Policy Principles and Possibilities for the UNC Nutrient Study

Jordan Reservoir at Seaforth Boat Dock, August 6, 2017. Water temp 78 F., Secchi depth .6 m, Conductivity ~ 140 ppm.

By Richard Whisnant, Ellen Gilinsky, and Jay Sauber

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Summary

The authors combined their experience with water quality programs and interviews with colleagues around the country to produce this set of recommendations and notes for use in the UNC Nutrient Study. The Seven Important Policy Principles are recommendations that we believe should be debated, discussed, and then put to use in some form as soon as possible, as the UNC team and stakeholders begin to chart a new nutrient management strategy for Jordan and Falls Lakes. The principles are:

1. **Science + Outreach + Governance**. Science leads this study; we expect it to result in a state-of-the art understanding of nutrient fate and transport in and around these reservoirs. Science in the service of public policy needs outreach and management “baked in” to ensure it is transparent and useful to stakeholders and the ultimate policy makers.

2. **Start by getting the primary goals right.** North Carolina’s water quality standards for nutrient sensitive waters were not created for the purpose of protecting these reservoirs. The designated uses should be refined, in a collective, consensus-based process, with the stakeholders. Appropriate water quality standards, based on scientific criteria—likely site-specific and seasonal—should then be tailored to support those uses.

3. **Collective responsibility and accountability.** North Carolina has been a national leader in creating groups of persons interested in water quality who allocate responsibility among themselves and hold each other accountable. This approach should be retained and expanded.

4. **Maximize local gains and co-benefits.** Beyond the refined water quality standards (Principle #2), every opportunity to create and adapt the nutrient management system so as to create local gains and co-benefits should be at least explored, and ideally, developed.

5. **Serious stakeholder engagement.** The management strategy we envision requires serious stakeholder engagement and a commitment to the hard work of consensus building. This means a need for funding and other resources to disseminate scientific knowledge that helps the stakeholders engage meaningfully. In particular, the experience from around the country shows how important local units of government and non-governmental organizations are in nutrient management. It cannot successfully be imposed solely from the state or federal government level.

6. **Constant concern for cost-effectiveness.** We have found no panaceas or silver bullets in our scan around the country. Successful nutrient management strategies at a watershed scale require a lot of resources. In order for resource commitments to be sustainable, there must be constant concern for cost effectiveness. In other words, there must be careful attention to the least costly ways to accomplish goals.

7. **Build a strategy that can learn and adapt.** There is more to learn about nutrient management and criteria development, and we suspect that will remain true for decades. Hence it is important to build a strategy that makes its premises clear, and then is flexible enough to adapt if and when more learning shows those premises to have been flawed.

Beyond these seven policy principles, this paper contains notes from our extensive interviews about nutrient management in other parts of the country. The notes are in the form of a policy matrix of control strategies and brief summaries of other major nutrient management programs and standards.

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Preface

Policy makers have known that Jordan Reservoir would have problems with algae since the first plans were discussed. Here is the conclusion of the original Environmental Impact Statement in 1971:

> “Of primary concern is the possible eutrophic tendency of the lake. ... The main concern expressed for the New Hope [Jordan] Lake is over the aspect of algae growth; a prime indicator of eutrophication. Studies have shown that, assuming that all other elements necessary are available, the amounts of nitrogen and phosphorus presently found in the influent are adequate to produce algae blooms in the lake. The blooms are likely to occur during the spring, summer, and fall months in the upper reaches of the lake where the nutrients enter. Excessive algae growth can become unsightly and cause taste and odor problems in water supplies. Direct withdrawal of water from the lake can be planned to avoid undesirable water characteristics.”

U.S. Army Corps of Engineers, Wilmington District. Final Environmental Impact Statement for New Hope [Jordan] Lake, 1971. Vol. 1 at 20.

The questions have always been how bad the problems would become and what could be done to control or manage them. The UNC Nutrient Study is a continuation of this long discussion.

I. Background

A. About this document

In the 2016 legislative session, the General Assembly of North Carolina put a set of Jordan nutrient management rules on hold. The rules were designed to reduce nutrient over-enrichment in the watershed of B. Everett Jordan Reservoir. Jordan Reservoir is a 21.7 square mile artificial impoundment, dammed in the early 1980s, that provides drinking water for many of the fast-growing areas in the Triangle region of North Carolina. Jordan Reservoir also provides recreation (swimming, boating, fishing, and hiking), aquatic habitat, and flood control for the region. The watershed drains a 1690 square mile region of North Carolina's piedmont.

When the legislature put the Jordan Rules on hold, it also directed the University of North Carolina at Chapel Hill to conduct a study, in conjunction with the N.C. Department of Environmental Quality and other experts, to recommend a nutrient management strategy for the Jordan watershed. The study is being conducted under the management of the UNC Policy Collaboratory, created by the legislature simultaneously with the study directive. In the spring of 2017, a team of scientists from UNC-Chapel Hill and North Carolina State University began studies of the lake and its watershed. At the same time, the authors of this report began a scan of nutrient management strategies in other parts of the United States, and particularly, as directed by the legislature, around the Chesapeake Bay. The goal was to identify policy innovations, successes, failures and other knowledge that could be brought to bear on recommendations for nutrient management in the Jordan watershed.

Some people feel that the Chesapeake Bay program is a poor model for other nutrient management strategies. They may dislike its strong federal presence, with implied or explicit threats of regulation. Or they may believe the scale of the Bay program (large geography, many jurisdictions and substantial federal funding) makes it inappropriate to compare to an intra-state watershed problem. We disagree. Beyond the NC General Assembly's particular mention of the Bay program, the authors believe there are many potential lessons there for others, including North Carolina. Sometimes applying those lessons will require a difficult exercise in scaling down policy approaches. At other times, the lessons transcend scale. Some of the lessons involve non-regulatory approaches—each state in the Bay program developed its own mix of implementation approaches, providing a wide range of policy choices.

Our scan and our collective experience with water issues extends well beyond the Chesapeake Bay. We have canvassed all the southeastern states to learn more about their approaches to nutrients and water quality standards. And we have considered and explain how other major multi-state efforts at nutrient management might be worth future study by those interested in a new approach in North Carolina.

The scientific sampling of the lake and watershed will likely take years to provide confident conclusions about nutrient sources, transport and fate in and around B. Everett Jordan Reservoir. It is only after those conclusions emerge that final recommendations on a nutrient control strategy can be formulated. This document is intended to provide a source of ideas for discussion, debate, and potential further investigation at that time. It also sets out some suggested principles to guide the scientific inquiry throughout the study.

South Fork Shenandoah River at Port Republic, Va (Shenandoah Valley). Virginia has used a mix of regulatory and non-regulatory approaches to nutrient reduction, focusing on wastewater treatment plants as well as stormwater and agriculture. Agriculture is important in the Shenandoah Valley. Debate continues over its water quality impacts, but there are certainly high quality stretches of water, such as this reach of the South Fork immediately downstream from one of Virginia's most productive agricultural areas. 10:25 am May 22, 2017. After scattered showers the previous day and night, low turbidity (NTU = 10). Conductivity ~ 180 ppm.

West Virginia has mostly used non-regulatory means to achieve its nonpoint source reductions. These include funding of basin coordinators who have successfully brought together farmers and local environmentalists to restore streams, such as this: South Fork of the Potomac at Moorefield. 9:30 am May 24, 2017. Drizzling rain ongoing and most of previous night, but turbidity < 10 NTU. Conductivity ~ 150 ppm.

Not all stories from the Chesapeake Bay are successes. Pennsylvania has lagged behind other states in reducing its loads of nutrients. Among the challenges are types of agricultural practices and farmers who completely reject government assistance.

Pequea Creek near Lancaster, 40.009311, -76.162069. June 17, 2017.

B. About the authors

Ellen Gilinsky

After receiving her Ph.D. in Zoology from UNC-Chapel Hill in 1981, Dr. Gilinsky began her professional career as a Chesapeake Bay Program Specialist for the Virginia Water Control Board. She continued to work on water programs directly related to the scope of work for this project all the way through to her retirement in January 2017 from the U.S. Environmental Protection Agency, where for six years she was Associate Deputy Assistant Administrator for Water, part of the senior management team at EPA with overall responsibility for national nutrient issues. She was co-chair of the Gulf of Mexico Hypoxia Task Force, a federal-state partnership addressing nutrient management problems across the entire Mississippi River Basin. She spent seven years as Director of the Division of Water in Virginia, overseeing that state's attempts to handle nutrient problems in the Bay. She has been directly involved in the nation's leading efforts to tackle the problem that North Carolina faces in this study, at both federal and state levels.

Jay Sauber

Jay Sauber worked for the North Carolina Division of Water Quality for 38 years before his retirement as Chief of the Environmental Sciences Section. There he managed North Carolina's efforts to monitor and assess surface water quality across the state, including the very watersheds that this study aims to help. He managed a staff of forty to fifty water quality scientists, technicians, and administrative staff in conducting a variety of water quality assessment and monitoring programs. Programs included: benthic macroinvertebrates, phytoplankton, fish community, intensive surveys for wasteload allocation, lake assessments, rivers and estuarine assessment, biological assessment, toxicology assessment, special studies, and permit related reviews. Outside of North Carolina, he has been a member of many groups addressing nutrient and other water pollution issues, including the EPA Headquarters Workgroup on Development of National Nutrient Criteria, the Water Pollution Control Federation, and the Board of Directors of the North American Lake Management Society. He has received both State and national level recognition for his work.

