Chesapeake Bay Program
Scientific & Technical
Advisory Committee

Watershed Response to Changes in Nutrient Loads:

The Best Uses of Monitoring and Modeling

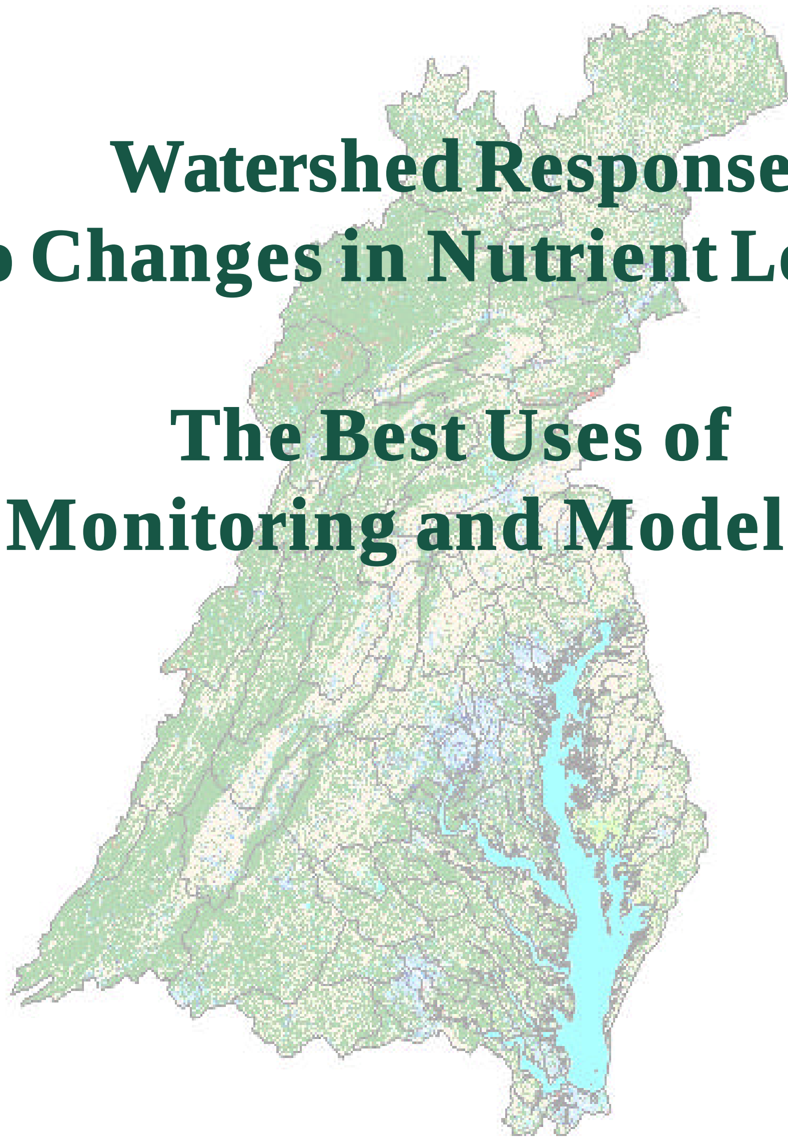

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TABLE OF CONTENTS

Page

Watershed Response to Changes in Nutrient Loads: The Best Uses of Modeling and Monitoring

EXECUTIVE SUMMARY

The management of a natural resource, such as the Chesapeake Bay, involves the use of numerical models which provide fundamental information necessary to set nutrient and sediment reduction goals and to track progress toward goal achievement. In addition, the maintenance of these load reductions after the year 2000 as a nutrient cap, despite an expected increase in population, requires the continued support of monitoring, research, and modeling.

A workshop entitled *Watershed Response to Changes in Nutrient Loads: The Best Uses of Modeling and Monitoring* was held in May 1997. The workshop focused on the effects of watershed processes and management practices on nutrient and sediment loads delivered to the Chesapeake Bay through non-tidal streams. The objective was to make a series of recommendations on how to integrate monitoring, research, and modeling activities, so that the triad of activities will provide better information on Chesapeake Bay nutrient and sediment loads. The recommendations from the workshop are summarized below.

