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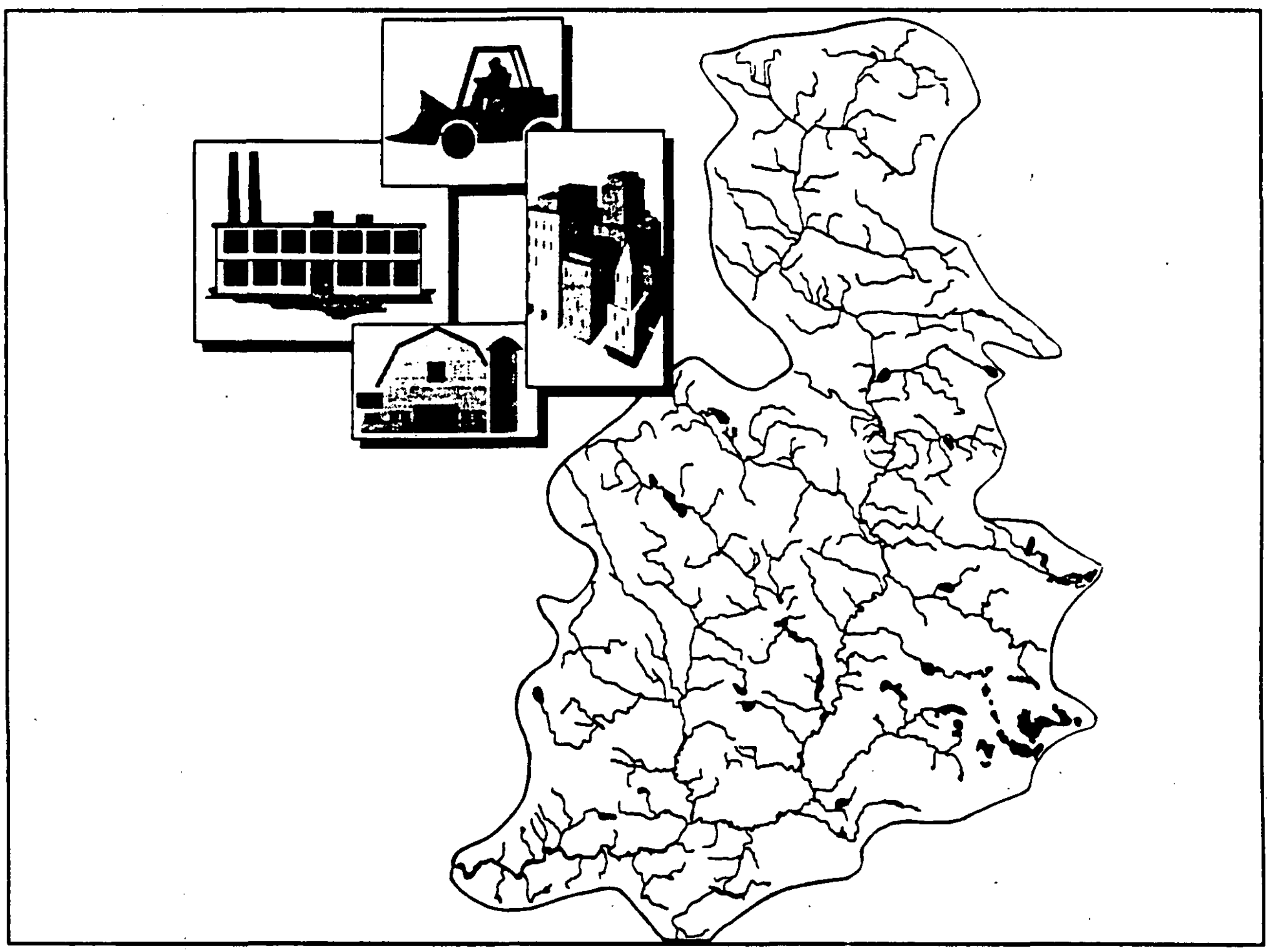
Workshop on the Water Quality-based Approach for Point Source and Nonpoint Source Controls

Meeting Summary

June 26-28, 1991
Chicago, Illinois



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WORKSHOP SUMMARY

Workshop on the Water Quality-based Approach for Point Source and Nonpoint Source Controls

Prepared by

Tetra Tech, Inc.
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for the

Office of Wetlands, Oceans and Watersheds (WH-553)
Office of Science and Technology (WH-585)
U.S. Environmental Protection Agency
Washington, D.C. 20460

FOREWORD

This workshop was organized to assess the state of the science and chart future directions for water quality-based pollution controls. Agencies concerned with water quality are beginning to address new challenges such as nonpoint source pollution, storm water discharges, habitat quality, and the condition of the resident ecological community. Addressing these challenges requires increasing the scales of analysis from river segments to watersheds, and from a simple low flow critical period to low and high flow periods and in some cases multi-decade timeframes.

It is also apparent that we will need to integrate various analytical tools in order to comprehensively address all of the phenomena in a large geographical area such as a watershed. Finally, there is a growing appreciation that attaining and maintaining water quality standards in many cases will require measures to control non-chemical stressors. The capability to predict the ecological response to controls on non-chemical stressors is a critical need.

The workshop participants discussed all of these topics and developed many ideas for improved approaches to water quality analysis. One particularly significant result is the dialogue begun between members of the different disciplines brought together for this workshop. The goals of the workshop were largely met and the findings are expected to establish a blueprint for future directions.

Bruce Newton

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ACKNOWLEDGEMENTS

The Workshop on the Water Quality-Based Approach for Point Source and Nonpoint Source Controls was jointly sponsored by the Office of Wetlands, Oceans and Watersheds (OWOW) and the Office of Science and Technology (OST). Bruce Newton, Chief of the Watershed Branch (OWOW) and Elizabeth Southerland, Chief of the Risk Assessment and Management Branch (OST) are acknowledged for their role in initiating the workshop and overseeing its success. Amy Sosin and Hiranmay Biswas were the EPA project managers. Karen Guglielmone of Tetra Tech is acknowledged for her help in coordinating the workshop and preparing this summary.

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1. OVERVIEW

1. Overview of the Workshop on the Water Quality-based Approach for Point Source and Nonpoint Source Controls

The Workshop on the Water Quality-based Approach for Point Source and Nonpoint Source Controls was held June 26, 27, and 28 in Chicago, Illinois. The purpose of the workshop was to explore the state-of-the-science and determine technical guidance needs for implementing section 303(d) of the Clean Water Act. More specifically, the workshop served to:

- Learn from national experts and the user community what tools are available to implement the 303(d) Total Maximum Daily Load (TMDL) process on a watershed basis, and what national technical guidance EPA should provide to the user community.

- Identify tools that can currently be incorporated into national technical guidance.

- Examine the trends of emerging science and technology, including ecological restoration, remote sensing, and geographic information systems (GIS) to identify promising approaches for future guidance.

- Identify tools that can integrate point source and nonpoint source pollution processes into a single integrated approach for solving water quality problems.

Carl Myers, Deputy Director of U.S. EPA's Assessment and Watershed Protection Division in the Office of Water, and William Diamond, Director of U.S. EPA's Standards and Applied Sciences Division in the Office of Science and Technology, opened the meeting. The first day continued with presentations on problem diagnosis, watershed-scale modeling, and data sources, tools, and investigations. Presentations on remote sensing and GIS, and predictive modeling of ecological restoration continued through the first half of the second day; then the workshop broke into four concurrent workgroup sessions. On the final day, the four workgroups reported their findings and recommendations.

This meeting summary includes the opening addresses, abstracts for each of the presentations, and a summary of the work and recommendations for each of the workgroup sessions.

Included as appendices are the list of participants, the agenda, and a summary of the special EPA data base presentation.

2. OPENING REMARKS

2. Opening Remarks

Carl Myers, U.S. EPA, Deputy Director, Assessment and Watershed Protection Division, OWOW

As part of the Office of Water's recent reorganization, the Office of Science and Technology (OST), the Office of Wastewater Enforcement and Compliance (OWEC) and the Office of Wetlands, Oceans and Watersheds (OWOW) have key responsibilities concerning the water quality-based approach to making point source and nonpoint source pollution control decisions. The Assessment and Watershed Protection Division (AWPD) of OWOW will be one of the primary users and promoters of this approach. The Standards and Applied Science Division of OST will be working with AWPD to incorporate it into the permitting process.

The Workshop on the Water Quality-based Approach to Point Source and Nonpoint Source Controls comes at a critical time. EPA has recently issued concise and useful guidance that explains the Total Maximum Daily Load (TMDL) process, and how it can help water quality managers make better decisions; reauthorization of the Clean Water Act (CWA) has created new language and a renewed emphasis on the entire TMDL process; and revised 303(d) regulations that will re-emphasize and re-enforce several aspects of the TMDL process, such as targeting and prioritizing watersheds, and developing TMDLs on schedule will be issued later this fall. More pollution management activities are focusing on watersheds and ecosystems, as opposed to individual permits or individual construction grants. EPA administrator, Bill Reilly, has shown great interest in advancing habitat protection and related issues, and is putting more emphasis on the wider geographic influences that affect specific water bodies. Much of this emphasis is a direct result of the 1990 Science Advisory Board report, *Reducing Risk*, which stated that as much importance should be placed on reducing ecological risk as on reducing human health risk. All this as EPA and the States begin to use the water quality-based approach more extensively.

Until now, some states have hardly used the water quality-based approach at all; some have used it a little; and others have used it extensively. Even the states who have used the process extensively, however, have largely focused on making specific decisions involving National Pollutant Discharge Elimination System (NPDES) permits for individual point sources -- often just looking at one or two specific chemicals. Although it is important and necessary to make such decisions, the TMDL process must now be used more broadly to address more complex pollution control problems, including nonpoint sources and multiple point sources within one watershed. It is important to move beyond the chemical-by-chemical, permit-by-permit approach to encompass all threats to a given watershed.

The Office of Water is working with the Regions and States on a Watershed Protection Initiative which will focus water management efforts and martial resources to help States make better, more comprehensive decisions and implement pollution control measures on a watershed basis. Many OWOW programs, such as the Nonpoint Source Program, the Wetlands Program, various coastal initiatives, and the National Estuary Program, already focus on watersheds and require managers to make water quality-based decisions. The goal of the WPI is to help re-orient all programs so that they operate on a targeted watershed basis.

What else do we need in order to move ahead with the water quality-based approach? This workshop should help to answer that very question. While it is easy to say water managers must use TMDLs to make decisions on the pollution controls necessary in a particular watershed, until now, we have not always been able to use available information beyond point source decisions. Recognizing why application of the TMDL process has been so limited, and that we must gather and develop the technological tools and the approaches and the methods that will let us use the TMDL process more broadly, is the key.

William Diamond, U.S. EPA, Director, Standards and Applied Science Division, OST

The reorganization of the Office of Water reflects the importance that is being placed on total water quality management. The reorganization also serves to focus more resources, attention, time, and decisions on making TMDLs an integral part of the entire water quality standards and permits process.

This new direction has been influenced by several factors. First, although the recently adopted State toxic water quality standards were controversial during Congressional reauthorization, they mean little unless they can be quickly translated into real pollution controls. The TMDL process can facilitate this translation. Second, the CWA Amendments on TMDLs have focused political attention on the TMDL process. The Baucus/Chaffee bill has several provisions relating to water quality-based decisions which, if enacted, would require rapid adoption of more comprehensive TMDLs. Third, over the last couple of years there has been more TMDL-related litigation, indicating to EPA that it is time to enforce section 303(d) more strictly. Negotiations on a suit in Alaska have recently closed; there are other suits pending; and EPA expects to see more as the courts are seen as a successful route to 303(d) enforcement. Finally, environmental programmatic needs are increasing and require increasingly complex decisions that can only be addressed through a comprehensive water quality-based approach.

The explosive expansion of the water quality criteria and standards program will probably continue through the early 1990s as we try to go beyond chemical specific criteria and deal with such long-standing environmental quality issues as contaminated sediment, nonpoint sources, combined sewer overflows, and habitat destruction.

This year EPA is proposing initial criteria to address contaminated sediment. A sediment management strategy to deal with the range of issues concerning State adoption of sediment standards is under development. One question that must be addressed is, how to model and track the standards? Another is, how to integrate the standards into the TMDL process?

Combined sewer overflows are a potential multibillion dollar problem that is being addressed by the CWA and several Agency programs. In order to deal effectively with this problem, wet-weather criteria must be developed. Environmental professionals and modelers must determine how to deal with nonpoint source pollutant loadings during wet-weather high flows. (Criteria for point sources and chemical specific toxics have traditionally been based on critical low flow concentrations.)

Habitat destruction is a serious threat to many watersheds. Biologically- and ecologically-based criteria must be established in order to address this problem. However, establishing such standards and criteria, and then making them applicable as regulations and policies is a tremendous challenge. Through an integrated watershed approach, the TMDL process offers a mechanism to address both point and nonpoint pollution sources that can degrade valued habitat.

TMDL assessment, monitoring, and modeling will play a crucial role in whether we meet these challenges successfully; and the Office of Water recognizes that more time, resources, and attention will be necessary. This workshop will serve two broad purposes. First, to learn from technical experts and water quality managers what technical issues must be addressed in order to successfully implement the TMDL process; and second, to prioritize the recommendations made by workshop participants. Establishing priorities is critical to the management and success of this program not only in the short term, but in the long term as well. Over the next couple of months we will be putting together a program plan based on the needs and priorities that we establish here at this workshop.

3. SECTION 303(d) OF THE CLEAN WATER ACT

3. Section 303(d) of the Clean Water Act

Bruce Newton, U.S. EPA, Chief, Watershed Branch,
Assessment and Watershed Protection Division, OWOW

Section 303(d) of the Clean Water Act

The water quality-based approach outlined in section 303 of the Clean Water Act has three major elements. Subparagraphs a, b, and c of section 303 establish State Water Quality Standards, which include water quality criteria, as well as designated uses and antidegradation provisions. Section 303(d) establishes the process for setting pollution control requirements to meet water quality standards. Section 303(e) requires a statewide water quality planning process. These elements are the essence of the water quality-based approach originally envisioned in 1972.

Section 303(d) itself is a three step process. The first step requires States to identify all waters that do not meet water quality standards or are not expected to meet water quality standards after the application of technology-based controls. The second step requires them to establish priorities among all identified water quality-limited waters. The third step is to develop a control plan that is termed a total maximum daily load (TMDL). [TMDL is a somewhat antiquated term as EPA moves to address such topics as habitat protection and nonpoint source controls; it is important not to be hindered by the limiting nature of this terminology.]

Section 303(d) was enacted in 1972, but was never fully implemented. This is largely because requirements for point sources were developed in conjunction with permit issuance. There are two principal reasons that EPA is now moving to more fully implement the water quality-based management process originally envisioned. The first is that the TMDL Process is a logical way to address certain non-traditional pollution problems, such as nonpoint sources, non-chemical stressors, and cumulative effects which are now recognized as major threats to water quality. It is, therefore, time to broaden the scope of decision making to include all pollution sources in a watershed. The ultimate goal is to be able to consider the landscape as a whole -- looking at both terrestrial and aquatic ecosystems together. This change in the scope of decision making fits well with the requirements of 303(d).

The second reason is to emphasize the several concepts inherent in the 303(d) process that will be necessary as we begin to address more complex water management problems. One key concept of the 303(d) process is targeting and setting priorities. Water quality managers have come to the conclusion that progress can only be made on water quality issues associated with nonpoint source controls through targeting. Targeting will lead to better coordination among more agencies and groups to develop pollution controls and protect critical habitat. Many of the decisions that need to be made, are made at the local level. This means that the public must be engaged more than in the past; and that is best done through targeting. There are also specific public participation requirements in 303(d) that will help to engage and educate the public.

Section 303(d) Guidance

EPA recently issued a guidance document on the water quality-based approach that establishes Agency policy in this area. The document outlines the programmatic requirements of the TMDL process. It is important to understand these requirements before discussing the technological tools that may be available to help decision makers. Specifically, the document sets out EPA expectations concerning 303(d) -- that States will do TMDLs, and that if they fail, the Agency will. It establishes Agency policy concerning nonpoint source waters -- that a TMDL must consider nonpoint sources, and that we expect progress in the area of nonpoint source control despite uncertainties in data and uncertainties inherent in the use of models. The Guidance also addresses policies concerning nonchemical stressors. EPA asserts that the TMDL process does apply to nonchemical stressors, to the extent that you can quantify the stressor and tie it to water quality standards. For example, if it is determined that designated uses are not being attained due to lack of stream side vegetation and a measure such as percent canopy cover can be tied to attainment of water quality standards, then a TMDL for percent canopy cover could be written.

The Guidance details procedural aspects of the TMDL program, such as the submission of lists -- which waters should be listed and which are exempt -- and the identification of waters targeted for TMDL development. Both within the program guidance, and in the regulation that we are in the process of finalizing, States are being asked to identify, target, and list waters for TMDL development on a two year cycle. This listing cycle corresponds closely with the process under section 305(b) which also requires reporting of water quality every two years.

EPA's role in administrating the TMDL Process is to review and approve or disapprove State lists, priorities, and TMDLs. If EPA disapproves any of these, it is obliged to assume the responsibility and do the work. A long series of court cases has also established that EPA is obliged to do the work if a State fails to.

The Guidance document also addresses the phased approach for TMDL development. This management approach applies where use of data and models result in a high degree of uncertainty. It establishes specific requirements for implementation schedules, monitoring, and water quality standards attainment after the implementation of pollution controls.

The phased approach strikes a balance between the need to move ahead and not wait for the perfect model or the ideal amount of data, and the statutory requirement that where there is uncertainty it must be accounted for with a margin of safety. The process provides a middle ground to move ahead where we do not have as firm an understanding as we would like, but also provides some safeguards in terms of follow-up monitoring and implementation schedules. If monitoring reveals that a TMDL is not as stringent as it should be, for example, it can then be revised.

The Workshop

The heart of the 303(d) process is predictive modeling. We need to be able to determine whether or not a control measure will result in the attainment and maintenance of water quality standards. We also need to be able to set defensible, realistic targets for allowable amounts of pollution. Predictive modeling permits us to do this.

Maintaining the diversity of participants at this workshop was important. Our intention was not to conduct a conference exclusively for modeling engineers to speak with each other about models; instead, we invited people from the remote sensing and geographic information system (GIS) community, and others involved with a fairly new area of research -- predictive modeling of ecological restoration. About twenty-five percent of the workshop participants are considered to be representatives of the user community -- people who can speak for the "customers" that we need to satisfy with regard to the level of expertise and usability of these models.

The objectives of this workshop are threefold:

1. To review the current state of the science to see exactly where we stand in the face of these new challenges;

2. To obtain expert recommendations about which approaches and tools can be used over the next three to five years; and

3. To obtain prioritized recommendations about which tools are most promising for development over the next five to ten years.

The workshop has been organized into key topic areas: Problem Diagnosis; Watershed Modeling; Data Sources, Tools, and Investigations; and Predictive Modeling of Ecological Restoration.

Problem diagnosis is important for watershed managers. When dealing with point sources it is fairly obvious which parameters need to be modeled. As we attempt to manage watersheds more comprehensively, it will be more difficult to discern which parameters are most important or indicative of the processes that need to be modeled.

