Service (NRCS) has developed a cost-share program that could facilitate manure transport from surplus to deficit areas. As the costs of implementing more complex or restrictive conservation or remedial measures increase, transport will become more economically viable. Additionally, as energy prices increase, alternate uses for manure, such as burning for electricity generation and digestion for methane production, will become more attractive. However, with bioenergy production, the nutrient-rich biochar (residues remaining after burning) or sludge (solids remaining after digestion) still need to be managed appropriately.

Another way to significantly decrease nutrients inputs to the Bay would be to limit the extent of animal operations to the nutrient carrying capacity of the watershed, considering the existing loads. Under such a scenario, if existing operations were unable to reduce their nutrient loadings through innovative manure management, some percentage of the animal protein production would need to be outsourced from the watershed. Clearly, this alternative has negative socioeconomic consequences (e.g., employment losses, economic decline of agricultural and rural communities), but it is an example of the type of bold action (and difficult policy decision) that may be needed to restore the Bay's ecosystem.

Incentive-Based BMP Programs

Voluntary incentive-based BMP programs can provide a low-cost approach to improve BMP implementation, maintenance, and tracking. Key to their success is identifying an incentive that has value to the landowner.

Providing landowners with regulatory relief has proven effective in Florida (see Box 2-2). A presumption of compliance with water quality standards given in exchange for voluntary BMP implementation, maintenance, and reporting has proven to be a powerful incentive. In Florida, participants of the incentive-based BMP program are required to maintain nutrient management plans and provide access to land management records and land parcel identification. See Chapter 2 for a more in-depth discussion of incentive-based BMP programs. USDA has recently begun discussions with EPA and Bay jurisdictions about creating a similar program in the Bay watershed, where farmers could agree to implement certain practices in exchange for presumptive compliance with regulations (A. Mills, USDA, personal communication, 2011).

Regulations

European countries have taken a regulatory approach to reduce agricultural nutrient contamination, and these strategies offer another model for possible consideration by the CBP. In many respects, agriculture in the Bay watershed is similar to agriculture in Denmark, where trends toward larger and more specialized farms with high animal production in the western parts of the country are spatially separated from specialized crop production in the eastern parts of the country. Nutrient management legislation was enacted in Denmark in the 1980s as part of the European Union's "Environmental Action Plan" and "Water Framework Directive" (De Clercq and Sinabell, 2001). See Box 5-4 for details of Denmark's agricultural nutrient management regulations.

Coupling regulatory requirements with incentives in Denmark created agricultural production systems that manage nutrients to limit surplus. These policy changes resulted in a decline in the national nitrogen surplus from 132 lbs nitrogen ac^{-1} in 1980 to 79 lbs nitrogen ac^{-1} in 2006 (a 41 percent decrease) (Kyllingsbæk and Hansen, 2007). Over the same period, phosphorus surpluses decreased from 26 to 10 lbs ac^{-1} (a 62 percent decrease), with a concomitant increase in the crop uptake of phosphorus from 24 percent in 1980 to 56 percent in 2006 (Maguire et al., 2009).

In Denmark, between 1989 and 2002, a significant decrease in total nitrogen concentrations occurred in 48 streams draining agricultural watersheds without major point sources as a result of these regulatory and incentive-based measures (Kronvang et al., 2005). The downward trend became more evident as the proportion of agricultural land in the watershed increased and was more pronounced for loamy than for sandy soils. In contrast, no significant trends could be detected for total phosphorus concentrations in streams draining agricultural watersheds. As in the Chesa-

BOX 5-4
Denmark's Agricultural Regulations to Enhance Water Quality

Danish agricultural regulations require specific measures (De Clercq and Sinabell, 2001), including:

- Nitrogen fertilizer applications are limited to 90 percent of the optimum for each crop.
- Manure can be spread on land from the beginning of February until harvest time in August. Manure can be spread until the end of September on certain crops such as grass and oilseed rape.
- At least 70 percent of the nitrogen applied in manure must be recovered by plant uptake.
- Manure storage capacity for a minimum of 9 months must be provided, with cost share incentives to construct storage facilities.

Additionally, almost all farmers are required to produce a yearly nutrient management plan. The only farmers that are exempt are those with fewer than 20 animal units (e.g., 20 mature cows under 1,000 lbs, 20 horses, 66 pigs weighing between 50 and 300 lbs, and 6,667 broilers under 5 lbs) and a low stocking rate (few animals per acre), often termed "hobby farmers." However, these farmers pay a tax on the nitrogen that they purchase.

Even though a surplus of phosphorus can still be added in areas with the highest animal densities, an upper limit of the phosphorus surplus was indirectly introduced with these regulations. Furthermore, the requirement for 9-month storage capacity for animal manure made it possible to shift from autumn to spring application. This resulted in further improvements in nutrient utilization and likely resulted in a reduction in manure-related phosphorus loading during the wet winter season (Schelde et al., 2006).

peake Bay Watershed, a lack of a response in phosphorus concentrations to management measures was attributed to legacy phosphorus and its resilience in lakes and estuaries, which may delay the full effects of such action plans (Maguire et al., 2009).

Even though the water quality results in Denmark are compelling, applying a similar such program with enhanced regulatory oversight of agriculture in the Bay watershed would be politically challenging in light of recent opposition to further regulation of agriculture by EPA voiced by several agricultural groups (Copeland, 2010). Further, farmers in the Bay watershed would be placed at a competitive disadvantage compared with those outside the watershed unless such changes were imposed nationally or unless financial support programs were put in place. One way to avoid such a competitive disadvantage is to establish a set of minimum performance standards that apply nationally. For example, Cox (2010) has described the role of what he calls "precision regulation" that would regulate behavior that is unequivocally damaging to water quality, such as requiring that cattle be fenced away from water bodies, that manure not be spread on frozen ground, or that there be riparian setbacks of crops from the edges of water bodies (Batie, 2009).

Urban Strategies

As noted in Chapter 1, the Watershed Model estimates that total nutrient and sediment loads from urban runoff and septic systems increased between 1985 and 2009, while loads from all other sectors decreased (see also Appendix A). This is likely due to a combination of urban growth and insufficient levels of BMP implementation or performance. For the entire watershed, an additional reduction in nitrogen loads of 23 percent for urban stormwater and 24 percent for septic systems will be required to meet TMDL goals, an ambitious and costly reduction target considering the added pressures of continued population growth and development. Several potential strategies for addressing these challenges are discussed below, including regulatory approaches for stormwater management and fertilizer use, enhanced wastewater management, and encouraging increased individual responsibility.

Regulatory Strategies

Three classes of regulatory strategies that could be used to improve urban nutrient and sediment management address: 1) stormwater management, 2) offsets for growth and development, and 3) limits on residential fertilizer use.

Stormwater Management. Common municipal policies to promote improved stormwater management include local regulations, codes, and ordinances; stormwater incentives or fees (discussed later in the chapter); and education and outreach (EPA, 2010j). Primary regulatory tools for implementing BMPs for regulated stormwater are stormwater construction general permits, which increasingly require LID techniques (e.g., rain gardens, permeable pavement) for new development, and the MS4 permit, which sets stormwater limits for existing development. Management of regulated urban stormwater is based on numeric, water quality-based pollutant wasteload allocations such as those published in the Chesapeake Bay TMDL; however, in the case of stormwater, permit limits may be expressed as implementation requirements in the form of BMPs.[8] This is consistent with the Bay TMDL's approach, and jurisdictional WIPs were also structured around BMP implementation to meet urban runoff allocations. However, stormwater rulemaking currently under development has proposed that numeric pollutant limits be incorporated into stormwater permits "where feasible."[9] If the final rule is adopted in accordance with this concept, stormwater general permits in TMDL implementation areas could be required to incorporate water quality-based effluent limits.

Watershed-based permitting can lead to cost savings as a consortium of permittees organize to distribute pollutant load allocations and contribute to monitoring and tracking efforts in their local or regional watersheds. An in-depth discussion of innovative stormwater management and regulatory permitting, including watershed-based permitting, is provided in *Urban Stormwater Management in the United States* (NRC, 2008).

Offsets for Growth and Development. Urban stormwater retrofits are much more costly and less efficient than BMPs developed as part of new development. Also, retrofits often rely on public funds, which can be difficult to procure and administer, while new development BMPs can be supported as part of the cost of construction. Cost savings from the use of LID techniques in new development compared to conventional BMP applications in existing development vary widely, but savings of 15 to 80 percent have been realized, with a few exceptions where LID technique costs exceeded conventional BMP costs (EPA, 2007). Therefore, a key goal for TMDL implementation should be to minimize increases in pollutant loads from new development to lessen the potential offset burden that would be required from existing development. One relatively easy urban/suburban nutrient management strategy to implement is a "no net increase in nutrient loading" requirement, which would apply to new construction and redevelopment when various transactions occur, such as land sales, zoning changes, or land-use changes. To go a step further, communities might even require a percentage reduction in loadings associated with these occurrences, especially for redevelopment, as a means to attain load

[8]November 22, 2002, memorandum from EPA, Robert H. Wayland, III and James A. Hanlon. Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs.

[9]November 12, 2010, EPA memorandum from James A. Hanlon and Denise Keehner, "Revisions to the November 22, 2002 Memorandum. "Establishing Total Maximum Daily Loads (TMDL) Wasteload Allocations (WLA) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs."

reduction goals. Significant nutrient reductions can be realized when communities encourage redevelopment using LID techniques over new building on undeveloped lands.

As discussed earlier in this chapter, future population growth creates challenges for urban pollution control management. Under current strategies, existing WWTP discharge flows are lower than their permitted capacity (plant design capacity) to allow room for population growth. Urban strategies could be more aggressive if wastewater plants were required to offset any additional loads beyond current loads rather than permitted loads.

Residential Fertilizer Use. An estimated 9.5 percent (3.8 million acres) of the Bay watershed is in turf cover, with 75 percent of that in residential lawns. Assuming that 65 percent of turfgrass is fertilized with nitrogen lawn fertilizer, almost 215 million pounds of nitrogen per year could be applied within the watershed (Schueler, 2010). Fertilizer contribution within urban/suburban stormwater runoff typically ranges between 10 and 25 percent of total stormwater nutrient loads, depending on soil conditions, fertilizer application rate, and application timing prior to storm events (Barth, 1995; Linde and Watschke, 1997; Groffman et al., 2004; Shuman, 2004). Estimates from an urbanized watershed near Baltimore indicate that approximately 53 percent of the total nitrogen input was from the application of fertilizers (Groffman et al., 2004). Model-based estimates of nitrogen loading to the Chesapeake Bay from all sources indicate that fertilizer residues from developed landscapes account for about 10 percent of the loading (Figure 1-6). Boesch and Greer (2003) estimate that urban and suburban development in the Bay watershed could increase by more than 60 percent by 2030, and residential turfgrass coverage increases with urbanization. Therefore, implementing strategies to reduce the nutrient loads from residential fertilizer application could increase the likelihood of achieving the overall CBP nutrient reduction goals. Schueler (2010) states that "by changing attitudes and behaviors about what constitutes a green lawn, it may be possible to achieve major runoff and nutrient reductions."

Restriction of residential fertilizer application and other landscape management actions have recently been enacted in New Jersey, Florida, Michigan, Minnesota, and Wisconsin (Box 5-5). Proponents of these efforts cite the cost-effectiveness per unit of nutrient loading reduced, community involvement, and educational opportunities as primary drivers. Although several states within the Bay Watershed have initiated some actions to address residential runoff through fertilizer management, most of the actions to date rely primarily on education, certification of lawn care professionals, and registration and labeling of residential fertilizer bags. New York is the

BOX 5-5
Examples of Residential Fertilizer Control Programs

New Jersey, Florida, Michigan, and Minnesota have recently enacted regulations to enhance water quality by restricting the application of residential fertilizer, and several have data showing the subsequent benefits of these regulations. In Minnesota, regional and state phosphorus fertilizer restriction laws were enacted in 2004 and 2005, respectively. 2006 estimates suggest that phosphorus fertilizer use (in tons) decreased by 48 percent after adoption of these laws. Much of these anticipated reductions in use were associated with the replacement and availability of phosphorus-free fertilizers at retail sales outlets (MDA, 2007).

A residential fertilizer law enacted in New Jersey in January 2011 requires that at least 20 percent of the nitrogen in all lawn fertilizers be in slow-release form, sets buffers between the turf on which fertilizer is applied and water bodies, prohibits the use of fertilizer during heavy rainfall, and bans the use of phosphorus in fertilizers (New Jersey Law A-2290).

To help manage nutrient loading to estuaries in Florida, several urbanized counties in southwest Florida have enacted residential fertilizer ordinances, which prohibit the application of phosphorus to lawns throughout the year (unless a soil test indicates the need for additional phosphorus) and nitrogen during the rainy summer months. Expected and observed water quality responses to residential fertilizer restrictions support consideration of their enactment. Modeled estimates of nitrogen loading under various residential fertilizer use scenarios indicate that moderate compliance (50 percent) with an ordinance that restricts the use of residential nitrogen fertilizer during the rainy season could reduce nitrogen loadings to Tampa Bay, Florida, by 4 percent of the urbanized load (TBEP, 2008).

Ann Arbor, Michigan, adopted an ordinance in 2006 that curtailed the use of phosphorus on lawns. After adoption, phosphorus levels in the Huron River dropped an average of 28 percent (Lehman et al., 2009).

exception: a 2010 law will prohibit the use of phosphorus-containing lawn fertilizer starting in 2012 unless establishing a new lawn or a test shows that the lawn is phosphorus-deficient. The law addresses phosphorus only because phosphorus is "usually the limiting nutrient in freshwater lakes" (Chapter 205 of the Laws of New York, 2010*ci*). No prohibitions on nitrogen fertilizer application are currently in effect in the Bay jurisdictions although legislative proposals are currently being considered (A. Swanson, personal communication, Chesapeake Bay Commission, 2011).

Wastewater Strategies

Technologies are available for reliable nitrogen and phosphorus removal at wastewater treatment facilities at or below 3 mg/L and 0.1 mg/L, respectively (EPA, 2008b), and according to model estimates (see Appendix A) for 1985 to 2009, nitrogen and phosphorus loads in wastewater decreased by 42 and 59 percent, respectively. However, an additional 27 percent reduction for nitrogen and 26 percent reduction for phosphorus (relative to 2009 levels) will be required to meet the TMDL wasteload allocation for wastewater point sources. Assuming limits-of-technology can be implemented, combined sewer overflows (CSOs)[10] abated, and performance sustained at wastewater plants throughout the watershed, the E3 model scenario (Appendix A) shows that nitrogen could be reduced by another 27 million lbs/yr and phosphorus by 3.27 million lbs/yr below the TMDL allocation. Costs of implementing these technologies remain the largest barrier.

Wastewater reuse for agricultural or urban landscape irrigation represents an untapped approach for further reducing wastewater nutrient loads. By beneficially reusing treated wastewater (also called reclaimed water) for irrigation, nutrient discharge is reduced and fertilizer applications on the irrigated lands can be reduced or eliminated (Asano et al., 2007). Landscape irrigation with reclaimed water is well accepted and widely practiced in the United States. Crook (2005) reported that more than 200 water reuse facilities provided reclaimed water for irrigation to more than 1,600 parks and playground. The treatment requirements for non-potable reuse for irrigation are not significantly greater than those already applied in most WWTPs in the Bay watershed, but the costs of distribution systems to supply reclaimed water to lands with large irrigation needs represent a significant barrier.