Watershed Model Refinements

- The Chesapeake Bay Watershed Model should be redesigned, refined, or other tools/approaches developed, to allow simulation at increased levels of spatial detail. Current monitoring results should be better utilized or expanded to allow proper calibration and verification of a Watershed Model with finer segmentation. This will allow the Watershed Model to be used to evaluate the effects of management in tributary sub-basins, evaluate the water quality response of the non-tidal tributaries to nutrient and sediment loads, as well as further refine total nutrient loadings delivered to the tidal bay.
- Expand the Watershed Model, applying recent HSPF model enhancements (e.g. land segment linkage capabilities), or formulating other approaches to provide for improved handling of ground-water lag times and variable ground-water

model) that may improve the spatial detail and process representation being requested by Chesapeake Bay Program managers, but which have not been applied at the scale of the Chesapeake Bay basin.

- Expand the Watershed Model to account for so-called "river-corridor effects"; processes in and near the streams that affect the storage, transport, and transformation of nutrients.

Watershed Model Input Requirements

- Undertake the necessary literature reviews, evaluations, and/or research necessary to develop a better understanding and assessment of the effectiveness and efficiency of the best management practices (BMPs) applied throughout the Bay basin.
- Further evaluate and refine inputs to the Watershed Model associated with land use categories, with specific emphasis on atmospheric deposition, agricultural lands, urban/suburban areas, and on-site waste disposal systems. Cropland applications of sludge and waste water, separate model categories for mining and wetlands, and individual crop categories (i.e., elimination of the composite crop approach) should be considered in future model refinements.

Monitoring Program Expansions

- Expand monitoring of tidal and non-tidal portions of the Bay watershed in order to better calibrate the Watershed Model throughout the Chesapeake Bay basin. Tidally influenced portions of the Bay watershed, which account for 25% of the total Bay basin land area, are especially lacking in Watershed Model calibration sites. Surface flow discharge from these land areas enter the Bay and tidal tributaries directly with little or no attenuation.
- Expand non-tidal tributaries water quality monitoring parameters to include more algal parameter endpoints, including analyses for phytoplankton, periphyton, and macrophyte biomass, because of their influence on nutrient dynamics, attenuation, and delivery to the Bay, and to fill an existing gap in Watershed Model calibration data.
- Utilize existing or initiate new, small-scale research-oriented monitoring in representative subbasins to provide better estimates of critical model parameters and provide data necessary to support expanded calibration efforts at the smaller scale.

BACKGROUND AND SCOPE

Managing a natural resource, such as the Chesapeake Bay, involves using numerical models for three objectives: (1) to determine the overall nutrient and sediment loads to the tidal Bay waters, (2) determine the portion of the nutrient and sediment loads that are controllable, and (3) to estimate the reduction in "edge of stream" nutrient and sediment loads under various management actions. This fundamental information is necessary for the Chesapeake Bay Program partners to set nutrient and sediment reduction goals and to track progress toward goal achievement. The Chesapeake Bay restoration and protection effort makes use of a Watershed Model based on the U.S EPA Hydrologic Simulation Program - Fortran (HSPF) computer code to provide an estimate of nutrient and sediment loads delivered to the estuary.

Based on results of the Watershed Model, the Chesapeake Bay Program partners adopted tributary basin-specific nutrient load reduction goals, and have developed and are now implementing these tributary strategies. Upon full implementation , the tributary strategies will result in putting the practices in place to achieve an overall reduction of 34 million kilograms of nitrogen and 4 million kilograms of phosphorus from point and non-point sources. Maintaining these load reductions after the year 2000 as a nutrient cap, despite an expected increase in population, requires continued support from monitoring, research, and modeling programs. Monitoring programs provide basic watershed information as well as model calibration data. Strategically directed research ensures that salient features of the watershed nutrient cycling and transport system are incorporated into watershed management decisions.

A workshop focused on *Watershed Response to Changes in Nutrient Loads: The Best Uses of Modeling and Monitoring* was held on May 19-20, 1997 in Harpers Ferry, West Virginia. The purpose of the workshop was to bring together managers and scientists to review how basic research on watershed processes and the collection of non-tidal monitoring data is linked with the Watershed Model development, calibration, and management applications. Watershed process research is used to develop the basic model relationships which represent the major features of nutrient and sediment transport, transformation, and fate. Monitoring is essential to calibrate the model to observed data and to determine whether adopted management strategies are having the intended effect.