How to model all pollution sources and impacts over larger geographic scales is a key technological issue of the TMDL Process. It is closely tied to data management, as well as monitoring issues. Modeling on a larger scale and consideration of nonpoint sources along with multiple point sources within a watershed requires the use of such technologies as remote sensing to provide relevant data, and GIS to integrate the data. A special demonstration has been provided on the current EPA data systems that are available for use. Participants are asked to learn about them and make recommendations about what EPA should be doing in the area of data systems management. Is the data management approach that we have taken the last couple of years appropriate? How should we be directing our resources with respect to this area?

Predictive modeling of ecological restoration is a vital, emerging field of research that has tremendous potential within the TMDL Process. It is a high priority at EPA, and this conference is the first step that EPA has taken to explore this new area. In the future, when a given stressor is identified in a watershed we expect to be able to make recommendations for specific management actions that will result in an anticipated ecosystem improvement.

The key to the success of this workshop is the breakout groups. These groups should focus their discussion on the tools that can be used by State and local governments. We hope the groups will also discuss how to establish a tiered hierarchy of applicable tools, from simple screening tools to more complex numeric models. Beyond models, the groups should identify what state and local governments need to manage watersheds, as well as barriers to implementation that EPA needs to address. Workgroup recommendations should be specific and realistic. These recommendations will be used to develop an agenda to guide EPA in guidance development, research, and implementation support over the next three to ten years.

4. KEY INSIGHTS

4. Key Insights

The Regional Perspective on Water Quality-based Point Source and Nonpoint Source Controls

Jon Grand, Deputy Director, Water Management Division, U.S. EPA - Region V

Personally and professionally, I am completely committed to the watershed-based approach to water management. It is the way I learned to deal with water resource issues and it seems artificial to separate point and nonpoint sources and to address water pollution facility by facility. The watershed-based approach is a more effective way to address water quality management. This workshop is an excellent opportunity to share information and experiences, promote the watershed approach, and develop a plan to overcome existing technical and institutional barriers to implementation.

With the 1987 amendments to the Clean Water Act (CWA), specifically the mandates to control storm water and nonpoint source pollution, most of the tools necessary to assist States with implementation now exist. The States can target regulatory efforts to protect waters from all sources of pollution.

So, why are we here?

The last 20 years have been a period of fairly significant environmental progress, but a recent article pointed out that while the threat of a silent spring may be abated, the danger of lifeless waterways looms ever larger. Fish and other animals that live in the North American waterways are disappearing much faster than land-based fauna. Without broad measures to protect water-dependent creatures from such threats as pollution, unnatural competition, and drainage and damming of vital habitats, the rate of extinction is liable to accelerate.

So, I ask you again. Why are we here?

Because in the last 15 years the North American breeding duck population has gone from 45 million to 31 million -- a 30% decrease. Because in the last few years there has been a dramatic and mysterious decline in amphibians. One study in Oregon showed over an 80% decline in frogs. Nobody knows why. Because worldwide it is estimated that two to three species become extinct per day. This is a rate comparable to cataclysmic extinction periods in the past.

Why are we here?

Because in the last century, 40 species of North American fish have become extinct due to habitat change and destruction, pollution, and overfishing. Because since 1986, poor quality eutrophic lakes have increased by 10%, while good quality mesotrophic lakes have declined by 15%. Because 50% of the 22,000 lakes classified by trophic status are listed as poor or very poor in water quality.

As you can see, the task of restoring and protecting our waters is far from complete. Clearly the more holistic watershed approach will be a factor, if we want to succeed at all. Region V has placed a high priority on the Great Lakes for pollution control activities. As recognized in the Great Lakes Water Quality Agreement of 1978, entered into by the United States and Canada, and by sections 108 and 118 of the CWA, the Great Lakes are a uniquely valuable freshwater resource. Keeping this in mind, a Great Lakes Initiative which marshals resources for use in a targeted watershed approach that is intended to protect the Great Lakes, has recently been established.

In addition to the Great Lakes' intrinsic importance, they are valuable as a national laboratory for developing effective approaches to control nonpoint pollution sources. First, the Great Lakes reflect a broad cross-section of common nonpoint source problems, including agricultural and urban runoff, in-place contamination, and high quality waters threatened by growth and development. Second, they afford the opportunity to provide a model for institutional problem solving relationships among two countries, three EPA regions, and eight states. Third, they are addressed by a number of statutory programs and EPA initiatives that control and abate point and nonpoint pollution problems comprehensively, thus supporting an opportunity to demonstrate integrated approaches to watershed protection.

Since the vast majority of pollution in the Great Lakes originates in Region V States, this Region has the lead for awarding Great Lakes set-aside funds. Set-aside funds will be used exclusively to support nonpoint source implementation projects in the Great Lakes basin that will demonstrate effective and innovative approaches that may be used nationally. These Great Lakes demonstration projects, as well as other 319 projects, will provide information that can be utilized to incorporate nonpoint source controls into total nitrogen daily load processes. Currently, the role of nonpoint source pollution control, which is largely reserved to State management regulation, is a main issue.

While the Great Lakes basin is Region V Water Division's geographic priority, it is important not to lose sight of the need to have strong programs in other areas. The development and implementation of strong watershed programs (a pollution prevention approach) will prevent water quality degradation and, therefore, the need to do total maximum daily loads (TMDLs) in the future.

In conclusion, I am encouraged by the efforts to enhance our water resources management capabilities. Successful water resource programs require several key elements: First, a strong state-local partnership; second, an integrated watershed plan for both watershed management and water resources use; and third, technical expertise. This workshop is one means to provide that technical expertise to help States effectively manage their water resources. Through discussions here, I hope that the basis for an ongoing dialogue, and a free exchange of technical knowledge and experience will be established.

Remember that what we do here does not affect us so much as the environmental legacy we will leave for future generations. Given your critical roles, you must ask yourself . . . How do you want that future to look?

The Watershed Approach from a Point Source Perspective
"Give me a number and I'll follow you anywhere!"

William Brandes, U.S. EPA, Chief,
Water Quality and Industrial Permits Branch

It is important to remind each other that we are trying to establish a truly integrated watershed approach that includes all pollution sources. The point source program has got to be part of this integrated approach. While nonpoint sources are significant, and there is a necessity to focus on them, control of point source pollution and the National Pollutant Discharge Elimination System (NPDES) program should not fall to the wayside.

The NPDES program consists of issuing permits to industrial and municipal point source dischargers throughout the country. It includes implementation of sewage sludge criteria, and also the new storm water permitting program. Currently, storm water is perhaps the most significant aspect of the NPDES program, representing a challenge that will loom large when we try to address pollution from a watershed perspective.

Before we are able to discuss the TMDL process and its role in water quality management, it is important to consider the true scope of our water pollution problems. For traditional sources there are 63,300 point sources, of which 7,300 are considered major. Assuming that 25% of those major permits and 10% of the remaining minor permits will need controls under the TMDL program, there will be approximately 1,825 major permits and 6,300 minor permits to include in the TMDL development process.

There are about 115,000 point sources for industrial storm water. That does not include approximately 215,000 oil and gas facilities, and 100,000 mining facilities. There are also about 220 municipal separate storm water sewer systems located in the major population centers of the country. These contain thousands of pipes and conveyances; authorities have no idea how many. There are about 1,000 systems in this country that have combined sewer overflows, and this is estimated to represent about 10,000 point sources.

All of these traditional and non-traditional point sources will require NPDES permits; and according to the CWA, they must meet water quality standards. The permit applications for stormwater are due sometime later this year and in the middle of next year. Once the applications are received, the CWA requires that a NPDES permit be issued within one year. Dischargers must then comply with specified limitations within three years. So, within the next four or five years, each of these hundreds of thousands of pollution sources are supposed to be in compliance with established water quality standards.

Setting priorities and targeting watersheds will be necessary in order to effectively address so many pollution sources within such a short time period. The NPDES program currently does not have a priority ranking system based on a watershed approach; the question of how to set priorities while issuing permits must therefore be addressed. Permits are generally on a five year cycle, and they must be re-issued on that cycle.

Scientifically defensible and implementable watershed scale TMDLs are a specific need of the NPDES program. This is the number permit writers would like to have and follow. Such TMDLs are needed because they form the basis for waste load allocations, which in turn are the basis of point source controls. Traditionally, scientifically defensible and implementable TMDLs have meant numbers. When we understand the basis of a number and its associated uncertainty, it is easier to put into a permit and enforce. There may be viable alternatives to numeric limits, however, and these alternatives should be discussed during the workshop. Whether they are numeric or not, a successful watershed approach, with a firm TMDL base, must be fully enforceable. That means that both NPDES dischargers and nonpoint sources are enforceable, Otherwise, all efforts in the watershed arena are wasted. The TMDL will not be effective.

Certain aspects of the TMDL process could facilitate the NPDES permitting process. Since the TMDL process considers all pollution sources in a given watershed at one time, permitting of multiple facilities within the same watershed can be coordinated. Since, under the TMDL process, a water quality standard is the focus for all pollutant dischargers, the use of water quality standards is further legitimized. The TMDL process opens the water quality basis for permitting to public comment; a weakness of the program in the past. The TMDL process can better address antibacksliding or antidegradation issues. If a permit limit is based on a TMDL and continued monitoring indicates that the TMDL is too stringent, associated permit limits can be loosened without violating antibacksliding and antidegradation requirements. Finally, the TMDL process simplifies and speeds up permit limit development.

So, give me a number and I'll follow you anywhere . . . as long as the process of establishing TMDLs on a watershed basis is kept practical. Many States that are trying to establish TMDLs have indicated that the point source permitting program suffers while a TMDL is being done. This is largely a question of resources -- there is only so much funding for State environmental programs, and when most of those resources are being dedicated to TMDL development, other programs take a back seat. Other water quality programs that will ultimately be influenced by the TMDL will stop until the watershed goals are determined. Establishment of TMDLs must therefore be fast and effective.

In summary, the point source permit program has specific needs and questions that should be addressed if it is to be an integrated part of the TMDL process. They are:

- In order to useful the TMDL, and the basis for that TMDL, must be easily understandable and clearly expressed. This will facilitate the translation of the TMDL into pollution controls.

- A reasonable amount of resources must be dedicated to the quick and effective establishment of a TMDL so that other water management programs for a watershed can proceed on schedule.

- All TMDLs must be accompanied by a load allocation scheme; otherwise implementation will become a nightmare as dischargers haggle over who was given what.

- Redefining or renaming "TMDL" would eliminate confusion with the traditional point source view of it as being chemical and facility specific.

- The use of ecological measures such as biocriteria, as TMDLs must be clarified. Can such measures be put into an NPDES permit?

- Finally, a comprehensive "how to" document is badly needed. There are numerous documents on waste load allocations and thousands of modeling documents, but the information is scattered. A comprehensive document that covers all of the aspects of TMDL development for watersheds with multiple pollutants and multiple pollutant sources would very useful.

5. SECTION PRESENTATIONS

5. Section Presentations

This section provides abstracts of the presentations that were given at the workshop. Any questions that were asked or comments that were made at the end of a presentation are provided at the end of each abstract.

PROBLEM DIAGNOSIS

Top-Down and Bottom-Up Approaches for Integrated Assessment of Point and Nonpoint Source Pollution

Kenneth L. Dickson
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Effective assessment and abatement of the impacts of point and nonpoint source pollution requires a watershed perspective and the use of a combination of physical, chemical, and biological resource characterization techniques. When looking at the watershed, using only bottom-up techniques (i.e., in-situ sampling, monitoring) is not sufficient. Techniques, such as remote sensing and geographic information systems (GIS), that look at the watershed from a total systems perspective -- from the top down -- must also be used.

Application of remote sensing and GIS to evaluate land uses in basins and watersheds, and to diagnose actual or potential water quality problems is more and more common. For example, the city of Dallas operates a number of reservoirs in the north central Texas region. There is no public control of the watersheds and several years ago, the City became concerned about nonpoint source impacts on the water quality in their reservoirs. Remote sensing and a GIS was used to evaluate the types of land uses in the region, to determine land use changes over time. This information was used with the universal soil loss equation to delineate areas with the largest erosion and and nutrient loss, and therefore, where the best locations for water quality monitoring of nonpoint source loadings might be. Once known, those problem areas were targeted for nonpoint pollution mitigation programs on a watershed basis. The information contained in the GIS for this project was also useful for siting of best management practices (BMP). The BMPs that were selected were sediment retention basins.

Bottom-up approaches for assessing point and nonpoint source pollution are also important and should be examined, since development of watershed mitigation plans requires knowledge of the stressor(s) impairing water quality. Ambient toxicity tests allow us to identify that there is a problem, but do not specify exactly what that problem is. Toxicity identification evaluations could help solve that limitation. In situ biological evaluations, such as rapid biological assessments, show population changes for species that are sensitive to specific stressors. These are techniques that need further research, but they are promising tools for water quality impairment diagnosis.

Questions

Q: How much did the remote sensing and GIS work for the project cost?

A: They cost less than $150,000.

Q: Why have no management plans been completed for the watershed if all of the data to do them is available?

A: The city of Dallas has not yet decided to commit the monetary resources to the public action/public involvement activities that would be required to complete such plans. The city, in fact, is a private utility where the reservoirs are concerned. As such, it has no regulatory authority in the reservoir watersheds. It must rely on extension services and cooperation from private landowners.

Q: How long must you monitor a water body in order to see the changes in water quality that are caused by the changes in land use shown by a GIS?

A: GIS can give you excellent information, when you are looking at long term trends in land use -- over years, or even seasonally for one year. It is possible to get satellite imagery for a watershed every sixteen days, but that may be overkill.

Q: We often see pollutant loading models where the fundamental driver of pollution is people, and the population is not included in the models, the analysis, or the presentation of the data. We use models, such as the Universal Soil Loss Equation, that pre-date the kind of population densities that we have today. Why would you not favor GIS, for example, that can take into account the available data on population densities and develop models that relate to the true cause of many water quality problems?

A: I agree. This issue is important and must be addressed. Census data could easily be overlaid in a GIS system to better define who is creating the largest pollution loadings. That depends on the scope of your study, however.

Diagnosis and Assessment Tools/Models for Determining Nutrient TMDLs

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The focus of this presentation is on techniques for estimating nutrient loadings, export fluxes, and balances for large watersheds. This presentation is a summary of four papers currently being published which utilized the numerous data bases of the upper Potomac River basin watersheds. The objectives are to:

1. describe the monthly and annual variability of nitrogen loading in the upper Potomac River basin, and the possible impact of this variability on implementing and evaluating BMPs;

2. determine the input and output flux rates of nitrogen and phosphorus for various land uses within the watershed and to compare these rates to other coastal watersheds;

3. determine various methods for establishing nitrogen mass loadings into coastal waters;

4. review input/output mass balances of nitrogen and phosphorus in the upper Potomac River basin watershed;

5. begin to determine the uncertainties in the mass loading and balance estimates;

6. examine how hydrology acts as a moderator of nitrogen processing within the watershed;

7. suggest how science may add to the workshop agenda.

Study Area

The study area is mainly the upper Potomac River basin (Figure 1). This basin was selected for several reasons. It is the second largest watershed in the Chesapeake Bay system and will be included in the December 1991 re-evaluation of nutrient removal requirements for the Chesapeake Bay. In addition, the Chesapeake Bay Watershed Model (Linker et al., 1991) is operational. Finally, numerous nitrogen management studies have been conducted in the region so that there is considerable data on nutrient sources, including annual basin nutrient loadings which were estimated by the Metropolitan Washington Council of Governments (MWCOG). A detailed nutrient inventory for the Potomac River basin was completed by J. Lugbill of the MWCOG in 1990.

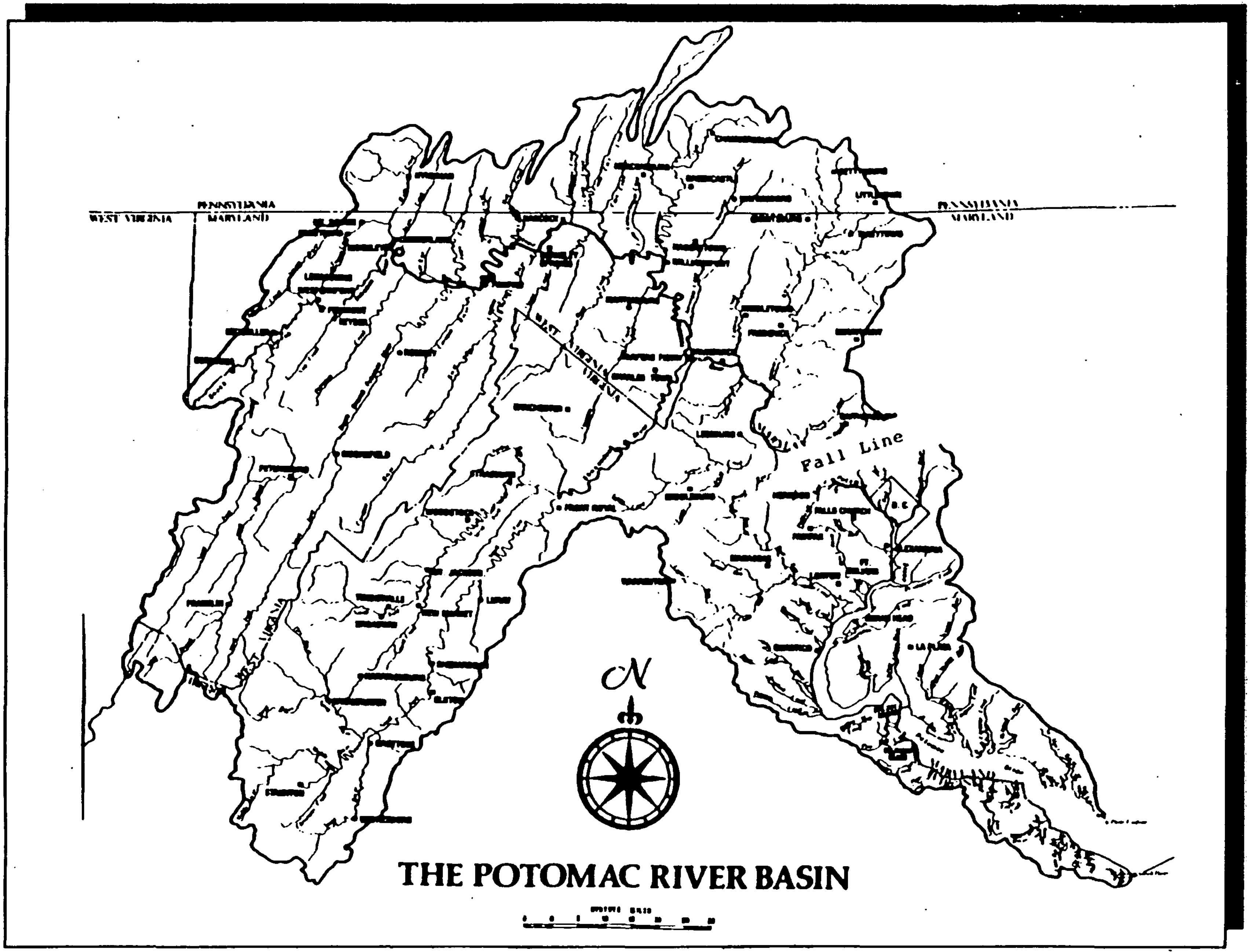

Figure 1. The Potomac River basin

Numerous other studies have been conducted on the nutrient fluxes of the Potomac River basin. Fisher and Oppenheimer estimated nitrogen input sources for the Chesapeake Bay in 1991 by two methods (Table 1). Of the 628 x 10^6 kg N yr^{-1} generated in the basin, their analysis suggested that 77% is retained in the watershed. Recent estimates of atmospheric nitrogen deposition have suggested similar rates.