Richard Whisnant

Richard Whisnant is the Gladys Coates Distinguished Professor of Public Law and Policy at the UNC-Chapel Hill School of Government. He holds degrees from Harvard University (J.D. *cum laude* and Masters in Public Policy) and from the University of North Carolina at Chapel Hill (B.A. in philosophy with highest honors). From 1993 to 1998, he was General Counsel to the N.C. Dept. of Environment, Health and Natural Resources. He served as law clerk to the Hon. Sam J. Ervin, III, United States Court of Appeals for the Fourth Circuit, and as an editor of the Harvard Law Review. Richard's publications include Rule Making in North Carolina (2005), Cleanup Law of North Carolina (2003) and Local Government for Environmental Policymakers (2002), as well as North Carolina's model Phase II, Universal, and Jordan watershed stormwater ordinances. He was the principal investigator for the North Carolina legislature's Water Allocation Study in 2007-11 and for an interdisciplinary team that assessed the operational flexibility of dam operations in the Roanoke River basin for the bi-state 216 Study of Kerr Dam.

II. (Seven) Important Policy Principles

1. Science + Outreach +Governance

This is a multi-disciplinary, science-led policy effort. But the science is being done primarily for the sake of better policy, not just to expand knowledge in the involved scientific fields. This means the science must be involved with the stakeholders from the outset and governed by a concern for the policy decisions that will ultimately be made.

The requirement to make nutrient management science transparent and responsive to stakeholders and policy decision makers' needs was made clear by our interviews all around the Chesapeake Bay. The Chesapeake Bay program is continuing to evolve as a large, complex set of committees that plan, discuss and review the science behind the models and the monitoring on which the Bay program rests. *See* Figure 1 Governance Structure of Chesapeake Bay Program. The federal/state collaborative effort of the Mississippi River/Gulf of Mexico Hypoxia Task Force is also an example of disparate stakeholders uniting around a single science-based goal of reducing nutrient inputs into the Mississippi River to improve both local water quality in their state watersheds as well as in the main stem Mississippi and the Gulf of Mexico.

The structures of the Chesapeake Bay Program and the Hypoxia Task Force are far more elaborate and costly than would be appropriate for watersheds, like Jordan and Falls, that are much smaller and that involve many fewer jurisdictions. However, the overall purpose of the Bay committee structure and the Hypoxia Task Force—to ensure all stakeholders, including policy makers, can understand and access the assumptions and data on which decisions are based—must somehow be replicated for Jordan and Falls. This will require continued funding of data collection, synthesis and communication well beyond the funding levels historically given to initiatives focused on the State's nutrient sensitive waters

2. Start by getting the primary goals right

An important lesson learned from other watershed programs is that goal-setting based on up to date science is key to making progress and getting stakeholder support. The Chesapeake Bay Program spent considerable time and effort on establishing realistic and meaningful goals for a better Chesapeake – such as more oxygen in the deeper waters to support living resources and more submerged aquatic vegetation to increase crab harvests-- which in turn directed them to focus on decreasing nutrient and sediment runoff into the Bay. Similarly, the Puget Sound Partnership spent considerable effort on developing shared goals and measures of progress, all based on science.

Neither the current designated uses of Jordan and Falls Reservoirs nor the State's long-standing, broad nutrient-sensitive waters criterion (an instantaneous chlorophyll-a standard of 40 mg/l applied everywhere) should be taken as a given. Instead, some structured, stakeholder-involved effort should create a more sophisticated, appropriate, consensus-based set of water quality standards for each reservoir based on science and accounting for actual uses and applicability. The uses will quite likely include the existing designated uses, but they should be refined to denote where each use should be applied and to what extent. For example: when, where and how there is primary contact recreation in the reservoirs? What aquatic life species and communities are most important to the stakeholders and the ecology of the reservoirs, and what are their habitat needs? What are the current and projected needs (quality and quantity) for water supply from the reservoirs? *See* Figure 3 Using habitats to define designated uses in Chesapeake Bay.

Once the designated uses are understood in greater detail and accepted by all stakeholders, then appropriate criteria can be developed to protect those uses. Chlorophyll-a may well be an important part of these criteria. But among the others that should be considered are dissolved oxygen, algal toxins and perhaps aquatic macrophytes. **The important policy principle is that the uses and the criteria should be real, widely understood and important.** This may require creation of seasonal, site-specific and narrative criteria. It will require close work between the stakeholders and the scientists, particularly ecologists, who understand the watersheds. The State's Nutrient Criteria Development Plan Scientific Advisory Council (SAC) has already begun the task of reconsidering nutrient related water quality standards. The work of the SAC, going forward, needs to be integrated with a refined understanding of the uses of the reservoirs, informed by the users themselves.

This work should begin as soon as possible, because the models that must ultimately be used to make sense of the scientific data that are already being collected have to connect with these water quality standards. The science and the goals can co-evolve for a period of time, but ultimately the models of nutrient fate and transport in the watersheds must embed the right water quality standards, or they will be practically useless, from a policy point of view.

3. Collective responsibility and accountability

All the successful programs we looked at had these things in common: levels of collective responsibility and universally clear accountability. Everyone needs to feel like a full equal partner in the solution. Similarly, there needs to be accountability for actions and public transparency of the results. Establishing clearly understood metrics that serve as measures of progress toward program goals is essential. The Chesapeake Bay Program has an elaborate online dashboard showing progress toward the goals of each source sector and by each state. The Gulf Hypoxia Task Force is currently working on common measures of success to use throughout the Mississippi River watershed.

North Carolina is recognized nationally for past work on nutrient management, and particularly for its use of collective responsibility and accountability. For example, the Lower Neuse Basin Association has demonstrated the ability of point source dischargers to work together to lower nutrient loads in a cost-effective manner. In the Neuse and Tar-Pamlico basins, the State recognized that the value of collective responsibility and accountability should extend beyond point source dischargers to include agriculture. The Jordan Lake Watershed Oversight Committee (WOC) was an example of an effort to allocate nutrient reduction loads to the agricultural sector and then let the sector figure out collectively (rather than farm by farm) the most efficient way to get reductions. This committee is charged with developing tracking and accounting methods for nitrogen and phosphorus loss from agricultural land in the Upper New Hope, Lower New Hope and Haw River Watersheds. This approach has merit. It should be continued and expanded. There should be a structure for all sectors to be involved with and aware of the practices and commitments of every other sector. For example, all the involved stormwater control programs should understand and share information on the efforts being made by other stormwater programs in the watershed. This will take careful planning, facilitation and resources.

4. Maximize local gains and co-benefits

The primary policy goal is the sustainability of the designated uses of these reservoirs. This primary policy goal may not resonate with everyone in the watershed, especially those who do not use these reservoirs for either recreation or drinking water (see Principle #2). Thus, no opportunity should be lost to maximize local benefits, including benefits outside the reservoirs. This includes designing scientific models and data presentations so that they can be used at local scales, not just at watershed scales. Each local government unit and other stakeholder in the watershed has its own set of concerns and needs for water. The Jordan (and Falls) strategies will be accepted and sustained much more readily if they help address those local concerns.

The Mississippi River/Gulf of Mexico Hypoxia Task Force addressed this issue head-on. While the ultimate goal of this group is to reduce the size of the hypoxic zone in the Gulf of Mexico to improve the fishery, this goal does not resonate for farmers in headwater states such as Iowa and Minnesota. What is important to them is the quality of the local streams that they use every day. Hence the focus of each state's nutrient reduction framework is local water quality that will improve the quality of the main stem Mississippi and the Gulf.

The Bay Program has also evolved to stress local benefits. For example, we met with stakeholders in West Virginia (with no direct connection to Chesapeake Bay) who have grown very committed to the Bay Program because it has helped with local projects. Similarly, the complicated models on which the Bay Program relies have increasingly been developed to work in smaller and smaller footprints, so that they can be useful to local governments as well as to the large, overall watershed.

5. Serious stakeholder engagement

Every one of these policy principles requires serious stakeholder engagement, not just "translation" of science and policy decisions to interested groups. The values of openness and consensus should underlie all policy decisions on a new nutrient management strategy for NC. Consensus here means "every stakeholder group can agree to live with every decision, or if a group disagrees, it must articulate an option that CAN be agreed to (lived with, if not supported fully) by all groups."

6. Constant concern for cost-effectiveness

All the major nutrient management efforts of which we are aware, and that can claim some measure of success, have evolved, in some cases over decades, to a constant concern for cost-effectiveness. That is, they may have started with the desire to just make some progress on the primary goals, to get something done, to work with whatever policy options were most obvious at the time. But eventually, their leaders have come to realize that nutrient management strategies are perpetual efforts. They cannot be sustained, over the long term, without attention to cost-effectiveness. In other words, is this (whatever decision is at hand) the best way to commit resources in order to attain the policy goals? Note the role of cost data in Figure 4 CBP current and planned integration of cost-effectiveness.

A concern for cost-effectiveness may seem inconsistent with the principle of "serious stakeholder engagement." Many policy makers who have struggled with the difficulty of getting stakeholders "on board" retreat from the messiness and time involved. But this is a question of time-frame. Decisions that offend stakeholder groups tend to pile up discontent over time, and eventually this "slow variable" of stakeholder discontent destabilizes or destroys the original plans.

Thus, in the long run, the concern for cost-effectiveness is fully consistent with consensus decision making. It can also lead to innovative solutions, such as water quality trading, that aim for the lowest--cost reductions that can be made, rather than going after only those solutions that are easiest to administer, such as in a permit.

Regarding cost-benefit analysis: the North Carolina legislature has expressed interest in assessment of costs versus benefits for the Chesapeake Bay program. It is possible to find someone who might venture an estimate at the net benefits of the Bay program. But anyone who understands cost-benefit analysis knows that analysis of programs that extend over long lengths of time (decades, for the Bay program), wide areas of space and many different actors (six states plus the District of Columbia, with actions at all levels of government) ends up being driven more by the assumptions than the actual data. Even the cost data are imprecise, as the Research Triangle Institute explained in 2012: ""[T]he total costs required to meet the TMDL goals cannot currently be defined precisely—due in part to the extensive mix of potential implementation tools and strategies…" (RTI 2012 at 6). The benefit side is, of course, even more difficult to quantify accurately. In the last section of this document, we have listed some of the economists and others who have attempted partial cost and/or benefit analysis of the Bay program or nutrient management in North Carolina. But we believe that a more worthwhile focus for policy makers, rather than some point or range estimate of net benefits, is to maintain a constant concern for cost effectiveness.