This workshop was focused on the effects of watershed processes and management practices on nutrient and sediment loads delivered to the Bay through non-tidal streams. The objective was to make recommendations on how to integrate monitoring, research, and modeling activities from the start, so that the triad of activities will provide better information on Chesapeake Bay nutrient and sediment loads. Integration of watershed monitoring, research, and modeling directed toward watershed management is a national as well as a regional need.

Workshop participants also developed a series of recommendations on watershed process research priorities. Such research will improve the numerical values for the parameters coded into the Watershed Model, and help form hypotheses about the effects of management practices. The workshop recommendations include: (1) prioritization of "targeted" research needed to assess the management of the Chesapeake Bay watershed, (e.g. watershed-scale process research, assessment of nutrient load delivery at a large watershed scale); (2) new monitoring activities to close existing information gaps in coastal plain tributaries and in-stream benthic processes; and (3) expansion of model processes and scale to include subwatershed nutrients and sediment information for local governments. These recommendations will assist in the refinement and further development of the Chesapeake Bay Water Quality Model and the development of the Basinwide Monitoring Strategy.

WORKSHOP FORMAT

The workshop consisted of a plenary session, with two invited keynote speakers providing background modeling information, followed by a series of breakout sessions focused on developing specific recommendations. Tony Donigian provided a summary on the scientific basis and process modeling capabilities of the HSPF model, with particular focus on the specific capabilities applied in the Chesapeake Bay Watershed Model. Lewis Linker then discussed where the model obtains its input data, how the model results compare in general with observations, and how the model scenarios are applied to Chesapeake Bay Program management issues. Workshop participants, consisting of technical program managers, policy makers, scientists, and engineers, were then divided into smaller challenge groups to focus on the data needs of the model for each part of the path taken by nutrients as they travel through a watershed. The challenge groups covered the following topics:

- Nutrient inputs
- Nutrient movements through watersheds
- Nutrient transformations within a watershed
- Response of nutrients to environmental management.

For each of the topics and associated challenge groups, a list of questions were provided to help guide the group deliberations and discussions (Appendix B). The challenge groups were charged with synthesizing the data needs and results of relevant scientific studies for their part of the nutrient flow path. A final joint session allowed each challenge group to present their recommendations to all of the workshop participants.

Plenary Session Presentations

U.S. EPA Hydrological Simulation Program – FORTRAN (Donigian)

The Hydrological Simulation Program-FORTRAN, known as HSPF, is a mathematical model developed under EPA sponsorship for use on digital computers to simulate hydrologic and water quality processes in natural and man-made water systems. It is an analytical tool which has application in the planning, design, and operation of water resources systems. The model enables the use of probabilistic analysis in the fields of hydrology and water quality management. HSPF uses such information as the time history of rainfall, temperature, evaporation, and parameters related to land use patterns, soil characteristics, and agricultural practices to simulate the processes that occur in a watershed. The initial result of an HSPF simulation is a time history of the quantity and quality of water transported over the land surface and through various soil zones down to the groundwater aquifers. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other quality constituent concentrations can be predicted. The model uses these results and stream channel information to simulate instream processes. From this information, HSPF produces a time history of water quantity and quality at any point in the watershed.

HSPF is currently one of the most comprehensive and flexible models of watershed hydrology and water quality available. It is the only available model that can simulate the continuous, dynamic event, or steady-state behavior of both hydrologic/hydraulic and water quality processes in a watershed, with an integrated linkage of surface, soil, and stream processes. The model is also unusual in its ability to represent the hydrologic regimes of a wide variety of streams and rivers with reasonable accuracy. It has been applied to such diverse climatic regimes as the tropical rain forests of the Caribbean, arid conditions of Saudi Arabia and the Southwestern U.S., the humid Eastern U.S. and Europe, and snow covered regions of Eastern Canada.

