

Water Quality Protection and Restoration

The Water Quality Protection and Restoration section of the *Chesapeake 2000* Agreement has the overall goal to achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health. The primary commitments to meet this goal include correcting nutrient and sediment related problems in the Bay by 2010, and having a Bay "free of toxics" (no toxic or bioaccumulative impact on living resources). Enhanced scientific information is needed to better understand the sources and effectiveness of remediation practices for nutrients, sediment, and contaminants as well as, their transport and fate. There is an immediate need to quantify what further reductions in nutrient loadings can be gained from existing BMPs, and which new BMPs can be implemented in the short-term. The scientific information to meet these needs must include improved predictive modeling, enhanced integration of watershed and estuary monitoring, and research.

Controlling Inputs from Watershed and Air

Priority Needs

1. Continue development of low cost, robust, effective technologies for pollutant reduction.
2. Improve understanding of lag time between BMP implementation and measurable improvements.
3. Undertake long-term targeted studies of the impacts of BMPs on sediment, nutrient, and contaminant movement through the watershed to the Bay.

Background

Nutrient enrichment (and to a lesser degree sediment loadings) is the major problem facing the Chesapeake Bay and its tributaries, threatening living resources, altering water quality, and posing greater and greater threats to sustainable Bay-related industries. It is therefore critical to expand our understanding of the loads to the system, from the air and land. Our accomplishments to date have been modest considering the focus on nutrient reductions over the last decade. The following recommendations are proposed in support of the goal to reduce loads in the system.

Recommendations

1. Recovery and Control Practices: Water and nutrient recovery and re-use from point sources are innovative practices that are being explored in Western Europe, Japan, and elsewhere. These practices should be investigated to see whether they are practical and efficient for the C2K reduction program. For example, phosphorus and ammonium recovery through precipitation with magnesium cations is a possible alternative for reducing loadings and encouraging reuse of these macronutrients. The development and application of diffuse-source controls and evaluation of their effectiveness remains one of the most important scientific challenges in the restoration and protection of water quality in the Chesapeake Bay.

2. **Agriculture:** As the major source of nutrients to the watershed, agriculture requires considerable attention in reducing nutrient loads to the water resources. Better data on feed, fertilizer, and manure use are needed. Sales of fertilizer are not decreasing in many areas of the Bay watershed. Is this due to non-changing applications on agricultural lands or a shift in the fertilizer use from agricultural to suburban lands? For animal manure, there is a need to determine the opportunities to manage the concentration of increasing animal production in the watershed, to control animal nutrient intake and excretion, and to reduce the resulting nutrient loading in the watershed. Studies should be supported to evaluate the effectiveness of different agricultural management practices to reduce landscape losses based on site-specific conditions, including soil, tillage, cropping conditions, etc. Economically sustainable soil, crop, and animal management practices, supportive policies, and effective means to encourage their utilization should be developed. Associated studies can evaluate the effectiveness of new approaches in nutrient-loss reduction strategies in agriculture, including yield reserve incentives to reduce over-fertilization, application of phosphorus indices, etc.

3. **Suburban Runoff:** The increasing development pressure around the watershed requires that research focus on the effects of the changing landscape. The effects of suburban water management practices on water flow, water quality, and the ecology of receiving streams needs to be better quantified.

4. **Air:** Atmospheric deposition is one of the largest sources of non-point pollution impacting the Bay. The quantification of dry and wet deposition of nutrients and pollutants still remains a problem: New technologies must be developed to provide better estimates of dry (and wet) deposition and for assessing their fate in nutrient processing in the watershed. However, specific source-receptor relationships are not well understood nor are the contributions from local point and area sources (transportation, animal husbandry, industry, etc.) Additional research is needed to identify and quantify local versus long-range inputs. This is particularly important with respect to nitrate and ammonium deposition.