7. Build a strategy that can learn and adapt

The science of nutrient fate and transport, and the system engineering (for example, water quality criteria and best management practices) that rest on that science, are still progressing. There is much that is not known and will not be known in the next several years, despite bringing the best currently available science to bear on the problems. This means the strategy must be designed from the outset as one that can learn and adapt. Investments will have to be made in control measures based on the best knowledge at the time. But funders, regulators and stakeholders should be aware that today's solutions are not likely to make nutrient problems disappear for all time. This implies a need for flexibility. It suggests bringing in as many people as possible, including regulated entities, as "problem solvers," and listening to their experience and local knowledge. The term "adaptive management" may be overused, but it has been critical to the progress of each of the states within the Chesapeake Bay watershed as they construct and re-construct their respective watershed implementation plans, and it is also applicable here in the Jordan watershed.

James River at Richmond, Va. April 17, 2017 from T. Tyler Potterfield Pedestrian Bridge. The James River does not contribute a large part of the Chesapeake Bay nutrient load But the cleanup of the Bay has worked in conjunction with Richmond's own development of its waterfront, now an attractive urban amenity.

Monday Creek at York River, Hayes, Va (Chesapeake Bay). 37.2811479, -76.3898995 April 20, 2017.

III. Notes for future policy discussion

A. Notable nutrient management strategies in the U.S. beyond the Chesapeake Bay

1. Gulf of Mexico/Mississippi River

The Mississippi River/Gulf of Mexico Hypoxia Task Force (HTF) is a federal/state partnership established in 1997 to work collaboratively on reducing excess nitrogen and phosphorus entering the Mississippi Basin and ultimately to reduce the size of the hypoxic zone in the Gulf of Mexico which is the downstream receiving water. Members of the HTF include five federal agencies and 12 states bordering the Mississippi and Ohio rivers. The National Tribal Water Council represents tribal interests on the HTF. EPA is the HTF federal co-chair; the position of state co-chair, established in 2010, rotates among the state members. Iowa is the current state co-chair. Senior staff, who meet as the Coordinating Committee, support HTF members. The majority of the work of the HTF is voluntary in nature.

The HTF is an example of successful collaboration by stakeholders separated by geography (12 states) and allegiance (environmental and agricultural interests) because they are united around a single science based goal of reducing nutrient inputs into the Mississippi River to improve both local water quality in their state watersheds as well as in the mainstem Mississippi and the Gulf of Mexico.

In the HTF work, science formed the foundation for identifying the problem and developing solutions. Science was done at the federal level to show that a pollution problem existed that was affecting the quality of water available to support a tourism and recreational and commercial fishing based economy (*Gulf Hypoxia Action Plan 2008)*; science at the state level, along with input from all stakeholders, was used to develop state nutrient reduction frameworks that detailed what needed to be done and by whom. Federal and state funds, along with significant contributions from the non-profit sector, universities and local businesses, are being used to support implementation of reduction frameworks.

Once formed and operating, the state/federal partnership of the HTF sought to build partnerships and alliances with universities, agribusiness, local governments, industries, and non-profits with interests within the Mississippi River Basin. This in turn attracted new sources of ideas and dollars to implement each states' strategy and also increased the acceptance and success of implementation.

The HTF identified accountability by sector as key to achieving joint goals. This translates into having the data to show what reductions are being made by whom and when, and how these reductions are reflected in water quality within the receiving streams, the Mississippi River and ultimately the Gulf of Mexico. It also means that all sectors need to agree on the metrics, the data collection methods, and the models that will be used to track success.

2. The Great Lakes

The 2012 Great Lakes Water Quality Agreement is a massive binational commitment between the United States and Canada to improve conditions in the Great Lakes. The key commitments made by the two nations regarding nutrients are laid out in Annex 4 of the agreement. They include developing binational substance objectives for phosphorus concentrations, loading targets and loading allocations for Lake Erie by 2016. Two years after that, the annex sets a goal to develop phosphorus reduction strategies and action plans to meet phosphorus concentration and loading targets. Other commitments deal with implementing reduction programs, identifying priority watersheds for treatment and sharing research findings.

The Great Lakes Water Quality Agreement is structured to involve jurisdictions at the international, state and local level. Annex 4 on nutrients sets out clear, agreed upon goals, as follows: 1. minimize the extent of hypoxic zones in the waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie; 2. maintain the levels of algal biomass below the level constituting a nuisance condition; 3. maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the Great Lakes; 4. maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the Great Lakes; 5. maintain an oligotrophic state, relative algal biomass, and algal species consistent with healthy aquatic ecosystems, in the open waters of Lakes Superior, Michigan, Huron and Ontario; and 6. maintain mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions in the eastern basin of Lake Erie.

The Annex 4 Objectives and Targets Task Team was created in September 2013 and is chaired by Canada and Ohio with 25 binational members. The goal of the Task Team was to recommend revisions to phosphorus target concentrations and loads to Lake Erie needed to achieve the Lake Erie Objectives prescribed by Annex 4 (Nutrients) of the Great Lakes Water Quality Agreement (GLWQA) Amendment of 2012. Annex 4 seeks revised target loads and objectives for all of the Great Lakes, and calls for Lake Erie to be evaluated first because of observed re-eutrophication beginning in the mid-1990s. The worsening condition has been manifested in three ways: a reoccurrence of cyanobacteria blooms primarily in the Western Basin; significant hypoxia conditions in the Central Basin hypolimnion; and the reoccurrence of major nuisance blooms along the northern nearshore of the Eastern Basin.

The Task Team convened several sub-teams, including scientists and modeling experts, to guide their work. The Team also endorsed adoption of an adaptive management process to track the response of the system, evaluate the effectiveness of management efforts, and update management recommendations. Such as process requires a monitoring program capable of tracking loading trends over time and in-lake responses, as well as studies directed at learning more about processes that may be important, but are incompletely understood. The Task Team also recommended updating the models at regular intervals as part of the adaptive management process.

Each state in the Great Lakes basin is also developing its own plans that are guided by the international agreement. Michigan's 2017 draft Domestic Action Plan is one of several plans from surrounding states, the Canadian province of Ontario, and the U.S. and Canadian federal governments. The final version, along with plans from other Lake Erie Basin states (Indiana, Ohio, New York and Pennsylvania), will be integrated into the U.S. Environmental Protection Agency's comprehensive plan scheduled for release in February 2018.

The Michigan Draft Lake Erie Domestic Action Plan (DAP) was developed by the Michigan departments of Agriculture and Rural Development, Environmental Quality, and Natural Resources to reduce the amount of phosphorus entering Lake Erie in order to help reduce persistent, intense algal blooms in the western part of Lake Erie, including those that are unsafe for people, and address low dissolved oxygen levels in the central basin of Lake Erie. It is the guiding document towards achieving a healthier Lake Erie ecosystem. Michigan's DAP affirms actions towards: 1) commitments under the Western Basin of Lake Erie Collaborative Agreement (Collaborative Agreement); 2) meeting the nutrient-related ecosystem goals for Lake Erie under Annex 4 (Nutrients) of the Great Lakes Water Quality Agreement (GLWQA); and, 3) process and tactics for Michigan to implement as a jurisdiction and in collaboration with local municipalities, nongovernmental organizations (NGOs), other stakeholders, as well as the states of Ohio, Indiana, Pennsylvania, New York, and the Province of Ontario. The DAP lays out specific objectives for the State of Michigan; actions to be taken or supported by the state agencies; program, policy and research gaps; and, an adaptive implementation strategy. Together, these provide a focus for allocating existing resources and helping to identify resource gaps. Finally, the DAP describes how Michigan will measure, track and report progress toward meeting its objectives.

3. Puget Sound

The Puget Sound Partnership (PSP) is a Washington State Agency that was formed under and receives partial funding from the EPA National Estuary Program. It has an Executive Director and staff and reports to a Leadership Council appointed by the Governor; there are also appointed technical boards that review the science and program outputs. While Puget Sound itself is not very similar to the North Carolina reservoirs that are the focus of this study, there are similar challenges in the main sources of nutrient pollution. In particular, stormwater, rather than agriculture is the main contributor of nutrients to the system, as the area has already addressed the effluent from wastewater treatment plants.

The PSP works because it unites diverse groups with a common goal to improve the public health, living resources and the economy associated with the Puget Sound Estuary. While it is run as a state agency, it brings together local governments, environmental and watershed groups, academic institutions, and federal partners such as NOAA, EPA, USGS, USACE, and others.

The PSP spent considerable effort on developing shared goals and measures of progress, all based on science. Then they developed a detailed action agenda focusing on near term actions and ongoing programs needed to reach the science based targets. From that they developed implementation plans for each action that lay out in more detail the work to be done and potential sources of funding. This drilling down approach is helpful in identifying specific actions, who will do them, how they will be funded and how they will be tracked.

The PSP has done a good job sharing progress with the general public, which in turn engenders more support for their programs. With all the stakeholders, they agreed on shared measures of progress that they display in an Annual Report as Puget Sound Vital Signs.

Although there are many issues that the PSP tackles, they have highlighted three focus areas: Prevent Pollution from Stormwater; Protect and Restore Habitat; Protect and Recover Shellfish Beds. It is interesting to note that they have identified lack of local capacity, finding sustainable funding and political will as obstacles to making progress on the stormwater front.

4. Lake Champlain

Lake Champlain water quality has shown nutrient impairment for decades, particularly from phosphorus. Major sources are the widespread agriculture in the area as well as stormwater runoff; there are only a few wastewater treatment plants that discharge into the lake and they have nutrient limits on their effluent. The State of Vermont did a TMDL for the Lake that was superseded by a TMDL done by EPA Region 1 after a series of lawsuits. The State is now developing a TMDL Implementation Plan in phases, with the first phase looking at the policy commitments needed to address the source of phosphorus pollution. Because of the large contribution of agriculture (50 to75%) compared to other sources, this example is not really comparable to the issues faced in the NC Reservoirs, but the funds established by the Vermont legislature are of interest, as well as the length of time they estimate to even get to implementation.