HSPF was first released publicly in 1980, as Release No. 5 (Johanson et al., 1980), by the U.S. EPA Water Quality Modeling Center (now the Center for Exposure Assessment Modeling); since its initial release, the model has maintained a reputation as perhaps the most useful watershed-scale hydrology/water quality model that is available within the public domain. Throughout the 1980's and early 1990's, HSPF underwent a series of code and algorithm enhancements producing a continuing succession of new releases of the code, culminating in the recent release of Version No. 11 in 1996 (Bicknell et al., 1996). HSPF applications since its initial release have been world-wide and number in the hundreds; on the order of 50 current active applications continue around the world with the greatest concentration in North America. Numerous studies have been completed or are continuing in the Pacific Northwest, Washington, D.C. metropolitan area, Minnesota, Connecticut, and the Chesapeake Bay region. Today the model serves as the focal point for cooperation and integration of watershed modeling and model support efforts between the Environmental Protection Agency and the U.S. Geological Survey. Over the years, development activities and model enhancements, along with these model applications, have continued to improve the model's capabilities and preserve its status as a state-of-the-art tool for watershed analysis.

The Chesapeake Bay Program uses the HSPF model as the framework for the Chesapeake Bay Watershed Model to determine total watershed contributions of flow, sediment, and nutrients (and associated constituents such as water temperature, DO, BOD, etc.) to the mainstem Chesapeake Bay and tidal tributaries (Donigian et al., 1986a; 1991). The Watershed Model represents pollutant contributions from an area of more than 64,000 sq. mi., and provides input to drive a fully dynamic three-dimensional, hydrodynamic/water quality model of the Bay. The watershed drainage area is divided into land segments and stream channel segments; the land areas modeled include forest, agricultural cropland (conventional tillage, conservation tillage, hay), pasture, urban (pervious and impervious areas), and uncontrolled animal waste contributions. The stream channel simulation includes flow routing and oxygen and nutrient biochemical modeling in order to account for instream processes affecting nutrient delivery to the Bay.

The Watershed Model is currently being used to evaluate nutrient management alternatives and tributary strategies for attaining the Chesapeake Bay Program’s goal of a 40 percent reduction in nutrient loads delivered to the Bay. In his presentation, Tony Donigian stressed that validity of a model application for a specific watershed depends on (1) the process modeling capabilities included in the model, (2) the input data available to support the application (i.e. through calibration), and (3) how the model capabilities are applied by the model user to address the specific issues of concern to managers and decision-makers in the specific watershed being studied. For the Chesapeake Bay Watershed Model, issues 2 and 3 (above) were addressed by Lewis Linker, Modeling Coordinator for the Chesapeake Bay Program Office.

Chesapeake Bay Watershed Model Capabilities and Calibration (Linker)

Lewis Linker's presentation was primarily directed toward a broad overview of the Watershed Model simulation capabilities and calibration results. Emphasis was placed on the importance of integrating watershed monitoring, research, and modeling information.
The point was made that regional programs need to have both a modeling and a monitoring program in order to provide information for effective management decisions in coastal eutrophication. Over the last decade and a half, the Chesapeake Bay Program has developed the standard of using the best monitoring, research, and modeling data available. It is the Program's insistence on the corroboration of all three sources of information that has made credible goal-setting and tracking of the nutrient reduction goal possible. Ultimately, each element is necessary. Monitoring sets the calibration of the models and provides "real world" findings to anchor the modeling and research work. Research provides a separate analysis and contributes to the scientific basis for the Program. Modeling is the focus of management strategy development, and projects the Bay water quality response to management actions taken in the watershed or airshed.

Additional work in developing estimates of periphyton and macrophyte biomass at mainstem river sites was recommended. Additional work in simulating the changing mature of agriculture (a dynamic industry) and with simulating the latest non-point source best management practices (BMPs), particularly the effects some BMPs have on ground water loads.

SUMMARY OF CHALLENGE GROUP RECOMMENDATIONS

NUTRIENT INPUTS SUMMARY RECOMMENDATIONS

The Nutrient Inputs Challenge Group focused on loadings from atmospheric deposition, agricultural lands, forestlands, urban/suburban land, on-site waste disposal systems, and point sources. The following summary recommendations for these categories, along with other general recommendations, were developed by the challenge group.

ATMOSPHERIC DEPOSITION

- Alternative methods of extrapolating individual monitoring station estimates of wet atmospheric deposition to the land and water surfaces across the entire Chesapeake Bay basin need to be assessed. The current method does not appear to provide sufficient spatial detail.

- Dry deposition inputs based on a fixed percentage of wet deposition needs to be reevaluated. This evaluation should include the recently released dry deposition estimates from the Clean Air Status and Trends Network (CASTNet), particularly the collocated wet and dry estimates.