More than 2 million individual homeowner septic systems are estimated by the Watershed Model to contribute 4 percent of the nitrogen load to the Bay (Figure 1-6). Few septic systems have been upgraded to include nitrogen removal capability, a technology that can be costly to install and generally requires specialized operation and maintenance services. Most WIPs propose transitioning homes from septic systems to public wastewater collection and treatment systems as the most cost-effective means to reduce nitrogen loading from septic systems. However, public sewer infrastructure is often not accessible to more rural homeowners, and concerns that sewer systems will promote higher density growth, adding to pollutant loads from

[10]Combined sewer systems collect stormwater and municipal sewage in the same infrastructure (i.e., pipes) for treatment at a wastewater treatment plant. Combined sewer overflows (CSOs) occur when heavy precipitation causes the total wastewater inflow to exceed the capacity of the treatment plant, and excess untreated wastewater is discharged directly into surface waters.

wastewater treatment plants have been expressed. Without septic system upgrades, some benefits in pollutant load reductions can be attained with proper maintenance practices, primarily inspection and regularly scheduled pumping, usually every 3 to 5 years. Some Bay jurisdictions require septic system permits or track maintenance within a regulatory framework to assure compliance. Upgraded systems for nitrogen removal are increasingly required, particularly when properties are in close proximity to receiving waters, when capacity for denitrification with groundwater transport is limited, or when new development occurs. In those cases, advanced treatment technologies may be beneficial and remove up to 50 percent of the nitrogen at the edge of the leach field if operated and maintained properly.

Enhancing Individual Responsibilities

To meet its nutrient and sediment reduction goals, the CBP must not only address large public or collective sources, such as sewage treatment plants, public lands and infrastructure, and agricultural and industrial entities, but everyday actions by watershed residents that are generally not regulated by law. Enhancing individual responsibilities, either through education, incentives, or regulations (e.g., restricting residential fertilizer use), can also contribute to the success of Bay restoration and to water quality improvements. Two areas already discussed where individual responsibilities could affect the Bay's response include septic system maintenance and upgrades and residential landscape management. Two additional areas include residential improvements to reduce stormwater runoff and dietary changes.

Residential Actions to Reduce Stormwater. When used in residential landscape management, LID practices have demonstrated nutrient and sediment reduction capability that can achieve pre-development loading conditions in some cases. Because developed land is linked to excess nutrient and sediment loads (10, 31, and 19 percent of the total nitrogen, phosphorus, and sediment loads, respectively, according to model estimates; see Figures 1-6, 1-7, and 1-8), widespread application of LID practices on a voluntary basis or through incentive programs could benefit Bay water quality. Practices that promote infiltration (e.g., rain gardens, pervious alternatives to paving, rain barrels, natural landscaping techniques) reduce runoff and the nutrients and sediments associated with runoff (NRC, 2008). Although these practices may be implemented on a voluntary basis, incentive programs can promote more widespread recognition of the benefits of LID practices and their application. Similarly, LID techniques can become desirable lifestyle features (e.g., natural landscaping) and produce cost savings (e.g., rain water reuse, reduced fertilizer/pesticide use).

Dietary Changes. Human sewage, mostly from wastewater treatment plants, accounts for approximately 25 percent of the nitrogen to the Chesapeake Bay according to model estimates (Figure 1-6). The source of this nitrogen is protein consumed by watershed residents. Two diet-related actions would result in less nitrogen being injected into septic systems and municipal wastewater treatment plants. First, given that, on average, people in the United States consume more protein than is recommended in dietary reference intake guidelines (IOM, 2005), a decrease in protein consumption would decrease nitrogen discharges in wastewater. Second, a shift from to a less meat-intensive diet would reduce nitrogen losses to the environment during the food production process (Howarth et al., 2002).

Air Pollution Strategies

As noted in Figure 1-6, atmospheric sources are estimated to contribute 33 percent of the nitrogen loads to the Bay. The Chesapeake Bay has realized benefits from large decreases in NO_x emissions from the Bay airshed resulting from the provisions of the Clean Air Act and its amendments, but the atmosphere is still a major source of nitrogen entering the Bay. Thus, more stringent controls on NO_x emissions from all sources will benefit both the Bay and watershed residents, and benefits will exceed costs, primarily because healthcare costs attributed to air pollution will decrease (Birch et al., 2011). Examples of approaches to further reduce NO_x emissions from power plants include operating installed NO_x control equipment more frequently, using low sulfur coal, or installing additional control equipment (e.g., low NO_x burners, selective catalytic reduction, or scrubbers) (EPA, 2010k).

Because of the significance of NH_x deposition to the Bay and its watershed (estimated at more than 6 percent of the total nitrogen loads to the Bay;[11] see Figure 1-6), controls on ammonia sources are also needed to reduce the significant impacts of crop and animal agriculture on the Bay. These controls are more difficult to implement for two reasons. First, there is no regulatory framework for ammonia, because it is not a criteria pollutant. Second, ammonia sources are diffuse, unlike the point sources of NO_x. These two difficulties notwithstanding, efforts to decrease ammonia emissions could significantly reduce nitrogen deposition to the Bay and its watershed. Strategies for decreasing ammonia emissions focus on livestock dietary manipulations to lower the pH of manure and reduce the protein content in feed. Dietary changes can be made to shift a portion of the

[11] The 6 percent of nitrogen from agricultural sources does not include NH_x deposition that is part of the undifferentiated "atmospheric deposition to tidal waters," which is estimated to make up 7 percent of the nitrogen loads to the Bay (Figure 1-6).

soluble nitrogen in urine to less soluble and more slowly degraded organic nitrogen in feces to decrease ammonia emissions (Powers, 2002). Additional strategies can be applied in manure management to reduce ammonia emissions, including applying chemical amendments that limit urea hydrolysis or lower the manure pH, minimizing moisture content, and using manure handling systems to separate feces from urine. Subsurface manure application using tillage equipment or injectors has been shown to reduce ammonia emissions compared to traditional surface application of manure. Additionally, covering manure storage areas can significantly reduce ammonia emissions, and ventilation systems with ammonia treatment systems can also be used (Powers, 2002; Becker and Graves, 2004).

Funding Considerations

As discussed previously in this chapter, the costs of meeting water quality goals pose considerable challenges to federal, state and local partners and to private individuals faced with changes to personal and business activities for implementation of water quality protection. How to pay for water quality protection, and other environmental public goods generally, is a perennial question. Although an extensive review of funding for CBP nutrient and sediment reduction strategies was beyond the committee's charge, the committee did not want to raise the issue of high costs without also discussing some potentially viable funding strategies.

Targeting Agricultural BMP Funding

Many land-based best management practices are available that can result in nutrient and sediment load reductions. However, cost-share programs to encourage adoption of BMPs will be most cost-effective if they are targeted to locations where allocation of available funds results in the greatest load reductions possible. Nutrient and sediment load reductions and associated water quality improvement goals are most likely to be achieved if staff and monetary resources available to a given jurisdiction are targeted to a prioritized list of watersheds and their associated receiving waters. Priorities should reflect both the opportunities for nutrient and sediment reductions, such as hydrologically active areas of high nutrient or sediment source availability, and the costs of BMPs appropriate for such locations. Target locations may include agricultural areas with shorter flowpaths to reduce nitrogen losses and, for phosphorus, runoff-prone areas and areas with high phosphorus soils or excess manure relative to crop needs. Targeting strategies for reducing nutrient and sediment loads to the Bay can also consider other environmental and socioeconomic co-benefits, such as carbon sequestration and increased wildlife habitat and diversity in riparian buffers, although targeting strategies that attempt to address too many objectives may be weakened.

Evidence of successfully targeting financial assistance for conservation is not easy to find; payments to farmers have historically been distributed broadly with limited attention to potential for environmental benefit (Schertz and Doering, 1999; Lichtenberg and Smith-Ramirez, 2003). Not surprisingly, targeting limited federal and state resources can be controversial because access to cost-share assistance is not available equally to all farmers in all areas. However, Florida has successfully targeted state and USDA/NRCS funding to agricultural BMP cost-share programs in the Suwannee River and Lake Okeechobee Watersheds. Strong state/federal working relationships coupled with effective educational materials and outreach to landowners through the state Farm Bureau, commodity organizations, and land grant university-based cooperative extension service educators have proven effective. An adaptive management strategy can improve the effectiveness of a targeting program. If targeted monitoring reveals that nutrient and sediment load reductions are not achieved by control practices implemented in targeted watersheds, then evaluation of practice effectiveness and effectiveness of financial incentives for motivating practice adoption can be undertaken within the limited targeted area and the program adapted as appropriate (see also Chapter 4). Similar BMP performance evaluation and modification strategies are key elements of the agricultural nonpoint source control program employed in Florida, for example, described in Box 2-2.

Nutrient Offset and Credit Trading

With limited federal and state funding for financial assistance, the EPA, the U.S. Department of Agriculture (USDA), and states are relying on nutrient offset and credit trading programs as an alternative funding model to reduce point and nonpoint sources of nitrogen and phosphorus as required by the TMDL. However, views conflict about the extent to which trading can be relied upon to make a significant contribution to reducing loads and/or to lowering the costs of reducing loads (Greenhalgh and Faeth, 2001; King and Kuch, 2003; Ribaudo et al., 2005; Shabman and Stephenson, 2007; Showalter and Spigener, 2007; Selman et al., 2010; Stephenson et al., 2010). Despite the development of almost 40 nutrient trading or offset programs across the United States, the number of successful completed trades is very small. In their nationwide review of programs, King and Kuch (2003) concluded that the few trades that have taken place have been primarily regulator-approved bilateral agreements negotiated between point source dischargers.

A number of supply and demand problems and institutional obstacles stand to limit the success of nutrient trading programs. Selman et al. (2010) concluded that the demand for nutrient offsets and/or credits in the Bay region is likely to be strong, especially because of the expectation of growth in the watershed, but the supply of credits is more uncertain, largely because of requirements that both point sources and nonpoint sources meet baseline requirements before generating credits. A potential geographical mismatch between potential supply and demand may also be problematic. Selman et al. (2010) point to several examples of basins that exhibit the potential for either excess nutrient credit supply or excess demand that, in the absence of inter-basin trading, will not be captured in nutrient trading.

Neither supply nor demand is generally assured, however. The availability of nutrient credits is constrained by several factors, many of which reflect questions about whether CWA and TMDL language offer sufficient flexibility to make nutrient trading a viable option. Point sources may be reluctant to reduce effluent discharges below allowed levels to generate credits out of concern that implementing more aggressive controls signals that current technology-based or water quality-based effluent limits (which are supposed to reflect the maximum possible levels of control) could be adjusted downward to reflect the exhibited attainability of more stringent limits (Stephenson and Shabman, 2010). Nutrient credits from agricultural nonpoint sources may be fewer than expected because of requirements that the agricultural sources achieve minimum levels of nutrient reduction before credits are generated (King and Kuch, 2003).

Baseline requirements for nonpoint sources and analogous technology-based limits for point sources will raise the costs of generating credits. Point and nonpoint sources will use lower-cost reductions to meet baseline requirements, making additional reductions to generate credits more costly. Recent research in Virginia also questions whether sufficient credits can be produced by agricultural nonpoint sources when trading ratios (e.g., requiring reduction of 2 pounds of nonpoint source reduction to generate 1 pound of offset) and the sheer number of protected agricultural acres required to generate offsets are considered (Stephenson et al., 2010).

Demand side obstacles to nutrient credit trading may be more problematic, yet they are more subtle (King and Kuch, 2003). There is some evidence that point sources may look for lower-cost alternatives to purchasing nutrient credits, including water reuse, constructed wetlands, biomass harvest, and removal of on-site septic systems (Stephenson at al., 2010). Demand is further constrained when existing point sources are required to meet technology-based standards before purchasing nutrient credits. Requiring that nutrient trades become part of point sources' NPDES permits may further dampen demand because risk-averse point sources may be reluctant to tie compliance with their NPDES permits to actions taken or not taken by a third party (King and Kuch, 2003; Stephenson et al., 2010).

Demand for nutrient credits to meet urban nonpoint-source limits may be limited because emerging stormwater programs are requiring developers to exhaust feasible on-site controls before purchasing nutrient credits (Stephenson and Shabman, 2010). New and expanding point sources are more likely than existing point sources to seek out nutrient credits to meet offset requirements (Selman et al., 2010; Stephenson et al., 2010). Even then, however, point sources may be hesitant to seek nutrient credits from nonpoint sources. Stephenson et al. (2010) determined, for example, that offsetting a discharge expansion of 1 million gallons per day (MGD)[12] under Virginia's nutrient trading program would require the application of continuous no-till on 10,000-25,000 acres of cropland. With average farm sizes ranging from 100 to 400 acres across Virginia's four river basins, offsetting even a 1 MGD expansion would likely involve contracting with several dozen farm operations—a high transaction cost proposition for any individual point source.

Taken together, these challenges suggest that nutrient offset or credit trading is not a panacea for reaching nutrient reduction goals at lower cost. Removal of institutional constraints that restrict supply and demand at federal and state levels will be required if states are to implement effective trading programs (King and Kuch, 2003; Shabman and Stephenson, 2007).

Funding Urban Stormwater Management

Funding urban stormwater management is fraught with challenges but some innovative approaches are being considered. Increasingly, local entities are providing incentives to promote adoption of stormwater BMPs by homeowners and businesses, including LID techniques and other green infrastructure approaches (EPA, 2010j). Incentives are not always monetary; other forms of encouragement to promote BMP implementation include development incentives offered to developers during the process of applying for development permits, such as zoning upgrades, expedited permitting, and reduced regulatory requirements. Awards and recognition programs can also encourage homeowner and commercial efforts (EPA, 2010j). Supplementary granting programs, such as the federal Section 319 nonpoint source program, can help to defray implementation costs for unregulated stormwater activities, but at about $200 million/year nationally, available funds will not provide for all of the TMDL's unregulated urban runoff control requirements.

[12]For comparison, the Alexandria Sanitation Authority in Alexandria (Fairfax County), Virginia, processes on average 54 million gallons of wastewater per day and serves about 350,000 people in the City of Alexandria and part of Fairfax County (see http://www.alexsan.com/).

Section 319 funds cannot be used to meet requirements of the MS4 or other stormwater permits. To meet MS4 stormwater quantity and quality requirements, some municipalities have instituted stormwater or development fees that are assessed based on type of land use and area of impervious surface and increasingly administered through stormwater utilities (EPA, 2008c).

> A stormwater utility (called a stormwater authority in Pennsylvania) is a mechanism to fund the cost of municipal services directly related to the control and treatment of stormwater. A stormwater utility will operate similarly as an electric or water utility. The utility will be administered and funded separately from the revenues in the general fund, ensuring a dedicated revenue source for the expense of stormwater management. (EPA, 2008c)

Generally, stormwater utilities collect fees from property owners based on the amount of stormwater runoff generated. Utilities commonly use an "equivalent residential unit" to establish fee rates, based on: (1) the amount of impervious cover in the parcel, regardless of size; (2) the intensity of development (i.e., the percentage of impervious cover relative to the entire parcel's size); or (3) an equivalent hydraulic area, based on the combined impact of impervious and pervious cover within a parcel (EPA, 2008c).