The Lake Champlain State Implementation Plan focuses on policy commitments to address the major sources of phosphorus that are contributing to exceedance of water quality standards: stormwater runoff from developed lands, construction sites and roads; discharging animal operations, agricultural runoff from poorly managed cropland and pasture; river and stream channel modifications and floodplain encroachments; forest management practices; wetland alteration and loss; legacy sediments.

The commitments presented in the Phase 1 Plan include new and enhanced regulation, funding and financial incentives, and technical assistance. They will require new and increased efforts from nearly every sector of society, including state government, municipalities, farmers, developers, businesses and homeowners. Vermont has determined that they need a twenty-year implementation schedule to allow for communities to plan and stage the necessary improvements to roads and stormwater infrastructure into long-term capital funding plans as a means of keeping costs and funding burdens down.

Once the modeling being done by EPA is completed to partition the loads into lake watershed segments, the actual level of reductions needed by sub watershed will be quantified and the commitments will become more specific.

Vermont passed funding legislation to establish a Clean Water Fund by imposing a 0.2% increase in Vermont's property transfer tax, which will raise approximately $5.3 million annually. The state established Ecosystem Restoration Grants dedicated to funding implementation of polluted stormwater runoff control projects to $3.75 million per year (from a current level of approximately $2.5 million) for the next two years. Finally, it increased agency capacity dedicated to implementation of the Vermont Clean Water Initiative.

In terms of transferrable information, Lake Champlain's stormwater control plan includes the basics: strengthen MS4 permits; provide technical assistance to communities; encourage local stormwater ordinances; promote green infrastructure. The state mentions that legacy sediments are an issue particularly in St. Albans Bay and indicate that in lake treatment may be needed, but they do not plan to address this issue until 2032.

B. Nutrient-related water quality standards in the Southeast

1. Georgia

There are a number of reservoirs in Georgia with hydrologic, use and operational characteristics similar, in some respects, to Jordan and Falls. Hence it is particularly interesting to the authors to compare Georgia's nutrient-related water quality standards to North Carolina's

State	Reservoir	U.S. ACOE	Drainage Area	Surface Area	Volume	Shoreline Length	Length	AVG/MAX Depth	Retention Time	Filled	Power
			Square Miles	Acres	acre feet	miles	miles	feet	days	or Construction	Generation
NC	Falls of the Neuse	U.S. ACOE	770	12,410	131,395	175	28	7.5/52		1981	No
NC	B. Everett Jordan	U.S. ACOE	1,690	13,940	215,130	180	16				No
GA	West Point Lake	U.S. ACOE	3,440	25,864	604,527	525	35			1962	Yes
AL/GA	Lake Walter F. George	U.S. ACOE	7,460	45,180	934,400	640	85	20.3/96	47	1963	
GA	Lake Jackson	Georgia Power	1,420	4,750	107,250	135				1910	Yes
GA	Lake Allatoona	U.S. ACOE	1,100	11,862	367,471	270		Avg/145		1949	Yes
GA	Lake Sidney Lanier	U.S. ACOE	1,040	38,000	2,064,600	692		Avg/256		1956	Yes
GA	Carters Lake.	U.S. ACOE	520	3,220		62		200/450		1977	

Georgia has approximately half a dozen reservoirs with site specific criteria for nutrients and chlorophyll a. The draft 2016 303(d) assessment list (not yet approved by EPA) places Lake Allatoona (Little River Embayment) in category 3 because the growing season average was exceeded only once in last five years. The Lake has a TMDL for chlorophyll a (2013), but even more interesting: it has a TMDL STATE OF GEORGIA TIER 2 TMDL IMPLEMENTATION PLAN. This plan summarizes state and local government responsibilities and programs.

So far it seems that Georgia does not have any specific rules or regulations or in-lake restoration processes under way.

It does seem that Georgia is "pushing down" requirements for watershed restoration efforts onto NPDES permittees through required Watershed Assessment and Protection Plans.

2. Kentucky

From Water Quality Standards, a narrative eutrophication standard:

Section 1. Nutrients Criterion. Nutrients shall not be elevated in a surface water to a level that results in a eutrophication problem.

No criteria for defining a "eutrophication problem"; no chlorophyll, no N or P standard.

From 305b report 2014

Reservoirs and lakes 96 percent fully support aquatic life designations.

Domestic Water Supply – Lakes and Reservoirs

Statewide there are 181,355 surface water acres assessed for this designated use.

Of those acres, 181,225 acres (>99 percent) fully support the use, 130 acres not supporting the use. All waterbodies not meeting this use are due to nutrient enrichment that result in taste and odor concerns.

3.1.5 Lake and Reservoir Monitoring

Lakes and reservoirs are monitored over the growing season (April through October) for designated use support determination and trophic state using the Carlson Trophic State Index (TSI) for chlorophyll a.

Water quality and physical measurements are made in spring, summer and fall, typically with an interval of six to eight weeks to allow sufficient time for seasonal changes to occur. Publicly accessible lakes and reservoirs are the set of these resources monitored in Kentucky.

In 2013 harmful algal blooms (HABs) were confirmed in Kentucky by the USACE in several reservoirs it manages. This prompted a collaborative effort between the USACE and the KDOW. Monitoring strategies and protocols for the KDOW are still under development and review. The program is relatively new. HABs can cause taste and odor problems in drinking water, consume excess dissolved oxygen that may result in stress or death in fish populations and produce toxins that affect human health. Through agency monitoring efforts, water bodies with HABs are sampled and counts of blue-green algal cells are made.

Since the 2012 Integrated Report, the agency has developed a comprehensive standalone document that explains all the elements that are necessarily considered when making designated use assessment decisions in preparation of the Integrated Report. The following overview of the reporting elements is provided to assist the reader to more efficiently use the report when information pertaining to water bodies of interest is needed.

Table 3.1.5-1. Lakes and reservoirs in the Green – Tradewater Basin Management Unit. Water bodies with new (2011 – 2012 water-year) assessment data for this reporting cycle are in bold type.

Lake or Reservoir	Size (Acres)	Basin	County	Latitude (dd)	Longitude (dd)
Barren River Lake	10,000	Green River	Barren	36.89233	-86.12259
Briggs Lake	19	Green	Logan	36.88812	-86.83244
Campbellsville City Reservoir	63	Green	Taylor	37.35754	-85.34135
Caneyville City Reservoir	75	Green	Grayson		
County Lake	22	Green	Metcalfe	37.04329	-85.60969
Freeman Lake	162	Green	Hardin	37.71536	-85.86917
Grapevine Lake	50	Green	Hopkins	37.30552	-87.47699
Green River Reservoir	8210	Green	Taylor	37.25074	-85.33757
Lake Liberty	79	Green	Casey	37.32263	-84.89537
Lake Malone	814	Green	Muhlenberg	37.0808	-87.0333
Lake Washburn	25	Green	Ohio	37.51812	-86.84842
Lewisburg Lake	51	Green	Logan		
Luzerne Lake	55	Green	Muhlenberg		
Mill Creek Lake	95	Green	Monroe	36.68234	-85.70079
Nolin River Reservoir	5790	Green	Edmonson	37.27914	-86.24699
Nortonville Lake	27	Green	Hopkins	37.18085	-87.46592
Rough River Reservoir	5100	Green	Grayson	37.61833	-86.49972
Salem Lake	99	Green	Larue	37.59128	-85.71097
Shanty Hollow Lake	135	Green	Warren	37.1552	-86.38987
Spa Lake	200	Green	Logan	36.94924	-87.02966
Spurlington Lake	33	Green	Taylor	37.38497	-85.25506
West Fork Drakes Creek Reservoir	67	Green	Simpson	36.72222	-86.5525
Lake Beshear	819	Tradewater	Caldwell	37.14776	-87.68234
Lake Peewee	360	Tradewater	Hopkins	37.34443	-87.5249
Loch Mary	135	Tradewater	Hopkins	37.27343	-87.52087
Moffit Lake	49	Tradewater	Union	37.57852	-87.85481
Pennyrile Lake	48	Tradewater	Christian	37.0729	87.66491
Providence City Reservoir	36	Tradewater	Webster	37.37583	-87.79639
Carpenter Lake	69	Ohio	Daviess	37.8456	-86.9814
City Lake	36	Ohio	Crittenden	37.30206	-88.09032
Kingfisher Lake	21	Ohio	Daviess	37.8447	-86.9769
Cap Mauzy Lake	84	Ohio	Union	37.62245	-87.85535

In 2013 monitoring by the USACE and KDOW confirmed potentially harmful algal blooms (HABs) exist in several reservoirs in the Commonwealth.

There are currently no regulatory water quality standards for HABs, but EPA is developing a human health advisory level for HAB toxins for the protection of drinking water. These advisory criteria were scheduled for release in 2016. For a list of water bodies with potential HABs, general information, the KDOW's strategy to stay abreast of this emerging water quality concern and access to USACE information, see the KDOW's webpage (http://water.ky.gov/waterquality/pages/HABS.aspx).

Division of Water/Harmful Algal Blooms

Boltz Lake (Grant Co.): Recreational Public Health Warning (updated 9/21/2016) Algal toxins present at unsafe levels. Kentucky Department of Fish and Wildlife Resources regulations prohibit swimming on this lake.

During 2014, the Kentucky Division of Water (KDOW) and the U.S. Army Corps of Engineers (USACE) identified the presence of potentially harmful algal blooms based on cell counts (the number of blue-green algae cells in a milliliter of water) at Barren River Lake, Beaver Lake, Campbellsville City Reservoir, Carpenters Lake, General Butler State Park Lake, Green River Lake, Greenbrier Creek Reservoir, Guist Creek Lake, Lake Reba, Long Run Lake, McNeely Lake, Nolin Lake, Reformatory Lake, Rough River Lake, Taylorsville Lake, and Willisburg Lake.