- The Chesapeake Bay Program relies entirely on others to provide atmospheric deposition data. If the National Atmospheric Deposition Program (NADP) and CASTNet monitoring were discontinued, the Chesapeake Bay Program would be without any ground-level measurements of atmospheric deposition. Consideration monitored at NADP or CASTNet sites. This is especially true in central and southern regions of the watershed. A number of monitoring sites should be located near and downwind of large agricultural operations to determine the magnitude and spatial extent of ammonium deposition from agricultural sources.

- The number of atmospheric deposition monitoring sites over open water should be increased. Currently, atmospheric deposition is measured at only one site (Smith Island, Maryland). Deposition to large water surfaces may be less than to adjacent land surfaces; thus, extrapolation of land-based deposition estimates to the surface waters of the Bay mainstem may overestimate direct deposition to Bay tidal waters.

AGRICULTURAL LANDS

- The use of a composite crop in the Chesapeake Bay Watershed Model should be discontinued. Land cover classification should be based on specific crops (e.g., corn, soybean, hay, alfalfa, pasture, etc.) to permit the calculation of the amount of nitrogen input from fixation by alfalfa and soybeans (see the fifth recommendation under atmospheric deposition).

- Manure loadings should be based on the acreage of each crop in each watershed segment that actually receives manure, not on "all agricultural lands" as is the current approach in the Watershed Model.

- Applications of fertilizer should also be based on the acreage of each crop, not a "composite crop" as is currently the approach taken in the Watershed model.

- The percentage of land in agricultural operations needs to be updated through the use of the 1997 Agricultural Census data when it becomes available. (Current estimates are based on 1992 Agricultural Census data.)

- Animal density numbers need to be updated more frequently.

- Current fertilizer application rates should be compared to aggregate "points of sale". Although this might be difficult for individual watershed segments, it would be a useful comparison for the watershed as a whole.

- Current application rates of fertilizers to specific crops should be reevaluated.

FORESTLANDS

- Forestlands should be subdivided into coniferous and deciduous forests; additional stratification may not be warranted at this time. Available GIS databases from the US Forest Service and state agencies would permit subdividing on the basis of forest cover types (e.g. northern hardwoods, southern hardwoods, etc.). Additional stratification based on management activities (e.g., percent actively managed) is desirable, since management activities on forestlands affects nitrate export.

URBAN/SUBURBAN

- Estimates of urban/suburban acreage per watershed segment should be updated.

- Delineation of urban/suburban areas into new versus old areas would be useful. The current storm water management practices, established in the mid-1970's, detain water on the surface and encourage evaporative lose and groundwater recharge thus reducing direct storm runoff. Delineation between new versus old (before mid-1970's) urban/suburban areas would improve model performance by routing more of the water to groundwater than to surface waters. This would also reduce the estimated nutrient inputs by increasing nutrient retention by the soil.

- Modeled runoff and nutrient export from urban/suburban areas need to verified with actual monitoring data from such areas. Such a monitoring program is currently underway near Villanova, Pennsylvania.

- The use of urea to melt ice should be included in the model. This may be an important source of nitrogen in runoff from urban areas, and its use is increasing.

ON-SITE WASTE DISPOSAL SYSTEMS

- The number of active on-site waste disposal systems in the watershed needs to be updated.

- Attenuation of nitrogen from on-site waste disposal systems as used in the Chesapeake Bay Watershed Model appears to be low. Additional studies need to be undertaken to determine the relative accuracy of this assumption. Studies addressing the variation in nitrogen deposition based on soil association and the type of on-site waste disposal systems also need to be conducted.

POINT SOURCE INPUTS

- Point source inputs of nutrients from municipal and industrial wastewater sites are adequate. Good information is available on the volume of flow and nitrogen and phosphorus concentrations. No additional recommendations are warranted.

OTHER RECOMMENDATIONS

- More single land use monitoring is for model calibration and verification.

- Consideration should be given to other available models, particularly for diagnostic purposes and the assessment of the impact of management strategies.

- Nutrient input data by watershed segment need to be consistent throughout the Chesapeake Bay watershed. Although this was not identified as a specific problem, several workshop participants indicated that variations in data collection and reporting by states can affect the consistency of nutrient inputs by Watershed Model segments.