Table 1. Estimated nitrogen input sources for the Chesapeake Bay (Fisher and Oppenheimer, 1991).

Sources	Differential Retention	Equal Retention
Point Sources	24%	29%
Atmospheric Nitrogen	25%	23%
Atmospheric Ammonium	14%	12%
Fertilizer	34%	16%
Animal Waste	4%	20%

A study by Jaworkski et al. (1991) determined mass balances for nitrogen and phosphorus for the upper Potomac River basin. A parallel study, conducted by Jaworkski and Linker in 1991, suggested that an "Input-Output Analysis Matrix" could be used to gain insight into nutrient sources and sinks on a watershed basis (Table 2). Further study by Groffman and Jaworski developed a linear relationship between nitrogen input and output fluxes for runoff and storage for various land use types.

Brief Summary of Analysis Conducted

Expanding on an nitrogen balance for the Chesapeake Bay by the Environmental Defense Fund (Fisher et al., 1988) and the MWCOG nutrient inventory for the Potomac River basin Lugbill, 1990), nutrient mass balances for the Potomac River basin were determined (Jaworski et al, 1991 and Jaworski and Linker, 1991). Groffman and Jaworski (1991) continued the analysis to determine the nitrogen input and output flux rates (kg ha^{-1} yr^{-1}) for various land uses within the watershed, and compared these rates to the coastal watersheds.

The high percentage of nitrogen (77%) estimated by Fisher and Oppenheimer (1991) in the Chesapeake Bay watershed and the 65% of nitrogen estimated by Jaworski, et al. for the Potomac River basin to be either volatilized, denitrified, or stored in soil, biomass or ground waters, suggest that nitrogen flow or flux across the various ecotones within the basin is the dominant factor that needs to be defined and quantified

To the author, the possible relationship between input and output flux rates suggests that there was great potential to further develop this relationship utilizing the ecotone concept suggested by Holland et al. (1991).

Table 2. The upper Potomac River basin, nitrogen mass balance calculations from 1983 to 1988 (kg x 10^6/yr).

Source (ha x 10^6)	INPUTS			OUTPUTS			
	Atmosphere	Animal Waste	Fertilizer	Point Source	Harvest	Lost to Atmosphere and/or Storage	Edge of Field Export
Forest	38.1	0.0	0.0	0.0	0.0	31.64	6.46
Urban	3.3	0.0	0.8	0.0	0.0	1.72	2.38
Agriculture	13.3	61.2	22.2	0.0	24.6	53.64	18.46
Water Surfaces	1.5	0.0	0.0	3.1	0.0	0.00	4.6
Subtotal	56.2	61.2	23.0	3.1	24.6	87.00	31.9
TOTAL	143.5			143.5			

River System Input	31.90
River System Loss	7.20
RIVER SYSTEM EXPORT	24.70

Conclusions

An analysis of the upper Potomac River basin and four watersheds in the Georgia coastal plain suggests that:

1. Highest nitrogen export occurs during periods of high surface water flows.

2. Monthly export was at a low of 0.01 kg month^{-1} for August 1966 with a high of 12.07 kg month^{-1} for November 1985.

3. Average annual nitrogen export form the basin varies over a factor of three from 10.6 to 33.2 kg x 10^6 yr^{-1}.

4. Export of nitrogen from the watershed is coupled closely to the hydrologic cycle.

5. Similarity of annual water yield and nitrogen yield time-series relationships indicate that processes which govern water yield also over nitrogen yields.

6. Of the 143.5 x 10^6 kg yr^{-1} total nitrogen input, about 42.6% came from animal waste.

7. About 60% of the 28.9 x 10^6 kg yr^{-1} of total phosphorus input came from animal waste.

8. River exports of nitrogen and phosphorus were 17.2% and 7.2%, respectively, of the total nitrogen and phosphorus inputs.

9. About 94.2 x 10^6 kg yr^{-1} or 65.6% of the nitrogen inputs were retained, lost to the atmosphere or stored within the watershed in either biomass or groundwater.

10. Of the 28.9 kg x 10^6 kg yr^{-1} total phosphorous inputs, 65.7% were retained in either the soil, biomass, or ground waters.

11. The greatest uncertainty in the nitrogen balance of the upper Potomac River basin is quantifying the amount of nitrogen lost back to the atmosphere or change-in-storage including the amount going to ground water.

12. For agricultural land use in the upper Potomac River basin, analysis suggests that there is significant annual nitrogen loading of ground water.

13. Current BMPs do not strongly affect nitrogen storage mechanisms within agricultural fields.

14. Development of innovative within-field, as well as off site, BMPs are important.

15. "First Principles" of science, hydrology and engineering can be applied to watershed pollutant management. There is hope!!!

References

Fisher, D., J. Ceraso. T. Mathew and M. Oppenheimer. 1988. Polluted Coastal Waters, the Role of Acid Rain. Environmental Defense fund, Washington, DC.

Fisher, D.C. and M. Oppenheimer. 1991. Atmospheric Nitrogen Deposition and the Chesapeake Bay Estuary. AMBIO. No. 3-4.

Groffman, P.M. and N.A. Jaworski. 1991. Watershed Nitrogen Management: Upper Potomac River Basin Case Study. Chesapeake Bay Res. Conference Proceedings.

Holland, M.M., P.G. Risser, and R.J. Naiman. 1991. Ecotones: The role of Landscape Boundaries in the Management and Restoration of Changing Environmental. U.S. Man and Biosphere Program and the Ecol. Soc. of Am., Washington, DC.

Jaworski, N.A., P.M. Groffman, A. Keller, and J.C. Prager (in revision, 1991). A Watershed Scale Analysis of Nitrogen Loading: The Upper Potomac River. Estuaries. Estuarine Research Federation.

Jaworski, N.A. and L. Linker, 1991. Uncertainties in Nitrgoen Mass Loadings in Coastal Watershed. Chesapeake Bay Research condreence Proceedings.

Jaworski, N.A. 1991. The Application of the Ecotone Concept in Defining Nutrient Managment Requirements for the Upper Potomac River Basin. Presented AMAB/UNESCO, IHP Workshop, Mikolajke, Poland, May 20-26,1991.

Lugbill, J. 1990. Potomac River Basin Inventory. Metropolitan Council of Government Washington, DC.

WATERSHED MODELING

Watershed Modeling and TMDL Assessments

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This presentation will focus on the potential use of watershed modeling techniques for Total Maximum Daily Load (TMDL) assessments. A general overview of watershed modeling will be provided, discussing both the nonpoint loading function and in-stream process components included in watershed models. The steps involved in the overall modeling process will be presented to demonstrate the various tasks of model input development, calibration, validation, and model testing. Available watershed models will be described through summary tables of model capabilities and limitations, with emphasis on the deterministic simulation of watershed (land surface and in-stream) processes at various levels of detail and complexity. Nonpoint load simulation procedures appropriate for different land use categories (e.g., agricultural cropland, urban, forest) will be discussed in conjunction with in-stream processes that affect that fate and transport of sediment, nutrients, and toxic contaminants.

The potential use of watershed modeling techniques to satisfy the assessment needs of the TMDL process will be explored in terms of the type of information generated by these models, the issues involved in selection of appropriate models, and the relationship of user and data needs for effective model application. Research, data, and model development needs will be identified to help focus program resources and objectives in areas that could most efficiently benefit future model use in TMDL assessments.

Questions

Q: Is uncertainty included in the model?

A: No, it is not. Although, in the last few years there have been more efforts to use combined techniques, such as Monte Carlo simulation along with deterministic models.

Q: How much effort has there been to link fate and transport models with the ecological effects of pollutant loadings?

A: There is an EcoRisk Research Program at EPA ERL in Athens, Georgia that has developed a model called PIRANHA. PIRANHA links pollutant loading, fate and transport, and food chain bioaccumulation in a geographic information system (GIS) context. It is in version 1.0 now, but it is not yet publically released.

Q: When we attempt to model a watershed system, many stream miles are omitted in order to decrease the complexity (and hence the computing time) of the model. There is a penalty for this simplification. Has any analysis been done on what you gain when adding complexity by adding higher order streams for better resolution within a watershed?

A: When you use smaller scales it is not clear that you are getting more detail; the discretization of your data is smaller. Although you may not lose detail when modeling on a large scale, there are other factors, such as computing time that must be considered. When the Chesapeake Bay was modeled on the order of 68,000 square miles for detailed soil and in-stream transport processes, modeling capabilities were dictated by the feasibility of doing it at that scale.

Q/C: It is important for modelers to clearly and concisely articulate the assumptions that are used to develop the models.

A: Extremely thick manuals that include all of the model assumptions are provided for many of the models I mentioned. Unfortunately, many users do not read through the manuals. If they did, the assumptions -- sometimes pages and pages of them -- would be evident. If one focuses in on a particular model application most of the time the information about important assumptions is there; sometimes -- many times -- the information is not as complete as it should be. For the comprehensive document on TMDL assessments that will be developed, it makes sense to make sure that the assumptions used in the various analyses are laid out clearly.

Water Quality Diagnosis and Assessment Tools/Models

Eugene D. Driscoll
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This presentation will provide an overview of screening methods that can be applied to characterize nonpoint source pollutant discharges (primarily urban stormwater runoff) and their receiving water impacts, and will also compare point source and nonpoint source loads and impacts.

In many cases, data limitations, system complexity, and budget and time constraints combine to preclude any meaningful load/impact predictions, which are usually the objective of formal complex models. The objective of analysis in such cases is limited to diagnosis of water quality and nonpoint source impacts based on the relatively limited information that is usually available. The diagnosis is then used to (a) support an assessment of the relative significance of different sources, (b) guide decisions for management plans, and (c) identify the most appropriate focus for continuing monitoring activities.

This presentation will discuss the general nature of the simplified screening methods, the types and availability of required input data, and the types of output results that can be generated. An example of how output has been used to assess the relative significance of point source versus nonpoint source pollutant load impacts on water quality will be presented. Approaches for addressing the TMDL issue, considering both point and nonpoint sources, will also be discussed.

An essential aspect of screening, or simplified analysis approaches is the time scale on which they are based. Normally, an average value is used for both the input parameters and the projected outputs. For example:

- Rainfall is converted to runoff using an average runoff coefficient (Rv). The value assigned for a catchment reflects the net effect of the deterministic elements (soil moisture and permeability, slope, depression storage, storm size), and can be estimated from available rainfall-runoff monitoring data, deterministic model runs, or the general percent impervious relationships that have been developed.

- Pollutant concentrations vary appreciably from event-to-event. A statistical analysis of available data is used to determine an appropriate "average" value (for a site, a group of sites, or a land use category), which can then be combined with runoff volumes to determine pollutant loads. Comparisons with larger data bases, organized in a comparable statistical manner, are used to improve the level of confidence in runoff concentration estimates based on limited monitoring data.

- Receiving water impacts are usually examined in either of two ways. For long-residence water bodies, such as lakes or bays, the operative parameter is usually cumulative loadings. Also, useful qualitative comparisons between point source and nonpoint source pollutant sources can often be made using comparative mass loadings. Where intermittent concentrations, rather than longer term mass loads are important, as in the case of assessing stream impacts, the statistical distribution of the runoff concentrations and flows are used to project the probability distribution of in-stream concentrations during storm events. Available models for performing this type of analysis include direct analytical procedures and Monte Carlo methods. In-stream storm concentrations can be expressed as return periods for concentrations that exceed applicable criteria. The probabilistic models provide a computational basis for combining point source and nonpoint source impacts.

Analysis can often effectively employ combinations that involve complex models and one or more of the simpler screening analysis elements identified above. A recent study for Santa Clara County, California, illustrates this. The program involved extensive monitoring, and the development of model projections of nonpoint source loads to South San Francisco Bay, for comparison with point source loads from publicly owned treatment works (POTWs). The EPA Storm Water Management Model (SWMM) was used to develop the runoff hydrology using rain data from a fairly dense rain gage network, so that significant orographic differences across the country could be properly reflected. Runoff quality model projections were based on the mean runoff concentration of the runoff quality. Model calibration was based on a comparison of projected total seasonal loads with loads developed from observed stream flow and concentration data.

A brief identification of some of the issues associated with the application of a TMDL concept to intermittent and highly variable stormwater discharge loadings, will be presented to serve as a reference for workshop discussions. One of the more important issues that should be addressed in the workgroup breakout sessions is the need to develop a consistent and useful interpretation of the legislative term "Total Maximum Daily Load", as it will be applied to nonpoint source discharges. Some of the difficulties associated with a literal interpretation include the following:

- MAXIMUM literally means "never, ever more than", which does not relate well to the substantial, inherent variability of rainfall driven nonpoint source discharges. We should perhaps consider interpreting "maximum" in terms of an appropriate return period, such as the "three years on average" that has been adopted for aquatic life toxic criteria for meals.

- DAILY LOAD applies reasonably well to POTW and industrial waste discharges which are usually characterized on a daily average basis. For nonpoint source discharges the operative time scale is that for a storm "event," whose average duration in the United States is on the order of six to twelve hours. Individual event durations range between one hour and 20 or 30 hours.

- For lakes or bays, daily or event loads are less significant in terms of water quality impacts, than cumulative loads over an extended period. Annual loads from nonpoint source differ markedly in wet and dry years, so that the concept of a return period is appropriate to consider, even in the case of annual loads.

TMDL is a meaningful concept for characterizing the total acceptable load to a water body segment, such that water quality objectives will not be violated under some selected design condition (e.g., stream flow and temperature). It relates well to continuous point sources and provides a framework for allocating present and future allowable loadings among a number of individual dischargers. The basic concept can, at least theoretically, be extended to address the regulation of pollutant load distributions between point source and nonpoint source discharges. However, if the concept is to be applied in a useful and meaningful way, it will be necessary to interpret TMDL in a manner that effectively reflects the important differences in the nature of point and nonpoint source pollutant discharges.

Questions

Q: Were the pollutant concentrations in the runoff that were reported as a mean value flow-weighted or time-weighted?

A: The event concentrations were flow-weighted means. The data that was developed for this example was either based on flow-in composite samples, or where it was a series of discrete individual samples they were integrated and then the event mean was estimated.

Q/C: One important advantage to working with empirical data, where it is available, is that you get a physical sense for how systems respond based on the data. It is an excellent reality check if you are involved with other complex or detailed modeling.

Model Capabilities (Agricultural and Urban)

Leslie L. Shoemaker
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Fairfax, Virginia

This presentation will discuss the suitability of available models for implementation of the TMDL process in both agricultural and urban areas. The TMDL process will first be described to highlight data requirements and the implementation process. Based on an evaluation of the data requirements, the need for screening models are will be described based on their ability to provide screening-level analysis for the TMDL process. A range of loading rate models will be evaluated, including annual load prediction techniques, spreadsheet models, constant concentration models, and screening models that are used by municipalities. Typical applications of loading rate models will be briefly outlined. The limitations of loading rate models will be evaluated and compared with the requirements for verification, accuracy, ease of use, and assessment of management effects.

Other options for screening-level analysis will be described, including "design storm" modeling, extrapolation from detailed models to develop long-term characteristics, simplified continuous simulation modeling, and statistical techniques. Example model results will be presented to quantify the benefits of various model types. A discussion of the requirements for verification, accuracy, ease of use, and assessment of management effects will be included for each option.

The use of more detailed models, such as HSPF (Hydrological Simulation Program - Fortran), SWMM (Storm Water Management Model), and CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) will be briefly discussed. In particular, the application criteria will be evaluated in relation to the associated level of effort. The cost benefits of model application will be described through examples. The benefit of using detailed models to predict in-stream pollutant concentrations on a continuous basis will be discussed. The associated costs for calibration and verification will be contrasted with the benefits of detailed simulation data.

Questions

Q: By going into more detail within a sub-basin, or going into a sub-sub-basin to the third and fourth order streams, do we really gain by it in terms of our predictive capabilities?

A: You gain predictive capability as you move to a smaller scale. You can do a more thorough job so far as modeling is concerned, allowing you to look at potential best management practices or management scenarios with a higher degree of accuracy. Going into a fourth order stream you can actually site a detention facility, for example, look at what is happening in that facility, and determine its effects on the watershed as a whole. That is good, but on the other hand, you have tremendously increased the amount of expended effort. You may not need or want to go into that much detail, depending on your goal. When modeling a very large area -- a basin such was the Chesapeake, for example -- a tiered approach should be taken. Determine where your hot-spots are using a screening-level model; then, use a more detailed or complex model for problem areas. This is particularly feasible if a GIS is available.

Model Capabilities - A User Focus

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From a practical perspective, the development of a TMDL and a National Pollutant Discharge Elimination System (NPDES) permit, and the calculation of nonpoint watershed loads are closely intertwined. Regulatory guidance states that the TMDL is equal to the sum of the waste load allocation (WLA) and load allocation or nonpoint allocation (LA). Hence the WLA (and ultimate NPDES permit) cannot be developed consistent with the TMDL unless the LA is defined. This presentation will review practical considerations in developing LAs as they relate to the TMDL and NPDES processes.

From a regulatory perspective, state staff typically need quick and simple approaches for calculating TMDLs and LAs for the large number of systems they regulate. Data, time, and resources are almost always limited. So far in the TMDL/LA process, we have seen either zero assumed for the LA, or the LA contribution has been set based on monitored in-stream concentrations. The Tualatin River and Dillon Reservoir are two examples where data were used (case presentation to follow). In another case, for the Columbia River dioxin TMDL, the LA was set after allocating the WLA to individual NPDES discharges. All told, the typical current regulatory approach to date has been simplistic, provides no information on the attainability of target LAs, does not assess the significance of changes in basin land use, and is typically constrained by a shortage of data.

At the other extreme from these simple approaches, rigorous predictive approaches are available to calculate watershed nonpoint loads and integrate them into the TMDL process. Research in the Great Lakes and Chesapeake Bay Basins are two examples. The Great Lakes studies probably demonstrate our earliest experience with TMDL type approaches.

International Joint Commission target loads were established in the 1970s to meet water quality objectives. Initial efforts focused on wastewater effluent restrictions. Since that time, rigorous modeling has been conducted in portions of the Great Lakes, such as Saginaw Bay, to evaluate the importance of nonpoint contributions and the tradeoff with additional point source reductions. The Saginaw Bay basin case study exemplifies how the use of intensive edge-of-field, minor drain and major tributary monitoring were combined with watershed modeling tools (ANSWERS [Areal Nonpoint Source Watershed Environment Response Simulation], and unit area loading) to calculate nonpoint loads under different scenarios. In this case, cost effectiveness analysis was conducted to evaluate tradeoffs among LAs and WLAs. The benefit and reliability of this approach is well proven, but the costs, skill level, and time commitment are prohibitive for typical regulatory use.