In 2015, KDOW began working with other agencies in the state to develop protocols for sampling and issuing HABs-related advisories based on microcystin and cylindrospermopsin toxin concentrations in the water. Cyanotoxin concentrations are a more reliable indicator of potential health concerns than relying on cell counts alone, as the presence of blue-green algae does not necessarily indicate that toxins are also present.

For the 2015 recreation season, KDOW and USACE revisited the lakes that had HAB recreational advisories in 2014 and collected samples for cyanotoxin testing during June-August of 2015. If the 2014 HAB advisory for a particular lake was already lifted, the lake was revisited to confirm that cyanotoxin levels were low. If the 2014 HAB advisory remained on a lake, two sets of toxin results were collected at least a week apart. If both sets of results were below a level of concern, the advisory was lifted. As of mid-August 2015, all advisories on Kentucky lakes had been lifted. The table below provides information on the advisory status and sample results for each lake as of 2016.

2014 HAB Lake Recreational Advisory Status

Lake/Reservoir	Advisory Posted	Advisory Removed	Most Recent Sample Results		
			Date	Total Microcystins (ppb)	Cylindrospermopsin (ppb)
Barren River Lake	June 2014	July 2015	7/30/2015	ND	0.07
Green River Lake	June 2014	July 2015	8/19/2015	ND	0.06
Greenbrier Creek Reservoir	June 2014	October 2014	8/18/2015	0.67	0.05
Nolin Reservoir	June 2014	July 2015	7/26/2015	ND	ND
Rough River Lake	June 2014	May 2015	8/19/2015	ND	ND
Taylorsville Lake	June 2014	May 2015	7/29/2015	ND	ND
Beaver Lake	August 2014	October 2014	7/29/2015	ND	ND
Campbellsville City Reservoir	August 2014	August 2015	8/6/2015	ND	ND
Carpenters Lake	August 2014	August 2015	8/5/2015	0.42	0.06
General Butler State Park Lake	August 2014	July 2015	7/8/2015	0.66	ND
Guist Creek Lake	August 2014	October 2014	8/6/2015	ND	0.06
Long Run Lake	August 2014	October 2014	7/8/2015	ND	ND
McNeely Lake	August 2014	October 2014	7/8/2015	0.37	ND
Reformatory Lake	August 2014	October 2014	7/8/2015	ND	0.07
Willisburg Lake	August 2014	July 2015	7/15/2015	ND	ND
Lake Reba	October 2014	July 2015	8/13/2015	1.67	0.12

ND=Not detected—the toxin concentration is so low (or not present) that it cannot be measured during analysis
ppb=parts per billion, equivalent to micrograms per liter

Drinking Water Use. Drinking water standards apply to the source water at point of intake. While all water bodies in the Commonwealth carry this DU, it is only implemented through water quality standards where an active drinking water intake is located. The drinking water use support was assessed by review of the Consumer Confidence Reports (CCR) over a five-year span. The annual CCR is based on the average annual quarterly results for contaminants as reported in MORs (monthly operating reports) and are required by the Safe Drinking Water Act.

3. South Carolina

South Carolina has a few lakes and reservoirs listed as not attaining water quality standards for N&P and chlorophyll. However, SC does not have any rules, regulations, or legislative programs for controlling NPS's or buffers or any in-situ remediation activities (i.e. SC has no buffer or re-development requirements). SC relies on volunteer or local government initiatives for NPS controls. SC also uses CWA competitive 319 grant funds for NPS control activities. Principally, SC is focused on NPDES and

MS4's management. They are also focused on developing TMDL's or management alternatives for the

Lower Catawba Chain Reservoirs including Cedar Creek, Fishing Creek, Great Falls and Lake Wateree Reservoirs. SC is conducting new water quality assessments for special studies to use as information enhancement for additional water quality modeling activities.

4. Tennessee

From 305b report.
Overall Use Support:
Tennessee has over 90 public reservoirs or lakes. Most lakes in Tennessee are reservoirs that were created by the impoundment of a stream or river. The only large natural lake is Reelfoot Lake, thought to have been formed by earthquakes in 1811.
Nutrients.
Almost 15,700 lake acres have been assessed as impaired due to nutrients.
This includes three small city lakes and one state park lake with 15,500 of the impaired acres represented by Reelfoot Lake.

Tennessee's water quality criterion for nutrients in lakes and reservoirs is currently narrative only. The exception is Pickwick Reservoir where a numeric chlorophyll *a* criterion has been adopted.

The assessment basis to consider lakes impaired is the level of eutrophication that interferes with the intended uses of the lake.

From State Standards

Narrative Nutrient Criteria
"The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and/or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected."
Nutrient Criteria (Narrative)
The primary designated uses that have nutrient criteria are fish and aquatic life and recreation. A specific nutrient response criterion based on chlorophyll *a* has been adopted for Pickwick Lake.
Waters are not assessed as impaired by nutrients unless biological or aesthetic impacts such as excessive algae growth, or downstream problems are also documented.
At least four nutrient observations are needed for a valid assessment, unless aesthetic or biological impairment is also observed.

.03-.02 GENERAL CONSIDERATIONS.

Tennessee water quality standards shall consist of the General Water Quality Criteria and the Antidegradation Statement found in Chapter 0400-40-03, and the Use Classifications for Surface Waters found in Chapter 0400-40-04.

Waters have many uses which in the public interest are reasonable and necessary. Such uses include: sources of water supply for domestic and industrial purposes; propagation and maintenance of fish and other aquatic life; recreation in and on the waters including the safe consumption of fish and shellfish; livestock watering and irrigation; navigation; generation of power; propagation and maintenance of wildlife; and the enjoyment of scenic and aesthetic qualities of waters.

The rigid application of uniform water quality is not desirable or reasonable because of the varying uses of such waters. The assimilative capacity of a stream for sewage and waste varies depending upon various factors and including the following: volume of flow, depth of channel, the presence of falls or rapids, rate of flow, temperature, natural characteristics, and the nature of the stream.

In order to permit the reasonable and necessary uses of the Waters of the State, existing pollution should be corrected as rapidly as practicable, and future pollution prevented through the best available technology economically achievable or that greater level of technology necessary to meet water quality standards; i.e., modeling and stream survey assessments, treatment plants or other control measures. (k) Other Pollutants - The waters shall not contain other pollutants in quantities that may be detrimental to public health or impair the usefulness of the water as a source of domestic water supply.

In lakes and reservoirs, the dissolved oxygen concentrations shall be measured at middepth in waters having a total depth of ten feet or less, and at a depth of five feet in waters having a total depth of greater than ten feet and shall not be less than 5.0 mg/L.

(k) Nutrients - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and/or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected. Examples of parameters associated with the criterion include but are not limited to: nitrogen, phosphorus, potassium, calcium, magnesium, and various forms of each. Interpretation of this provision may be made using the document Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion and/or other scientifically defensible methods.

(m) Biological Integrity - The waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or, in the case of wadeable streams, substantially different from conditions in reference streams in the same ecoregion. The parameters associated with this criterion are the aquatic biota measured. These are response variables. Interpretation of this provision for any stream which (a) has at least 80% of the upstream catchment area contained within a single bioregion and (b) is of the appropriate stream order specified for the bioregion and (c) contains the habitat (riffle or rooted bank) specified for the bioregion, may be made using the most current revision of the Department's Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys and/or other scientifically defensible methods. Interpretation of this provision for all other wadeable streams, lakes, and reservoirs may be made using Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA/841-B-99-002) or Lake and Reservoir Bioassessment and Biocriteria (EPA 841-B-98-007), and/or other scientifically defensible methods. Interpretation of this provision for wetlands or large rivers may be made using scientifically defensible methods. Effects to biological populations will be measured by comparisons to upstream conditions or to appropriately selected reference sites in the same bioregion if upstream conditions are determined to be degraded.

TN AL MS border lake

(i) Nutrient Response Criteria for Pickwick Reservoir: those waters impounded by Pickwick Dam on the Tennessee River. The reservoir has a surface area of 43,100 acres at full pool, 9,400 acres of which are within Tennessee. Chlorophyll a (corrected, as described in Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998): the mean of the photic-zone (See definition) composite chlorophyll a samples collected monthly April through September shall not exceed 18 µg/L, as measured over the deepest point, main river channel, dam forebay.

Additionally, the state has developed regional numeric interpretations of some narrative criteria such as nutrients and biological integrity.

In lakes and reservoirs, the dissolved oxygen concentrations shall be measured at middepth in waters having a total depth of ten feet or less, and at a depth of five feet in waters having a total depth of greater than ten feet and shall not be less than 5.0 mg/L.

Tennessee Nutrient Reduction Framework Document.

Excessive nutrient loading also has effects outside of Tennessee: USGS estimates that 5.5% of the total nitrogen flux and 5.3% of the total phosphorus flux delivered to the Northern Gulf of Mexico is contributed by sources in Tennessee (Alexander et al, 2008).

Increases in nutrient loading mirror growth in population and corresponding increases in agricultural activities and urban development.

The Tennessee Nutrient Reduction Framework*, is* the rationale and the methodology used to accomplish long-term nutrient reduction in Tennessee waters. The strategy used for point source nutrient reduction is discussed in Appendix A. Agricultural nonpoint source nutrient reduction strategy is described in Appendix B.

[It] encompasses nutrient reduction strategies for both point and nonpoint sources.

Training and technical support was given to TDEC and municipal employees to assist them in the optimization of nutrient removal at municipal wastewater treatment plants.

Monitoring Lakes

Tennessee has 29 large reservoirs ranging from the 1,749 acre Chilhowee Reservoir to the 99,500 acre Kentucky Lake.

Twenty-seven of these reservoirs are managed by the Tennessee Valley Authority (TVA) (Table 2) or the U.S. Army Corps of Engineers (USACE) (Table 3).