- Mined lands should be included in the model as a separate land cover category.

- Wetlands have a pronounced effect on both runoff and nutrient retention and should be included in the model as a separate type of land cover.

- Better documentation by watershed segment is needed for the acreage included under BMPs.

- More "edge of field" studies need to be undertaken to determine the effectiveness of BMPs.

- Monitoring is needed to determine the effectiveness of BMPs under high flow episodes.

- A literature review of small watershed research studies should be conducted to identify potential research sites and past research studies and data bases of importance to the Chesapeake Bay Program and the Chesapeake Bay Watershed Model.

- The variable source area concept indicates that the hydrologic responsiveness of a watershed is highly variable in time and space. Only very small portions of a watershed actively contribute flow and nutrients during low flow periods, and progressively larger portions are active with increasing soil moisture content and storm size. Based on the variable source area concept, runoff from the entire watershed would occur very infrequently and only during extreme events. The application of this concept to the Chesapeake Bay Watershed Model suggests that some portion of the watershed would be more active hydrologically than other portions and that nutrients applied to these hydrologically active zones would be more readily available than those applied to less responsive areas of the watershed. This concept has been shown to work exceptionally well on the level of small watersheds and should be incorporated into the Chesapeake Bay Watershed Model.

- The impact of frozen surface soils, particularly in urban/suburban and agricultural areas on affect the amount and timing of surface runoff and the amount of nitrate exported from these lands is an important consideration in the performance of the Watershed Model.

- The application of municipal sludge and waste water to surface soils is increasing in the Chesapeake Bay watershed. An analysis needs to be conducted to determine the extent and rate of such applications and their location. If warranted, this practice should be included in the Chesapeake Bay Watershed Model as a potential source of nutrient input.

- Further study of the residence time of groundwater inputs needs to be conducted. The group suggested that the current modeled groundwater inputs are too rapid.

NUTRIENT MOVEMENTS THROUGH WATERSHEDS SUMMARY RECOMMENDATIONS

In general, the Chesapeake Bay Watershed Model appears to incorporate most of the processes affecting the transport of nutrients. However, for many of the processes there are questions whether the scale of simulation is appropriate. That appropriateness is determined, of course, by the uses of the Watershed Model. Discussion in the group session, as well as in the plenary session, suggested that there may be new uses for the model.

The initial purpose of the Watershed Model was to determine water, nutrients, and sediment in the tidal Chesapeake as inputs to the Water Quality Model. For this purpose, the initial criterion for a successful Watershed Model may have been to deliver a reasonably accurate time series of loads to the Bay. The model was structured and calibrated to meet that criterion. However, with implementation of the nutrient reduction strategies, there is increasing interest in what happens within the non-tidal watershed. This information will aid in determining a) where in the basin to implement nutrient controls to have the greatest impact on fall line loads; b) what impact nutrient reductions will have on local watershed; and c) the time lag between control action and resultant load reduction at the fall line.

- The Chesapeake Bay Program should enhance the Watershed Model to simulate water quality changes and transportation of nutrient and sediment loads **within the watershed** in a reasonably accurate way. The scale of processes in the current Watershed Model should be evaluated to ensure they are appropriate for this new objective. Currently, watershed characteristics are treated as uniform values for model segments which average 1,000 square miles in area, and processes (e.g. channel scour; mixing of nutrients within the groundwater unit) occur instantly and uniformly within segments.

- The current non-tidal monitoring programs should be evaluated to determine if the data collection is adequate to fully calibrate the Watershed Model at the scale of individual segments. The ultimate goal should be a calibration monitoring station for each Watershed Model segment.

- Monitoring on small watersheds (including aquifers) characterized by nearly uniform land use/cover, slope, etc. would help provide transport rates for many of these processes.

NUTRIENT TRANSFORMATIONS WITHIN A WATERSHED
SUMMARY RECOMMENDATIONS

- The spatial resolution of the Chesapeake Bay Watershed Model should be increased in order to improve accuracy and to increase the number of processes that can be represented.

  The Watershed Model currently is based on segments that average approximately 700-800 square miles in area; however, the model is being used to evaluate management practices that can only be implemented on a farm scale which may only be a few acres. The difference between the scale of modeling and the actual scale of implementation is a significant limitation on model accuracy and utility. Improving the spatial resolution of the Watershed Model will improve its accuracy by allowing the use of data that is currently available for additional calibration or verification. In addition, improved spatial resolution of the Watershed Model would allow processes, such as nutrient delivery and groundwater fate/transport, to be better represented.