Based on a Connecticut study, Fuss and O'Neill (2010b) concluded that stormwater utilities could effectively support implementation of LID by providing subsidies for LID demonstrations, funding for operation and maintenance, technical assistance in LID design and installation, and funding for retrofits for water quality improvements. The City of Portland, Oregon, instituted a Clean River Rewards Program that incentivizes participation by providing discounts on stormwater bills of homeowners who implement particular practices to "contain the rain" (City of Portland, 2006). Nationally, in 2009, stormwater utility fees varied widely, ranging from $8 to $160 per year for a single family home with an average fannual ee of $44 (Fuss and O'Neill, 2010b).

Funding Monitoring Strategies

As described in Chapter 4, monitoring and evaluation of reported ambient stream water quality, particularly at a small watershed scale, is a critical part of understanding the field-scale effectiveness and timescales of response following BMP implementation. Identifying sufficient funds to support an ambient monitoring program capable of detecting potential changes in local water quality in response to BMP implementation can be difficult for individual private entities, small municipalities, and even states.

NRCS has recently developed an interim Conservation Practice Standard (#799) to encourage monitoring and evaluation of BMP effectiveness by private landowners. It is being made available on a pilot basis, with 75 percent cost-sharing support through the NRCS Environmental Quality Incentives Program (EQIP), in a number of states that are part of the Mississippi River Basin Healthy Watershed Initiative (MRBI). The most landowner interest, to date, has been in Missouri, where state funds were used to cover the landowners' portion of the costs and cover the technical expertise needed to implement monitoring protocols. However, overall, landowner participation has been limited (Thomas Christensen, NRCS, personal communication, 2011). No plans have been made to extend the pilot program to the Bay watershed states, although such an arrangement could be promising, particularly if coupled with targeted small-watershed monitoring initiatives that would complement the landowners' edge-of-field monitoring. If applied in the Bay watershed, collaboration between landowners and state or federal agency representatives or university scientists would be needed to develop monitoring plans and to install equipment.

One example of a successful local government collaboration to provide financial support for ambient water quality monitoring is the Southern California Stormwater Monitoring Coalition (SMC). The SMC was formed in 2001 as part of the Southern California Coastal Water Research Project (SCCWRP), a collaborative public agency created in 1969 to conduct coastal environmental monitoring and research.[13] The SMC was the result of a cooperative agreement among the Phase I municipal stormwater NPDES lead permittees, the NPDES regulatory agencies in Southern California, and SCCWRP. [14] The SMC members agreed, with EPA cooperation, that NPDES compliance monitoring schedules would be adjusted periodically to make available funding that may be appropriately re-directed to support cooperative ambient monitoring and reporting efforts.

To enhance support for CBP monitoring efforts (and adaptive management), local and regional governments and industries within Bay subwatersheds may wish to consider similar cooperative efforts. One option is re-directing some funds currently used for individual NPDES compliance monitoring toward an established localized ambient monitoring program or a collaborative effort between different monitoring programs using standardized data collection approaches to allow data collation and comparison. Similarly, some percentage of federal funds provided to agricultural and other landowners to cost-share BMP implementation could be directed to existing or collaborative ambient water quality monitoring programs specifically designed to detect potential changes in stream water quality

[13]See http://www.sccwrp.org/.
[14]See http://www.socalsmc.org/.

associated with BMP implementation. As noted in Chapter 4, such monitoring programs would need to be carefully targeted toward addressing specific uncertainties related to practice effectiveness and Bay response if the monitoring is to support adaptive management.

Establishing a Chesapeake Bay Modeling Laboratory

The final strategy that the committee presents in this chapter addresses improving the scientific and modeling support for the CBP to increase the likelihood that the program will meet its ultimate goal—recovery of the Chesapeake Bay. The committee was not asked to—and did not—review the models. However, the models that collectively make up the Chesapeake Bay Model (i.e., the Airshed Model, the Watershed Model, and the Bay Model; see Box 1-1) are central to the proper allocation of restoration resources, evaluation and planning, and the ongoing adaptive management of the Bay in a changing future. The models have been used to estimate the loading reductions of nitrogen, phosphorus, and sediment necessary to achieve water quality and living resources objectives (i.e., the TMDLs). Models are used to estimate the effect of BMPs on loading reductions to the Bay, thereby providing essential information for planning and evaluating implementation strategies. Models are central to forecasting the Bay's response to future loading reductions and to system perturbations, such as climate change and annual differences in precipitation to the watershed. Thus, models are essential to the success of the CBP. As a consequence, they need to be continuously evaluated as new data are collected, updated as mechanistic understanding increases, and scrutinized for inconsistencies and possible computational and scientific inaccuracies.

The models presently reside in two locations: the Watershed Model at the EPA Chesapeake Bay Program Office and the Bay Model at the U.S. Army Waterways Experiment Station. Only a few technical professionals are completely familiar with the details of the models, their history of development, and the long series of changes and improvements that have been made over the 25 years of development. This is a fragile and precarious situation. Although the codes for both models are publicly available at the Chesapeake Community Modeling Program (CCMP), they are complex and using them would pose a challenge for even experienced modelers. There is no active community involved in exercising these models. The documentation that exists for the models is no substitute for a community of scientists and engineers who understand their inner workings and have actually used the models. This is in sharp contrast to other modeling communities, for example the climate modeling community, in which there are multiple modeling efforts, some of which are centered in national laboratories, and for which comparisons of the various models is a common practice (e.g., Macadam et al., 2010). The Chesapeake Bay hydrodynamic modeling community shares some of these characteristics, but the Airshed, Watershed, and Bay Models do not.

The CCMP has held and continues to hold open and regular meetings during which progress in building, calibrating, and using the models is discussed. However, these models are not used by academics for research investigating the mechanisms that control ecological responses of the Bay. The number of persons at present who can actually make computations is limited to a very few, and there are just two senior scientists among the CBP modeling group—one each for the Watershed Model and Bay Model. Their time in the past has been completely committed (actually over-committed) to the tasks associated with building, calibrating, and using the models to fulfill various management requirements, most recently the development of the TMDL. As a consequence time has been unavailable for the critical cooperative work with the scientific community that would enable a much wider familiarity with and acceptance of these models.

Credibility of these models among the scientific, engineering, and management communities that are concerned with understanding, managing, and protecting Bay water quality is critically important. A recent analysis by LimnoTech (2010), which used a USDA model designed to simulate changes in nutrient loading resulting from conservation practices on crop land in the Bay watershed, reported discrepancies with the CBP Watershed Model, including the amount of agricultural nutrients that reach the Bay. The LimnoTech report has fueled a growing backlash against the Bay TMDL and spurred several members of the House Agriculture Committee to conclude that the CBP models used to develop the TMDL are "fatally flawed" (Blankenship, 2011). Although this NRC committee did not analyze the LimnoTech report or the discrepancies in the models, this issue highlights how technical concerns regarding the CBP models can undermine support for the CBP goals and strategies, the details of which are developed and evaluated using the models. Because the models are not widely used outside the CBP, they lack credibility with the broader scientific community that would result from a history of independent applications. Thus, the academic community has largely been unable to weigh in on this recent controversy, although the CBP Scientific and Technical Advisory Committee is planning an independent review of the LimnoTech report.

Considering the magnitude of the remediation costs and the value of the Bay resource, this situation needs to be addressed. The atmospheric and oceanographic communities have national laboratories (i.e., the National Center for Atmospheric Research [NCAR] and the Geophysical Fluid Dynamics Laboratory [GFDL], respectively) that are centers for the development of atmospheric and oceanic circulation models and more recently the climate models that are used to forecast the possible consequences of various climate-related control measures. A similar laboratory entrusted with the stewardship of the Chesapeake Bay models could be developed for the CBP and charged with evaluating monitoring data and uncertainty in model simulations, improving the predictive skill of the models, and continuously seeking model improvements to accommodate new scientific understanding of the system. Such a laboratory could also be central in designing and improving the CBP monitoring programs, evaluating the consequences of adaptive management experiments, helping to understand where and why pollution controls did not perform as effectively as planned, identifying science gaps, and evaluating the consequences of climate change. Finally, it would be the place where sound technical analysis and advice could be obtained by managers for the inevitable changes that will be necessary as nutrient and sediment reductions are implemented and the resulting responses of the Bay ecosystem are evaluated.

When specific issues are raised, smaller scale models built to answer specific questions could be implemented and/or developed as part of the laboratory's research. A lab would have the personnel to do the development and would not be wed to one watershed model or one Bay model. A laboratory could also facilitate improvements to the models to support the 2017 re-evaluation of the TMDL and the WIPs.

Involvement of the academic community in a laboratory is vitally important. The flow of ideas among the policy, management, and academic communities is a crucial part of the continuing development of state-of-the-art models and understanding. Faculty could form research associations with lab personnel, and lab personnel could have appointments in academic departments. The success of NCAR and GFDL is due in part to their proximity to research universities. Recognition of the need for improved integration of the academic community and the CBP modeling program is not new.[15] What is new is the recommendation that an actual laboratory be established that fulfills the functions listed above and is more than just a virtual association of collaborating individuals. Instead, the committee envisions a modeling laboratory as a physical location, following the examples of NCAR and GFDL.

The actual institutional sponsorship of the laboratory, its relationship to management agencies, and the makeup of the research staff would require serious deliberation. There are tradeoffs to be considered. A lab that is too "academic" might not be responsive to immediate needs. A focus that is too "operational" would merely continue the current situation where scientific functions are not given sufficient priority. A lab with too many varied responsibilities would dilute the effort from a focus on modeling.

[15] See http://ches.communitymodeling.org/documentation/pdf/ModelPreamble.PDF.

Surveying similar labs and their successes and failures would be a useful exercise. The NOAA Great Lakes Environmental Research Laboratory, the EPA research labs, and the Everglades Interagency Modeling Center are additional examples worth examining.

An important component of the work of a modeling laboratory would be the integration of monitoring with modeling efforts, as recommended in Chapter 4. A laboratory could contribute to designing future data collection efforts, relocating sampling stations where the uncertainty of the Bay response is largest, locating monitoring stations in the watershed where loading reductions are predicted to have the largest observable changes, and supporting adaptive management experiments. Because monitoring is costly, any improvement in existing monitoring efficiency could make resources available for other needs.

Integrated modeling and monitoring is also needed to help determine whether CBP management actions are working as anticipated (STAC, 1997, 2005), and this requires models that can accurately simulate the time scales of BMP response and nutrient storage and transport. Time lags between land-based BMP implementation in the Bay watershed and full responses in nutrient and sediment loadings (see Box 1-3), however, remain poorly understood and have not been quantified. The existing models incorporate some of the necessary mechanisms, but others are clearly missing or are not well calibrated. For example, the Bay Model includes a sediment model that is capable of calculating lag times associated with the degradation of organic nitrogen and the storage of inorganic phosphorus (see Figure 1-2), but the land simulation in the Watershed Model has no routing from the land surface to the streams to account for nutrient storage in soils, nor a sediment model for the stream beds, and thus no associated lag times. BMPs are, instead, modeled as instantaneous and permanent pollutant reductions. Also, the groundwater lag in the Watershed Model is virtually nonexistent (hours to days). To incorporate this time lag would require coupling to a separate groundwater model to simulate lags based on groundwater flow (G. Shenk, CBPO, personal communication, 2011). Increases in nitrogen in the Choptank River, as described by Hirsch et al. (2010; see Figure 1-12b) are representative of groundwater and surface water interactions that are not simulated well by the Watershed Model.

Through a Chesapeake Bay modeling laboratory, disciplinary scientists and engineers and modelers could collaborate to quantify lag times in the Bay watershed and translate the phenomena into operational calculation frameworks. Additional intensive monitoring in small watersheds could be conducted to quantify the time scales of contributing mechanisms. Model hindcasting could be used to analyze whether existing models are capable of accurately forecasting the course of Bay remediation and elucidate the strengths and weaknesses of the present formulations.[16] If deemed necessary, additional smaller-scale models could be developed to simulate the time frames of BMP responses. This research would be essential to respond to concerns that management plans are not performing as expected and to support the analysis of progress. Additionally, if significant lag times between implementation of land-based BMPs and nutrient loads reductions are determined, the research could help maintain public support for continued efforts and investments in Bay recovery.

CONCLUSIONS

Reaching the long-term CBP nutrient and sediment reduction goals will require substantial commitment from each of the Bay jurisdictions and likely some level of sacrifice from all who live and work in the watershed. Jurisdictions not only need to significantly reduce current loads, but they will need to take additional actions to address future growth and development over the next 15 years. Additionally, the Bay partners will need to adapt to future changes (e.g., climate change, changing agricultural practices) that may further impact water quality and ecosystem responses to planned implementation strategies. To reach the long-term load reduction goals, Bay jurisdictions and the federal government will need to prepare for the challenges ahead and consider a wide range of possible strategies, including some that are receiving little, if any, consideration today.

Success in meeting CBP goals will require careful attention to the consequences of future population levels, development patterns, agricultural production systems, and changing climate dynamics in the Bay Watershed. Nutrient and sediment management efforts are taking place in the context of a quickly changing landscape and uncertain outcomes that could significantly affect the strategies needed to attain the TMDL goals. For example, an increase in the concentration of livestock or dairy animals near processing and distribution centers would mean a greater concentration of manure nutrients in these areas than has existed in the past. Additionally, Bay jurisdictions may need to adjust future milestone efforts to larger than anticipated population and more intensive land-use development scenarios, as well as climate change influences. Further and continued study of future scenarios is warranted to help Bay partners adapt to a changing future.

Helping the public understand lag times and uncertainties associated with water quality improvements and developing program strategies to

[16]For example, starting with 1950 simulations, the CBP could calculate the relationship between loadings to the bay and the water quality responses from 1950 to the present. The computations can then be verified against observations to better understand the lag times incorporated in the model.

account for them are vital to sustaining public support for the program, especially if near-term Bay response does not meet expectations. Although the science and policy communities generally recognize the uncertainties inherent in water quality modeling, load projections, and practice effectiveness and expect that water quality successes will lag implementation, the same may not be true of the broader public. If the public expects visible, tangible evidence of local and Bay water quality improvements in fairly short order, they will almost certainly become frustrated. In the absence of a concerted effort to engage Bay residents in a conversation about the dynamics of the Bay and how and when improvements can be expected, CBP partners should anticipate and be prepared to respond to an impatient or disillusioned public. By developing small watershed-scale monitoring efforts that highlight local-scale improvements and associated time lags in water quality as they occur, the CBP can better understand and inform the public about anticipated responses to, and expectations for, nutrient control measures.

The committee identified potential strategies that could be used by the CBP partners to help meet their long-term goals for nutrient and sediment reduction and ultimately Bay recovery. The committee did not attempt to identify every possible strategy that could be implemented but instead focused on approaches that are not being implemented to their full potential or that may have substantial, unrealized potential in the Bay watershed. Because many of these strategies have policy or societal implications that could not be fully evaluated by the committee, the strategies are not prioritized but are offered to encourage further consideration and exploration among the CBP partners and stakeholders. Examples include:

Agricultural Strategies

- **Improved and innovative manure management.** Possible strategies include expanded CAFO permitting programs, guidelines and/or regulations to control the timing and rates of manure application, innovative manure application methods, transport of manure to watersheds with the nutrient carrying capacity to accept it, alternative uses (e.g., bioenergy production), animal nutrition management to reduce nutrient loading, and limits on the extent of animal operations based on the nutrient carrying capacity of the watershed.
- **Incentive-based approaches and alternative regulatory models.** Several approaches have been used successfully elsewhere to increase the use of agricultural BMPs for the purpose of improving water quality. Florida developed a voluntary, incentive-based BMP program that provides regulatory relief in exchange for BMP implementation, maintenance, and reporting. Denmark's nutrient management program provides an alterna-

tive model that couples agricultural regulatory requirements with incentives and has resulted in large reductions in nutrient surpluses. The CBP could facilitate an analysis of the costs and potential effectiveness of various incentive-based and regulatory alternatives.