All but four are routinely monitored. Seven are shared with other states.

These shared lakes include Kentucky Lake, Lake Barkley and Dale Hollow (Kentucky), South Holston Lake (Virginia), Guntersville Lake (Alabama), Pickwick Lake (Alabama and Mississippi), and Calderwood Lake (North Carolina).

Expertise and data are available from TVA, USACE and Alcoa Power Generating Incorporated (APGI).

Table 2: Reservoirs sampled by TVA

Beech
Melton Hill
Blue Ridge
Nickajack
Boone
Normandy
Cherokee
Norris
Chickamauga
Parksville
Douglas
Pickwick

- Ft. Loudoun
- South Holston
- Ft. Patrick Henry
- Tellico
- Great Falls
- Tims Ford
- Guntersville
- Watauga
- Hiwassee
- Watts Bar
- Kentucky
- Wheeler

Table 3: Reservoirs sampled by USACE

- Dale Hollow
- Old Hickory
- Center Hill
- Cheatham
- J. Percy Priest
- Barkley
- Cordell Hull

TN has 16 Medium Reservoirs (251- 1000 acres)

Six are fishing or recreational lakes managed by the TWRA.

Eight reservoirs are managed by TVA, with 3 of these routinely monitored by TVA's Vital Signs Monitoring Program.

One reservoir is monitored by Alcoa Aluminum for power production and one is municipal water supply reservoir.

Small Reservoirs (< 250 acres)

Tennessee has 1,302 documented reservoirs smaller than 250 acres (a total that only includes reservoirs that are permitted under the Safe Dams or ARAP programs).

C. Matrix of policy tools for nutrient management strategies

The following pages present a spreadsheet used by the authors to track policy ideas and to highlight things that might deserve deeper study, once the full team has confident conclusions about the limiting nutrients and the fate and transport of nutrients through the Jordan and Falls watersheds. Cells with nothing in them do not mean there is no such program in that column's area, just that the authors did not hear particular accomplishments, concerns or other stories from sources who focused on those areas. The first four columns are nested categories (more general to more particular) of issues or policy possibilities. The remaining columns are various geographies: "CBP" is "Chesapeake Bay Program" in general, then four states with which we consulted, then a catchall ("other") for various locations, then the last two columns contain notes about the Jordan and Falls watersheds in North Carolina.

Cells colored green represent success stories, as told to us. Cells colored yellow represent cautionary tales. Red cells were problems from the point of view of the implementing program.

1. Standards and goals

In accordance with the first and second of our seven important policy principles, we looked at how some other programs established their nutrient related water quality standards and their decisions about non-attainment of those standards –i.e. methods for Clean Water Act §303(d) listings. In every case we found that showed potential promise, the other states' water quality criteria were more complex and more closely tailored to practical applications (seasonality, site specificity, annual variations, durations, frequency). Furthermore those states with relatively more modern criteria than North Carolina's instantaneous chlorophyll-a standard from the 1970's had relatively more practical methods for determining non-attainment.

standards		CBP in general	Md	Pa	Va	WV	Others	NC/Jordan	NC/Falls
	Chlorophyll a	general Bay narrative	Bay narrative		seasonal and location specific; 10 - 23. The James River story.		Georgia reservoirs: site and season specificity	40 mg/l instant	40 mg/l instant
	Instream N, P								
	DO	site specific, seasonal			Multiple criteria--SAV, DO not just local P,N				
	SAV	site spcific, seasonal							
	water clarity	applies during SAV growing season							
	pH								
	cyanotoxin								
impairment status		Goals are set in the model; if chose the wrong goals, modeling fails to produce desired result.			"Get the goal right first. Then stick with it."			Impaired for chlor a; EPA approved State created TMDL	Impaired for Chlor a; State alt management strategy
designated uses		defined carefully with the users; specific to sites, seasons, species						swim, water supply, aquatic life, &c--not site spec in NC	swim, water supply, aquatic life, &c--not site spec in NC
use attainment problem									

2. Input load reduction

stormwater				CBP in general	Md	Pa	Va	WV	Others	NC/Jordan	NC/Fal
	Environmental education										
	Stormwater control in general						reductions are backloaded, look painful starting round 3 of WIPs, not cost effective. All MS4 requirements count towards TDML				
		SCM permitting								required, local or Stat	
		SCM inventory and mapping									
		SCM financial responsibility								required	
		SCM local ordinance process and approval								required	
		SCM compliance assurance			triennial maintenance required to keep credits					required	
		Local stormwater utilities								$incented; fees allow	
			Extent of coverage								
			Fee amounts and usage								
	New construction										
		SCM for new construction			Md does not credit all scm, but credits are reconciled thru CBP NEIEN	slow implementing ms4s	Va credits all scm in watershed for Bay program, not just things over and above MS4	slow implementing MS4s		required	
			Erosion & sediment controls							required	
			post-construction standards							required	
			SCM maintenance		Larry notes Balt won't do it…no credits? Model needs to allow credits.					required	
			traditional engineered SCM							required	
			LID: bioretention							evolving	
			LID: green roofs								
			LID: permeable pavement								
			LID: rain barrels	this and other homeowner or distributed "microcredits" began to be allowed in 2013 see http://www.chesapeakebay.net/channel_files/19144/attachment_c--uswg_approved_homeowner_bmp_crediting_policy_111913.pdf			Richmond and some other stormwater utilities have app/phone driven microcredit approaches, but utilities not generally favorable towards them (it costs revenue). But they can get credit under model. **See also VCAP http://www.tjswcd.org/vcap.php funding through soil and water districts, a "voluntary regulatory" program.**				
			LID: soil amendment								
			LID: tree boxes								
		Density limits								required	
		Conservation development design/ESD			ESD first						
		Land use restrictions								in water supply wate	
	Transportation										
		Routing considerations									
		SCM for transportation projects								required	

wastewater											
	source reduction										
		detergent composition								low P required, 1980s	
	WWTP processes										
		Improve treatment efficiency, plant level			Most reductions to date from advanced nutrient removal at WWTP (Flush tax)		Most of reductions in loads thus far from $2B spent (~$900MM State) to take ~50 of 93 significant dischargers to limits of technology			tertiary	
		how are NPDES permits implemented for N & P control?	N limits				operators like: annual load limits, mass based (no or few concentration limits), far afield targets allows scheduling (see trade row), maximizing capital investment efficiency			R: mass loads equivalent to a con. of 3.0 mg/L nitrogen or 0.18 mg/L phosphorus at the permitted flow (new sources)	
			P limits				WLA given based on design flow, allowing big room under caps for most			R: existing sources ha	
		Optimize existing equipment									
		Biological nutrient removal (BNR)									
		Chemical phosphorus removal									
			Struvite extraction and reuse								
		Consolidate, remove inefficient plants									
		Reduce bypass									
	Sewer system management										
		Operational permits for collection system								yes	
		Reduce collection system overflows								reporting requiremer	
		Reduce breaks									
	OSWW management						Va has not really grappled with this; estimate 5% of Bay loads				
		Mapped including failed septic									
		Better maintenance									
		Repair or replace failed systems					Lynnhaven River a local success story, but not driven by Bay program				
		Advanced septic with nutrient removal									
	Group/umbrella compliance						trading between POTWs essentially a giant project scheduling system. Modeled on Neuse/Tar Pam. Very successful.			yes, in subwatershed	
	Fees/payments in lieu									yes	

Note that reductions from upgrading wastewater treatment plants (point sources) are far and away the greatest load and percentage reductions across the Chesapeake Bay program states. They were also the biggest source of nutrients when the program began. Nonpoint sources of all types continue to be much more difficult to reduce and to measure, just as they were recognized to be in the 1970s.

agriculture, silviculture									Lake Champlain, Vermont		
	State mapping of soil N & P				Part of Phosphorus Management Tool						
	State mapping of groundwater N										
	State mapping of operations						Farm Act sec. 1619 a real problem; NRCS will share aggregated data with a non regulatoy agency e.g. soil and water , Va Conservation & Recreation ("DCR")				
	CAFOs										
	Nutrient management plans				Maryland also has some safe harbor but dubious efficacy		Resource Management Plan/Safe Harbor for certified facilities "If I put all this in, you are done with me for at least a decade"				
		nonCAFO fertilizer management	farm scale planning			Plain sect farmers show tradition of strong land ethic doesn't necessarily equate to good practices for water quality					
			applicator training or licensing								
		nonCAFO feed management									
		nonCAFO crop management		improved yields (both tons and protein) in crops may dictate more N and P application. Similarly for pastures--better grasses reduce erosion							
			crop advisors								
			cover crops		don't oversell single bmps...flexibility key to different farms		Cover crops and no till or cons. Tillage are "part of the basic fabric of farming around the Bay."				
			conservation tillage								
		nonCAFO manure management									
			planning								
			manure sheds or other structures								
			manure to energy								
		nonCAFO mortality management									
		nonCAFO field management/erosion cm	stream exclusion for cattle				VA SL-6 practice specially funded at 100%, see commission report				
			gully and ditch reveg								
			tile drain interception tech.								
	treatment	lagoons									
		constructed wetlands		farm ponds can be good treatment for P if managed right (not for wildlife)							

atmospheric deposition											
	waste lagoon covers										
	water endpoints in air quality stds										
	metals emissions standards										
marine uses											
	boat head pump out						Lynnhaven River				
	no discharge zone for boats										
general											
	Riparian buffers										
		Design and permitted uses									
		Stream definition									
		mitigation for losses									
	Engineered barriers			gypsum curtains							
	Conservation lands				Part of the program, but hard to credit		Yes, and Bay program enforces quality. Check Virginia Forever				
	Constructed wetlands, general								See Boise for P treatment in diversion ditches (flocc)		
	Credit trading						1. Big expansion in MS4 purchases from POTWs. 2) Nutrient banks, mostly for the MS4s. 3) no real expectation of ag - city				
	Wildlife sources				Farm ponds can help with P but not so much if managed for wildlife					2017 Duke study on gulls and landfills	

Chesapeake Bay nonpoint source challenges are similar to Jordan's and Falls.' Stormwater runoff is a major challenge; the costs of retrofits are huge. Once the drainage infrastructure and pavement are in place, the water quality effects are likely to remain for decades. Susquehanna River at Wrightsville, Pa. Note stormwater outfall on right. 40.0285900, -76.5279119.