If the state of the art in watershed tools for TMDL/LA use is examined, it is evident that powerful tools are available, but involve heavy staff, schedule, and data burdens. Limited staff, schedule, and data, however, often require regulatory staff to seek out the most basic approaches, which have little predictive capability. There is, therefore, a need for easy-to-use tools that link models with readily available data bases.

The key concepts in striving to meet this regulatory need are exemplified by these phrases:

1) "easy to use;"
2) "linked models and data;" and
3) "readily available data."

Fortunately over the last decade we have seen substantial advances in simple, user friendly models, data linkages, and the use of GIS to better manage available data. Case Studies are presented to show the evolution and availability of these technologies, and to highlight the remaining need for a simple watershed/water quality model that is linked to GIS data bases. A newly developed prototype is demonstrated.

The presentation is closed with a brief overview of available technology, gaps, and regulatory needs. Key policy issues are also outlined, relating to design flow and episodic or cumulative effects which complicates the TMDL/LA analysis.

Questions

Q/C: The Wallon Lake Study involved looking at forested land and residential land uses. Determining cover for such land use practices is more simple than for agricultural uses where crop types and tillage practices must be considered. The Saginaw basin, however, is highly agricultural, and alternative land use practices (such as fertilizer management and conservation tillage) were evaluated using a more sophisticated modeling tool -- the ANSWERS model.

Q/C: The "solution" to nonpoint source pollution problems included GIS and nonpoint source models to get to nonpoint source controls, presumably. I would like to point out that the Coastal Zone Management Act (CZMA) Guidance has an even simpler solution to the nonpoint source problem; although it appears to digress a bit from the TMDL approach: "Implementation of nonpoint source management measures has been intentionally divorced from identified water quality problems because of the enormous difficulty of establishing cause and effect linkages between land use and water quality." Specifically, this says, "Hey, a TMDL isn't needed. We're going straight to the implementation measures and we're going to make everyone apply them."

A: (by Bruce Newton) We must recognize that there is a definite split in this country with respect to the regulatory approaches used to clean up impaired waters. One is the water quality-based approach, which is what this workshop is focusing on. The other is the technology-based approach. For the water quality-based approach, you develop pollution controls in order to attain specified water quality standards, controlling only as much pollution as is needed. The technology-based approach requires that all polluters apply controls; whether the control is needed or not. The CZMA amendments of last year set forth some technology-based approaches for the nonpoint source arena.

Q: If a State was to take a technology-based approach for nonpoint source controls on an impaired water body, and then submit that to EPA with a monitoring element and an explanation that it was intended to be an iterative approach would that be accepted as a TMDL?

A: (by Bruce Newton) It would have to be considered on a case-by-case basis; but it would probably not be accepted as a TMDL unless there was sufficient evidence to show that water quality was considered. If there was sufficient evidence then it would be considered a TMDL under the phased approach.

North Carolina's Basinwide Water Quality Management Approach to Developing TMDLs

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The North Carolina Division of Environmental Management (NCDEM) has determined that the requirements of Section 303(d) of the Clean Water Act will be fulfilled by the Division's ongoing basinwide water quality management initiative. NCDEM's initiative involves the development of management plans that address both point and nonpoint source pollution for each of the seventeen major river basins in the State. These management plans will include strategies for controlling targeted pollutants based upon the integration of chemical and biological monitoring, modeling, state and federal rules and regulations, and best professional judgment. Where appropriate, TMDLs will be comprised of management practices or strategies and will not necessarily include specific numeric loads.

Consistent and effective management within a given river basin requires consideration of pollutant sources and their interaction from the headwaters of the basin to its mouth. However, analyzing water quality on a basinwide scale poses a formidable challenge, particularly for model development. North Carolina surface waters cover more than 37,000 miles and are comprised of a wide diversity of systems (i.e., streams. rivers, lakes, estuaries, wetlands). These waterbodies are placed in a variety of geologic settings with multiple designated uses. More than 3000 NPDES discharges exist across the State, along with several hundred ambient monitoring stations. Aggregating the tremendous amounts of data for each basin into useful analytical frameworks is, therefore, no small task.

Increased access to sophisticated computer hardware and software (i.e. high speed/large memory personal computers and work stations, GIS technology, and relational database management software) along with the establishment of a well balanced and experienced Water Quality program staff, puts NCDEM in the position to truly implement Clean Water Act mandates for whole basin management (i.e., Sections 303(d) and 303(e)). Even with this well developed infrastructure, management tools must remain at a practical level. Resource constraints prohibit the development of highly complex, mechanistic models for all surface waters in the State; therefore, NCDEM has chosen to combine a moderate modeling approach with an aggressive field monitoring approach to develop and monitor the performance of its TMDL strategies.

For conventional wastes (e.g., BOD, NH_3), the Division will focus on calibrating large-scale QUAL2E and WASP (Water Quality Analysis Simulation Program) models along the main stream of the basin and on tributaries with significant pollutant loads where the State's empirical desk top model does not simulate the system accurately. The focus of these models will be on point source management with nonpoint source mechanisms incorporated into background and runoff parameters.

Nutrients are being addressed through the use of nutrient budgets, empirical models, and mechanistic models. Both point and nonpoint sources are included in the analyses. Modeling analyses are restricted to watersheds that are found or suspected to be sensitive to excessive nutrient loading.

NCDEM currently limits toxics using a simple mass balance technique in which interaction among various point and nonpoint sources is usually not considered. Since it is not practical to perform complicated mechanistic toxics modeling (e.g. T0XIWASP, HSPF) for an entire basin, the State is developing a GIS-based mass balance model which accounts for all point sources of a given toxicant within the entire basin. Nonpoint source interaction is accounted for in background and runoff concentration assumptions. More complex toxics models are developed on a case by case basis where local problems are sufficient to warrant the expenditure of substantial resources associated with this type of model development.

GIS appears to be the key to successful basinwide data analysis. The GIS system allows staff to readily aggregate information on pollutant loading, stream flow, stream hydrography, stream classification, land use, and chemical and biological monitoring. This tool enhances staff ability to assess water quality trends, prioritize areas of concern, determine model input, and display model results within the basin setting.

While NCDEM's modeling capabilities continue to improve, many issues remain to be addressed. The State's technical needs include how to establish linkages between various model types and GIS, how point and nonpoint sources should be addressed (since critical flows for point sources occur during low flow conditions and critical flows for nonpoint sources typically occur during high flow conditions), and how to evaluate toxics data when most of the values are less than the detection level. Although these research needs remain, the State is moving forward with its basinwide management approach to developing TMDLs.

Questions

Q: How will North Carolina incorporate biological data into the modeling?
A: Biological data will be used in the GIS as an overlay to determine where the problem areas are.

Model Integration and Data Access Tools

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During the past twenty years, EPA has tackled the cleanup of streams, lakes, and estuaries through WLA of point source discharges of pollutants. EPA's agenda for the future concludes that nonpoint source pollution is a major contributor to remaining water quality problems. Urban and combined sewer overflow issues are now urgent because of recent legislation.

The Office of Research and Development (ORD) in the past has conducted research efforts in developing models that can be used on watershed or basin scale problems. These models, notably HSPF, integrate the hydrology, chemical, and land management factors into frameworks for developing exposure and water quality management strategies. These research efforts were concentrated during the middle to late 1970s. Nonpoint source research during the 1980s has been limited mainly to model support and assistance in application. Very little research has been conducted to improve modeling capabilities or to take advantage of the ease of use of modern personal computers and work stations.

A set of water quality and nonpoint source loading models are available and supported by the Center for Exposure Assessment Modeling. These include the water quality models QUAL2E, WASP4, and HSPF, the nonpoint source models HSPF and PRZM (Pesticide Root Zone Model), the mixing zone expert system CORNMIX, and the probabilistic dilution model DYNTOX. Other specialized hydrodynamic and sediment transport models are also available. DBAPE, a national soils database and parameter estimation program, is available for rural nonpoint source analysis. These models and databases are distributed and user assistance is provided. Training courses are provided with resources from the Office of Water.

In addition to these EPA-supported models, other models and techniques have been developed by Federal agencies such as United States Department of Agriculture (USDA) or universities, and are used for particular tasks such as designing storm series or estimating soil erosion. For urban runoff, spreadsheets and regressions using National Urban Runoff Program (NURP) data and United States Geologic Survey (USGS) data have been developed and are in partial use. For agricultural runoff, the field scale USDA model GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) is in use, and different basin-scale models such as the SWRRB (Simulator for Water Resources in Rural Basins), AGNPS (Agricultural Nonpoint Source Pollution), and ANSWERS may be promising.

In the next five years, we need to make the transition from the existing WLA framework to the more comprehensive TMDL framework, which integrates WLA point source issues with nonpoint source load allocation concerns. To accomplish this, we need more comprehensive models and databases that are easier to use for wider application.

ORD should begin now to develop a generation of computational models that can accurately represent the interactions of land and aquatic ecosystems within landscape mosaics.

These models should be capable of accepting land use patterns and landscape configurations that occur in actual watersheds, rather than relying on large-scale aggregation which neglects the small-scale patch interaction important in real landscapes. Further, these models must be easy to use.

Research needs can be divided into model integration, database development, watershed processes (including both loadings from land uses and in-stream effects of nonpoint source loading), and groundwater/surface water interactions. These are briefly discussed below. A five year program is needed with stable funding to complete this next generation TMDL modeling package.

Model Integration

Several existing models, databases, and computational techniques address different watershed issues. The best of these existing models should be modified and linked to address EPAs watershed issues. Software is needed to integrate improved models and databases with modern pre- and post-coprocessors for ease of use. The resulting products should incorporate point and nonpoint source models, low and high flow conditions, perennial and intermittent loading, near field and far field effects, and chemical concentrations with biological response.

Database Development

A limiting step in the application of current models is often the availability of data in the proper form. Comprehensive databases of physical, chemical, and biological parameters must be developed and made available. Spatially variable data must be incorporated into a GIS that is linked to the models. Such data includes soil properties, land use, vegetative cover, predominant habitats and species, population density, meteorological and climatological patterns, stream flow, drainage areas, and urban characteristics.

Watershed Processes

More accurate models of land use and subsequent pollutant loading, and resulting in-stream effects of these loadings are needed for watersheds containing streams, lakes, and estuaries. To better estimate non-urban and mixed land use loadings, research is needed on BMP effectiveness. Such as the effects of buffer strips on sediment, nutrient, and agrochemical runoff. The incorporation of channel erosion into watershed loading models is necessary, as are improvements in algorithms that handle runoff, infiltration, and evapotranspiration. For urban/combined sewer overflow (CSO) loadings, screening estimates would use regression equations based upon NURP and additional USGS data bases, where relationships are developed with region, land use, dry weather deposition, climatological parameters. A data base for urban runoff controls needs to be made available to the user. For detailed evaluation and design purposes, SWMM and HSPF need to be enhanced with more physically-based quality procedures, and linked to the proper databases for ease of use. Scour and deposition of sediment and associated pollutants on the land surface and in the sewer system should be better characterized.

In-stream effects of watershed loadings includes the ability to predict the effects of sediment loading on habitat alteration, as well as the fate of persistent chemicals such as metals, dioxin, and PCBs (polychlorinated biphenyls). The interplay between surface water and benthic nutrients, the growth of benthic macrophytes, and the resulting water quality and habitat perturbations is a significant research need. The incorporation of benthic submodels, including sediment oxygen demand, into water quality models will give the ability to predict stream recovery following episodic loading events (such as CSOs) or upgrades in treatment of nonpoint source controls.

Groundwater-Surface Water Interactions

Chemicals that infiltrate may threaten groundwater resources directly, and surface water resources through base flow. Linkage between existing groundwater quality and surface water quality models must be developed and integrated with proper data bases.

Questions

Q: You seemed to indicate that you are against tightly integrated models to simulate processes that affect watershed water quality. Since a watershed is a tightly integrated system, why wouldn't you try to model its processes in an integrated fashion?

A: Yes, instead of one main model that a user would have to learn entirely, I would prefer to have three or four separate models in series. There might be one person in a State agency who understands runoff processes. He would be able to use one model to produce files of loadings to a stream. The State agency might have a different person who knows receiving water processes; he could take and use the loading files without understanding all of the details of the runoff model. He only needs to understand his receiving water model. There are, however, some benefits from doing an integrated assessment automatically. It is more efficient, for example.

Q: Does the Center in Athens have funds for technical support to people within the Agency?

A: Yes. The Center does have funds for technical support that is available to anybody, not just Agency personnel.

Q: Is SYMTOX available through the Center?

A: It was recently updated and we are becoming familiar with is in Athens. It is not in a standard distribution yet; but, it is a simple model and will not be hard to distribute soon.

DATA SOURCES, TOOLS, AND INVESTIGATIONS

Multistage Remote Sensing Data Applications for GIS Data Base Development in Support of Nonpoint Watershed Modeling

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With the proliferation of geographlc information systems (GIS) in both academia and government, there has been a tremendous increase in demand for remote sensing as a data input source to spatial data base development for nonpoint watershed modeling applications. Products derived from remote sensing are particularly attractive for GIS data base development because they can provide cost-effective, large area coverage in a digital format that can be put directly into a GIS. Because remote sensing data is collected in a raster format, the data can be cost-effectively converted to a vector or quadtree format for subsequent spatial watershed modeling analysis.

The approach of using multiple sensors to create spatial data bases with variable levels of spatial and categorical resolution is currently being applied to develop cost-effective land cover/land use (LC/LU) data bases for large area watersheds. Remote sensing satellite platform sensor combinations of particular importance for watershed modeling application include LANDSAT Thematic Mapper (TM) for land cover mapping, and SPOT panchromatic data for land use delineation. Resolution enhancements can be added in a multistage approach over "selected" areas using higher resolution aircraft scanner data and/or aerial photography to meet specific model data input requirements.

Satellite and aircraft multispectral data will be presented to demonstrate the attributes of each data type in terms of spatial and spectral data content. Application(s) of each data type will also be addressed. An overview of the satellite data processing for the 68,000 square mile Chesapeake Bay watershed data base construction project in support of the Agency's EMAP (Environmental Monitoring Assessment Program)-LC program and the Chesapeake Bay Program Office, will be provided. An application of multistage satellite and multiple aircraft sensor data for ecological process studies being conducted at Green Bay, Wisconsin and at Saginaw Bay, Missouri, will be presented in closing.

Questions

Q: Remote sensing and GIS currently provide a static display of data. Is it possible to animate the display to show change over time?

A: Yes. There is a lot of research going on in that area. Currently, are two methods are available. One is image differencing. The other involves doing a classification for two points in time, and then comparing the results. The accuracy of your data must be known, however, so that the comparison is of actual changes in the landscape, not error. Animating the display to show change over time is an integral part of the EMAP-LC program. EMAP involves updating the landscape characterization data bases for the entire country on a 10-year cycle to look at change and, eventually, trends.

Q: What is the minimum space you would need on your computer disk to generate GIS displays? Is it at all feasible on an IBM 386?

A: I would recommend that you use a work station. How much data you are going to enter and manipulate needs to be considered, however. That will determine how much disk space you need.

Q: The Chesapeake Bay classification system represents a lot of work. Stage one was agriculture; stage two broke out two categories, one of which was crops; stage three broke the crop category down into ten crops. How much effort and expense was involved with doing the stage three breakout?

A: Crops are difficult because their growth stages must be captured in the imaging in order to do a thorough job. This means that the data must be ordered up front. The satellites that we have up now -- LANDSAT 4 and LANDSAT 5 -- are not being operated unless a request is made, because the sensors are past their life stage.

GIS for Nonpoint Source Watershed Modeling Applications

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The EMSL-LV Spatial Analysis Team is charged with the application of GIS to the mission of the EPA. During the last two years, the Team has been addressing the use of GIS to support nonpoint source pollution modeling. Two projects will be addressed that will show the use of various models to understand the effect of management practices on sediment delivery. The two projects are summarized below.

Arizona Rangelands Water Quality Project

The Arizona Rangelands project demonstrates the use of geographic information system (GIS) technology to support nonpoint source pollution modeling. In particular, the Agricultural Nonpoint Source Pollution (AGNPS) model was used to model sediment loading and delivery in the surface waters of the Wet Beaver Creek watershed of north-central Arizona. The objectives of the project were (1) to support Arizona Department of Environmental Quality in its watershed management practices, and (2) to provide the EPA with standard operating procedures for linking the ARC/INFO GIS with AGNPS.

Blackfoot River Nonpoint Source Pollution Modeling

GIS techniques are being used to develop the basic data layers, analytical procedures, and graphic user interface necessary for watershed-level modeling of nonpoint source pollution. Because silviculture is the predominant land use activity in the watershed, the USEPA/ESFS Water Resources Evaluation Nonpoint Sources Silvicultural (WRENSS) model was selected to characterize nonpoint inputs to Blackfoot River subwatersheds.

Some concluding remarks will be offered on use of models, data preparation, quality control, and management perceptions.

Questions

Q:. Can you provide some feeling for the error involved with using satellite imagery and GIS, and the magnitudes of alternatives that result?

A: There is no readily available, quantifiable method to tell us that the data derived from satellite imagery are plus or minus a certain accuracy at a certain confidence level. That is one area that must be explored.

GRASS Waterworks - An Interface between GIS and Models

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GRASS Waterworks is a tool box of utilities written at Michigan State University for use by the U.S. Department of Agriculture Soil Conservation Service (SCS) and other organizations involved in soil and water conservation and environmental planning and assessment. It helps to analyze the field and watershed-scale parameters needed to model hydrologic processes that are affected by the agricultural management decisions concerning water quality, erosion, and sedimentation control. This tool box can be thought of as a preprocessor of parameter information for use in water quality modeling.

GRASS Waterworks is also an interface between GRASS and AGNPS at this stage of development. GRASS, the Geographical Resources Analysis Support System, was developed by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (US CERL), in Champaign, Illinois. The GRASS version used is the SCS version. AGNPS is a computer simulation model developed to analyze the water quality of watershed runoff. This interface is developed using the UNIX shell scripts on the AT&T 6386 computer.

The goal of GRASS Waterworks is to use GIS techniques to derive model parameters. It requires basic map layers, such as the digital elevation model (DEM), soils, streams, and LC/LU (frequently derived from remote sensing), and the soils data base to provide information. The tool box then works interactively with users to derive all of the 22 parameters needed by the AGNPS model. Output from GRASS Waterworks is an organized data input file which can be converted into DOS data format and put directly into to the AGNPS model.

Future development of GRASS Waterworks will focus on incorporating additional parameters so that it can be use with models, such as NLEAP (Nitrate Leaching and Economic Analysis Package), GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), EPIC (Erosion-Productivity Impact Calculator), and NPURGE.

Questions

Q: What size watershed can GRASS Waterworks together with AGNPS handle optimally?
A: From a few acres to about 50,000 acres.

Q: Monte Carlo simulation is used often by modelers to determine where the sensitivity lies in the model variables. Now, with GIS, can similar kinds of Monte Carlo simulation be done with the spatial arrangement of the cells to see if, in fact, shuffling the cells makes a difference?
A: We have done some research in that area and it is daunting. Depending on how many of those cells you take and how you calculate the slopes, spatial sensitivity of the data can be very high.

Q: Does the AGNPS user need to know how to use GRASS, also?
A: No extra burden would be placed on the user to learn the model. The idea of expert systems and shells is to have the shells as transparent as possible.