Urban Strategies

- **Regulatory models that address stormwater, growth and development, and residential fertilizer use.** Watershed-based permitting for urban stormwater can lead to cost savings if a consortium of permittees chooses to organize to distribute pollutant load allocations and contribute to monitoring and tracking efforts in their local or regional watersheds. Restrictions on nitrogen and phosphorus residential fertilizer application are cost-effective methods of nutrient load management in urban and suburban areas. Communities could also adopt regulations to restrict land-use changes that would increase nutrient loads from stormwater runoff or cap wastewater treatment plant discharges at current levels, requiring offsets for any future increases.
- **Enhanced individual responsibility.** Enhancing individual responsibilities, either through education and incentives or through regulations, can also contribute to the success of Bay restoration and to water quality improvements. Examples of actions that individuals can take to improve water quality include increasing application of low-impact design and residential stormwater controls, changing residential landscape management, maintaining and upgrading septic systems, and changing diets.

Cross-cutting Strategies

- **Additional air pollution controls.** Although the Chesapeake Bay has realized substantial benefits from the Clean Air Act, the atmosphere remains a major source of nitrogen entering the Bay. More stringent controls on nitrogen emissions from all sources, including NO_x and agricultural ammonia emissions, will benefit both the Bay and the people who reside in its watershed.

Innovative funding models will be needed to address the expected costs of meeting Bay water quality goals. Targeting agricultural BMP cost-share programs is not always politically popular, but it can produce greater reductions at lower cost than will distributing resources broadly with little attention to water quality impacts. Although nutrient trading among point and nonpoint sources is often cited as a mechanism to reach nutrient reduction goals at lower cost, its potential for reducing costs is limited. Stormwater utilities offer a viable funding mechanism to support stormwater management efforts of municipalities. Funding for monitoring will also be needed, and successful regional monitoring cooperatives in other parts of the United States may be useful models.

Establishing a Chesapeake Bay modeling laboratory would ensure that the CBP would have access to a suite of models that are astate-of-the-art and could be used to build credibility with the scientific, engineering, and management communities. The CBP relies heavily on models for setting goals and evaluating nutrient control strategies; thus, the models are essential management tools that merit substantial investment to ensure that they can fulfill present and future needs. Currently, only a few technical professionals are fully knowledgeable of the details of the models and their development. The models are not widely used outside the CBP and, therefore, are unfamiliar to the broader scientific community. Credibility of the models is essential if the CBP goals and strategies are to be accepted and have widespread support. A Chesapeake Bay modeling laboratory would bring together academic scientists and engineers with CBP modelers to examine various competing models with similar objectives and work to enhance the quality of the simulations. An important component of the work of a modeling laboratory would be the integration of monitoring with modeling efforts. Joint research investigations focused on evaluating the success of the Bay recovery strategies could be centered in the laboratory, such as studies on the role of lag times in the observed pollutant loads and Bay responses. A close association with a research university would bring both critical review and new ideas. A laboratory could also facilitate improvements to the models to support the 2017 re-evaluation of the TMDL and the WIPs.

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Appendixes

Appendix A

Model Estimated Nitrogen, Phosphorus, and Sediment Loads by Sector for Five Scenarios

TABLE A-1 Total Nitrogen Loads by Source (million pounds per year)

Source	1985	2009	TS	TMDL	E3
Agriculture	161.8	109.4	71.5	69.4	54.0
Urban runoff	21.0	20.4	15.7	15.6	7.7
Point source	90.9	53.2	44.3	39.1	23.7
Septic	8.2	11.0	7.4	8.4	4.6
Forest	55.9	49.3	50.8	50.9	48.3
NTW atm. deposition	4.1	2.5	2.6	2.6	2.3
All Sources	341.9	245.8	192.3	186.0	140.6

TABLE A-2 Total Phosphorus Loads by Source (million pounds per year)

Source	1985	2009	TS	TMDL	E3
Agriculture	9.2	7.3	5.5	5.1	4.4
Urban runoff	2.3	2.4	1.9	1.7	0.6
Point source	10.1	4.2	4.2	3.1	1.0
Septic	0.0	0.0	0.0	0.0	0.0
Forest	2.3	2.4	2.5	2.5	2.5
NTW atm. deposition	0.1	0.2	0.2	0.2	0.2
All Sources	24.0	16.5	14.3	12.6	8.7

TABLE A-3 Total Sediment Loads by Source (million pounds per year)

Source	1985	2009	TS	TMDL	**E3**
Agriculture	6,830	5,240	3,794	3,887	3,441
Urban runoff	1,234	1,283	1,067	798	131
Point source	144	71	29	229	32
Septic	0	0	0	0	0
Forest	1,435	1,495	1,577	1,539	1,501
NTW atm. deposition	0	0	0	0	0
All Sources	9,643	8,089	6,467	6,453	5,105

NOTES: Loads are as delivered to the Chesapeake Bay under five simulations of the Phase 5.3 watershed model. The scenarios are modeled using the same hydrologic conditions (1985-2005) and changing land use, point source, and BMP conditions. The scenarios include 1985 baseline conditions, 2009 progress, the tributary strategy (TS) goals based on the cap loads set in 2003, total maximum daily load (TMDL), and maximum feasible reduction (E3) scenarios. The E3 scenario is a "what if" scenario of watershed conditions with theoretical maximum levels of managed controls on load sources ("everything, by everyone, everywhere"), with no cost and few physical limitations to implementing BMPs for point and nonpoint sources. Source sectors include agriculture, urban runoff, point sources (including wastewater), septic systems, forested lands, and non-tidal waters atmospheric deposition (NTW Dep). Note that in these simulations, atmospheric deposition is considered separately only when it falls directly on non-tidal waters, and otherwise, the source is attributed to the land-use type on which the deposition falls.
SOURCE: S. Ravi, CBPO, personal communication, 2011.

Appendix B

Best Management Practices and Load Reduction Efficiencies Used in the Watershed Model

TABLE B-1 Best Management Practices and Load Reduction Efficiencies Used in the Watershed Model

Non-Point Source Best Management Practices and Efficiencies Currently Used in Scenario Builder *(Values in parentheses are in progress of official approval)*

Agricultural BMPs		How Credited
Nutrient management		Land-use change
Forest buffers (varies by region		Efficiency, Land-use change
Wetland restoration (varies by region)		Efficiency
Land retirement		Land-use change
Grass buffers (varies by region)		Efficiency, Land-use change
Non-urban stream restoration		Mass reduction/length
Tree planting		Land-use change
Carbon sequestration/alternative crops		Land-use change
Conservation tillage		Land-use change
Continuous no-till (varies by region)		Efficiency
Enhanced nutrient management		Efficiency
Decision agriculture		Efficiency
Conservation plans	High-till	Efficiency
	Low-till	Efficiency
	All hay	Efficiency
	Pasture	Efficiency
Cover crops		Efficiency
Commodity cover crops		Efficiency
Stream access control with fencing		Land-use change
Alternative watering facility		Efficiency
Prescribed grazing/PIRG		Efficiency
Horse pasture management		Efficiency
Animal waste management livestock		Efficiency
Animal waste management poultry		Efficiency
Barnyard runoff control		Efficiency
Loafing lot management		Efficiency
Mortality composters		Efficiency
Water control structures		Efficiency
Poultry phytase		Application reduction
Swine phytase		Application reduction
Dairy precision feeding and forage management		Application reduction
Poultry litter transport		Application reduction

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
N/A	N/A	N/A
19-65%	30-45%	40-60%
7-25%	12-50%	4-15%
N/A	N/A	N/A
13-46%	30-45%	40-60%
0.02 lb/ft	0.003 lb/ft	2 lb/ft
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
(10-15%)	(20-40%)	(70%)
(7%)	(N/A)	(N/A)
(4%)	(N/A)	(N/A)
8% 3% 3% 5%	15% 5% 5% 10%	25% 8% 8% 14%
Varies	Varies	Varies
Varies	Varies	Varies
N/A	N/A	N/A
5%	8%	10%
9%	24%	30%
N/A	20%	40%
75%	75%	N/A
75%	75%	N/A
20%	20%	40%
20%	20%	40%
40%	10%	N/A
33%	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A

Continued

TABLE B-1 Continued

Agricultural BMPs	How Credited
Ammonia emissions reduction (interim)	Application reduction
Poultry litter injection (interim)	Efficiency
Liquid manure injection (interim)	Efficiency
Phosphorus sorbing materials in ditches (interim)	Efficiency

Resource BMPs	How redited
Forest harvesting practices	Efficiency
Dirt & gravel road erosion & sediment control—Driving surface aggregate + raising the roadbed	Mass reduction/length
Dirt & gravel road erosion & sediment control—with outlets	Mass reduction/length
Dirt & gravel road erosion & sediment control—outlets only	Mass reduction/length

Urban BMPs	How credited
Forest conservation	Land-use change
Urban growth reduction	Land-use change
Impervious urban surface reduction	Land-use change
Forest buffers	Efficiency, land-use change
Tree planting	Land-use change
Abandoned mine reclamation	Land-use change
Wet ponds and wetlands	Efficiency
Dry detention ponds and hydrodynamic structures	Efficiency
Dry extended detention ponds	Efficiency
Infiltration practices w/o sand, vegetation	Efficiency
Infiltration practices w/ sand, vegetation	Efficiency
Filtering practices	Efficiency
Erosion and sediment control	Efficiency
Nutrient management	Efficiency
Street sweeping	Efficiency
Urban stream restoration	Load reduction/length

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
15-60%	N/A	N/A
25%	0%	0%
25%	0%	0%
40%	0%	0%

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
50%	60%	60%
0	0	2.96 lb/ft
0	0	3.6 lb/ft
0	0	1.76 lb/ft

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
N/A	N/A	N/A
N/A	N/A	N/A
N/A	N/A	N/A
25%	50%	50%
N/A	N/A	N/A
N/A	N/A	N/A
20%	45%	60%
5%	10%	10%
20%	20%	60%
80%	85%	95%
85%	85%	95%
40%	60%	80%
25%	40%	40%
17%	22%	N/A
3%	3%	9%
0.02 lb/ft	0.003 lb/ft	2 lb/ft

Continued

TABLE B-1 Continued

Urban BMPs		How Credited
Septic connections		Systems change
Septic denitrification		Efficiency
Septic pumping		Efficiency
Bioretention	C/D soils, underdrain	Efficiency
	A/B soils, underdrain	Efficiency
	A/B soils, no underdrain	Efficiency
Vegetated open channels	C/D soils, no underdrain	Efficiency
	A/B soils, no underdrain	Efficiency
Bioswale		Efficiency
Permeable pavement w/o sand, vegetation	C/D soils, underdrain	Efficiency
	A/B soils, underdrain	Efficiency
	A/B soils, no underdrain	Efficiency
Permeable pavement w/ sand, vegetation	C/D soils, underdrain	Efficiency
	A/B soils, underdrain	Efficiency
	A/B soils, no underdrain	Efficiency

BMPs	Hydrogeomorphic region(s)
Forest buffers	Appalachian plateau siliciclastic non-tidal
	Blue Ridge non-tidal; mesozoic lowlands non-tidal; valley and ridge carbonate non-tidal
	Coastal plain dissected uplands non-tidal
	Coastal plain dissected uplands tidal; coastal plain lowlands tidal; coastal plain uplands tidal; Piedmont crystalline tidal
	Coastal plain lowlands non-tidal
	Piedmont crystalline non-tidal
	Coastal plain uplands non-tidal
	Piedmont carbonate non-tidal
	Valley and ridge siliciclastic non-tidal

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
N/A	N/A	N/A
50%	N/A	N/A
5%	N/A	N/A
25% 70% 80%	45% 75% 85%	55% 80% 90%
10% 45%	10% 45%	50% 70%
70%	75%	80%
10% 45% 75%	20% 50% 80%	55% 70% 85%
20% 50% 80%	20% 50% 80%	55% 70% 85%

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
54%	42%	56%
34%	30%	40%
65%	42%	56%
19%	45%	60%
56%	39%	52%
56%	42%	56%
31%	45%	60%
46%	36%	48%
46%	39%	52%

Continued

TABLE B-1 Continued

BMPs	Hydrogeomorphic region(s)
Grass buffers	Appalachian plateau siliciclastic non-tidal
	Blue Ridge non-tidal; mesozoic lowlands non-tidal; valley and ridge carbonate non-tidal
	Coastal plain dissected uplands non-tidal
	Coastal plain dissected uplands tidal; coastal plain lowlands tidal; coastal plain uplands tidal; Piedmont crystalline tidal
	Coastal plain lowlands non-tidal
	Piedmont crystalline non-tidal
	Coastal plain uplands non-tidal
	Piedmont carbonate non-tidal
	Valley and ridge siliciclastic non-tidal
Wetland restoration (ag and urban)	Appalachian plateau siliciclastic non-tidal
	Coastal plain dissected uplands non-tidal; coastal plain dissected uplands tidal; coastal plain lowlands tidal; coastal plain uplands tidal; coastal plain lowlands non-tidal; coastal plains uplands non-tidal
	Blue Ridge non-tidal; Mesozoic lowlands non-tidal; valley and ridge carbonate non-tidal; Piedmont crystalline tidal; Piedmont crystalline non-tidal; Piedmont carbonate non-tidal
Continuous no-till	Coastal plain dissected uplands non-tidal; coastal plain dissected uplands tidal; coastal plain lowlands tidal; coastal plain uplands tidal; coastal plain lowlands non-tidal; coastal plains uplands non-tidal
	Appalachian plateau siliciclastic non-tidal; Blue Ridge non-tidal; Mesozoic lowlands non-tidal; valley and ridge carbonate non-tidal; Piedmont crystalline tidal; Piedmont crystalline non-tidal; Piedmont carbonate non-tidal; valley and ridge siliciclastic non-tidal
Cover crop early drilled rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings*
	Mesozoic lowlands/valley and ridge siliciclastic**

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
38%	42%	56%
24%	30%	40%
46%	42%	56%
13%	45%	60%
39%	39%	52%
39%	42%	56%
21%	45%	60%
32%	36%	48%
32%	39%	52%
7%	12%	4%
25%	50%	15%
14%	26%	8%
10%	20%	70%
15%	40%	70%
45%	15%	20%
34%	15%	20%

Continued

TABLE B-1 Continued

BMPs	Hydrogeomorphic region(s)
Cover crop early other rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early aerial soy rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early aerial corn rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard drilled rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard other rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop late drilled rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop late other rye (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early drilled wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early other wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
38%	15%	20%
29%	15%	20%
31%	15%	20%
24%	15%	20%
18%	15%	20%
14%	15%	20%
41%	7%	10%
31%	7%	10%
35%	7%	10%
27%	7%	10%
19%	N/A	N/A
15%	N/A	N/A
16%	N/A	N/A
12%	N/A	N/A
31%	15%	20%
24%	15%	20%
27%	15%	20%
20%	15%	20%

Continued

TABLE B-1 Continued

BMPs	Hydrogeomorphic region(s)
Cover crop early aerial soy wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early aerial corn wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard drilled wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard other wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop late drilled wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop late other wheat (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early drilled barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early other barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop early aerial soy barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
22%	15%	20%
17%	15%	20%
12%	15%	20%
10%	15%	20%
29%	7%	10%
22%	7%	10%
24%	7%	10%
18%	7%	10%
13%	N/A	N/A
10%	N/A	N/A
11%	N/A	N/A
9%	N/A	N/A
38%	20%	20%
29%	20%	20%
32%	15%	20%
25%	15%	20%
27%	15%	20%
20%	15%	20%

Continued

TABLE B-1 Continued

BMPs	Hydrogeomorphic region(s)
Cover crop early aerial corn barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard drilled barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Cover crop standard other barley (low-till gets only TN efficiency)	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early drill wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early other wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early aerial soy wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early aerial corn wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop standard drill wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop standard other wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
15%	15%	20%
12%	15%	20%
29%	7%	10%
22%	7%	10%
24%	7%	10%
19%	7%	10%
17%	N/A	N/A
15%	N/A	N/A
12%	N/A	N/A
7%	N/A	N/A
15%	N/A	N/A
12%	N/A	N/A
7%	N/A	N/A
6%	N/A	N/A
15%	N/A	N/A
11%	N/A	N/A
12%	N/A	N/A
7%	N/A	N/A

Continued

TABLE B-1 Continued

BMPs	Hydrogeomorphic region(s)
Commodity cover crop late drill wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop late other wheat	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early drill barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early aerial soy barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early aerial corn barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop standard drill barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop standard other barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop standard other rye	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**
Commodity cover crop early other barley	Coastal plain/Piedmont crystalline/karst settings* Mesozoic lowlands/valley and ridge siliciclastic**

*Coastal plain dissected uplands non-tidal; coast plain dissected uplands tidal; coastal plain lowlands tidal; coastal plain uplands tidal; coastal plain lowlands non-tidal; coastal plain uplands non-tidal; valley and ridge carbonate non-tidal; Piedmont carbonate non-tidal.

TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
7%	N/A	N/A
6%	N/A	N/A
13%	N/A	N/A
11%	N/A	N/A
9%	N/A	N/A
6%	N/A	N/A
6%	N/A	N/A
5%	N/A	N/A
13%	N/A	N/A
11%	N/A	N/A
15%	N/A	N/A
11%	N/A	N/A
12%	N/A	N/A
10%	N/A	N/A
18%	N/A	N/A
14%	N/A	N/A
15%	N/A	N/A
11%	N/A	N/A

**Appalachian Plateau siliciclastic non-tidal; Mesozoic lowlands non-tidal; Piedmont crystalline tidal; Piedmont crystalline non-tidal; valley and ridge siliciclastic non-tidal; Blue Ridge non-tidal.
SOURCE: http://archive.chesapeakebay.net/pubs/NPS_BMP_Table1.8.pdf

Appendix C

Details on Tracking and Accounting by Bay Jurisdiction

DELAWARE

The following information was compiled from the watershed implementation plan (WIP; DE DNREC, 2010), responses to a committee questionnaire (J. Volk, DE DNREC, personal communication, 2010), and personal communication for factual corrections (E. Goldbaum, DE DNREC, personal communication, 2010).

1) Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?

Point Source:

- Delaware currently uses the Permit Control System to track wastewater facility permitted loads (reported monthly through discharge monitoring reports) and will transition into the Integrated Compliance Information System (ICIS) that is transparent, accessible, and fully compatible with EPA decision tools.

Non-point source:

- **Septic** - Delaware Department of Natural Resources and Control (DNREC) uses the Environmental Navigator database to track all permitted septic systems, including licenses, service providers, site evaluations, permits, inspections, and violations, and includes GIS capability.
- **Stormwater** - Eight state and local government agencies inspect stormwater BMPs implemented and report to the CBP. Six out of the eight agencies store the information in an electronic database (Excel, Oracle,

Access, etc.), whereas two agencies have a paper data storage system. Changes to existing collection, report, and verification procedures are underway and will become statewide in the next few years. A new database, MudTracker, will be used to track post-development stormwater BMPs, resolving consistency issues for several jurisdictions. An Access database is in development to be used to track MS4 permits.

- **Land use** - DNREC tracks loads impacted by land-use change using two models, Nutrient Budget Protocol and Delaware Urban Runoff Management Model (DURMM).
- **Agriculture** - The Farm Service Agency (FSA) and the Natural Resources Conservation Service (NRCS) will report data through the USGS, which will then transfer the data to the Watershed Model. This system is not yet final, however; that data was submitted by the state to the CBP for the 2010 data submission. Additionally, other state-funded practices are issued and tracked through the Dept. of Agriculture, such as the manure relocation program and the nutrient management plan cost share program.
- **Forest -** Dept. of Agriculture tracks data on urban tree planting, afforestation, and forest harvesting practices.

2) Are the practices geo-referenced?

Non-point source:

- **Septic** - Septic systems are geo-referenced in the Environmental Navigator.
- **Stormwater** - All permanent stormwater BMPs being added to the MudTracker database used by DNREC, Kent Conservation District, and Sussex Conservation District are geo-referenced. Stormwater BMPs in the Chesapeake Bay drainage have been given the highest priority for input to MudTracker and is expected to be completed in 2011. In addition, New Castle County Special Services maintains its own database of stormwater BMPs, as does the Delaware Department of Transportation, which are also geo-referenced. This should provide over 90 percent coverage of the permanent stormwater BMPs in the Chesapeake by the end of 2011.
- **Land use** - DURMM and the Nutrient Load Protocol uses tax parcel identification numbers, which can be geo-referenced.
- **Agriculture** - Through an agreement between the FSA and the USGS (and a similar pending agreement between the NRCS and the USGS), cost-shared agricultural BMPs reported are aggregated by watershed and reported directly into the Bay model. Most of the state's agricultural BMPs are reported through these two agencies, although it is unclear how many of BMPs cost-shared by other programs are geo-referenced.

- **Forest** - Yes, the Dept. of Agriculture geo-references BMPs and stores the data in shapefiles. The data is reported to DNREC's 319 Program.

3) **What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

- **Septic** - DNREC tracks groundwater discharges on site specific systems. There are routine annual inspections on systems larger than 2,500 gallons per day, and these systems must be operated by licensed operators. Delaware also requires owners of advanced treatment systems less than 2,500 gallons per day to enter into contract with a licensed service provider who inspects these systems twice a year and sends the inspection reports to DNREC annually. Conventional on-site systems less than 2,500 gallons per day are not required to be inspected. Delaware is in the process of revising our regulations to require these systems be inspected by a licensed Class H inspector at the time of sale statewide.
- **Stormwater** - The industrial stormwater program requires monitoring of stormwater effluent, but no verification of being within permit guidelines. For new development, the collection, reporting, and verification of stormwater nutrient and sediment controls is the responsibility of delegated agency, with oversight by the DNREC Sediment and Stormwater Program. The current Delaware Sediment and Stormwater Regulations require that all delegated agencies' program elements include a process to review/approve sediment and stormwater plans, perform field inspections of both construction and post-construction BMPs, and inspect permanent stormwater BMPs on a regular basis.
- **Agriculture** - To ensure that practices reported as "new" did not previously exist, the state will review aerial photography and records to establish the implementing year as best as possible. Field verifications are completed by each of the partner agencies.

4) **What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

Voluntary practices are currently not tracked or reported.

5) **How does the tracking and reporting system incorporate quality controls and protect against double-counting?**

Delaware is using aerial photography to verify agricultural BMPs and reduce redundancy information tracked, although it remains unclear what percentage of the reported data is checked. Once the Mudtracker database has been populated, there will only be one data entry for an individual development project. Although multiple BMPs can be added to a single project, any duplication would be detected during the next maintenance inspection cycle. The New Castle County Department of Special Services has a similar procedure in place.

"The Quality Assurance Manager reviews all data for reasonableness and errors.... It is the responsibility of the implementing organization to verify that all data reported to the DNREC-DWR-WAS is complete, correct, and complies with all rules and policies of that organization. The independent Quality Assurance Manager conducts an additional review of compiled NPS BMP data for completeness, anomalies, errors, or questionable levels of implementation through a status and trends evaluation as a validation procedure."

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

No, currently there is no procedure in place to remove agricultural BMPs from records when a farm parcel is developed, which may result in the same parcel receiving additional reduction credits for stormwater or wastewater practices.

7) **What practices may be undereported?**

There are unreported, under-reported, and unverified BMPs in each non-point source sector—agriculture, stormwater, and onsite wastewater. For the stormwater and onsite wastewater sectors, reporting issues stem from the lack of databases; however, databases for both sectors are under development and should start yielding improved data sets within the year. In the agriculture sector, only BMPs that receive state or federal cost-share dollars get reported because those are the practices on file.

Strengths and Weaknesses

- Although multiple reporting systems are currently in place, significant efforts are underway to develop databases and schema that will allow improved data transfer to EPA via NEIEN, thereby reducing double counting and other data errors. Although the process is not yet completed, much progress has been made.

DISTRICT OF COLUMBIA

The following information was compiled from the WIP (DDOE, 2010), responses to a committee questionnaire, and personal communication for factual corrections (H. Karimi, DDOE, personal communication, 2010, 2011).

1) **Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?**

Point source:

- DC collects monthly wastewater discharge reports (DMR—Discharge Monitoring Report) from the District of Columbia Water and Sewer Authority (DC WASA) for loads from Blue Plains and the Combined Sewer System.

Non-point source:

Overall, the District Department of the Environment collects, reports, and verifies best management practices.

- **Septic** - not applicable
- **Stormwater** - The DDOE tracks and does inspections of stormwater management for construction sites >5,000 sq ft in an agency database. The new MS4 permits will require monitoring after a year of implementation by the facility to the agency. Many non-point source activities are funded, tracked and verified through the MS4 program/permit.
- **Landuse** - DDOE collects, reports and verifies management practices.
- **Agriculture** - not applicable
- **Forest** - D.C. forests are largely managed by the National Park Service.
- **Other** - Stream restoration and wetland projects funded by the 319 Clean Water Act, Bag Bill, and other sources of funding are tracked separately from the MS4 program.

2) **Are the practices geo-referenced?**

Yes, but some information is not geo-coded and must be divided up evenly by watersheds in the District.

3) **What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

- **Stormwater** - During the construction process, compliance inspections are conducted, followed by a final inspection upon the completion of construction. The Watershed Protection Division, Inspection and Enforcement Branch conducts maintenance inspections of all stormwater management facilities twice a year during the first five years of operation and at least once every two years thereafter, to ensure completion of scheduled maintenance and servicing of the stormwater management facilities.

- **Other** - Tree plantings are checked to see if they have survived (Nutrient Management Subcommittee, 2008). Inspections are conducted after completion of wetland mitigation projects to ensure the project meets mitigation requirements.

4) **What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

All voluntary practices installed through DDOE's RiverSmart programs are designed and installed to meet DDOE specifications. Those who request a impervious surface fee reduction will be randomly inspected. For larger, commercial projects, demonstration of volume of water retained, along with a inspection may become part of the approval process for the fee reduction.

5) **How does the tracking and reporting system incorporate quality controls and protect against double-counting?**

The Plan Review Database serves as a tracking and reporting system for stormwater BMPs to protect against double-counting of control measures and ensuring that practices reported as new did not previously exist. The same process applies to voluntary measures.

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

Facilities in our plan review database are permitted facilities and have a maintenance contract/program and are repaired or replaced as needed. These facilities will be with the property for the lifetime of the building. If the building or lot is redeveloped the property will be subjected to more stringent BMPs than in the past.

7) **What practices may be undereported?**

- Street sweeping is underreported/not reported because of difficulty translating area swept into weight of captured material.
- Forest conservation, because National Park Service lands are not credited as "permanently preserved." Riparian buffers are not credited at this time by the Bay Program. Most of Rock Creek, the C&O canal, and large swaths of the Potomac and Anacostia have buffers, mainly because they are surrounded by Federal park lands.
- Activities on private lands that are not permitted or installed through a DDOE program are unknown and unreported.

Strengths and Weaknesses

- There is one sole District agency (DDOE) in charge of collecting and reporting the data.
- Most of the loads and load reductions come from a single source.
- The District has a highly developed system for tracking permitted BMP installations.
- The BMP data is currently based on approved stormwater plans, not on what is actually installed. They are working on recording BMP data based on final inspection.
- Working to correct a problem that the BMP tracking database does not include area treated for each BMP, and instead includes total site area.

MARYLAND

The following information was compiled from the watershed implementation plan (WIP; MDE et al., 2010) and responses to a committee questionnaire (J. Horan, MDE, personal communication, 2010).

1) Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?

Point sources:

- Maryland Department of the Environment (MDE) collects monthly wastewater discharges from Discharge Monitoring Reports (DMRs) and Monthly Operating Reports (MORs) submitted under NPDES permits.

Non-point Sources:

- **Septic** - MDE tracks installation of septic upgrades for nitrogen removal from local health department's reports. The Water Quality Financing Administration collects data on septic connections to wastewater treatment facilities and reports this information via MDE. The name of the applicant, location, the date of the septic system installation and the description of BAT septic systems installed or maintained are tracked by the state.
- **Stormwater** - Local government agencies submit stormwater best management practices (BMPs) based on MDE's Notice of Construction Completion form, which is compiled in Maryland's Urban BMP database. MDE conducts triennial reviews for all local stormwater management programs and requires a stormwater management practice completion form and maintenance and inspection of all BMPs at least once every three years. Stormwater retrofits and urban water quality improvement projects are reported in BayStat.

- **Agriculture** - Maryland Department of Agriculture tracks agricultural BMPs and reports the information monthly to BayStat. The Conservation Tracker database now allows Soil and Conservation District staff to track BMPs without state funding alongside cost-shared BMPs. Nutrient management plans are submitted annually by the farmer. The operation, crops grown, fertilizer use, acreage managed, and animal production are tracked to determine percentage of nutrient management plans in compliance.
- **Land use** - There is no centralized system to track new development. However, the MDPropertyView database is updated annually and includes statewide data from the Maryland State Department of Assessments and Taxation that can be used to identify the number, acreage, and location of parcels that have been developed each year. In addition, every 5 years Maryland Dept. of Planning (MDP) updates and releases a statewide land use data layer. These periodic updates also are used to provide an indication of the level of development within the state.
- **Forest, wetlands** - Department of Natural Resources track natural filter BMPs, such as forest, tree plantings, and wetlands, and the data are reported monthly to BayStat.

Maryland's tracking and reporting scheme is also outlined in Figure C-1.

2) **Are the practices geo-referenced?**

Non-point source:

- **Septic** - Yes. Reporting requirements include location.
- **Stormwater** - Yes
- **Land use** - Yes.
- **Agriculture** - information not provided
- **Forest, wetland** - Yes, GIS coordinates are provided.

3) **What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed, and maintained over the lifespan of the practice according to state/USDA practice standards?**

Non-point source:

- **Septic** - Each upgraded system is required to be inspected and have necessary operation and maintenance performed by a certified service provider at a minimum of once per year. Certified service providers are required to report to MDE all inspections and maintenance performed for nitrogen removal systems. MDE project managers conduct site visits and construction inspections of septic connections to wastewater treatment facilities and findings are documented as Construction Monitoring Reports (CMRs).