3. Mitigate effects

The North Carolina legislature has directed special attention to nutrient treatment in the lakes. This list of options presents possibilities for reducing the harmful effects of excess nutrients after they have already entered the reservoirs or the streams that feed the reservoirs.

In situ: physical				CBP in general	Md	Pa	Va	WV	Others	NC/Jordan	NC/Falls
	dredging						Elizabeth River (toxics)				
	aeration									SolarBees tried, failed	
	stream restoration										
In situ: biological											
	bivalves										
	algal floways										
	wetland rafts										
	other biological strategy										
		food web manipulation									
In situ: chemical											
	copper compounds										
	hydrogen peroxide										
	clay or other flocculation									2017 legislation	
flow regime									TVA sees this as primary tool		
	hypolimnetic withdrawal									possible given water quality gates in dam; operations issue?	

Brock Environmental Center, looking out on the Lynnhaven River, Virginia Beach, Va. April 22, 2017. Environmental education through the Chesapeake Bay Foundation and many other groups has helped build a consensus around the importance of clean water in the Bay region, a consensus that transcends political and demographic differences.

4. Process and finance issues

There are many policy concerns beyond methods and "best management practices" for load reduction or *in situ* harm reduction. In fact, as discussed in our policy principles for nutrient management, the most important matters have to do with the process for nutrient management decision making and the system for governing the modeling, monitoring and adaptation of the nutrient strategy.

There is a separate team from the UNC Environmental Finance Center working on finance issues regarding Jordan and Falls. However, funding and financing are so central to almost everyone with whom we talked that we have included a few notes here.

finance					"flush tax" and "rain tax" have provided large funding, similar ($Bs) to Va.		1. WQIF (1997): 10% of state surplus each year allocated to water infrastructure. Huge boost to have this with bipartisan support to maintain thru the years. Added Natural Resources Commitment Fund later, for ag cost share in and outside Bay watershed 2. Giving partial funding (cost share or competitive grants) has really promoted both good projects and cooperative stimulus 3. Cost effectiveness of controls has risen in importance over time (chart). 4. Predictable, level funding for POTW (not for NPS) has helped that sector	state lottery proceeds go partly to CBP			
cost benefit in general				Spencer Phillips & Beth McGee (2016) Ecosystem Service Benefits of a Cleaner Chesapeake Bay, Coastal Management, 44:3, 241-258, DOI: 10.1080/08920753.2016.1160205. But on cost side EPA failed to complete requested BCA	"cost effectiveness" is increasingly the key for the whole program		Virginia and Maryland agree that cost effectiveness has become more and more central as the program has matured				
role of science				The Bay program brought good science to the table for everyone as a primary thing . Shared science and models.							
	science and engagement			take time to get all stakeholders in on the science as early as possible							
	science governance			Need high level stakeholder involvement in the science--build a network of trust							
	transparency and scaleabilit			over time it's become more and more important that the models can be scaled down for use by local governments at scales of interest to them							

In many places around Chesapeake Bay, as in this field near Gloucester Point, Va., the positive environmental work is obvious: cover crops, conservation tillage, educational signage.

				CBP in general	Md	Pa	Va	WV	Others	NC/Jordan	NC/Fa
accountability measures										"collective compliance" model liked by ag--assign load reduction to whole ag sector, not farm by farm	
	short term benchmarks						2 year milestones plus long terms goals: evolved to this, credit Tayloe				
	long term benchmarks						Long time frames help greatly with capital cost				
	tracking system for measure			NEIEN system (environmental information exchange network) allows different governments' terms and plans to be made commensurate							
	contingencies if fail			Credits from the model have temporal duration component-helps with commensurability			EPA rigidity has backfired. Need attainable goals. OTOH, the TMDL really did light a fire under sub-state actors, esp. local governments				
stakeholder engagement in general				consensus approach--but if you object, you have to come up with viable alternative that all accept	first focused on watersheds, but have evolved to counties: "authoritysheds"						
	government support for watershed interest groups							central to the non-regulatory strategy--state coordinators bringing together ag and environmental groups			
adaptive management framework				you aren't going to know enough to make fully informed deicsions at any given time. Be fairly rigorous about what you do understand, be really rigorous on monitoring, learn by doing. Can't do giant experiments, not politically sustainable, so take your best shot but be clear about why you are doing it, what the timeline is for responding, then what you learned. Plan for iterating strategy needs to match lag time for system response even if that is decadal.		P in saturated sediments behind dams an example of need for adaptive process					
consistent communications strategy across watershed					Use "reported progress" not "modeled results" to explain model vs monitoring		Stakeholder drafting of statutes and detail in statutes a positive thing in Va				
high level political participation and agreement				Legislative: CB Commission. Executive: Exec. Comm of CB program. But be wary of program bureaucracy and christmas tree effect, e.g. Obama EO	"bay cabinet" shows high level commitment		also a Governor's cabinet with high level commitment.				
remote sensing											
modeling							huge federal contribution, but should have been made more open and easily iterative.				

IV. Sources for this document

A. Legislative directive regarding the UNC Nutrient Study

During the 2016 legislative short session the NC General Assembly approved a special provision in the annual budget bill, House bill 1030, Section 14.13 "Development of New Comprehensive Nutrient Management Regulatory Framework." This section directs UNC-Chapel Hill to "oversee a continuing study and analysis of nutrient management strategies and compilation of existing water quality data specifically in the context of Jordan Lake and Falls Lake."

B. People and organizations consulted

The authors are indebted to the many people with whom they have discussed nutrient management and related problems through the years. In the three months prior to publishing this report, they benefitted particularly from interviews and discussions with the following persons and organizations. The views expressed in this report are those of the authors alone, not necessarily those of any of these persons or organizations.

Tom Basden, Extension Specialist/Nutrient Management, West Virginia University,
Rich Batiuk, Assoc. Director for Science, Analysis and Implementation, EPA Bay Program
Russ Baxter, Deputy Secretary of Natural Resources, Virginia
Megen Dalton , Shenandoah Soil and Water Conservation District director
Shanda Davenport, Virginia Beach stormwater
Nick Dispaquale, Director, EPA Chesapeake Bay Program
Hilary Harp Falk, National Wildlife Federation, Mid-Atlantic office
Ben Grumbles, Secretary, Maryland Dept. of the Environment
Alana Hartman, W.V. Chesapeake Bay Coordinator, Upper Potomac Watershed
Tom Hebert, Consultant to Agricultural Nutrients Policy Council
Ted Henefin, General Manager, Hampton Roads Sanitation District
Ann Jennings, Virginia Coordinator, Chesapeake Bay Commission
Greg Johnson, Virginia Beach stormwater
Sean Jones, Jones Family Farms, Maryland
Teresa Koon, Director, Watershed Improvement Branch, WV Dept. of Env'tal Protection
Scott Mandirola, Deputy Sec'y and Director of Water & Waste Management, W.V. DEP
Lee McDaniel, Harford County, Md SWCD Supervisor and past president, NASWCD
Ann Mills, GWU (formerly USDA, Deputy Secretary for Natural Resources and Conservation)
David Paylor, Secretary, Virginia Dept. of Environmental Quality
Skip Styles, Director, Wetlands Watch
Bill Tharpe, Harford County, Maryland Soil and Water Conservation District director
Christophe Tolou, Minority Chief Counsel, U.S. Sen. Com. on Env't and Public Works
Verdant View Farms, Lancaster County, Pa.
Tony Young, US Army Corps of Engineers, Wilmington District

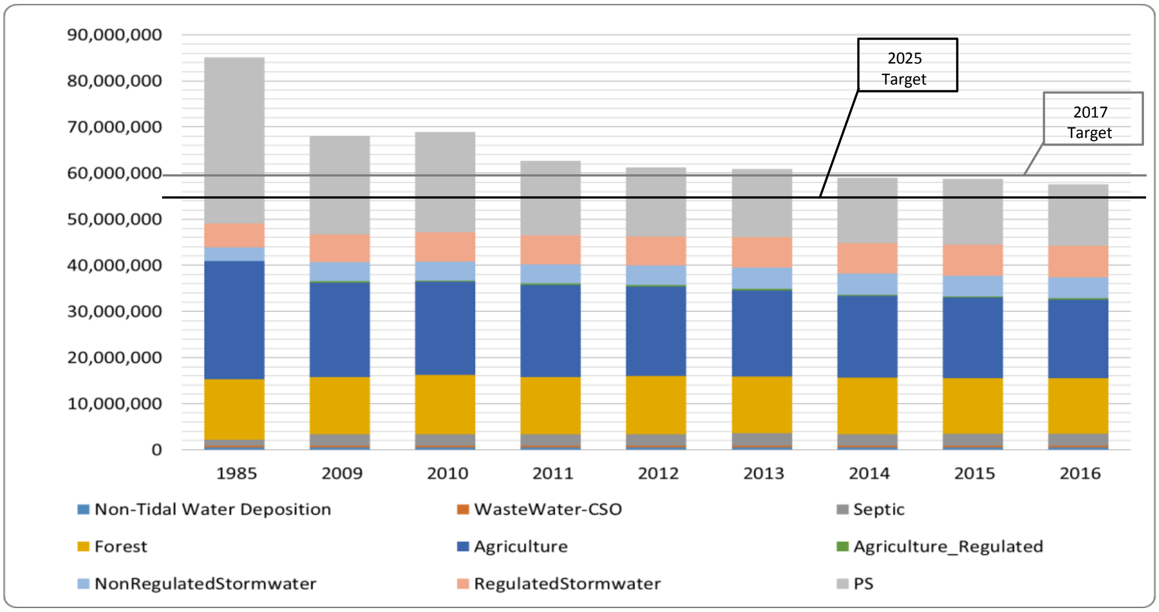
C. Figures and charts

The governance structure for the Chesapeake Bay Program has evolved into a large, complicated organization. While NC's nutrient strategies for Jordan and Falls watersheds neither need nor could support such a large structure, they will need some way to fill most of the functions provided by the Bay program. The figures and charts that follow were created and shared by the Chesapeake Bay Program and should be copied and distributed only with attribution to that source.