Q: Why did the Soil Conservation Service choose to use GRASS instead of ARC-INFO, which EPA uses?
A: ARC-INFO cannot be used on a field office personal computer; GRASS can and it is easier to use.

Remote Sensing of Agricultural Practices, and Downstream Water Quality as Influenced by Sediment from Nonpoint Sources

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A series of experiments funded over ten years have addressed measurements of nonpoint sources of sediment in watersheds and tributaries of Lake Erie. The goals were to implement a combination of on-site sampling and remote sensor technologies for measurement of causal factors and transport mechanisms of sediments. The studies focused on the lake bed and glacial till soils farmed in watersheds of the Sandusky River, and techniques to measure suspended sediments that are transported through Sandusky Bay to nearshore Lake Erie.

A detailed study of farmed fields in Seneca County, Ohio, was conducted from 1988-1990. Fifty-five field sampling sites were visited every two weeks from March to October. We evaluated fields with corn and soybean crops, lake bed and till soils, conventional and conservation tillage practices, and farms with and without tile drainage. The field data collection was coordinated with overpasses of the LANDSAT satellite, to evaluate the utility of satellite data for measuring factors influencing nonpoint source pollution. Measurements were conducted during the drought of 1988, the normal rainfall year of 1989, and the high rainfall year of 1990.

Results will be reported with a special emphasis on parameters important to 303(d) activities. Results are related to characteristics of sedimentation, crop and residue cover (LAI, wet biomass, actual yield), and general capabilities of remote sensor data that can assist in 303(d) efforts.

A second experiment demonstrated remote sensing capabilities for measurement of suspended sediments in Lake Erie waters. A combination of on-site sampling, multiple-date satellite data, and results of a water quality hydrodynamic model were used to follow and quantify the transport of sediments from Sandusky Bay into nearshore Lake Erie. We focused on a storm period in 1981 when the bulk of sediments from nonpoint sources were transported into the open lake. Remote sensor data were used to make thematic maps of surface suspended sediments, and were used to validate results from a water quality hydrodynamic model.

These experiments demonstrated many of the capabilities of remote sensor data for evaluations of nonpoint sources, and the results also present the "continuum" of the problem from source farm lands to the impacted area -- eutrophic Lake Erie.

The Trials, Tribulations, and Successes of Using Remote Sensing, GIS, and Modeling

by Carol Russell
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During my tenure at the Arizona Department of Environmental Quality (ADEQ), I experienced a number of trials and tribulations while using remote sensing, GIS, and modeling to evaluate the potential impacts of nonpoint source pollution. This article briefly relates not only my problems, but also my ultimate success using these methodologies. I hope my experience will facilitate their use by others.

To have a common basis for discussion, I will briefly describe my team's methodology and define terms. In the examples that follow, remotely sensed data originated from satellite imagery and aerial photos. "Remotely sensed" data is collected using sensors not in direct contact with the object. A GIS was then used to interpret our remotely sensed data and compare it accurately with other available data. A GIS is a computer system that stores, analyzes, and displays spatially related data. The GIS data layers were then used as input parameters for our modeling efforts. Our models were designed to simulate the transport of sediment within a watershed in order to determine the effects of nonpoint source pollution, which results from diffuse land uses.

In order to gain perspective on remote sensing, GIS, and modeling, it is helpful to use the imagination. Picture the galaxy, then increase the resolution until you can see our solar system. Increase the resolution more to obtain a view of the earth as seen from the moon. Even more, our continent; then Arizona, the Phoenix area; Sun City; a back yard; a pond. Although the scene changes, it can be argued that we are looking at the same thing in each instance. Nevertheless, it is clear that the shift in perspective radically affects what we perceive. Similarly, the usefulness of remote sensing tools in the decision-making process is dependent on perspective and scale.

Remote Sensing, or "Can the answer be seen?"

One of our first trials, and also our first success using remotely sensed data at the ADEQ addressed a pesticide problem encountered in the western Phoenix metropolitan area. Painted Rock Reservoir is located at the terminus of a watershed where the pesticide residues were so high in the fish tissue samples that the entire state park was closed. Our efforts to employ remote sensing to determine the origin of the pesticides were unsuccessful for three reasons: (1) We were unable to correlate visible land uses with pesticide use; (2) we were unable to visualize the contaminant transport mechanisms; and (3) the project area was enormous. Simply put, we were using a picture to provide an answer, when the answer could not be seen.

Although remote sensing did not yield an answer to this pesticide problem, it is nevertheless a valuable tool that can address other types of problems successfully. For example, in the Maryvale area near Sun City, there was a leukemia cluster in children that, we hypothesized, was caused by residual pesticides in the soil. Land use in the small area had recently changed from agricultural to residential. Using remote sensing, the Arid Lands Research Center in Tucson mapped the land use changes over time using aerial photographs and a GIS. Remote sensing and GIS mapping then were used to stratify soil samples in order to make a statistically verifiable and scientifically defensible evaluation that residual agricultural pesticides coincided with the leukemia deaths.

Note that when one maps changes in land use, it is necessary to begin with a base map that can then be modified for changes each year. Mapping each year separately and then trying to overlay them will not work because of technical differences in equipment, shot angle, lens distortion, etc., in the images taken over the years.

How does this example relate to water quality? The data generated on the pesticide residues will be combined with geographically indexed data on water quality, crops grown, soil types, and water usage to advise farmers on a site-by-site basis. Farms will be targeted by the calculation of risk potential to reduce the loading of sediment and associated absorbed pesticides that may be moving downstream to Painted Rock Reservoir. The intent is to "keep the soil down on the farm," so to speak.

GIS and Time

Tribulation and success number two involved Arizona's Nonpoint Source Assessment program. A GIS was used on a statewide basis to help determine what types of nonpoint source pollution were causing nonattainment of water uses. Our intent was to maximize personnel efficiency, because site visits could not be made to each watershed to determine potential pollution sources. The methodology seemed reasonable since types of nonpoint source s are, essentially, land uses. We encountered, however, many problems. The latitudes and longitudes of facilities permitted for water discharges to surface and ground water were not accurate, and most were not even mapped. The maps that did exist were not current. For example, the most recent statewide map of irrigated land was charted in 1969! Furthermore, we made the assumption that all lands in Arizona outside of cities and military reservations were used for grazing, since in the state even wilderness areas were grazed.

In retrospect, we could have visited every watershed in Arizona in the time it took to construct the data base. Additionally, after one year of training to become fluent in the use of GIS technology, our people became a prized commodity. Most government agencies cannot compete with private sector salaries, and ADEQ lost people for this reason. The only tangible success of this endeavor was a beautiful set of maps that raised management's awareness of nonpoint source problems in Arizona, and potential uses of GIS technology. Unfortunately, GISs are a very expensive and time-consuming method to make pretty maps.

An indirect benefit of the project was the development of more detailed GIS data bases. For example, the Department of Water Resources annually maps agricultural land in active management areas for water conservation purposes. This ensures that no additional land goes under cultivation. Additionally, wetland and riparian vegetation in special areas of concern have been mapped with the assistance of the U.S. Fish and Wildlife Service to determine acreage loss.

Modeling and Gross Estimates

The third example, the Arizona Rangeland Study, attempted to determine if water quality standards would be consistently violated if forested lands were converted to range land. In Arizona, where water is a premium resource, a proposal surfaced to augment the water supply by vegetation manipulation -- cutting trees. At ADEQ, we were concerned with the water quality implications of this proposal. Choosing a model, however, was difficult. We needed to know the event-related nonpoint source pollution loading, and no current model provided the information accurately on a watershed level; we anticipated, however, that the Water Erosion Prediction Project (WEPPS) under development by the Soil Conservation Service, the Forest Service, and the Bureau of Land Management would provide the needed information. We chose the AGNPS because of its similarity to WEPPS regarding parameters that could be derived from GIS covers. We also conducted sensitivity analyses to determine the validity of our GIS and other parameter inputs.

The primary weakness of the AGNPS model was the rainfall parameter. Precipitation distribution is highly variable in Arizona, whereas the model would take only one measurement of rainfall across the entire watershed. We attempted to use Kriging programs to estimate more accurately the distribution of rainfall based on real measurements, but the AGNPS program would not accept the data. Furthermore, the AGNPS model is field-based rather than watershed based, and the very steep terrain we encountered resulted in questionable results. We concluded that the model could only be used for qualitative, and not quantitative, predictions. Nevertheless, the program may be successful in the future when final decisions are made regarding the water augmentation project. In addition, we anticipate success in using the model derived for this one watershed on other watersheds for prioritization purposes.

Questions

Q: How many people in the State water quality agency have worked using satellite imagery for their projects? Were there other expert sources (e.g., universities) that could be tapped to help develop and use the GIS.

A: The ENSL lab in Las Vegas has been helpful. Arizona has made a direct commitment to the utilization of GIS, and the sharing GIS information across the board has made it more economical to use remote sensing as a tool in water quality and wildlife management. The Fish and Game Department uses it, and also the State Land Department for fire prevention. Unfortunately, there are not enough people within ADEQ who know how to use the tools. The technical expertise is not there. It takes from one to three years to become truly comfortable not only on a technical level, but on a management level, too. In general state level managers are weak in their understanding of how much time data generation requires, whether their questions be answered using remote sensing, GIS, and/or modeling, and whether they can afford it?

Q: What is the turnover rate among state "technical experts" in ADEQ?

A: An individual who has expertise in remote sensing and GIS can command almost double what he can make with the state; therefore, turnover of experts at the State level is high -- about 1 per year.

PREDICTIVE MODELING OF ECOLOGICAL RESTORATION

An Overview of Ecological Assessment and Restoration Tools

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Restoration of aquatic ecosystems requires knowledge of the biological physical, and chemical components of these systems and identification of the spatial scales at which they interact. Assessment of aquatic systems typically involves analysis of functional (e.g., production, decomposition, nutrient dynamics) and structural (e.g., species richness, trophic structure) elements that are important to maintenance of system health and stability.

Anthropogenic influences that adversely effect functional and structural aspects of aquatic systems occur at variety scales ranging from a few square meters to hundreds of square kilometers. Assessment of these influences requires recognition of spatial and temporal scales of importance. Conventional means of measuring important ecosystem components along with the development of biological indices that integrate both structural and functional information can describe system health. Emerging technologies (geographic information systems [GIS]) for quantifying watershed and land use characteristics that influence aquatic systems show much promise for defining and relating spatial features to ecological end points. Several multivariate statistical techniques are available for integration of complex data and determination of limiting environmental features.

The most effective restoration methodologies address limiting environmental features at scales complementary with the processes that cause disturbance. Most often the focus is on aquatic-terrestrial ecotones. These ecotones moderate the exchange of nutrients and other materials across the landscape. Knowledge of the morphology of ecotones is particularly important when attempting to restore wetlands and streams. In streams, the dynamic nature of stream channels and response of these channels to common perturbations must be taken into account before designing restorative measures. In a large river restoration project in Idaho, the major restoration design feature revolved around creation and revegetation of a floodplain for a meandering river. Ecological restoration can be an effective means of reducing pollutant loadings to aquatic systems.

Questions

Q: How much did the Idaho restoration project cost?

A: The approximate construction cost of this project was one million dollars per mile. In this case, the cost was justified as a one time expenditure that had a restorative effect on sixty kilometers of stream with endemic chinook salmon populations.

Q: What scale should watershed planning/restoration occur at?

A: It depends on the scale of the problem. If the problem is a road crossing that causes erosion into a stream, a local solution is usually all that is required. However, the most persistent and difficult nonpoint source problems are often the result of cumulative effects (many erosive road crossings) or large scale practices like agriculture. Large watersheds may be the only effective scale at which to deal with these problems.

Q: What are the implications of linking biological integrity to the physical chemical status of a stream?

A: When discussing pollutant control on a watershed basis, it is important to know what impacts pollutants have on the aquatic biological communities. As scientists, we would like to understanding or be able to predict the observable, quantitative linkage/change in a community when a specific pollutant loading is reduced by twenty percent, for example.

Application of Tools for Ecological Restoration
Predictive Modeling

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Although restoration techniques exist for wetland, lake, and running water ecosystems, modeling efforts have been focused on predicting the effects of restoration on lotic ecosystems. The recently introduced concept of hydraulic stream ecology suggests that a primary template influencing the distribution of riverine organisms is the complex hydraulic conditions which exist as the result of the interaction of depth, velocity, and substrate. Thus, with the aid of simulations which combine the physical habitat preferences of riverine organisms and predictions of changes in hydraulic patterns after structure placement, it is possible to weigh the estimates of available habitat by response factors which indicate tolerances to certain conditions at each mitigation site. It must be remembered that most of these models are not at the stage of predicting "true" ecological response (i.e., changes in production, biomass, recruitment, etc.), but offer stream managers a scale to compare relative magnitudes of improvement or success of the restoration effort.

Examples of application of these models include the prediction of the effects of placement of a single structure (a flow re-regulation dam) on trout fisheries with and without alterations of release schedules from peaking hydropower facilities and an extensive physical restoration of meander, substrate, and habitat structure after coal surface mining. In both cases, components of the Physical Habitat Simulation (PHABSIM) [maintained by the U.S. Fish and Wildlife Service as a portion of the Instream Flow Incremental Methodology] were used to predict the effects of habitat improvement.

In combination with the Branched Implicit River Model (BIRM) to predict changes in stage, a dynamic advective water quality model, RIV1, maintained by the U.S. Army Engineers' Waterways Experiment Station, has been successfully used to predict the changes in basic water quality parameters downstream of Wolf Creek Dam on the Cumberland River in Kentucky. A subroutine, RIV1H allows the "placement" of in-stream structures in the model. In this case, a reregulation dam affected both water quality and the amounts of available habitat for rainbow and brown trout. Trout habitat availability was predicted by linking RIV1H water surface elevation predictions and surveyed whole-valley profiles to the hydraulic simulation, IFG4. The predicted changes in hydraulic patterns were combined with habitat preference curves for trout species (juveniles and adults) in the HABTAT simulation to indicate that reregulation (even with turbine uprates which increase maximum discharges) effectively increased habitat availability. Since predicted water quality changes were within optima provided by toxicological studies, no additional weights were applied. However, if the response curves are available, this same technique can be used to predict combined effects of water quality and structural change in the river system.

In coal surface mine restoration projects on the Tongue River, Wyoming, PHABSIM was used to predict the amount of available macroinvertebrate and fish habitat prior to placement of restoration structures. The model predicted that, after implementation of restoration, changes in water surface elevation and velocity downstream of these structures would dramatically increase habitat availability and, presumably, diversity and density of the fauna. Macroinvertebrate densities and diversities were a full three-fold higher than unrestored sections and fish densities (although primarily transient individuals) were three to five times higher than unrestored areas. Monitoring of the fauna for two years indicated that a source-distance effect must also be incorporated into future models. That is, areas further downstream (even as short as one kilometer) may take 300 to 600 days longer to equal the community structure of areas immediately adjacent to sources of faunal colonizers. This research also revealed the need for future research into the effects of changes in hydraulic pattern on colonization rates. If it were possible to construct "suitability for optimal colonization curves," PHABSIM could be used as a predictive response model for future restoration projects.

Projected research on the effects of in-stream structures to control nonpoint sources from agricultural areas, combinations of in-stream habitat improvements and cascades of low head re-regulation weirs, and long term studies of habitat improvements and recruitment of endangered mussel fauna and host fish will allow the "fine tuning" of existing models to better predict effective management strategies to stressed ecosystems.

Ecosystem Assessment and Restoration: The Role of Modeling and Predictability

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Modeling the effects of stresses on ecosystems should be conducted with the objective of assessing both current and future status of the ecosystem. This objective can be achieved by placing the ecosystem into a framework of structure and function, and modeling the ecosystem with a structural equation modeling procedure called LISREL.

Using LISREL, it is possible to develop empirically-based models that combine aspects of simulation modeling with statistical analyses and hypothesis testing. Modeling with LISREL generates a measure of the stability of the ecosystem, thereby generally predicting the ultimate fate of the ecosystem. These models can be analyzed further to provide additional information concerning the future status of the ecosystem including (1) ecosystem sensitivity -- what functional pathway within the ecosystem, when perturbed, results in the greatest change in the stability of the ecosystem, (2) ecosystem projection -- given a set of parameter values for the structural components of the ecosystem, what happens to the structural components at some time in the future, (3) perturbation analysis -- what happens to the structural components and the overall integrity of the ecosystem if an anthropogenic stress affects the ecosystem, and (4) hierarchial structure — at what level of taxonomic/tropic/functional resolution does the system gain/lose stability when impacted by an anthropogenic stress. This information can be used to develop risk assessment protocols for ecosystems, and as an aid in restoration of ecosystems known to be impacted by anthropogenic stresses.

Questions

Q: What was the time step used for the calculations; and how much data collection is necessary to validate LISREL?

A: The data was collected each summer; although, it may have been better to shorten that time step to early-summer, mid-summer, and late-summer. Since the model is empirical, the classical validation techniques that were discussed yesterday during the watershed modeling presentations, are not applicable.

6. WORKGROUP BREAKOUT SESSIONS

WORKGROUP #1: WATERSHED MODELING

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INTRODUCTION

The breakout session focused upon one simple question: "How (if at all) should models be used in the Total Maximum Daily Load (TMDL) process?" There was significant debate and many differences of opinion among those responsible for developing TMDLs and those responsible for complying with them. A compromise approach was generally agreed upon, although two unresolved issues were identified.

DISCUSSION

State of the Science

Watershed models are used to estimate loadings from both point sources and nonpoint sources of pollution from urban and rural land use activities, and are particularly useful in the pollution allocation phase of the TMDL process. EPA currently distributes two relatively complex watershed models -- Hydrologic Simulation Program - Fortran (HSPF) for urban and rural mixed land use activities, and Storm Water Management Model (SWMM) for urban land use activities. EPA also provides some limited technical support for these models, but such support needs to be expanded if they are to be used on a wider scale. U.S. Department of Agriculture Soil Conservation Service (USDA SCS) has developed six simpler and more user-friendly models that may be useful to the TMDL program. They are Agricultural Nonpoint Source Pollution Model (AGNPS), Simulator for Water Resources in Rural Basin-Water Quality model (SWRRBWQ), Erosion-Productivity Impact Calculator (EPIC), Groundwater Loading Effects of Agricultural Management Systems (GLEAMS), Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS), and Nitrate Leaching and Economic Analysis Package (NLEAP).

GLEAMS, CREAMS, EPIC, and NLEAP are field scale models and therefore have limitations with regard to the TMDL process. The SWRRBWQ model can be applied on a watershed basis for continuous simulation, however, additional development of model components for nutrient and pesticide transport is underway. The AGNPS model is watershed based, but is currently limited by application to design storms only. USDA is currently upgrading the model to include continuous simulation as well.

One limitation that was identified by the Workgroup is a lack of available data to permit proper validation of nonpoint source model applications. Use of these state-of-the-science models with that data that is currently available was deemed appropriate only for determining relative impacts, not for predicting absolute loadings. A second concern was that there are multiple Federal agencies each supporting different nonpoint source models. It would be helpful to States, local governments, and other model users if the Federal agencies coordinated their efforts.