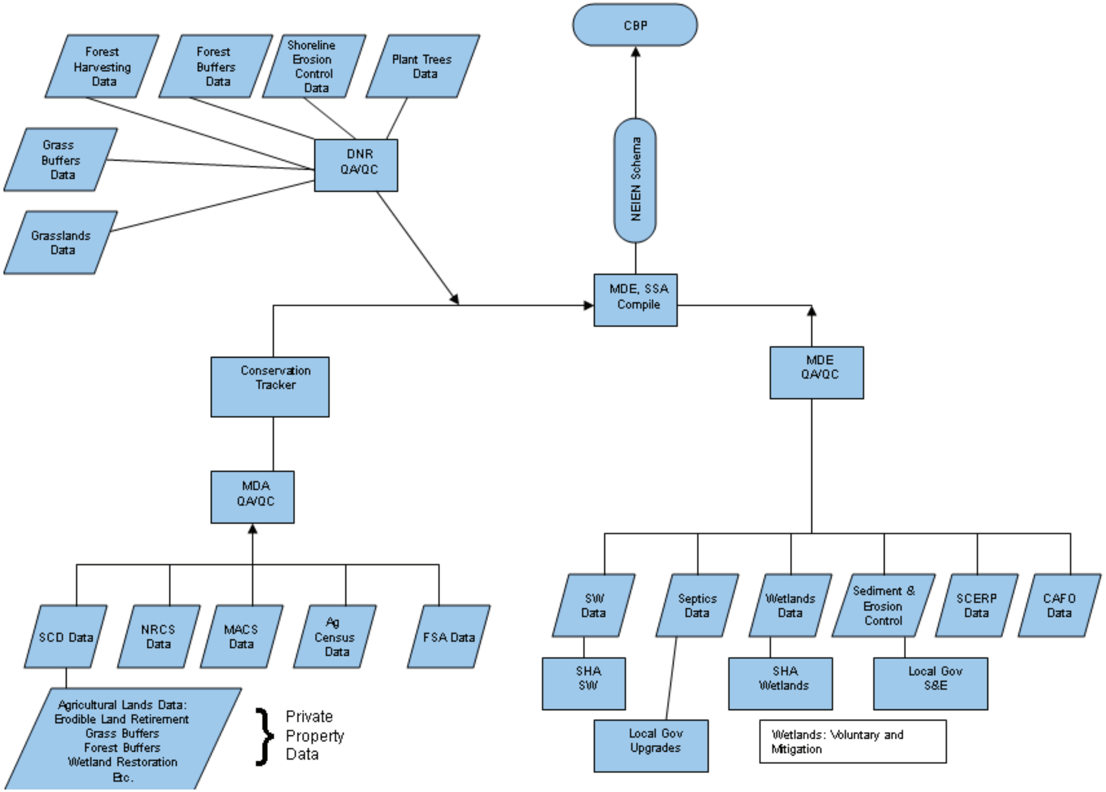

FIGURE C-1 Current tracking and reporting scheme from Maryland's WIP.
Source: MDE et al., 2010

- **Stormwater** - MDE requires regular maintenance and inspection of all BMPs, at least once every 3 years. MDE has over 33,000 facilities in its urban BMP database. More than 22,000 of these have been verified by MDE's Science Services Administration.
- **Agriculture**
  - o MDA aims to conduct field checks for 10% of all BMPs implemented within active maintenance life span to ensure they continue to function according to design standards. However, recent staffing levels have allowed rates of only 7-8 percent annually.
  - o The Maryland Agricultural Water Quality Cost Share (MACS) program aims to spot check 10 percent of all funded practices each year (this check is in addition to the inspection that takes place during BMP construction).
  - o For the MDA Cover Crop Program, Soil Conservation Districts inspect 100 percent of participants who fall certify (at least 20 percent of each participants acreage is inspected). An additional random check of 10 percent of the contracts is conducted in the spring.
  - o Manure transport program- tracking and verification for manure transport is based on the following procedures: a) selection of up to 10% of any of the active and completed agreements; b) inspections conducted as a result from a complaint from an adjacent property owner of others; and c) inspections in conjunction with a nutrient management implementation review.
  - o Nutrient Management Plans: MDA strives to complete approx. 400 randomly selected field inspections per year, which include a review of the plan and all farm records as well as a visual inspection of other BMPs on the farm. Plans are also reviewed at MDA headquarters. Farmers must have their nutrient management plans reviewed and approved to participate in state incentive programs.
  - o CAFOs: MDA plans to conduct up to 100 site inspections at CAFO/MAFO operations to ensure they are meeting their permit requirements.

4) **What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

Maryland will also be initiating a pilot program where soil conservation districts would conduct on farm walking inventories of all of the current practices farmers have installed without incentives. An on-farm nutrient calculation tool will be utilized to assess the farm and to analyze additional management options.

5) **How does the tracking and reporting system incorporate quality controls and protect against double-counting?**

Point source:

- The point-source data undergo an extensive analysis, editing, and verification process prior to input in the MDE database., including: (1) checking for missing & redundant values, (2) checking data ranges against permit values, (3) comparing monthly averages to previous year's, and (4) graphically analyzing data to identify errors or gaps.

Non-point source:

QA/QC provided by MDE, MDA and Science Services Administration according to Figure B-1. Details of quality assurance practices for agricultural BMPs, including numerous procedures to protect against double counting, are outlined in Maryland's QAPP. MDE working with local governments to develop tracking and reporting protocols to ensure no double-counting for stormwater BMPs.

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

Once a BMP exceeded maintenance life (~10-15 years), that BMP is removed from the list.

7) **What practices may be underreported?**

- Stream restoration information because there is no mechanism for reporting and no requirement to do so.
- Septic upgrades done by local government where state funding is not involved.

Innovative practices not currently approved by the CBPO.

Strengths and Weaknesses

- Maryland's Bay Stat is used to record data on point source control upgrades at a monthly rate.
- Conservation Tracker can be used to account for voluntary practices.
- Developing a GIS-based tracking system for all BMPs.
- A large amount of time is spent geo-locating the practice when the location is not provided.
- Limited staff resources are an impediment in tracking/accounting efforts.

NEW YORK

The following information was compiled from the WIP (NY DEC, 2010) and responses to a committee questionnaire (P. Freehafer, NYSDEC, personal communication, 2010).

1) Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?

Point source:

- The New York State Department of Environmental Conservation (NYSDEC) collects monthly wastewater discharges from DMRs submitted under NPDES permits.

Non-point source:

- The Upper Susquehanna Coalition (USC) accounts for the nonpoint source implementation (primarily agriculture and wetland related). Only practices accounted for on-the-ground are reported to the Bay Program. NYSDEC collects the data for the USC model from the Notices of Intent it receives from applicants for stormwater permits.

2) Are the practices geo-referenced?

USC geo-locates and field checks agricultural practices.

3) What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?

Non-point source:

- **Septic** - None reported.
- **Stormwater** - None reported.
- **Agriculture** - USC field checks all practices.

4) What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?

None reported.

5) How does the tracking and reporting system incorporate quality controls and protect against double-counting?

- Strategies to prevent double-counting not reported.
- Quality control procedures outline in the QAPP (USC, 2002). USC does a simple analysis in Excel to search for outliers in the database and compared with the appropriate hard copy. USC will select 50 data

sheets and compare the hard copy to the data entered and uses this test as an estimate of data entry reliability.

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

Information not provided.

7) **What practices may be underreported?**

Urban and septic practices are generally not reported because of a shortage of staff resources and their relative low contribution to nutrient loads in the NY portion of the watershed.

Strengths and Weaknesses

- USC provides a reliable comprehensive accounting of all agriculture land uses and practices implemented.
- Urban and septic practices are generally not reported because of a shortage of staff resources.

PENNSYLVANIA

The following information was compiled from the WIP (PA DEP, 2010), responses to a committee questionnaire, and personal communication for factual corrections (P. Buckley, PA DEP, personal communication, 2010, 2011).

1) **Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?**

Point source:

- The Pennsylvania Department of Environmental Protection (PA DEP) tracks monthly wastewater discharges from DMRs submitted under NPDES permits.
- CAFOs are reported to the EPA similar to the reporting mechanism for agricultural BMPs.

Non-point source:

- **Septic** - No one. Pennsylvania is not including a septic nutrient reduction program due to limited technology options, limited contribution to the Bay, and limited benefit relative to cost. In Pennsylvania, on-lot sewage treatment systems are regulated by Sewage Enforcement Officers at the local government level (sub-county). There are approximately 1200 municipalities in Pennsylvania's Chesapeake watershed. Pennsylvania does not maintain a statewide database of those systems and does not have the staff or other resources necessary to create such a system.

- **Stormwater** - PA DEP tracks stormwater BMPs from the NPDES MS4 annual reports. At this time there is no database or process for compiling and reporting of the stormwater BMP data. Construction site BMPs are reported in permit applications submitted to DEP, but this information is not compiled due to staffing limitations. Instead, for CBP reporting, an estimate was made of the acres of urban land with stormwater BMPs using Act 167 county stormwater management plans, construction permit acreage data, and conservative best professional judgment.
- **Land use** - information not provided.
- **Agriculture** - PA DEP collects data from various sources shown in Table C-1. Conservation districts are now tracking manure transport, although these files only cover approximately 50 percent of the manure transport, and additional data collection efforts are being developed through the Department of Agriculture.
- **Forests** - PA DEP tracks new riparian forest buffers, whereas urban tree canopy expansion and forest land conservation are tracked by DCNR Bureau of Forestry.

2) **Are the practices geo-referenced?**

Non-point source:

- **Septic** - No
- **Stormwater** - No
- **Agricultural BMPs** - Only to county or watershed code scale

3) **What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

Non-point source:

- **Septic** - none
- **Stormwater** - Construction-related stormwater BMPs are permitted and verified. These practices are reported to DEP; but at this time there is no centralized tracking database specific to these practices. It is anticipated that these practices eventually will be entered into the non-point source data repository.
- **Agriculture** - Verification and quality assurance of the BMPs implemented are considered to be the responsibility of the federal and state agencies and the NGOs providing the information. It is beyond the capacity or responsibility of the PA Water Planning Office to complete such tasks. No information is provided in the WIP about state agency-level verification.

TABLE C-1 Sources of Agricultural BMP data in Pennsylvania.

Data Source	How Information is Received	Geographical Reporting Level
DEP Stream Fencing Program	Electronic spreadsheet from program database	County/SWPC
DEP Chesapeake Bay Implementation Grant	Electronic spreadsheet from program database	County/SWPC
DEP Section 319 Non-point Source Program	Paper spreadsheet based on review of GRTS database	County/SWPC
DEP Abandoned Mined Land Reclamation Program	Electronic spreadsheet from program database	County
DCNR Forest Stewardship Program	Electronic spreadsheet from program database	County
Pa. Act 6 Nutrient Management Program	Electronic spreadsheet from program database	County/SWPC
Pa Stream Relief Program	Electronic spreadsheet from program database	County
Pa Growing Greener Grant Program	Electronic spreadsheet from program database	SWPC
Pa. Act 102 Erosion and Sedimentation Program	Electronic spreadsheet from program database	County
PDA Agri-Link Program	Spreadsheet received by e-mail from PDA Office	County
FSA Conservation Reserve Program	Spreadsheets downloaded directly from FSA Pa website	County
FSA Conservation Reserve Enhanced Program	Spreadsheets downloaded directly from FSA Pa website	County
NRCS Environmental Quality Incentive Program	Spreadsheets downloaded directly from NRCS Pa website	County
USDA Rural Development Program (septic system hookups to treatment facilities	Listing received by e-mail from USDA Pa Rural Development)	County and Township
PSU Center for Dirt and Gravel Road Studies	Electronic Spreadsheet	County
USDA National Agricultural Statistics Service	Spreadsheet download from website	County
American Farmland Trust	Spreadsheet received by e-mail	County
PDA - Reap Program	Electronic Spreadsheet	County
DEP Nutrient Trading Program	Electronic Spreadsheet	County/P4.3 Model Segment

SOURCE: PA DEP (2010).

4) What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?

Plans for tracking and verifying voluntary practices are under development.

5) How does the tracking and reporting system incorporate quality controls and protect against double-counting?

Not described in WIP or QAPP. Like all states, Pennsylvania tracks practices by funding sources, which it states should help reduce double-counting.

6) Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?

Not described in WIP or QAPP.

7) What practices may be underreported?

Cover Crops, no-till cultivation, manure storage, stream fencing, rotational grazing, stream bank protection, street cleaning, municipal sewage connections, managed precision agriculture, precision feeding, forest harvesting practices, established wetlands, and forest harvesting practices.

Strengths and Weaknesses

- The current tracking and reporting systems have insufficient funds and resources to reliably track BMPs implemented by all sectors. There are state programs that do not have centralized databases.
- DEP has developed a non-point source BMP repository to store all the non-point source BMP information that will be collected. DEP is in the process of populating the repository with information from state programs. The repository has been structured so that individuals or environmental groups will be able to enter BMP information which they privately implement apart from state or federal cost-shared programs.

VIRGINIA

The following information was compiled from the WIP (VA SNR, 2010), responses to a committee questionnaire, and personal communication for factual corrections (A. Pollock, VADEQ, personal communication, 2010, 2011).

1) **Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?**

Point source:

- VA Department of Environmental Quality (DEQ) collects total annual nitrogen and phosphorus discharges in wastewater under NPDES permit requirements. Discharge monitor reports are also required in the Nutrient Watershed General Permit, and DEQ publishes an annual discharge report for all facilities covered by the general permit.
- Modeled flows and event mean concentration data are used to calculate loads from combined sewer systems reported by the state.

Non-point source:

- **Septic** - Virginia Department of Health (VDH) uses Virginia Environmental Information System (VENIS), a statewide database that captures all new applications for permits. VDH also has an internal goal of capturing 10 percent of the legacy systems per year. The Department of Conservation and Recreation (DCR) tracks and reports septic pump-out practices.
- **Stormwater** - The Department of Conservation and Recreation (DCR) receives reports from MS4 localities on installed BMPs as a condition of their permits. A Stormwater Management Enterprise web site is in development to digitally track and report urban/suburban BMPs installed by localities.
- **Landuse** - not covered separately in Virginia's WIP.
- **Agriculture** - Agricultural BMPs are reported through the Agriculture Cost Share Program Tracking Database by DCR and DEQ tracks poultry litter transport between counties in Virginia. DEQ inspects permitted AFO related BMPs.
- **Forest** - Department of Forestry tracks BMPs.

2) **Are the practices geo-referenced?**

- Agricultural cost shared practices have point locations. Virginia is developing system for point locations for nutrient management plans and stormwater BMPs. (W. Keeling, VA DCR, personal communication, 2010)
- VDH is working to capture point locations for onsite (septic) BMPs.

3) **What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

Point source:

- CAFOs permitted under the VPDES regulation will be inspected at least once every 5 years based on a risk-based inspection strategy by DEQ staff in order to verify implementation of the required BMPs.