Figure 1 Governance Structure of Chesapeake Bay Program

Virginia Delivered Nitrogen Loads

CBWM v.5.3.2



Virginia Delivered Phosphorus Loads

CBWM v.5.3.2

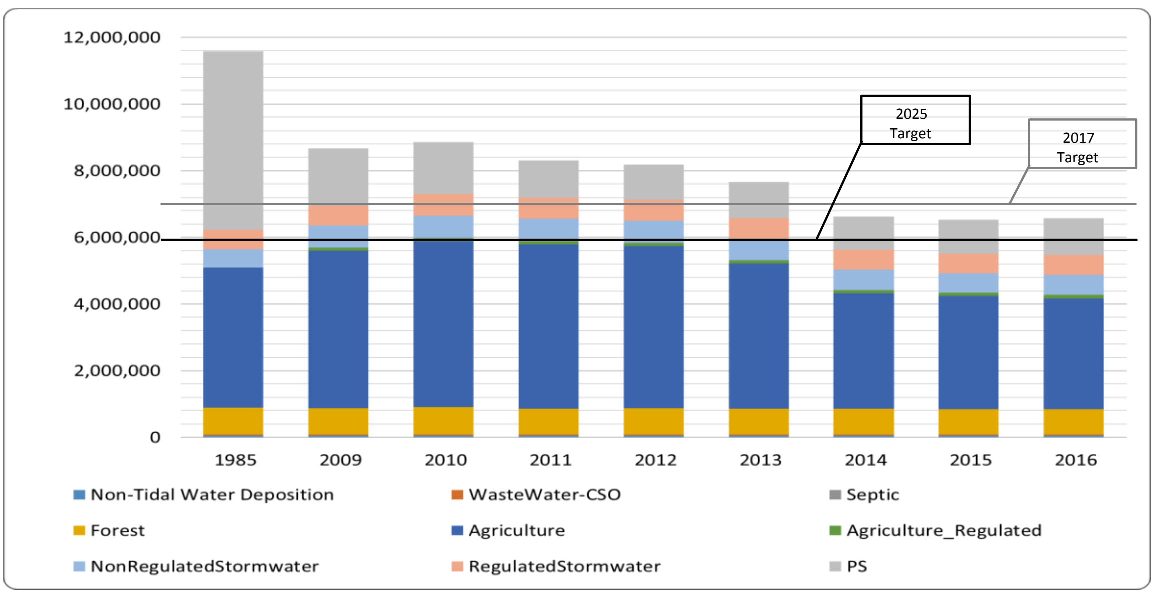


Figure 2 Chesapeake Bay nutrient loads over time

The Chesapeake Bay Program has reduced nitrogen and phosphorus loads beyond its mid-point (2017) goals. However, the reductions so far have come primarily from point sources (advanced nutrient removal at wastewater treatment plants). A mid-point assessment of all the Watershed Improvement Plans is now underway. *From Chesapeake Bay Program Briefing for UNC Study Team, June 22, 2017.*

Use Habitats to Define Designated Uses

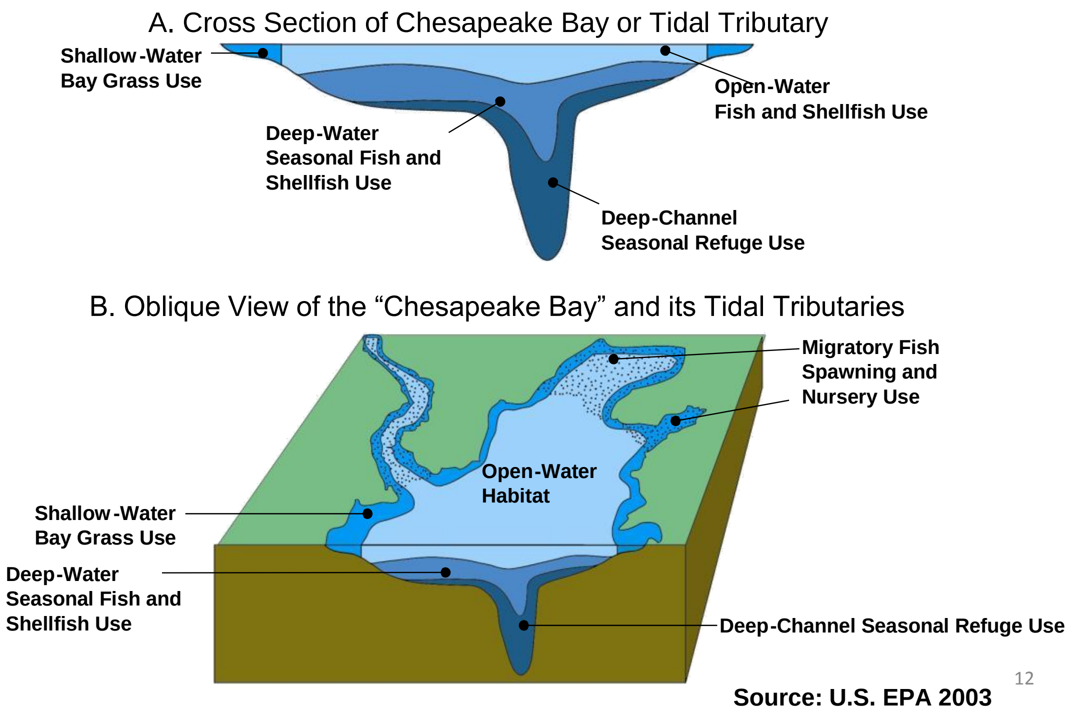


Figure 3 Using habitats to define designated uses in Chesapeake Bay

The Chesapeake Bay Program designed its targeted load reductions based on a careful delineation of the actual habitat needs in the Bay. They divided the Bay not only into 92 tidal stream segments, but also into three depth zones that correspond to the needs of different aquatic species. This "fish-eye view" of the watershed identified uses including shallow-water bay grass use, open-water fish and shellfish use, migratory fish spawning and nursery areas, deep-water seasonal fish and shellfish use, and deepchannel seasonal refuge use. Different criteria are applied to each use based on the species found there: grasses in shallow water, adult fish in open water, oysters in deep water,crab food in the deep channel, and so on.

The water quality criteria were created to support the actual uses in these 3 x 92 zones. This delineation helps meets the needs of upstream users, shellfish aquaculture, crab and other fisheries, and non-game species. While neither Jordan nor Falls Lakes has the huge fisheries of the Bay, we recommend a similar process for identifying actual uses and the zones of the watersheds that support those uses.

Cost Effectiveness and Optimization

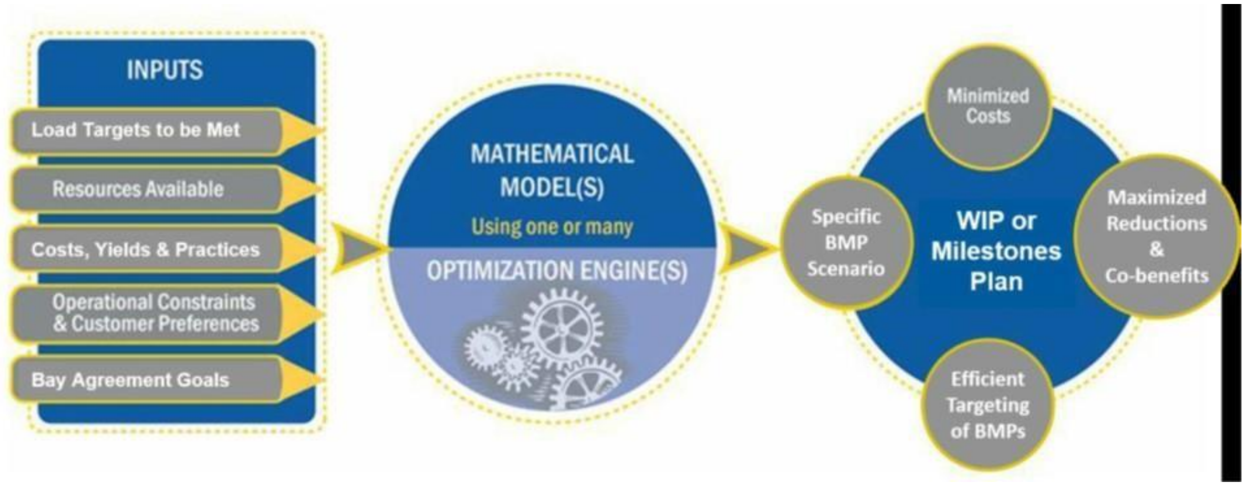


Figure 4 CBP current and planned integration of cost-effectiveness

The Chesapeake Bay Program has evolved to a constant concern for cost-effectiveness. *From Chesapeake Bay Program Briefing for UNC Study Team, June 22, 2017.*

D. References

This is not a comprehensive list of references. It is a repository focused on studies of costs and/or benefits of nutrient management strategies mentioned in this report.

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Chesapeake Bay Watershed Blue Ribbon FInance Panel 2004. Saving a National Treasure FInancing the Clean up of the Chesapeake Bay. A Report to the Chesapeake Executive Council	2004	
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King and Hagen 2011. Costs of Stormwater Management Practices in Maryland Counties	2011	
Spencer Phillips & Beth McGee (2016) Ecosystem Service Benefits of a Cleaner Chesapeake Bay, Coastal Management, 44:3, 241-258, DOI: 10.1080/08920753.2016.1160205	2016	
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