5. **Research on Spatial Controls for Nutrients, Sediments, and Contaminants:** Research is needed to improve estimates and locations of nutrient, sediment, and contaminant sources, transport pathways, and sinks in the watershed, starting with the synthesis of existing data and metadata. The effects of watershed storage and associated time lags, e.g. groundwater inputs, should be evaluated. Further, because chemical contaminants are delivered through air and water, air trajectory and deposition technologies are critical to future Bay efforts. Air shed modeling for volatiles from urban and rural sources needs to be quantified.

6. **Evaluations of Control Options:** Develop an accurate inventory of implemented BMPs and conduct long-term targeted studies of the impacts of BMPs on sediment, nutrient, and contaminant movement through the watershed to the Bay. It has been noted repeatedly that benthic organisms also alter fluxes of nutrients and resuspension susceptibility. Thus, the potential influences of biotic factors should be considered in future CBP activities. Further, the interactions of contaminants and sediments, including

the effectiveness of source controls (e.g. urban runoff), sedimentation, and the degree of subsequent release from sediments versus long-term burial, should be investigated further.

7. Sediment Loading: Stream-bank erosion, its controlling factors, estimates of loadings from the watershed, and its impact on aquatic resources, must be quantified. These are critical in order to update sediment mass balance estimates and understand the potential effects and response lags of sediment management practices. Research is also needed to improve understanding of internal and external sediment sources and sediment transport dynamics in the Bay, and to better understand the relative importance of these sources for suspended sediment levels, turbidity, and sediment accumulation. The first step is to synthesize existing data, identify additional data needs, and identify poorly understood but critical processes.

Watershed and Estuarine Monitoring

Priority Needs

1. Perform strategic monitoring to validate the model and maintain the land use, atmospheric, and water quality monitoring programs for a period of sufficient length to distinguish longer-term trends, with the objective of improving estimates of uncertainties and variances in atmospheric deposition and impacts on water quality.
2. Improve sediment monitoring to identify sources, and determine impacts on water clarity.
3. Improve monitoring methodologies.

Background

Development of *Chesapeake 2000* followed analyses suggesting that the previous 40% reduction goal for nutrients had not translated to significant nutrient and chlorophyll reductions nor alleviated the low DO problem. It is absolutely critical to implement rigorous monitoring programs in the current decade, designed specifically to assess effectiveness of those management programs implemented to fulfill *Chesapeake 2000* goals.

Recommendations

1. Monitoring Data: Field observations must be made for all activities undertaken to meet *Chesapeake 2000* goals, implying pre- and post-management observations through time. These data include all relevant water quality parameters at sampling frequencies needed for determining ecosystem health and recovery. At a minimum, the water quality criteria parameters DO, chlorophyll, and water clarity are mandatory. Note: similar data collections through time are also needed for other valued *Chesapeake 2000* priorities including living resources such as oysters, exotics, SAV, fish and crab stocks, etc.). When possible, real time data collection should be encouraged for data assimilation modeling (see below) and remote sensing capabilities should be incorporated into standard monitoring activities of the CBP.

Event-driven sediment and nutrient loadings can dramatically overwhelm background average conditions. Monitoring programs must include event-based sampling to resolve background levels that can dramatically alter the system's long-term nutrient and sediment 'memory'. *In-water* sensors for nutrients (wet and dry chemistry, laser and solid state electronics) and pollutants (mass spectrometers, high performance liquid chromatography) are now available and can be routinely employed. Adequate on-ground surveys must be conducted to determine causative factors influencing the large-scale land use changes occurring in the watersheds. Atmospheric monitoring stations and networks should be established in critical areas to measure nutrient fluxes.

Land use, atmospheric, and water quality monitoring programs should be maintained for a period sufficient to distinguish longer-term trends from short-term pulses thereby improving estimates of the uncertainties and variances in basic atmospheric and water quality.

2. **Sediments:** The role of sediments in water clarity and burial of native oyster populations is acknowledged throughout the Bay. However, the sources of sediments remain unclear. Data are required in routine collections to determine fall line sediment loadings, open boundary loadings, shoreline erosion contributions, and resuspension loads. Susceptibility of sediment to erosion from bioturbation, biodeposition, and presence/absence of SAV must be quantified and georeferenced. Monitoring and modeling of stream-banks as a potential source of sediment to downstream water bodies should be investigated. Currently there is no model available to evaluate the effects of different buffer types on bank stability and erosion.