Non-point source:

- **Septic** - Septic pumpouts are reported to VA DCR for the localities subject to the requirements of the VA Chesapeake Bay Preservation Act. VDH is working to capture pump out data in those counties located within the Chesapeake Bay watershed that are not subject to the requirements of the VA Chesapeake Bay Preservation Act. In addition, any BMP that is also defined as an "alternative onsite sewage system" (AOSS) requires at least an annual inspection by a licensed AOSS operator with a report to VDH.
- **Stormwater** - DCR conducts inspections of land disturbing activities to confirm the details included in the annual reports and conducts approximately 1,500 to 2,000 inspections on permitted activities.
- **Agriculture** - Once installed, Soil and Water Conservation Districts must certify that the practice fulfills all BMP requirements. BMPs that receive state financial incentives are subject to field spot checks for the practice lifespan to determine if a BMP is damaged and not performing its intended purpose. DCR monitors the implementation of installed BMPs by randomly selecting 5 percent of the installed practices within a program year, and 5 percent of the prior multi-year BMPs for field inspections, except where statewide the practice exceeds 400 total installations, in which case only 20 installations of that practice need to be checked. AFOs permitted under the VPA regulation are currently inspected annually by DEQ staff and after 7/1/2011 at least once every 5 years based on a risk-based inspection strategy in order to verify implementation of the required BMPs.

4) **What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?**

"Virginia's 47 Soil and Water Conservation Districts will be the primary mechanism for collection, verification and data entry for agricultural BMPs. DOF will collect, verify and report voluntary forest BMP data. DCR's web-based Agricultural BMP Tracking Program is currently used by all 47 SWCDs and will be modified for voluntary BMP entry, storage and reporting. The strategy calls for a multi-phased approach with Phase I pilot effort beginning in 2011 and the Phase II expansion statewide effort beginning in 2012 and continuing with Phase III in 2013" (VA SNR, 2010). No procedures have been developed as of 2010.

5) **How does the tracking and reporting system incorporate quality controls and protect against double-counting?**

- With the NEIEN reporting protocol NRCS will be reporting data directly to EPA. VA received NRCS raw data and conducted analysis of the NRCS and VA Agricultural Cost Share program raw data to determine possible duplicate records. A list of possible duplicate ID numbers (NRCS Object ID) were submitted to NRCS and USGS so that these records could be removed from the NRCS BMP data. USGS is responsible for aggregation and NEIEN reporting via agreement for USDA.
- QA/QC procedures detailed in the Quality Assurance Project Plan (VA DCR, 2006). The quality assurance of the data provided by NRCS, VDOF, and DMME is the responsibility of the respective agency. DCR does perform periodic spot checks on data reports. VA DCR is updating the existing QAPP to document changes to the tracking and reporting systems. This will include descriptions of the NEIEN processes VA DCR has implemented.

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

- Random inspections are performed for the longer term, multi-year agricultural BMPs, to confirm that the practices are continuing to perform as designed and implemented. No mention of a practice or credit life is provided.
- BMPs for onsite sewage (septic) systems, with the exception of pump outs, are considered permanent. See #3 above for verification procedures.

7) **What practices may be underreported?**

- Hook ups of on-site septic systems to centralized systems are not tracked.
- Non-cost-shared agricultural practices.
- Urban stormwater BMPs on land developed over last 20 years.
- Practices not approved by CBP.

Strengths and Weaknesses

- There has been inconsistent, or in most cases, a lack of reporting of installed stormwater management practices, and most are reported in paper format. A new Stormwater Management Enterprise Web site is being proposed to address this problem.

- Data for onsite sewage systems, including installed BMPs, is not currently geo-coded. VDH's VENIS data base has the capability to store this information and VDH will be working in the future with field offices to begin collecting point locations. Capturing sewer connections (septic BMP) will require cooperation of local government units that are not part of onsite sewage permitting processes at this time.

WEST VIRGINIA

The following information was compiled from the WIP (WV WIPDT et al., 2010), responses to a committee questionnaire, and personal communication for factual corrections (T. Koon, WV DEP, personal communication, 2010, 2011).

1) **Who is responsible for collecting, reporting, and verifying nutrient and sediment controls?**

Point source:

- West Virginia Department of Environmental Protection (WVDEP) tracks monthly discharges of significant facilities (>0.4 MGD) and all new facilities from NPDES permits into the Permit Compliance System (PCS) reports.

Non-point source:

- **Septic** - WVDEP staff collects this information by making calls to relevant agencies, utilities, and businesses.
- **Stormwater** - WVDEP tracks and reports industrial stormwater management practices and maximum disturbed concurrently registered area by county on an annual basis. DEP is also developing a standardized form for MS4s for tracking implementation of runoff reduction practices and retrofits. The WV DEP Construction stormwater program will collect post-construction stormwater BMPs for MS4 and non-MS4 area development.
- **Land use** - WV DEP construction stormwater program will collect land-use information through the construction stormwater permit for MS4 and non-MS4 areas.
- **Agriculture** - Federal agencies (NRCS, FSA) have tracking protocols and summarized data can be obtained from their online database. WVDA tracks nutrient management plans, WVCA tracks all agricultural state cost-shared practices as well as those from watershed associations and NGOs. WV Dept. of Agriculture and the WV Conservation Agency will work to develop tracking and reporting protocols to account for non-cost-shared practices.

2) Are the practices geo-referenced?

Under the Construction Stormwater General Permit, latitude and longitude is provided on the application. When state agency partners are involved in riparian buffer, wetland, stormwater retrofit, or stream restoration projects, latitude and longitude are usually known and on file, but have not been transmitted to CBPO as part of the annual data submission. For most other practices, especially the agriculture BMPs reported by NRCS, the number of units of a given BMP are added and reported as one number per county. All practices have been reported by county.

3) What are procedures for tracking and verifying that regulatory and contracted practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?

Non-point source:

- **Septic** - information not provided
- **Stormwater** - WV does not have a system in place to verify whether post-construction stormwater BMPs were ever actually installed, or whether the number of acres ultimately draining to them was correct, or whether they have been adequately maintained over the years. The WVDEP plans to develop protocols for annual inspections to certify that new and existing regulated and unregulated urban stormwater BMPs are in place and functioning as intended.
- **Agriculture** - The WVDA plans to use current nutrient management planners to assist with tracking and reporting activities while they are in the field. CAFO verification protocols have not been fully implemented. NRCS employs a system of inspecting completed practices and spot-checking through the life of the cost-sharing contract.

4) What are the procedures for tracking and verifying that voluntary practices are properly designed, installed and maintained over the lifespan of the practice according to state/USDA practice standards?

Procedures for tracking both agriculture and post construction stormwater voluntary practices are in development.

5) How does the tracking and reporting system incorporate quality controls and protect against double-counting?

- The MS4 annual report and the DEP Construction Stormwater tracking systems will be compared to ensure all land use, runoff reduction and retrofit BMPs are reported and to prevent double counting within the MS4s.
- For nonpoint source agriculture BMPs reported by multiple agencies, DEP staff has questioned those agencies when needed to make sure they

are not reporting the same practices. When in doubt, the conservative choice has been made.

6) **Does the non-point source practice and program implementation data include a practice/credit life? What is the process for removing practices from the tracking systems once they have expired, are out of date, are not functioning as designed, or no longer exist?**

No information provided.

7) **What practices may be underreported?**

Non-cost shared BMPs.

Strengths and Weaknesses

- WV relies upon staff-intensive data collection methods for some data collection (e.g., calling agencies to get data on septic systems installed or numbers of systems pumped). They lack the web-interfaces to facilitate easier data reporting.
- The NRCS database was not designed with CBP reporting needs in mind and could be improved to ease BMP reporting.

Appendix D

Two-Year Milestone Implementation, 2009-2010

The data provided in this appendix reflect responses to the committee's request to the Bay jurisdictions for implementation progress on their first milestones. The jurisdictions were specifically asked to provide the data reported to the CBP in December 2010, covering the period July 1, 2009 to (at least) June 30, 2010, and some jurisdictions provided additional data beyond this window. Readers should note the dates of each reporting period carefully. Some jurisdictions were only able to report July 1, 2008 to June 30, 2009, although the committee notes that this period largely occurred before the two-year milestone program was announced in May 2009, and may not be representative of the pace of progress throughout the remainder of the first milestone.

It is worth noting that the committee received inconsistent information on the official start date of the first milestone period (July 2008, January 2009, or July 2009) and its length (2.5 years, 3 years, or 3.5 years) from the EPA and the Bay jurisdictions. The original milestone publication (CBP, 2009b) generally cited the first milestone as a three-year period, ending on December 31, 2011; thus, for the purpose of this analysis, the committee assumed a three-year milestone period.

The pace of implementation progress can be evaluated generally by comparing the percentage of the goal accomplished over the period reported relative to the percentage of the first milestone period covered in the data provided. For example, if a jurisdiction provided implementation data for a 12-month period (or 33 percent of the assumed three-year milestone period), the percentage of each implementation goal accomplished can be evaluated relative to the 33 percent threshold. That is, if the practice implementation has met or exceeded 33 percent of the goal, the pace of implementation of that practice meets or exceeds the pace needed to meet the first milestone. However, such an analysis without accompanying load reduction estimates has only limited value to an overarching assessment of a jurisdiction's progress, as discussed in Chapter 3.

DELAWARE

	2009-2011 Milestone	Shortfall in Identified Actions
Nitrogen	292,072 lbs	264,229 lbs
Phosphorus	0	5,958 lbs
Sediment	NA	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2008– June 30, 2009 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Identified in 2009 Milestone Document			
Agricultural practices			
Cover crops, late (acres/yr)	18,600	6,595	35
Cover crops, early (acres/yr)	18,600	16,600	89
Forest buffers (acres)	2,700	2,226	82
Wetland restoration (acres)	420	286	68
Tree planting (acres)	200	162	81
Poultry litter transport (tons/yr)	55,100 (maintain current levels)	Maintained current levels	100
Nutrient mgmt (acres)	177,000 (maintain current levels)	Maintained current levels	100
Urban/suburban			
On-site pumpouts (systems/yr)	8,800	Working on reporting mechanisms	0
Reduction of Invista's permitted load	Reduce to 215,350 lbs nitrogen[1]		0
Added actions since 2009:			
Stormwater actions previously not reported	No data	NA	NA
Denitrification in septic systems from improved reporting	No data	NA	NA
Sewer hookups from improved reporting	No data	NA	NA
Agricultural practices previously not reported	No data	NA	NA
New BMPs that may get approved	No data	NA	NA
Results from new state CAFO regulations	No data	NA	NA
Onsite waste water and stormwater regulations to be finalized in 2011	No data	NA	NA

NOTE: These data reflect milestone actions that were largely accomplished before the two-year milestone strategy was announced.
[1]Now aiming for 172,00 lbs by early 2011.
SOURCE: J. Volk, DE DNREC, personal communication, 2010.

DISTRICT OF COLUMBIA

	2009-2011 Milestone
Nitrogen	159,000 lbs
Phosphorus	0 lbs (already met)
Sediment	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2009– November 12, 2010 (17 months)	% Goal Achieved (in 47% of 1st milestone)
Urban/Suburban			
Plant trees to expand tree canopy by 5 percent by in 25 years (trees planted per year)	4,150	In Progress: Anticipate 4,150 trees planted by end of 2011	unknown
New tree box standards	No numeric goal specified	Draft prepared	NA
Install rain gardens (rain gardens)	100	82	82
Install rain barrels (rain barrels)	250	700	280
Install downspout connections (connections)	300	700	233
Lot-level stormwater retention through RiverSmart Homes program	No numeric goal specified	>1,000 home audits; 142 Bay-scape projects; 25 perv. paver projects	NA
LID in DC Dept. of Transportation (DOT) projects (%)	24%	30% DOT projects incorporated LID	125
Train federal facilities on new stormwater requirements	No numeric goal specified	1 workshop held with 5 agencies	NA
Green roofs (ft^2 converted)[2]	2.5 million	200,000 ft^2 in 2009	8[2]
Implement program to control discharges from District and federally owned facilities	No numeric goal specified	Upgraded stormwater management plan, 2009	NA
Auto repair shop education campaign in Hickey Run (pilot)	No numeric goal specified	Inform businesses of proper BMPs during inspections	NA
Inspect all auto repair shops, laundromats, dry cleaners once every 5 yrs	20% annual inspection rate	266 facility inspections have been conducted	Cannot calculate

DISTRICT OF COLUMBIA (continued)

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2009–November 12, 2010 (17 months)	% Goal Achieved (in 47% of 1st milestone)
Develop and implement pet waste strategy	No numeric goal specified	Implementation of strategy will continue through 2011	100
Mandate installation and use of pumpout stations at all DC marinas	No numeric goal specified	Mandate in Marina standards Act of 2008	100
Restoration of Watts and Pope branches (miles restored)	2.7	Construction to begin in 2011	0
Replace sewer lines (miles replaced)	1.5	Replacement has begun and will continue into 2011	unknown
Complete a street sweeping study and implement long-term enhanced street sweeping and fine particle removal	No numeric goal specified	Study completed in 2010 Implementation to begin in 2011	NA
Implement and promote new stormwater regulations that require LID construction as a first option and mandate training for site managers	No numeric goal specified	In development as of 11/10	NA
Implement impervious area-based SW fee	No numeric goal specified	Fee program finalized and implemented in fall of 2010	100
Review and update zoning regulations to encourage green building	No numeric goal specified	Draft text is being brought before Zoning Commission as of 11/10	NA
Retrofit 100 catch basins for trash control	100	110 basins retrofitted	110
Install 1,000 storm drain markers annually	1,000	1000/yr	100
Install litter trap demonstration projects to divert 6,800 pounds of trash by 2011	6,800	Installed 2 in-stream trash traps, collected 6,585 lbs trash	97

Continued

DISTRICT OF COLUMBIA (continued)

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2009–November 12, 2010 (17 months)	% Goal Achieved (in 47% of 1st milestone)
Determine the type of trash control devices that would be the most effective in retaining large debris and sediment in hot-spot areas	No numeric goal specified	Contract with Earth Conservation Core and Howard University to test trash abatement devices	In progress
Point source			
Enhanced ENR at Blue Plains by 2014	No numeric goal specified		In progress
CSO control, May 2009	Reduce N to 70,298 lbs/yr		Completed

[2] The District of Columbia reports that this number was miscalculated, and was originally intended to reflect the goal of 20% green roof coverage by 2027. The District now anticipates the goal will be met by 2017.

SOURCE: S. Sand, DC DOE, personal communication, 2010.