- Small scale experimental studies should be conducted to evaluate the model's capability for simulating management practices. These studies should be performed at the farm scale to evaluate the effectiveness of management practices. Model algorithms should also be evaluated at that scale to determine their capability for representing the appropriate transport processes. Studies also need to be performed to provide information on processes that affect nutrient and sediment loads from the "edge of field" scale to the small basin scale.

- Sensitivity analysis of the Watershed Model parameters is needed to determine which parameters are most important to the accuracy of the simulations. This will allow improved representation of sediment and nutrient transport, facilitate future calibration efforts, and assist the selection of management practices.

- Improved monitoring and simulation of groundwater flow and transport processes are important for the accurate representation of nitrogen responses to management practices. Currently the Watershed Model algorithms do not accurately represent ground water transport processes and do not utilize information critical to the accurate representation of ground water transport. To improve ground water simulation, three tasks should be performed. (1) The ground water transport algorithms should be improved to more accurately simulate flow and transport to stream base flow. (2) Digital geographic information on aquifer volumes and lithogeochemistry should be developed. (3) The monitoring of surficial groundwater quality (<25 ft) needs to be increased since most current ground water monitoring is for deeper wells that in general do not interact with surface water.

- Simulation of river corridors and floodplains needs to be improved in the model to more accurately simulate sediment and contaminant transport. Floodplain processes are critical to the storage and remobilization of a variety of contaminants, including phosphorus. Currently, floodplains are not represented in the model, except as part of the stream cross-section. One example of a constituent that is not accurately simulated because of floodplain interaction is total organic nitrogen. Monitoring data indicate that total organic nitrogen increases substantially in the rising limb of hydrographs, but this effect is not reproduced by the Watershed Model, possibly because floodplains and scouring are not represented. An approach for correcting this includes: 1) establishing test stream reaches for upstream/downstream reach studies of interactions of streams and floodplains; 2) quantifying scouring during events and associated increases in total organic nitrogen during the rising limb of hydrographs; and 3) incorporating periphyton scour and floodplain scour in the model to improve total organic nitrogen simulation if needed. A similar approach can be used for constituents that are affected by floodplain interaction.

- To improve the accuracy and spatial representation of the Watershed Model, the number of water quality monitoring sites should be increased for enhanced calibration and verification. Specifically, the number of sites should be increased on the major non-tidal rivers' mainstems and throughout the watershed's coastal areas. Synoptic sampling studies should be performed to select long-term sampling locations. Sites should be selected and designed for long-term continuous discharge and water quality data collection since short term data records are of limited value for model calibration and verification.

RESPONSE OF NUTRIENTS TO ENVIRONMENTAL MANAGEMENT SUMMARY RECOMMENDATIONS

•MANAGEMENT NEEDS

- The Chesapeake Bay Watershed Model should be refined/expanded to explicitly enable Bay Program managers to better address the following issues
  - Atmospheric reductions resulting from Clean Air Act implementation
  - Forest management practices (the Watershed Model currently does not include forest activity contributions to reductions);
  - Wetlands management and restoration (including forested wetlands);
  - Septic system management (since many communities are outgrowing their systems and adding to urban nutrient run-off problems);
  - Impervious vs. pervious land management;
  - Impacts of build-out on nutrient export; and
  - Impacts of BMPs on local, non-tidal freshwater rivers and streams water quality and aquatic life.

- The optimum Chesapeake Bay Watershed Model should:
  - Address multiple, more specific land uses;
  - Have more calibration points (preferably one for each model segment obtained either from increased monitoring or sharing of data already being collected);
  - Account for unusual events (like major storms), and take groundwater changes into consideration; and
  - Account for BMPs adjusted to the actual hydrology of the area, rather than modeled hydrology.

MODELING NEEDS

- Better spatial resolution for better estimates of delivery efficiencies within the model segments.

- Assurance that the Limit of Technology (LOT) definitions are realistic.

MONITORING NEEDS

- Monitoring at the “exit point” from each Bay Watershed Model segment.