3. **Management Practice Evaluation:** Evaluation of the effectiveness of diffuse source controls and best management practices through rigorous monitoring is a critical need, through synthesizing existing studies of small watersheds and by conducting future studies coupling modeling and monitoring in selected small watersheds.

Predictive Modeling of Inputs, Transport, and Ecological Responses

Priority Needs

1. Couple existing predictive models and monitoring observations to improve development and refinement of models.
2. Develop a comprehensive sediment transport modeling capability for the watershed and its estuary, supported and informed by appropriate research on processes and patterns.
3. Encourage the development and/or implementation of alternative and innovative modeling approaches.
4. Determine the forces driving land use changes, best management practice implementation, and economic sustainability of resource-dependent activities.

Background

Modeling of pollutant (nutrients, sediments, and contaminants) sources, transport, and effects and monitoring of inputs, water quality, and biological responses have been keystone technical tools for the Chesapeake Bay Program, and must remain central to future activities in the decade. Data transfer, assimilation, and analysis tools are sorely needed as the volume of data delivered in the future may outstrip the resources available to interpret the data.

Recommendations

1. **Modeling Predictions:** Continued improvements in modeling and as recommended above, monitoring, are required. Predictions from existing models and observations from monitoring must be more effectively coupled, including the development and routine use of data assimilation models where real-time data can provide for better approximations of real-world observations.

2. **Sediment Transport Modeling:** Development of a comprehensive sediment transport modeling capability for the estuary, supported and informed by appropriate research on processes and patterns, is necessary. A set of models should be built into the framework of the several hydrodynamic models, but they should incorporate new forcings (e.g., surface waves), additional inputs (fall line sediment loadings, open boundary loadings, and shoreline erosion), and an explicit sediment bed to account for changes in erodibility and sediment sequestration. The set should include multiple sediment particle classes (e.g., sand, slowly settling fine particles, and rapidly settling flocs), consider potential interactions between these classes, and be open to inclusion of biological feedbacks such as changes in sediment erodibility due to bioturbation, biodeposition, or SAV bed development. Both shallow and deep subenvironments should be modeled, the former for their potential importance as SAV and oyster habitat and the latter for their importance as zones of particle accumulation and recycling.

3. **Multiple Modeling Approaches:** Encourage the development and /or implementation of alternative and innovative modeling approaches. The development of *multiple* modeling approaches should be encouraged, rather than reliance on single models. Although using multiple modeling approaches may produce different answers regarding outcomes or consequences, the variability provides some measure of confidence and a more realistic understanding of uncertainties for managers and policy-makers. Exchange programs should be implemented for scientists and program managers between institutions developing and using models.

4. **Implementation and Sustainability:** The forces driving land use changes, best management practice implementation, and economic sustainability of resource-dependent activities in the Bay and its watershed should be determined. For example, both agricultural and suburban diffuse sources must be considered in their longer-term socio-economic contexts. Potential changes in input stressors that result from socio-economic forces, e.g., governing animal production and intensification, atmospheric deposition,

population growth and development, must be considered. Complementary policy education should be based on these outcomes. Many forces drive change in the Bay and its watershed. Guided change must acknowledge these forces and influence those that will contribute to Bay and watershed restoration.

5. **Integrated Models:** Development/improvement of integrated models of watershed nutrient, sediment, and contaminant transport within the framework of the watershed model, to better understand connections between land-based management controls and Bay loadings, is necessary. This effort should link upland water quality models and in-stream models to enhance our ability to evaluate the impact of control measures on aquatic resources.

6. **Epidemiological Modeling:** State-of-the-art epidemiological modeling should be applied to the region to identify likely areas for greater potential health impacts from historically higher air and water contaminants. In turn, the results should focus health care and increased evaluations for indicators of exposure that might be useful in future assessments in other areas.