MARYLAND

	2009-2011 Milestone	**Revised Goal, Considering Growth**
Nitrogen	3.75 million lbs	3.90 million lbs
Phosphorus	193,000 lbs	
Sediment	NA	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions identified	Completed between July 1, 2009–April 2011 (21 months)	% Goal Achieved (in 58% of 1st milestone period)
Agricultural Practices			
Cover crops (acres)	145,634	220,945	152
Nutrient management plan enforcement (acres)	100,000	4,159	4
Soil conservation & water quality plans (acres)	257,049	191,451	74
Continuous no-till conservation (acres)	150,000	150,000	100
Precision agriculture (acres)	100,000	0	0
Livestock waste structures	80	65	81
Water control structures	125	46	37
Dairy manure incorporation technology (acres)	2,500	476	19
Stream protection with fencing (acres)	5,400	5,098	94
Manure transport (tons)[3]	10,000	-8,562	0
Poultry waste structures	50	13	26
Stream protection without fencing (acres)	2,000	1,722	86
Cropland irrigation management (acres)	92,800	92,800	100
Poultry litter treatment (tons)	15,000	0	0
Vegetative open channels (miles)	6	0	0
Runoff control systems	175	136	78
Vegetated environmental buffers (acres)	15	13	87
CAFO buffers (acres)	2,500	0	0
Urban/Suburban			
Wastewater treatment plants ENR (pounds)	740,000	128,372	17
Urban nutrient management regulations (acres)	220,000	0	0
MD Healthy Air Act (pounds)	305,882	0	0

Continued

MARYLAND (Continued)

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions identified	Completed between July 1, 2009–April 2011 (21 months)	% Goal Achieved (in 58% of 1st milestone period)
Blue Plains BNR upgrade (pounds)	315,000	190,000	60
Stormwater runoff management retrofits (acres)	90,000	39,319	44
Septic retrofits inside of critical area (systems)	1,080	779	72
Septic retrofits outside of critical area (systems)	1,920	739	38
Septic hookups to WWTPs	703	32	5
66 state-owned DNR septics (systems)	66	20	30
Natural Filters on Private Land			
Streamside grass buffers (acres)	2,250	2,220	99
Streamside forest buffers (acres)	550	350	64
Wetland restoration (acres)	600	564	94
Retire highly erodible land (acres)	2,500	2,299	92
Natural Filters on Public Land			
Forest brigade (trees)	1,000,000	352,800	35
Wetland restoration—public lands (acres)	555	85	15
Streamside forest buffers—public lands (acres)	345	47	14
Marylanders plant trees	75,000	46,574	62
Streamside grass buffers—public lands (acres)	69	24	35
Cover crops (revised leases on public lands) (acres)	764	0	0

[3]Manure transport is annual practice; goal is 10,000 tons above baseline of 35,000 tons transported out of watershed annually.
SOURCE: H. Stewart, MD DNR, personal communication, 2011.

PENNSYLVANIA

	2009-2011 Milestone
Nitrogen	7.3 million lbs
Phosphorus	300,000 lbs
Sediment	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions identified	Completed between July 1, 2008– June 30, 2009 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Agricultural practices			
Animal waste management systems (all types) (systems)	275	206	75
Carbon sequestration/alternative crops (acres)	25,740	1,859	7
Conservation planning (acres)	327,599	70,199	21
Continuous no-till (acres)	86,567	3,698	4
Cover crops-std planting (acres)	147,818	66,273	45
Enhanced nutrient mgmt (acres)	450	1,278	284
Erosion & sediment control (acres)	181	8,118	4,485
Forest buffers (acres)	19,059	7,135	37
Forest harvesting practices (acres)	125	103	82
Grass buffers (feet)	1,161	1,123	97
Land retirement (acres)	58,876	12,353	21
Mortality composters	22	2	9
Non-urban stream restoration (feet)	215,088	24,897	12
Nutrient management (acres)[4]	128,000	24,294	19
Off-stream watering w/ fencing (acres)	6,143	736	12
Off-stream watering w/ fencing & rotational grazing (acres)	21,249	5,552	26
Off-stream watering w/o fencing (acres)	7,335	211	3
Other conservation-tillage (acres)	88,924	-5,558	-6
Manure transport (poultry liter) (tons)	55,659	51,121	92
Poultry phytase (tons)	19,626	6,542	33
Precision rotational grazing (feet)	NA	29	NA
Horse pasture managment (acres)	NA	1	NA
Field borders (feet)	NA	405,113	NA
Urban/Suburban practices			
Stream restoration (urban) (feet)	4,400	0	0
Stormwater mgmt (all types) (acres)	8,690	3,091	36
Reduced impervious cover (acres)	NA	48	NA
Tree planting (acres)	15,065	1,464	10
Septic connections (number)	7,353	2,430	33

Continued

PENNSYLVANIA (Continued)

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions identified	Completed between July 1, 2008– June 30, 2009 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Other practices			
Abandoned mine reclamation (acres)	2,219	1,294	58
Dirt & gravel road erosion & sediment control (feet)	124,913	318,012	255
Wetland restoration (acres)	1,548	136	9

NOTE: These data reflect milestone actions that were largely accomplished before the two-year milestone strategy was announced.
[4]EPA's 2011 milestone fact sheet lists 473,801 acres of nutrient management. Pennsylvania noted that this is in error. The correct number is 128,000.
SOURCE: P. Buckley, PA DEP, personal communication, 2011.

VIRGINIA

	2009-2011 Milestone	Shortfall in Identified Actions
Nitrogen	3.39 Million lbs	990,000 lbs
Phosphorus	470,000 lbs	35,000 lbs
Sediment	NA	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2009–June 30, 2010 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Agricultural practices			
Cover Crops (acres/yr)	118,800	93,094	78
Small Grain Commodities, harvestable (acres/yr)	37,900	25,729	68
Agricultural Nutrient Management (total acres)	~~258,000 new~~[5] 875,600	414,114	47
Conservation Tillage (NRCS) (acres/yr)	47,500	39,686	84
Continuous No-Till (State Cost-Share) (total acres)	80,900	94,382	118
Animal Waste Management Systems (new systems)	241	41	17
Runoff Control AWMS (new systems)	32	4	13
Off-stream Watering with Fencing (new acres)	89,600	13,045	15
Forest Buffers (new acres)	9,676	1,201	12
Grass Buffers (new acres)	2,084	6,672	320
Wetland Restoration (new acres)	36	68	189
Retirement of Highly Erodible Land (new acres)	18,800	4,253	23
Reforestation (new acres)	12,500	3,153	25
Agricultural Stream Restoration (new linear feet)	13,117	0	0
Urban/Suburban			
~~Wastewater plant improvements~~	~~233,000 lbs N, 126,000 lbs P Reduced~~	NA NA	NA NA
Stormwater Management BMPs (new acres)	48,800	5,982	12
Erosion and Sediment Control (acres)	61,000	NA[6]	NA

Continued

VIRGINIA (Continued)

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions Identified	Completed between July 1, 2009– June 30, 2010 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Additional Urban Nutrient Management (acres)	133,166	21,224	16
Septic System BMPs (Pumpouts)	806	28,109	3,487

[5]Strikeouts reflect disagreement with CBPO over the original goal.
[6]Currently not mapped to NEIEN system or reported for period ending June 30, 2010. Plans are to map these data sources to the NEIEN system for the 2011 data call due December 2011.
SOURCE: A. Pollock, VA DEQ, personal communication, 2011.

WEST VIRGINIA

	2009-2011 Milestone
Nitrogen	42,254 lbs
Phosphorus	3,364 lbs
Sediment	NA

Nutrient Reduction Practice (units)	2009-2011 Milestone Actions identified	Completed between July 1, 20– June 30, 2010 (12 months)	% Goal Achieved (in 33% of 1st milestone period)
Agriculture			
Off-stream watering w/ fencing and rotational grazing (acres)	14,000	5,484	39
Cover crops (acres)	1,500	2,071	138
Forest buffers (acres)	200	730	365
Grass buffers (acres)	200	0	0
Manure transfer (tons)	14,000	10,664	76
Animal Waste Management Systems (systems)	11	23	209
Non-urban stream restoration (feet)	4,000	6,082	152
Urban/suburban			
Wet ponds and wetlands (acres drained)	500	123	25
Dry extended detention ponds (acres drained)	500	489	98
Urban filtering practices (acres drained)	50	0	0
Erosion and sediment control (acres)	1,400	1,307	93
Wetland restoration (acres)	5	0.2	4
Septic connections (systems)	364	138	38
Septic pumpings (systems)	6,800	2,876	42
Septic denitrification (systems)	2	0	0

SOURCE: T. Koon, WV DEP, personal communication, 2010.

Appendix E

Water Science and Technology Board

DONALD I. SIEGEL, *Chair*, Syracuse University, New York
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ANITA A. HALL, Senior Program Associate
MICHAEL J. STOEVER, Research Associate
SARAH E. BRENNAN, Senior Program Assistant

Appendix F

Biographical Sketches of Committee Members and Staff

Kenneth H. Reckhow, *Chair*, is chief scientist in Global Climate Change and Environmental Sciences at RTI International and professor emeritus of water resources in the Nicholas School Faculty division of Environmental Sciences and Policy at Duke University. Dr. Reckhow's research activities have concerned the development, evaluation, and application of models and other assessment techniques for the management of water quality. Recent work by Dr. Reckhow's group has focused on the assessment of nonpoint source pollution on surface water quality and the development of total maximum daily loads (TMDLs). He has served on many National Research Council (NRC) committees, including as chair of the Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction and as a member of the Committee on Restoration of the Greater Everglades Ecosystem. He received a B.S. in engineering physics from Cornell University and an M.S. and a Ph.D. in environmental science and engineering from Harvard University.

Patricia E. Norris, *Vice Chair*, is the Gordon and Norma Guyer and Gary L. Seevers Chair in Natural Resource Conservation at Michigan State University. Her professional interests focus on the economics of natural resource conservation, incentive-based natural resource conservation and environmental policy, and conservation education. She has conducted research and developed outreach programs addressing issues in soil conservation, water quality, groundwater management, wetland policy, land markets, land-use conflicts, and farmland preservation. In her extension work, she has focused largely upon natural resource policy issues, working with private resource owners, local governments, and state and federal agencies as they address the needs for and impacts of institutional change. Dr. Norris teaches courses in public policy analysis and natural resource and environmental economics. She received a B.S. in Agricultural Economics from the University of Georgia and M.S. and Ph.D., both in Agricultural Economics, from the Virginia Polytechnic Institute and State University.

Richard J. Budell is the director of the Florida Department of Agriculture and Consumer Services' Office of Agricultural Water Policy. In this position he is responsible for the management of statewide programs to ensure that the water quality goals and water quantity needs of Florida's agricultural industry are achieved. This includes the development and implementation of regional programs to encourage agricultural producers to adopt voluntary, incentive-based management practices designed to address water quality concerns, and the development and implementation of programs to address agriculture's nonpoint source impacts on water bodies targeted for the establishment of TMDLs under the federal Clean Water Act. Mr. Budell received a B.S. from Boise State University and an M.S. from Florida State University.

Dominic M. Di Toro (**NAE**) is the Edward C. Davis Professor of Civil and Environmental Engineering in the Department of Civil and Environmental Engineering at the University of Delaware. He has specialized in the development and application of mathematical and statistical models to stream, lake, estuarine, and coastal water and sediment quality problems. Recently his work has focused on the development of water and sediment quality criteria for the U.S. Environmental Agency (EPA), sediment flux models for nutrients and metals, and integrated hydrodynamic, sediment transport, and water quality models. He is a member of the National Academy of Engineering and served on the NRC Committee on Sediment Dredging at Superfund Megasites. He received a B.E.E. in electrical engineering from Manhattan College, an M.A. in electrical engineering from Princeton University, and a Ph.D. in civil and geological engineering from Princeton University.

James N. Galloway is associate dean for the sciences and Sidman P. Poole Professor of Environmental Sciences at the University of Virginia. His research interests include the chemistry of natural waters, anthropogenic alterations of biogeochemical cycles, and atmospheric chemistry. Current activities include research on the acidification of streams in Shenandoah National Park, the composition of precipitation in remote regions, air-sea interactions, and the impact of Asia on global biogeochemistry. Dr. Galloway has received numerous honors and awards, including the 2008 Tyler

Prize for Environmental Achievement for his work demonstrating the pervasive and persistent effects of reactive nitrogen on Earth's environment. He has served on many NRC committees, most recently the Subcommittee on Air Emissions from Animal Feeding Operations. He received a B.A. from Whittier College and a Ph.D. in chemistry from the University of California, San Diego.

Holly Greening is director of the Tampa Bay Estuary Program (TBEP). Ms. Greening oversees a unique federal, state, and local partnership dedicated to the preservation and restoration of Florida's largest open-water estuary. She manages TBEP's varied technical and public outreach efforts, and she serves as the chief liaison between the program and the elected officials, scientists, regulators, and citizens that serve on its various committees. Ms. Greening's professional career has focused on implementation and management of freshwater and estuarine projects for state, federal, and private entities. She has served on the Governing Board of the Estuarine Research Federation and three recent NRC committees on coastal issues, including the Committee on Causes and Management of Coastal Eutrophication, and she is a member of the Ocean Studies Board. She received an M.S. in marine ecology from Florida State University.

Andrew N. Sharpley is professor of soils and water quality in the Department of Crop, Soil, and Environmental Sciences at the University of Arkansas. His research investigates the cycling of phosphorus in soil-plant-water systems in relation to agricultural production systems and water quality and includes the management of animal manures, fertilizers, and crop residues. He evaluates the role of stream and river sediments in modifying the amounts and forms of phosphorus transported to lakes and reservoirs in Arkansas. He has previous experience with the NRC, having served on the Committee on Causes and Management of Coastal Eutrophication. He received a B.Sc. in soil science and biogeochemistry from the University of North Wales and a Ph.D. in soil science from Massey University.

Adel Shirmohammadi is associate dean for research in the College of Agriculture and Natural Resources and associate director of the Maryland Agricultural Experiment Station at the University of Maryland. His research interests include modeling as a tool to predict movement of pesticides and nutrients from watersheds in response to hydrological events, ground water pollution, and how to prevent nutrient movement into the ground and surface water systems. Dr. Shirmohammadi uses field and watershed scale monitoring to develop and to validate mathematical models for identifying best management practices. His research also involves interfacing nonpoint source pollution models with geographic information systems (GIS) for pollution identification. He received a B.S. in agricultural engineering from the University of Rezaeiyeh, Iran, an M.S. in agricultural engineering from the University of Nebraska, and a Ph.D. in biological and agricultural engineering from North Carolina State University.

Paul E. Stacey is research coordinator for the Great Bay National Estuarine Research Reserve. He was formerly the director of the Planning and Standards Division in the Connecticut Department of Environmental Protection's Bureau of Water Management, where he oversaw agency participation in the Long Island Sound Study (LISS) and Long Island Sound (LIS) management programs and the state's nonpoint Source Program. As a principal state water quality analyst and manager focusing on cultural eutrophication, Mr. Stacey is well versed in the study of reactive nitrogen sources; air, watershed, and coastal nitrogen dynamics; environmental effects; and management. He is also an expert on programs and policies related to nitrogen control in an integrated protocol because of Connecticut's implementation of the most extensive nitrogen-trading program in the country. Mr. Stacey received a B.A. in psychology from the College of the Holy Cross, a B.S. in wildlife and fisheries from Utah State University, and an M.S. in fisheries biology from Colorado State University.

STAFF

Stephanie E. Johnson, study director, is a senior program officer with the Water Science and Technology Board. Since joining the NRC in 2002, she has served as study director for ten studies, including congressionally mandated reviews of Everglades restoration progress. She has also worked on NRC studies on desalination, water reuse, contaminant source remediation, the disposal of coal combustion wastes, and water security. Dr. Johnson received a B.A. from Vanderbilt University in chemistry and geology and an M.S. and a Ph.D. in environmental sciences from the University of Virginia.

Michael J. Stoever is a research associate with the Water Science and Technology Board. He has worked on a number of studies including Desalination: A National Perspective, the Water Implications of Biofuels Production in the United States, and the Committee on Louisiana Coastal Protection and Restoration. He has also worked on NRC studies on Everglades restoration, the effect of water withdrawals on the St. Johns River, and the WATERS Science Network. Mr. Stoever received a B.A. in political science from The Richard Stockton College of New Jersey in Pomona, New Jersey.