Limitations of Tools and Data

Other federal agencies, the Regions, and States have been mandated to develop TMDLs as soon as possible using whatever data are available. A primary concern among these groups, as well as EPA, is the availability of models that can be quickly and easily applied to the TMDL process. Use of "state of the science" models was not considered to be necessary or even desirable given the limited expertise and funding among most users. Use of simple models is considered acceptable as long as the approach to develop the TMDL is reasonable from a scientific point of view.

Those responsible for complying with TMDLs (e.g., U.S. Forest Service, USDA) do not believe that the predictions of currently available models are sufficiently reliable to base management decisions that may require expensive pollution control measures. Although models are useful in determining relative impacts, their ability to predict absolute pollutant concentrations is highly suspect.

TMDL Applicability

Consensus

A loose consensus on the use of modeling in the TMDL process was eventually reached. The consensus approach closely matched the "Phased Approach" described in EPA's *Guidance for Quality Based Decisions: The TMDL Process* (EPA, 1991), even though the great majority of workgroup participants had not yet seen this document. The steps of the Phased Approach are:

1. Perform simple, screening level modeling using existing data to define a "Phase I" TMDL in the timely fashion required.

2. Implement the pollution controls identified in the Phase I TMDL.

3. Conduct a monitoring program to: a) determine if the Phase I controls are appropriate for compliance with applicable water quality standards, and b) provide a database for more rigorous modeling.

4. Perform additional modeling and develop a Phase II TMDL, if monitoring data show that the Phase I TMDL was inappropriate.

Unresolved Issues

Two issues were identified by the group that remain unresolved:

1. How quantitative must the Phase I TMDL be?

2. By what process should a TMDL consider the range of potential flow conditions that might affect pollutant loading to a water body?

Discussion of development and use of the Phase I TMDL lead to a stalemate between the regulated community and the regulators. To facilitate the permitting process, regulators have an obligation to define specific, quantitative load allocations (LAs) and waste load allocations (WLAs) for a Phase I TMDL. The regulated community believes that Phase I TMDL modeling should be used only to screen the relative effectiveness of various pollution control strategies, and that quantitative LAs based on screening level modeling would be too unreliable to base a permit requirement on them.

The second unresolved issue pertains to flow conditions for which the TMDL will be applied. Point source NPDES (National Pollutant Discharge Elimination System) permit limits have traditionally been calculated based on low flow conditions, since pollutant concentrations are highest, and therefore most critical, during low flow periods. Most nonpoint source pollutant contributions are highest during high flow, or storm events, when runoff from construction sites, and agricultural or silvicultural areas is most likely. However, point sources are still a consideration at high flow, and some nonpoint sources are important at lower or average flows. The specific process by which the TMDL should consider the range of potential flow conditions was unclear to the group.

RECOMMENDATIONS

Seven categories of recommendations based on both short-term (S) and long-term (L) needs were identified.

Guidance

- Convene a small group of experts from each facet of the TMDL process to explore the existing science, provide immediate short-term technical guidance, and develop a long-term strategy for developing TMDLs. (S)
- Implement the long-term strategy identified by the expert group. (L)
- Continually update and refine TMDL guidance. (L)

Case Studies

- Compile and evaluate existing watershed and TMDL modeling efforts. (S)
- Build a long-term record of case studies among Agencies, Regions, and States, focusing upon model validation and uncertainty. (L)
- Conduct more work on an inter-Agency level. (L)

Research

Geographic Information Systems (GIS)/Data Management

- Develop a working prototype linking GIS to TMDL modeling, concentrating on how GRASS and ARC-INFO should or should not be integrated, how to integrate GIS and remote sensing data into both static and dynamic models, and how national data bases can be made more accessible with a long term view of the eventual development of operational systems. (S)

- Develop operational systems linking GIS to TMDL. (L)

Design Storm versus Continuous Simulation

- Prepare a monograph -- a description of the pros and cons, dos and don'ts, whys and wherefores, and alternative views -- critically exploring this subject in order to develop fast, simple, easy, standardized ways of looking at watershed modeling for nonpoint sources. (S)

- Begin directed studies of this subject. (S)

- Continue directed studies. (L)

User Support/Modeling Usability

- Improve documentation of existing models, making sure that they are available. (S)

- Create a centralized model support center that will be run jointly by all federal Agencies in order to facilitate model support to State and local governments, and consultants. (S)

- Increase the amount of targeted training for use of models within the TMDL process. (S)

- Standardize the presentation shell for more user friendly access to various models. (S)

- Provide easy to use screening models. (S)

- Continued evolution of models. (L)

Ecological Links

- Examine linkages between available models and ecological habitat, i.e. velocity, sediment transport, stream morphology. (S)

- Examine linkages between models and existing ecological assessment tools (i.e., Index of Biotic Integrity [IBI], Rapid Bioassessment [RBA]). (S)

- Develop linked watershed-water quality-ecology models. (L)

Monitoring to Support Models

- Monitoring guidance on the proper procedures and techniques required to collect data that can be useful in the available models. (S)

- Description of current monitoring activities. (S)

- Application of other technologies, i.e. remote sensing to take advantage of the Earth Observation System (EOS)/NASA program, to get the kind of data we need to do TMDL assessments. (L)

- Develop a long term monitoring strategy. (L)

WORKGROUP #2: DATA SOURCES, TOOLS, AND INVESTIGATIONS

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INTRODUCTION

The Workgroup focused its discussion on the following questions:

1. How can remote sensing information and geographic information systems (GIS) be used in the Total Maximum Daily Load (TMDL) process?

2. What are the limitations of using remote sensing and GIS with watershed models?

3. How can improvements be made to remote sensing and GIS as data tools?

4. Where are there gaps in knowledge?

5. What are recommended actions for research and guidance?

DISCUSSION

State of the Science

Determining Land Use/Land Cover (LU/LC)

As nonpoint source pollution controls are integrated into the TMDL process, accurate information of LU/LC will be essential. For example, nutrient, sediment, and pesticide loads from agricultural watersheds cannot be estimated without data on the extent and type of cropland, pasture land, livestock operations, etc. Furthermore, ecological considerations (i.e., habitat extent, juxtaposition, interspersion, etc) may become important components of TMDLs. Remote sensing technology can provide LC/LU data in a format that can be input directly into watershed models or converted to vector based GIS data base coverage.

The workshop presentations illustrated the use of remote sensing technology to provide detailed LU/LC information (i.e., determine the crop cover type of individual agricultural fields, delineate wetland boundaries, perform species specific measurements of forest crown closure or size class). The level of detail that can currently be obtained using remote sensing is dependent on the sensor being used, prevailing atmospheric conditions at the time of data collection, and the temporal variability of the target(s) of interest. In general, aerial photography can provide the greatest level of LC/LU detail and is the most cost effective method for small study areas (i.e., less than 200 square miles); and satellite imagery has the potential to provide similar levels of LC/LU detail over large study areas (i.e., greater than 200 square miles). Satellite derived data has the added advantage of direct input into GIS without costly intermediate data transfer steps.

Modeling and Model Verification

A few point source and nonpoint source models are now being operated in the GIS environment. This is especially relevant where distributed input data (as in AGNPS [Agricultural Nonpoint Source model], WRENSS [Water Resources Evaluation Nonpoint Sources

Silvicultural model] and some other nonpoint source models) are used and where outputs are best displayed in graphical format.

Currently, LANDSAT imagery is being used in conjunction with GIS for watershed modeling and even multi-basin level planning. Examples of watershed applications were presented by Hewitt, Lunetta, Bartholic, and Lyon during the first part of the Workshop.

TMDL Applicability

Session participants identified several ways in which remote sensing data and GIS could be used in the TMDL process.

Integrating Information

GIS is a valuable tool for integrating the many types of data with LU/LC information to State and local officials, including TMDL developers. (The Assessment and Watershed Protection Division [AWPD] in EPA's Office of Wetlands, Oceans and Watersheds is currently compiling case studies on the use of GIS in water quality and watershed planning.)

Monitoring of Best Management Practices (BMPs), Wetlands, LU/LC

The phased approach will require the installation of BMPs, and possibly the protection and restoration of sensitive areas such as wetlands and riparian zones. At the basin level, remote sensing could reduce the cost of monitoring both the installation of BMPs and LU/LC changes within sensitive areas.

Sampling Network Design

GIS systems can aid in the design of sampling networks. As an example, EMSL-LV has designed an Reach File 3 (RF3)-GIS data bridge which has been implemented by OIRM. This bridge will promote data sharing between RF3 and GIS users. The functionality of GIS will provide a system for sampling network design using RF3 as a base information layer. The EMAP Program has already implemented this plan for the Surface Waters Resource Group.

Monitoring the Water Quality of Lakes, Bays and Estuaries

As a check on the overall effectiveness of TMDLs in a watershed or basin, remote sensing data for certain parameters (e.g., sediment, chlorophyll a) may be used to track long-term water quality. For example, after calibrating satellite measurements to field data from synoptic surveys, satellites might monitor estuarine water quality much more frequently and extensively than is possible in situ.

Other uses for remote sensing data that were mentioned by the Workgroup were model verification and two-dimensional mixing zone analysis.

Limitations of Tools and Data

Remote Sensing

Current LANDSAT sensors are cost effective for large-area (i.e., greater than 200 square miles) applications, while TMDLs may require higher resolution data for small watershed studies. In most watershed studies, a multistage remote sensing approach will provide the best results. Multistage remote sensing provides complete watershed coverage at the coarsest spatial and categorical resolution (i.e., one hectare/EMAP [Environmental Monitoring and Assessment Program]-LC stage two), with selective higher spatial and/or categorical resolution for a selected geographic area or categorical element of a watershed to meet modeling requirements. (The spatial resolution of remote sensing data can be to the sub-meter level and categorical resolution, down to the species level.) LU/LC is becoming available for much of the country at about one hectare resolution using LANDSAT Thematic Mapper (TM) imagery, but use classifications are fairly gross for some LU types. For example, LANDSAT imagery is being processed for EMAP-LC to lump all forest land cover types into three categories -- evergreen, deciduous, and mixed.

A potential problem of significant concern is the status of the existing LANDSAT sensors and the United States near-term commitment to the LANDSAT program. Currently, LANDSAT 4 and 5 are in operation. However, both satellites are long past their designed operational life. LANDSAT 5, the principal TM data acquisition platform is beginning to degrade, and its replacement, LANDSAT 6, is not scheduled for launch until the spring-summer of 1992. We are currently seven to ten years from deploying the next generation of satellite sensors being developed under the Mission-to-Planet-Earth, Earth Observation System (EOS).

Obtaining detailed crop type delineation data using remote sensing typically requires multiple remote sensing data collections to coincide with local crop calendars for a high degree of accuracy. Detailed crop type delineation using satellite imagery is hit and miss due to the lack of multiple growing season data collections for most locations.

Other limitations of remote sensing/GIS tools and data include:

- Uniform standards for remote sensing and GIS data quality are not in place (e.g., for data referencing requirements);

- Merging data from multiple platforms (e.g., SPOT [pan.] and LANDSAT TM) is routine, but it is the most cost effective means of providing high resolution large area LC/LU data at this time.

- Aerial photography can provide highly detailed LU/LC information, but is expensive and can require multiple flyovers for certain applications (e.g., determining crop cover)

Geographic Information Systems

Widespread use of GIS has been limited by the resources (hardware and personnel costs) required to support them. The systems in current use for state-wide or regional use tend to be complex and resource demanding. Many States lack staff that are trained to use them, and therefore, when a potential application is identified, environmental planners must often wait months to obtain expert help. The fact that different Federal agencies use different systems (EPA supports only ARC-INFO; the Department of Agriculture Soil Conservation Service (SCS) supports GRASS) complicates data transfer decisions.

The situation is changing rapidly. Many PC-based GIS systems are currently on the market and the hardware evolution will soon bring high-performance work stations within the budget of many State agencies. The Federal agencies and vendors are in the process of agreeing upon a spatial data transfer standard which will promote data sharing among many different platforms. Finally, GIS technical support centers, such as EMSL-LV, are pioneering GIS applications that are directly applicable to watershed process modeling and management.

Given the evolution of the technology and technical support, use of GIS in a TMDL framework is a realistic goal. States should begin to seek guidance and support from the EPA Regional GIS Teams. These Teams have been established in each Region to, in part, promote EPA-State data sharing. The Regional GIS Teams, in turn, can call upon the EMSL-LV GIS Research and Development Center for assistance in planning and implementing systems to support the TMDL process.

In the past, watershed protection and water quality planning have not been priority programs for State GIS centers. Some State governments have been developing GIS capabilities for years (e.g., Illinois, Michigan), but do not yet use the systems widely for watershed or water quality planning. This too is beginning to change. Both Montana and South Carolina have embarked on ambitious plans to begin state-wide watershed planning supported by GIS. (Contacts for these States are Gary Ingman, Montana Department of Health and Environmental Services, or Anne Marie Hale, South Carolina Water Resources Commission).

<u>State of the Science</u>

The overall lack of technical guidance and understanding about integrated PS/NPS TMDLs is a current obstacle. Remote sensing and GIS experts need to know detailed program requirements and objectives so they can improve on the tools that exist.

To develop useful tools, EPA needs to know present and future State/local capabilities, especially regarding data analysis platforms like GIS. The goal is to develop tools that can be widely used. GIS technology is forging ahead, while State and local governments tend to have equipment from the early 1980's, if they have any at all. Different types of users should be profiled. (Note: AWPD is pulling together information and case studies of State/local GIS use for watershed planning in support of this recommendation.)

Since many State water agencies are not close to having GIS capability, there is a need to know how other platforms (e.g., the EPA/NCC mainframe computer) can be used to support the data needs of TMDL development.

Specific technical and institutional issues about remote sensing and GIS integration are discussed in a series of articles in the June 1991 issue of Photogrammetric Engineering and Remote Sensing. Two excellent sources of information for potential GIS users are: *Geo Info Systems* published by Aster Publishing, and *GIS World* published by GIS World Inc.

RECOMMENDATIONS

Research

Geographic Information Systems

- Develop GIS/model interfaces so that models operating outside a GIS platform can access GIS data layers; modelers then do not need to learn ARC-INFO programming.

- For special applications, develop models and tools within the GIS environment that can make intensive use of distributed GIS data, with user-friendly macros for the modelers; an example is the nutrient budget program being developed by the Research Triangle Institute for basin planning in the Albemarle-Pamlico Estuary Study Area.

- Establish data quality standards for TMDL modeling.

- Develop raster-to-vector data conversions (and vice-versa). The power of GIS in TMDL modeling may be best realized with raster-based systems; such systems can best process distributed data like LU/LC and soil types. SCS's GRASS system is raster-based; ARC/INFO is vector-based, but will be available as a raster-based system within the next year.

Remote sensing

EPA should:

- Participate in the development of new sensors (e.g., for the EOS sensors).

- Explore opportunities to utilize multiplatform remote sensing data (e.g., LANDSAT TM and SPOT [pan.] data in combination for priority watersheds).

- Perform urban and agricultural TMDL pilots to demonstrate the use of remote sensing, GIS, and models in concert with State and local agencies. Projects should cover the range of capabilities, tiers of complexity, and costs. They should evaluate State/local capabilities and support development of implementation guidance.

- Develop standardized classification systems for GIS and remote sensing-oriented data such as LU/LC, soil type, and topography.

Guidance

- Technical guidance about integrated point and nonpoint source TMDLs is needed. This guidance should include case studies; however, since the number of integrated point and nonpoint source TMDLs is extremely limited, the guidance should also include experts' judgement about remote sensing and GIS data requirements for future TMDLs.

- With the above in mind, an ongoing forum should be established for GIS and remote sensing experts, modelers, and others responsible for TMDL development. A workgroup, for example, could deal with some of the technical and administrative issues identified above (e.g., data needs, data quality, sensor design, standardized remote sensing and GIS products, user interface improvements, information exchange).

- Guidance on common spatial data references and on scale and resolution issues is needed (e.g., which base maps to use).

- Guidance on GIS quality assurance and quality control issues is needed.

- An evaluation of the ability of current GIS systems to meet TMDL users' needs is recommended. Guidance should also address basic infrastructure needs and promote the States' efforts to acquire this infrastructure.

- GIS and remote sensing considerations should be added to the Appendix E list of models in the April 1991 TMDL policy guidance.

General

- Improve access to data from EPA databases. The current Office of Information and Research Management effort to create data access methods should be encouraged (Project GATEWAY). Other opportunities should be explored, including data sources from the Departments of Agriculture and the Interior.

- Models should be designed to use remote sensing data and GIS; remote sensing data collection should be designed to fit the best models.

- In anticipation of national availability of remote sensing data, data storage/data management issues should be addressed early.

- Standard remote sensing products should be developed and distributed. If EPA expects local and State use of remote sensing data, the agency needs to recommend and produce standard products; users at the State and local level usually cannot process raw satellite data, for example.

- To effectively use remote sensing/GIS tools, a new regulatory framework for TMDLs may be needed. For example, the technology supports the incorporation of riparian zone protection/restoration into TMDLs, while the regulatory framework appears to be a bottleneck.

WORKGROUP #3: PREDICTIVE MODELING OF ECOLOGICAL RESTORATION

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INTRODUCTION

Ecological restoration and predictive modeling of ecological response is a rapidly emerging area of research. In order to effectively integrate consideration of ecological restoration into the Total Maximum Daily Load (TMDL) process, several questions must be addressed. The Workgroup discussion focused on some of these questions:

1. How should we define ecological restoration? What is the goal of ecological restoration?

2. What are our current capabilities to predict ecological response? What are existing empirical relationships that can be used in predictive ecological response models?

3. How can predictive modeling of ecological restoration be integrated into the TMDL process?

4. What are our needs? (near term and long term)

5. What are recommended actions?

DISCUSSION

State of the Science

After some discussion, the Workgroup developed consensus definitions of ecological restoration and the purpose of predictive modeling of ecological response:

- The goal of ecological restoration is to establish a viable, functioning and sustainable ecosystem by providing an appropriate physical, chemical, and biological environment. The resulting ecosystem should be similar in its natural processes to adjacent ecosystems and/or meet appropriate biological criteria.

- The goal of predictive modeling of ecological restoration is to be able to accurately predict community changes (e.g., changes in the abundance of a key species) due to changes in the environment (stressors).

The Workgroup discussed the desired endpoint of an ecological restoration effort. The definition above states that restoration should result in an ecosystem similar in characteristics to adjacent areas. This immediate goal -- to mimic an existing nearby system -- is based on the necessity for a source of colonizers. Restored ecosystems should also be stable, and be able to deal, to some degree, with various stressors. The realistic endpoint of an ecological restoration project may vary with the size and scope of the project; site-specific characteristics must be taken into consideration. Workgroup members concluded, however, that the <u>ultimate</u> goal of restoration is a return to pristine, undisturbed conditions.

Limitations of Tools and Data

One barrier to successfully predicting ecological response through models is the current lack of appropriate ecological data (especially long term data). Indeed, decisions must often be made with little or no data. However, the Workgroup concurred that the role of predictive models should not necessarily be to precisely quantify or to establish causality, but to communicate the relationships between ecological restoration efforts and the resulting benefits.