7. **Uncertainties Exploration:** Continued exploration of uncertainties in model predictions is necessary. A stochastic approach should be adopted, adding model components where necessary, to more realistically reflect uncertainties by expressing predictions in terms of probabilities. Further, the use of estimates stated in terms of statistical probability should be considered, allowing improved estimation of the time required before the effects of nutrient and pollutant management practices can be meaningfully measured.

8. **Cost-Benefit Analyses:** The decade-long implementation of restoration practices should be rigorously evaluated for the likely cost versus benefits from the planned management. The gains of some proposed restoration activities, although highly endorsed by watershed inhabitants, may be prohibitively expensive for the value derived in undertaking the activity.

9. **Local Application:** User-friendly models that permit scenario runs for different land uses in a region are important tools to be distributed with training to the smallest planning bodies. These include land uses, exports, and economic valuations that ultimately decide adoption of one zoning versus another.

Ecosystem Responses to Input Reductions

Priority needs

1. Investigate nutrient equivalency.
2. Determine the relationships between inputs and living resources.

Background

The final, and in some ways most important, need is to understand the likely responses of the Chesapeake Bay ecosystem to pollutant reduction through an integrated analysis of load reduction impacts that are dependent on physical, chemical, and biological characteristics of the system. As has been shown on several occasions, altering one parameter for a system, e.g., loadings per year, often does not express itself linearly nor predictably through the system, as there are multiple interactions between chemistries, organisms present or absent from a locale, and water movements through space (horizontal and vertical) and time (e.g., seasonal temperature optima for a population). For example, as discussed in the Living Resource section, we must improve our ability to monitor, understand, and simulate the factors (water clarity and availability of propagules) that are affecting SAV recovery in different areas of the Bay and its tidal tributaries. This information is needed to improve restoration and increase SAV acreage but will have dramatic feedbacks on biodiversity and nutrient processing. And as noted in the same section, we must understand the influences of oyster restoration on water quality (and water clarity) in the Bay; increasing oysters could remove more nutrients, plankton, and sediments and perhaps reduce pelagic forage fish needed for pelagic production in higher trophic levels. Lowered cultural eutrophication will have huge impacts and it is critical to quantify responses expected from the strong restoration effort in the watershed.

Recommendations

1. **Investigate Nutrient Equivalency:** The issue of whether or not nitrogen removal can be traded for phosphorus removal, and vice versa, needs to be resolved as soon as possible.
2. **Relationship between Inputs and Living Resources:** This knowledge is critically needed for the development of restoration strategies.
3. **Harmful Algal Blooms:** As one indicator of coastal eutrophication in some systems, increases in frequencies and impacts of blooms of harmful algae provide good indications of system imbalance. We must improve our understanding of the factors causing harmful algal blooms and how nutrient and circulation/hydrology (residence times) affect algal communities.
4. **Temporal Heterogeneity in Forcing Functions and System Responses:** We must better define the relationship between the rate and timing of pollutant delivery to the Bay and the responses of water quality and living-resources in the Bay and its tidal tributaries; this includes identifying and quantifying base and event flow import. *In water* and field-team focused event sampling for nutrients, salt, and sediment should be routine, with event-based data incorporated into all load estimates.
5. **Toxics and Biota:** We must further define the effects of contaminants on the living resources of the Bay and its watershed, as chronic exposures likely alter populations subtly, therefore making food web impacts difficult to identify. Synergistic impacts of

classical pollutants and emerging contaminants on Bay living resources and the public must be assayed. Chronic low-level exposures to water- and air-borne suites of materials can result in far greater threats than exposures to single compounds. A much-expanded assessment of the impacts of multiple compound exposures under the air and water environments of the region has to be incorporated into monitoring plans for the coming years. This might include expanded EPA partnerships with various agencies, e.g., NIH, CDC, to develop bioindicators of exposure, for both low level single compounds to mixtures of many compounds and the variety of water and atmospheric conditions inherent to the area.