- Monitoring that demonstrates linkages between water quality and living resource responses in upland areas of the watershed.

Appendix A

WORKSHOP AGENDA

Day One, May 19

9:00 am	COMMENCEMENT (Joseph Bachman, Workshop Chair) Welcome and presentation of Workshop purpose, structure, and goals Introductions of workshop participants and Challengers
9:30	CHESAPEAKE BAY WATERSHED MODEL *How HSPF models a watershed*: Tony Donigian, AQUA TERRA Consultants
10:15	Break
10:30	CHESAPEAKE BAY WATERSHED MODEL (cont.) *How the Chesapeake Bay Watershed Model is put together* :Lewis Linker or Modeling Subcommittee Staff
11:15	CHALLENGE TEAM SESSIONS : Challengers (leaders) will introduce themselves and set the "ground-rules". The Challenger will present a stage-setting overview of each Challenge. Initial stock taking and bounding.
12:00 pm	LUNCHEON
1:30	CHALLENGE TEAM SESSIONS: Work toward answers and solutions
3:30	Break
3:45	PROGRESS REPORTS: Brief reports of progress and problems
6:30	DINNER (on your own)
Evening	CHALLENGE TEAM SESSIONS (Continued, if necessary)

Day Two, May 20

8:30 am	CHALLENGE TEAM SESSIONS
11:10	CHAIRMAN & CHALLENGERS MEET CHECK OUT
12:00pm	LUNCH (provided)
1:00	CHALLENGE TEAM REPORTS/RECOMMENDATIONS PARTICIPANT DISCUSSION
3:00	ADJOURN

Appendix B

QUESTIONS FOR CHALLENGE GROUPS

Questions to consider for overall workshop recommendations:

Is current monitoring sufficient to evaluate how well the Chesapeake Bay Watershed Model simulates management strategies?

Is additional monitoring needed to provide better input data to the Watershed Model?

What kind of monitoring program is needed for evaluating models constructed at scales smaller than the entire Chesapeake Bay watershed?

Would alternative monitoring and modeling approaches provide more realistic simulation of the Chesapeake Bay watershed?

Challenge Group 1: Nutrient Inputs

What kinds of data are used in the Chesapeake Bay Watershed Model as values for nutrient inputs?

What percentages of total nutrient inputs come from each of the following sources: atmospheric deposition, fertilizer application, manure, on-site sewage disposal, point sources?

How are these percentages determined?

Much of the data on fertilizer use, livestock numbers, septic tanks, etc. are compiled on the basis of political subdivisions or other geographic units that don't correspond to model segments. How are these values converted to values for a model segment? What procedure can be used to convert the available data if a new model segmentation system is created?

How are nutrient data from atmospheric deposition monitoring generalized as input to the model? What would be an optimal density of monitoring of atmospheric deposition?

What are the research priorities to provide a better understanding or better estimates of nutrient inputs?

Challenge Group 2: Nutrient movement through the watershed

Which inputs to the watershed model affect the simulation of nutrient movement through the watershed?

How does HSPF treat ground water, both in terms of water flows and volumes and solute transport of nutrients?

What are the criteria used to calibrate a model?

How many monitoring stations are used for calibration of the entire Bay watershed model? what is the optimal number of stations to calibrate?

How does one monitor a watershed to document the movements of nutrients through it?

What are the research priorities to better understand how nutrients move through a watershed?

Challenge Group 3: Nutrient transformations within a watershed

What chemical and physical processes within a watershed will affect the concentration of nutrients discharging from the watershed?

What chemical and physical processes are simulated by the Chesapeake Bay Watershed Model?

What data are input to the model to run the simulation of chemical and physical processes?

What is the optimal monitoring needed to document the occurrence and quantitative extent of these processes?

What are the research priorities to provide better ideas of the most important chemical and physical processes affecting nutrient transformations?

Challenge Group 4: Response of nutrients to environmental management

What types of environmental management that may affect nutrient concentrations are planned for the Chesapeake Bay watershed?

How does the Watershed Model simulate each management strategy?

How well does the model simulate effects of management strategy at scales smaller than the total watershed (i.e. nutrient loads from selected model segments)?

What results from the model provide a measure of anticipated effectiveness of a management strategy?

Appendix B

What types of monitoring would provide the best tests of the effectiveness of a management strategy?