With this role in mind, the Workgroup acknowledged the importance of simple empirical relationships for use in modeling (as opposed to detailed, deterministic approaches). Many empirical relationships that can be incorporated into predictive models have already been identified. Examples of these include the relationship between distance from a colonization source and colonization rate, and between stream flow and macroinvertebrate abundances. The Workgroup agreed that identification of new empirical relationships is also necessary in order to link various instream characteristics to riparian, out-of-stream components.

Further, the Workgroup recognized that models must be consistent with existing policy requirements. There is a need for models with varying levels of complexity and resolution since site-specific conditions may call for different levels of accuracy.

TMDL Applicability

To successfully integrate ecological restoration into the TMDL process requires a direct link between restoration and management. The Workgroup concluded that TMDLs must be redefined to include habitat and ecological and restoration criteria.

In terms of models, the Workgroup concluded that there is not necessarily a need for new models. Rather, there is a need for appropriate linkages among existing models and validation of these linkages for the TMDL process. Further, as part of the TMDL process, improved monitoring programs will help to test model effectiveness, as well as provide information, for model refinement.

A hierarchical approach to TMDL development can be used in order to effectively link existing models. This could be accomplished by initially using screening level models to target watersheds; more complex and site-specific models could then be used to focus on targeted areas. Such a tiered approach would enable us to deal with complex ecological systems.

While improved data as a result of research and ongoing projects allow the use of increasingly complex models, uncertainty - in the accuracy and predictive capabilities of models, and in ecological criteria that are developed - is still an issue. The Workgroup, however, maintained that the establishment of ecological criteria, despite some uncertainty, is critical for the development of TMDLs.

RECOMMENDATIONS

The following is a short list of near-term and long-term needs that the Workgroup identified:

- Identify models that can be used and linked together for predicting ecological response (as part of this effort, develop a compendium of models to summarize their capabilities and availability).
- Validate and assess linked models to test the models and relevant criteria (feedback loop).
- Develop a compendium of case studies that can be used to demonstrate successful (and unsuccessful) approaches for TMDLs.
- Develop a compendium of best management practices (BMP) and document BMP successes and failures.
- Develop simple empirical relationships and identify response and community metrics (e.g., regionally specific) that can be incorporated into predictive models for ecological restoration.
- Develop regionally (spatial/temporal) relevant biological criteria.
- Develop ecological criteria.
- Classify waterbodies by their recovery/restoration potential.
- Develop public education/outreach programs to communicate (e.g., through case studies) the benefits of ecological restoration at the local level.
- Develop a regulatory framework that will allow enforcement of ecological restoration.
- Develop mechanisms to integrate restoration projects into watershed programs (move away from a program-by-program approach).

From the needs described above, the following were established as priorities that will serve as recommendations for immediate action:

- Develop ecological criteria (spatial and temporal).
- Develop a compendium of models.
- Develop a compendium of case studies.

- Develop a classification scheme for waterbodies based on their restoration/recovery potential.

- Develop a targeted monitoring feedback loop to evaluate models and criteria.

WORKGROUP #4: POINT SOURCE ISSUES

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INTRODUCTION

Water quality-based effluent permits for individual point sources have been used to control impacts on receiving water quality for decades. The Total Maximum Daily Load (TMDL) process proposes to change this permit-by-permit approach. TMDLs must consider all of the point and nonpoint pollution sources in a watershed that contribute to a water quality problem, and then allocate allowable loads to each source. Integrating point source waste load allocations (WLAs) with nonpoint load allocations (LAs) to establish a TMDL, however, creates various management and technical challenges. Identifying and evaluating these challenges from a point source perspective was the objective of the Point Source Workgroup.

DISCUSSION

Urban Runoff and Overflow

Urban runoff can severly impact water quality. Overflow from combined sewer and storm water drainage systems has long been an acknowledged water quality problem. Several recent developments, however, have placed new emphasis the evaluation and control of these pollution sources. First, TMDL development will require evaluation and control of all pollution sources, including combined sewer overflows (CSOs) and storm water. Second, new storm water permitting regulations will create a new data base characterizing storm water discharge throughout the nation. Third, a National CSO Policy is being implemented state by state, requiring very specific actions for CSO characterization and control.

State of the Science

Methods for collecting urban runoff and overflow data have been refined and reliable equipment and methodologies now exist to characterize and quantify these pollutant loads. The data that has been collected using these methodologies is abundant, but highly variable. To date, the National Urban Runoff Program has collected the largest nationwide data base, but countless other engineering studies have been or are being conducted. Deficiencies in data on receiving water impacts may be the only major information gap. This need not hinder TMDL development, however, since water quality impacts, which tend to be site specific, can be assessed during the TMDL analysis.

There are numerous methods and models that quantify combined sewer and storm water overflows. Fairly sophisticated, yet reliable models are also available to simulate the time variable nature of wet weather urban overflows (e.g. SWMM, ILLUDAS, DR3M, STORM). Many of these tools can be used to provide long term continuous simulation, and are well suited to address most of the parameters of concern. Simple methods, such as the Rational Method and the EPA simplified Storm Water Managment Model (SWMM), that are somewhat less accurate are also available, but they are most appropriate for storm water runoff.

Concentration criteria are available for most media and pollutants of concern. The only exception is for clean and contaminated sediments. The criteria are well suited for evaluating overall impacts, but computational methods and/or models are required to evaluate transient impacts. Fortunately, numerous methods and models are available to calculate water quality impacts, but the detailed temporal data on loads and system hydrodymamics that are necessary to support the modeling are typically not available.

TMDL Applicability

Urban, wet weather pollution loads must be considered by TMDLs because they impact water quality and often impair designated uses. However, the analysis must be tailored for different pollutants. Impacts from nutrients, sediments, and persistent toxicants are generally not episodic and should be analyzed on a seasonal, yearly, or period-average basis. In contrast, transient impacts from oxygen demand, metals, toxic organics, and bacteria need to be evaluated in an episodic context to identify transient violations in water quality criteria.

Unfortunately, the differences among these problems pose difficulties for TMDL analysis. For example, no simplified methodology exists to quantify the loadings and impacts of parameters with cumulative impacts. Complex methods are available, but they are too complex and costly for routine TMDL analyses. For episodic impacts, methods are available but there is no guidance on how to select suitable design conditions for an episodic TMDL analyses, and there is no guidance on to how to integrate critical drought flow TMDL analysis for continuous loads with the analysis for episodic storm impacts. A simple framework is needed to consider both continuous and transient wet weather loads for TMDLs.

Limitations of Tools and Data

Models and data are available to incorporate urban runoff as a pollutant source in a TMDL analysis. Several important limitations were noted, however:

- Simple loading and impact analysis procedures that are targeted for rapid implementation by regulators are not available. Available methods may be applicable, but need testing and demonstration.

- A simple flow criteria or design condition is not available to regulatory analysts for calculation of urban wet weather TMDLs. The equivalent to a mean 7-day, 10-year low flow and/or rainfall criteria needs to be developed for wet weather urban conditions.

- No methods or policies exist for integrating episodic and continuous impact considerations in one TMDL or one TMDL framework.

Sediment Criteria

To protect beneficial uses, water pollution regulation has historically focused on meeting water quality concentration criteria. This may have protected sediments indirectly, but no explicit evaluation was ever performed. EPA will soon complete a multiyear research effort to develop explicit sediment quality criteria for protection of beneficial uses. The existence of new sediment criteria will place new demands on the TMDL process.

State of the Science

Data, methods and models for evaluating sediment quality are being developed. Data collection methods for sediment are well developed, and a substantial data base is being created; therefore, once quality criteria are defined, established procedures are available to evaluate compliance. Sediment criteria for six organic pollutants are targeted for promulgation by EPA by fall 1991. Metals criteria are targeted for late 1992.

A computational methodology or a mathematical model is needed to relate pollutant loads to sediment conditions. Researchers have developed several models that relate pollutant loadings, overlying water concentrations, and sediment concentrations (e.g., WASP, MICHRIV, SMPTOX3). These models are very effective for simulating dynamic equilibrium conditions among sediments, water quality, and loading. The equilibrium model approach assumes that substance partitioning between water and solids is always in instantaneous equilibrium. The models, however, are best suited for relatively steady conditions. They are not suited for highly transient conditions, or conditions with large changes in loading.

TMDL Applicability

The development of sediment criteria will impose new quality objectives on TMDL analysis. Linking pollutant loading to sediment quality is an appropriate consideration and is relevant for persistent toxicants. If implemented, however, these criteria will compete with water quality-based concentration criteria when establishing the TMDL. In practice, it is assumed that both will need be calculated and the most stringent used.

Use of sediment criteria in the TMDL process creates two immediate concerns. First, sediment quality reflect the cumulative effects of pollutant loading over a long period. A TMDL intended to meet sediment criteria, however, will probably need to be expressed as a period-averaged condition. Unfortunately, there are no established procedures that define how to compare a period-averaged TMDL with an episodic or a drought flow TMDL. Second, the TMDL approach does not address the significance of historical contamination. In water quality based analyses, historical conditions are less important because of flushing (except in large lakes and reservoirs). Sediment contamination has a much longer residual memory that complicates the TMDL analysis. Will past contamination prevent standard compliance despite zero loading?

Limitation of Tools and Data

The role of sediment quality criteria in TMDL analysis has not yet been unexplored. Theoretically, the equilibrium modeling approach used in many EPA supported models is capable of relating pollutant loading to sediment concentrations, but for relatively steady conditions. Nonetheless, the exploration and demonstration of the approach for TMDL development is only now being undertaken. The procedures are promising, but require specific case study demonstrations to identify technical deficiencies and policy needs.

On another level, the equilibrium model approach supported by EPA models is significantly deficient in several areas. First, the approach is weak in addressing historical contamination. The models have not proven effective for simulating large changes in sediment conditions, an area requiring more research. Second, available models are not well suited for evaluating dramatic changes caused by highly variable hydraulic conditions which greatly alter sediment settling, transport, resuspension, and erosion. Finally, long term sediment bed transport is not well incorporated into available quality models. Considerable research on sediment transport has been done, but there has been very little done to link the hydraulics with water and sediment quality modeling research.

Biocriteria

One objective of the Clean Water Act is to restore and maintain the biological integrity of waterways. Various physical and chemical criteria have been used as an indirect measure of water quality. Recent research, however, is developing ecological criteria to directly measure the health of water bodies.

State of the Science

Techniques to measure and quantify aquatic populations are well developed and documented. However, a consistent relationship between pollutant discharge and ecosystem health as measured by population, biomass, and species diversity or the presence of indicator species has not yet been established. Appropriate and consistent indices of ecosystem health are not yet defined. One obstacle is natural variations in habitat that can impact population dynamics and can exacerbate or minimize pollution impacts, making it difficult to define specific aquatic health criteria.

Whole effluent toxicity testing is one approach that has been heavily researched in the laboratory, and applied successfully to regulate point source discharges. Its use as a direct measure of ecosystem health is appealing, but there is little to indicate that the adverse impacts observed under controlled laboratory conditions reflect the adverse impacts may or may not occur in an uncontrolled, field environment. Furthermore, to use ecological criteria in a regulatory context, reliable methods to relate decreases in effluent loading or urban runoff to improvements in the field are needed. The technology is not currently available.

TMDL Applicability

Although ecological criteria are not well suited for direct use in TMDL calculations at this time, such criteria can play an important, secondary role in the overall TMDL processs. Two applications were identified as promising:

1. Biocriteria can be useful as an objective test of the effectiveness of an existing TMDL to protect ecosystem health; they may be used to justify relaxation or tightening of a WLA or LA in an existing TMDL calculation.

2. Biocriteria may also be well suited as a screening tool to examine attainability of designated uses in water bodies targeted for TMDL analysis. The result would be better selection of applicable chemical specific criteria for TMDL computations.

Limitation of Tools and Data

Without methods to quantitatively link pollutant source and environmental processes to effects (i.e., biological measure), direct use of biocriteria for calculating pollutant allocations within a TMDL is not possible. Specific criteria are undeveloped at this time, and the comprehensive data needed to quantitatively support such criteria are lacking. As a result, available data, criteria and models are considered to be too limited, as they exist today, for applicability to the TMDL process.

RECOMMENDATIONS

The Point Source Workgroup evaluated the significance of the TMDL process to point source WLAs and control. Numerous technical and policy issues were identified that available data, technology, guidance, and policy could not immediately resolve.

Marketing TMDLs

The TMDL process is not necessarily familiar to State regulatory staff; therefore, in the near-term EPA needs to provide technical support, funds, and guidance which encourage TMDL development. The Workgroup recommends that EPA should:

- Target funds to support state efforts in TMDL development.
- Develop and support a TMDL "SWAT" Team of experienced practitioners who would travel from state to state (or Region to Region) helping regulators develop a system for TMDL implementation and trouble shooting individual problems with TMDL analysis.
- Expand support for hands-on workshops conducted by experienced TMDL practitioners to train state staff in each EPA Region in implementing TMDLs.
- Develop institutional and technical guidance that promotes the merits of the TMDL process. Specifically, the concept of WLA and LA tradeoffs must be better defined and marketed as an attribute of the TMDL process to encourage states and regulated NPDES (National Pollutant Discharge Elimination System) permit holders to invest their effort and money. Tradeoffs between load reductions and habitat improvement also need to be explored in order to identify the most cost effective means to meet water quality objectives.

Technical Guidance

"Guidance for Water Quality-based Decisions: The TMDL Process" is the only TMDL-related guidance which addresses both point and nonpoint issues in an integrated fashion. This document, although valuable from a programmatic perspective, was not designed to address technical issues. A TMDL "technical primer" is needed to outline integration of point source waste load allocations with nonpoint source load allocations and the technical steps and considerations involved in TMDL development. Case studies that will serve as TMDL templates would be included. Particular attention should be focused on episodic versus cumulative and continuous impacts, plus drought flow versus wet weather, high flow TMDLs. This primer would precede a more comprehensive Technical Support Document that is recommended to follow in two to three years.

More specifically, future technical guidance on the following subjects should be considered:

- Institutional and technical aspects of trading point source WLA with nonpoint source LA.

- Case study documentation of TMDLs that have been implemented,

- TMDLs for multiple pollutants and whole effluent toxicity (WET). (This should consider synergistic and antagonist effects, as well as calculating a representative return frequency for toxic conditions and comparing it to the one in three year EPA guidance recommendation.)

- Simplified methods of analyses to characterize CSOs and storm water. Also, simple flow and rainfall "design" criteria (or procedures) are needed to allow rapid and widespread TMDL calculations.

- Technical guidance to explore and define how existing data, methods, and models can be used to calculate TMDLs consistent with new sediment criteria.

- Guidance on allocation of point and nonpoint source loads.

- Re-evaluate the <u>Technical Support Document for Water Quality-based Toxics Control</u> with respect to wet-weather issues, including wet weather criteria, effluent and permit statistics, storm load whole effluent toxicity, and mixing zones.

<u>Research</u>

The following four areas were identified as long-term needs:

- **Multiple Pollutants:** There is little information about multiple pollutant interactions and whole effluent toxicity from multiple sources. Research is needed on additivity, and procedures for calculating toxicity recurrence intervals when all toxic parameters and pollutant sources are considered in an integrated fashion.

- **Biological and WET Criteria:** TMDLs have traditionally focused on specific chemical concentrations. The TMDL process must be evaluated with respect to the role of whole effluent toxicity criteria and biological criteria.

- **Best Management Practices (BMPs):** Comprehensive information on BMP effectiveness is lacking. Simple models are needed to calculate the effectiveness of structural BMPs, and a comprehensive review of available performance data for nonstructural BMPs must be compiled. In addition, the significance of ground water and surface water interactions must be explored for BMPs that rely on infiltration for pollutant control.

- **Sediment Contamination and Transport:** Technical research and guidance are needed to evaluate the transport and fate of historically contaminated sediment. Understanding the dynamics of these sediments is a key to matching TMDL calculations to the attainability of beneficial uses.

7. CONCLUSIONS

7. Conclusions

The objectives of this workshop were to review the current state of the science with respect to watershed modeling, predictive modeling of ecosystem restoration, and remote sensing and geographic information systems to see exactly where we stand in face of these new challenges; to obtain expert recommendations about which approaches and tools can be used to help implement the 303(d) Total Maximum Daily Load (TMDL) process over the next three to five years; and to obtain prioritized recommendations about which tools are most promising for development over the next five to ten years.

Overall, workgroup discussions and subsequent recommendations covered a wide variety of topics. Many were highly technical and topic specific, but there were several cross-cutting themes that related directly to the TMDL process and integration of technology to address the specific needs generated by implementation of the TMDL program.

TMDL SWAT TEAM

Workgroup #1 , #4, and #2 each indicated in their recommendations that EPA should develop and support a core team of experts who are experienced using a particular technology within the TMDL framework. This idea was also promoted during the closing Workshop discussion. The role of this TEAM would be to provide technical support to the Regions, States, and local governments who will be developing and implementing TMDLs. Not only would they trouble shoot individual problems with TMDL analysis, but this small group of experts would continue to explore the potential use of existing science and technology for TMDL analyses, to provide immediate short-term technical guidance, and to develop a long-term strategy for developing TMDLs.

CASE STUDIES

Throughout the course of the Workshop, the desire for case studies demonstrating both the successful and unsuccessful development and/or implementation of TMDLs was discussed. Other, more specific documentation would include case studies involving model validation and uncertainty, and use of predicted ecological response to drive pollutant management decisions. It was considered important to build a long-term record of such case studies that would be known of and accessible to all Federal agencies, EPA Regions, and States.

RESEARCH

Most of the Workgroups discussed the need to develop technology interfaces to existing link tools, making their use more amenable to the TMDL process. This was an especially relevent point among the remote sensing, GIS, and modeling experts who need to develop a working prototype linking GIS land use/land cover information to watershed modeling pollutant transport and load estimates.

Other, more programmatic conclusions were also reached and general comments made during the course of the workshop. They are stated below.

- The States and EPA should make a concerted effort to integrate the TMDL process into the 314, 319, and 305(b) programs.

- Section 404 permits require a certification under 401 that water quality standards will be met; it appears that a TMDL calculation would be needed for such actions to demonstrate compliance with standards, including loadings due to erosion.

- EPA should work more closely with the U.S. Department of Agriculture Soil Conservation Service to institute the TMDL process in agricultural programs to better address nonpoint source issues.

- Additional guidance is needed on how States can prioritize TMDL needs using available tools.

- EPA should identify and address disincentives that may exist to applying the TMDL process to nonpoint sources.

- Nonpoint source best management practice guidance was recently developed in response to the Coastal Zone Act Amendments of 1990 (Proposed Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, U.S. EPA, Office of Water, May 1991.)

APPENDICES

EPA MAINFRAME DATA AND TOOLS FOR WATERSHED ASSESSMENTS
Exhibit and Demonstrations for Workshop Attendees

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ABSTRACT

Work stations with direct access to the EPA National Computer Center were available during the workshop. The work stations provided an opportunity for attendees to learn more about many national water quality data files and systems available to state and EPA programs and to immediately see data and graphics based on specific questions. A number of displays were provided covering trend analysis, spatial analysis of water quality in streams and lakes, and screening and prioritization of drainage basins using STORET water quality data. The Reach File, Water Quality Analysis, and STORET Systems were used extensively to prepare the displays and were accessed on the mainframe when responding to an attendee's inquiry.

INTRODUCTION

Significant achievements have been made in addressing water quality problems over the past 20 years. Despite these achievements, significant work still remains to address key environmental issues such as nonpoint source pollution. Over the past two years, EPA has developed program guidance that combines existing Clean Water Act mandates (Section 303(d)) with input from Regional and selected State representatives to develop an integrated approach for addressing point and nonpoint source pollution problems (***Guidance for Water Quality-based Decisions: The TMDL Process***).

The development of total maximum daily loads (TMDLs) for watersheds often involves the evaluation of both point and nonpoint pollution sources. As a result, data must be integrated from numerous sources. An approach taken by many investigators is to proceed using a staged effort; that is, to compile and analyze data that are readily available and then collect additional data to fill in the gaps. This approach is particularly useful when targeting limited resources for further work, prioritizing watersheds for detailed assessments, performing preliminary assessments, or assembling data for transfer to a geographic information system (GIS) or PC environment.

While some States have made significant progress in building GIS capabilities for watershed analyses, many do not have the expertise or funding to acquire this capability within the next few years. An alternative is to use nationally available hydrologic and water quality data and applications software on EPA's mainframe. Recent and ongoing system enhancements provide significant capability to conduct integrated point and nonpoint source assessments on a watershed, regional, or national scale, taking advantage of national data bases on stream flow, hydrologic routing, land use, point sources, and water quality. The purpose of this exhibit and demonstration was to stimulate discussion on whether the EPA mainframe can meet the needs and goals discussed at this workshop.

OVERVIEW OF EPA'S MAINFRAME

EPA's NCC/IBM mainframe provides numerous tools (applications) for integrating a wide variety of data that are nationally available. A detailed listing of available conversational procedures and data files is presented at the end of this paper. This exhibit demonstrated selected tools that can be readily used with limited local watershed knowledge and limited hardware/software capabilities. A summary of mainframe data sources and tools that may help meet the needs and goals of this workshop is presented in Table A.1. Access to EPA's mainframe is summarized in Table A.2.

Table A.1. Summary of selected data sources and tools available on the mainframe

Data sources and tools demonstrated at this exhibit	Other selected data sources and tools available on the mainframe
• STORET	• Waterbody System (WBS)
• Permit Compliance System (PCS)	• Digital Line Graph (DLG)
• Reach File (RF1, RF3)	• Digital Elevation Model (DEM)
• Industrial Facilities File (IFD)	• Land Use/Land Coverage
• Environmental Data Display Manager (EDDM)	• Census
• Mapping and Data Display Manager (MDDM)	• Ground water data
• Downloading to PCs (dBASE, LOTUS 1-2-3, ARC/INFO)	• Toxic Release Inventory (TRI)

Table A.2. Work station access to EPA's mainframe

Dial up	Direct connect (EPA and States)
• PC -- 1200/2400 bps modems/XTALK, PROCOMM	• Cluster controller -- terminal or PC with coax connect
• PC -- 2400 bps modem emulator 3270	• LANs -- Novell netware 286/386 (EPA now has 147 file servers connecting approximately 7,000 work stations)
• PC -- 4800 bps modem emulator mainframe APA/GDDM graphics	

EXAMPLE APPLICATIONS

Clean Lakes System

The Clean Lakes System has been developed to provide water quality reports, analyses, summaries, and graphical displays for lakes that are part of the Clean Lakes Program. Currently, a prototype system is operating on EPA's mainframe computer at the National Computer Center (Research Triangle Park, North Carolina). Figure A.1 represents many of the lakes already entered into the location data base. The Clean Lakes System provides access to the Reach File, STORET, the Permit Compliance System, the Industrial Facilities Discharge File, and the Clean Lakes Program data base.

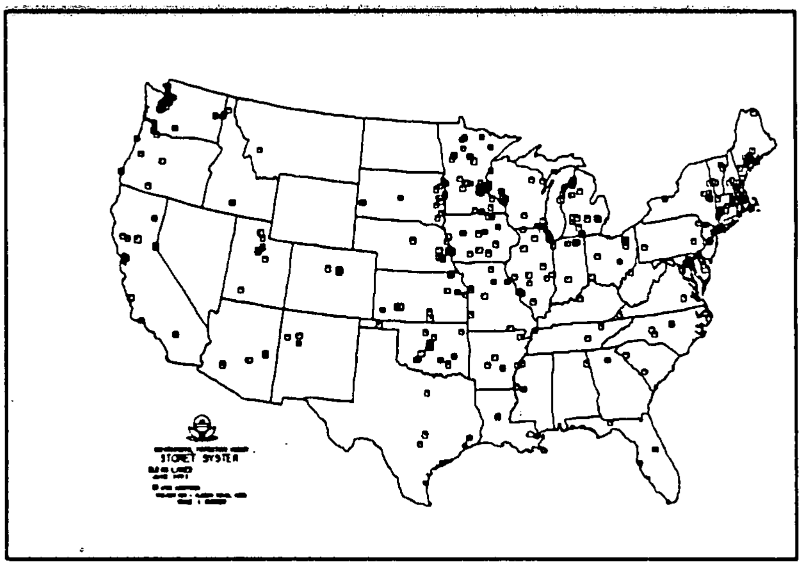

Figure A.1. Locations of lakes in the Clean Lakes Program

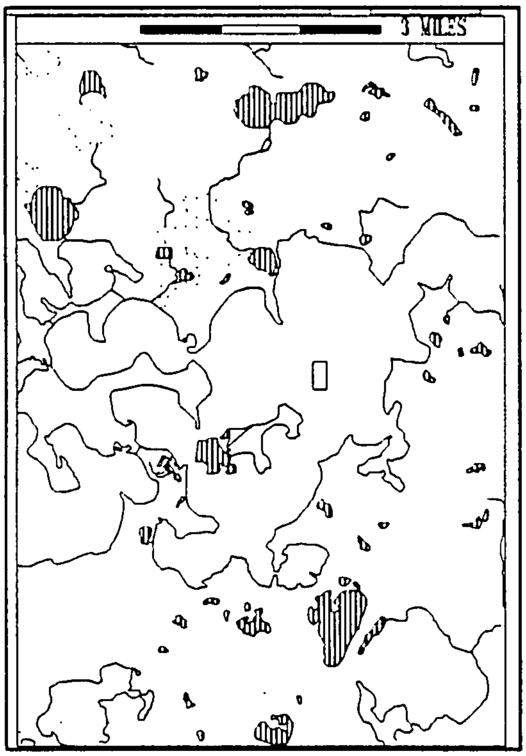

Figure A.2. Detailed 7.5 minute map using Reach File 3

By providing an integrated analysis tool,

- Analysts can quickly gather information and data to identify existing or potential sources of pollution.

- Decision makers can assess diagnostic information to define procedures for controlling the sources of pollution.

- Managers can assess the post-restoration improvements in lake water quality.

Graphical displays, analyses, and reports are immediately available by selecting a lake from the directory listing displayed on the terminal. Initially, a detailed 7.5 minute quadrangle map such as Figure A.2 for Lake Minnetonka, Minnesota using Reach File 3, would be useful to identify the location of tributaries, water quality monitoring stations, and point source dischargers.

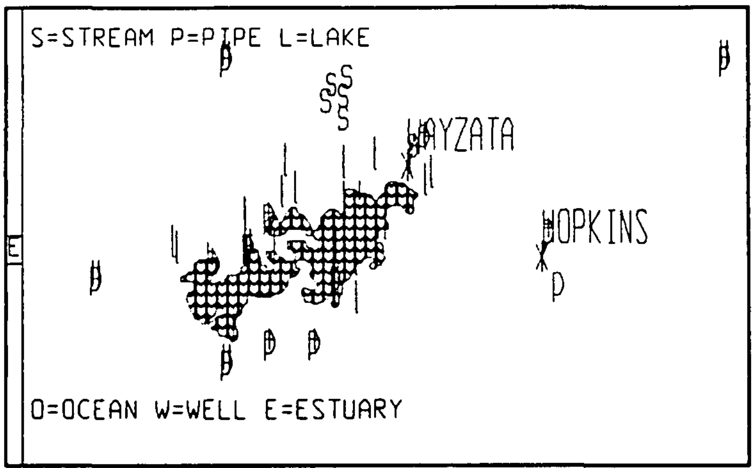

Figure A.3. Location of NPDES Facilities and Water Quality Monitoring Stations

In Figure A.3, only the shoreline of the selected lake is displayed along with nearby cities, NPDES dischargers (P), ambient stream monitoring stations (S), and ambient lake monitoring stations (L). Data from specific stations can then be displayed interactively. In the figure below (Figure A.4), the user selected a time series plot of Secchi Depth. Within seconds, the Clean Lakes System accessed data from STORET and graphically displayed ten years of data at the users terminal.

In many cases, assessing and summarizing all of the available data at each lake can be rather time consuming. To support screening level analyses, the Clean Lakes System produces a Manager's Summary of the water quality monitoring data. In Figure A.5 the number of observations outside desirable levels for indicator variables are summarized for all ambient lake monitoring stations.

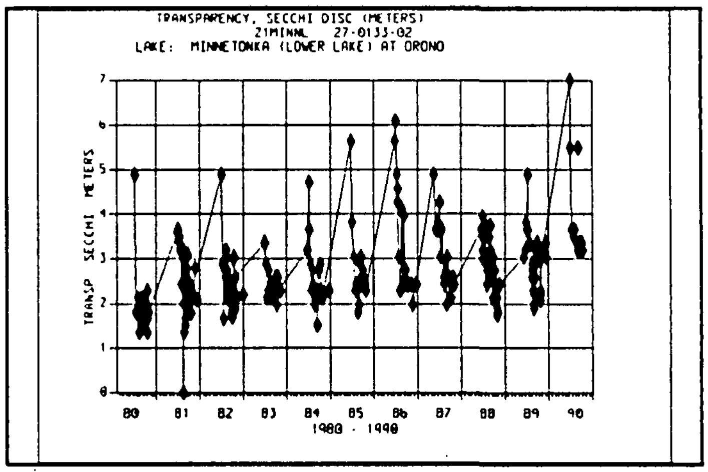

Figure A.4. Graphical display of water quality data

```
***** CLEAN LAKES SUMMARY -- SINGLE LAKE ANLAYSIS *****                    5
      NUMBER OF OBSERVATIONS FOR WHICH INDICATOR       17:31 THURSDAY, FEBRUARY 28, 1991
      VARIABLES MAY BE OUTSIDE DESIRABLE LEVELS

DES. LEVELS:  WATER TEMP <=89 DEG F (31.67 DEG C)
              6.0 <= PH <= 9.0
              DISSOLVED OXYGEN >= 2.5 MG/L
              TOTAL PHOSPHORUS <= 0.02 MG/L
              FECAL COLIFORM   <= 400 CTS/100ML
***********          REPORT 2           **********
```

YEAR	WAT TEMP NUM OUT. DES. LEV.	WAT TEMP NUM OF OBSERV.	PH NUM OUT. DES. LEV.	PH NUM OF OBSERV.	DO NUM OUT. DES. LEV.	DO NUM OF OBSERV.	TOT PHOS NUM OUT. DES. LEV.	TOT PHOS NUM OF OBSERV.	FEC COL. NUM OUT. DES. LEV.	FEC COL. NUM OF OBSERV.
1972	0	22	1	28	4	22	28	28	.	0
1976	.	0	.	0	.	0	.	0	.	0
1980	.	0	.	0	..	0	.	0	.	0
1983	0	221	0	136	9	221	23	23	.	0
1984	0	881	77	877	113	874	161	167	.	0
1985	0	824	42	822	95	823	172	172	.	0
1986	0	635	51	635	97	639	110	111	.	0
1987	0	326	47	326	65	326	51	52	.	0
1988	0	394	0	394	65	394	65	72	.	0
1989	0	409	0	403	69	409	120	120	.	0
1990	0	817	2	817	99	760	160	160	.	0
	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======
	0	4529	220	4438	616	4468	890	905	0	0

Figure A.5. Manager's summary report

Reach File

The Reach File provides hydrologic connectivity between geographic locations and historical data created for the express purpose of performing hydrologic routing for modeling programs. Reach File, Version 1 (RF1) contains over 68,000 stream reaches covering 100% of the continental US and is indexed to STORET, IFD, drinking water supplies, stream gages, and fish kills.

In Figure A.6, one watershed in western Michigan is depicted. This figure was created by using the mapping procedure in STORET. In this case, the user requested that cataloging unit 04050006, which corresponds to the lower reaches of the Grand River, Michigan, be plotted with the state boundary as a background. Figure A.7 is a closer look at the same watershed using MDDM. Various options available in MDDM allow one to flag nearby cities, dischargers, and monitoring stations. Figure A.3 is an EDDM example with these flags turned on for Lake Minnetonka, Minnesota.

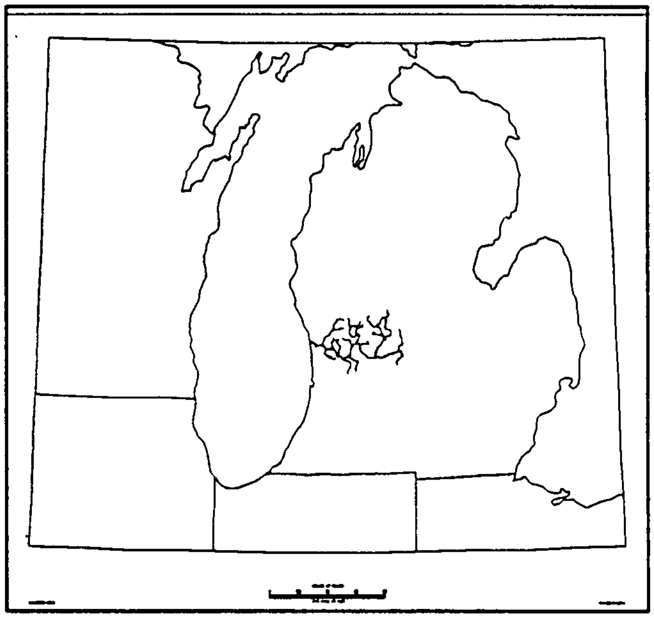

Figure A.6. RF1 rivers in sample watershed

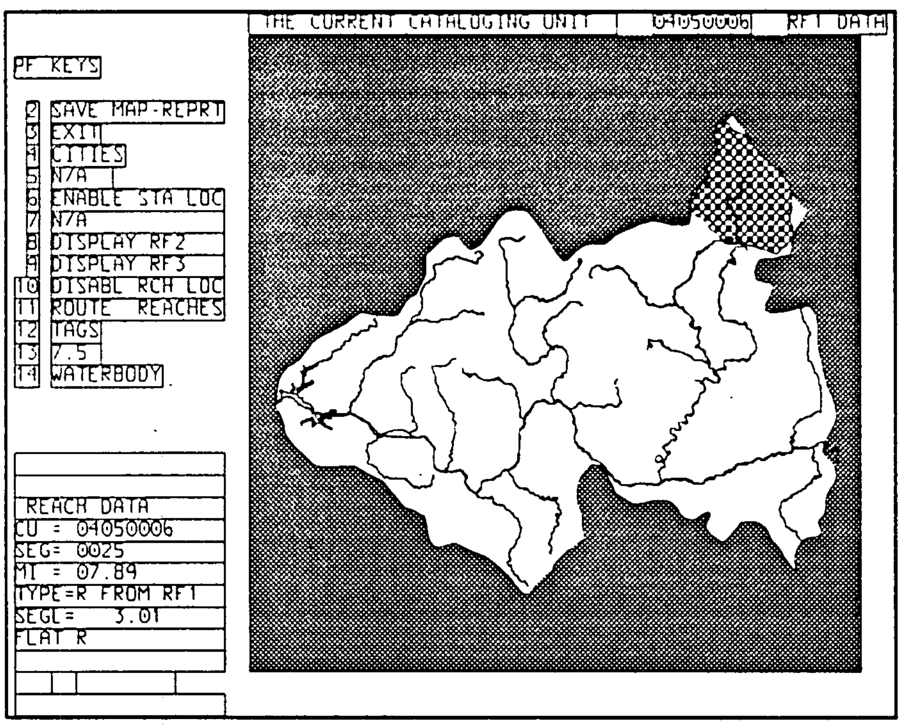

Figure A.7. Cataloging unit 04050006 using MDDM

The reader should also notice the shaded portion of the watershed in Figure A.7. This subwatershed is a user-defined boundary of latitudes and longitudes. Perhaps this could be a priority area within the watershed.

Using Reach File 3 (RF3), detailed hydrography is displayed for the subwatershed (Fig-ure A.8). With more than 3,000,000 new reaches added to create Reach File 3, the level of detail will allow more detailed evaluation. RF3 information can also be downloaded to ARC/INFO compatible files. Unlike ARC/INFO, the Reach File is coded to know which way the water flows. As a result, one can search up and downstream for the location of water quality monitoring stations, water supplies, and dischargers.

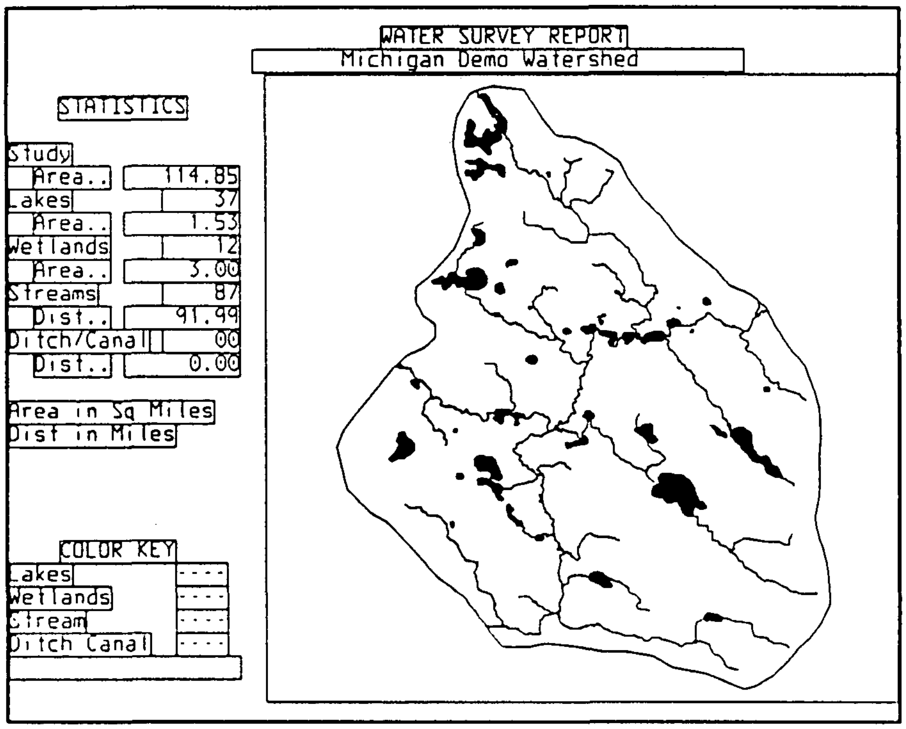

Figure A.8. Subwatershed using RF3

In Figure A.9, a two mile by two mile window is displayed. The lake is from the western side of the example subwatershed (see Figure A.8). A monitoring station is identified as well.

By integrating many data sources (at many different scales), RF3 can support basin planning. This potential is summarized in Figure A.10.

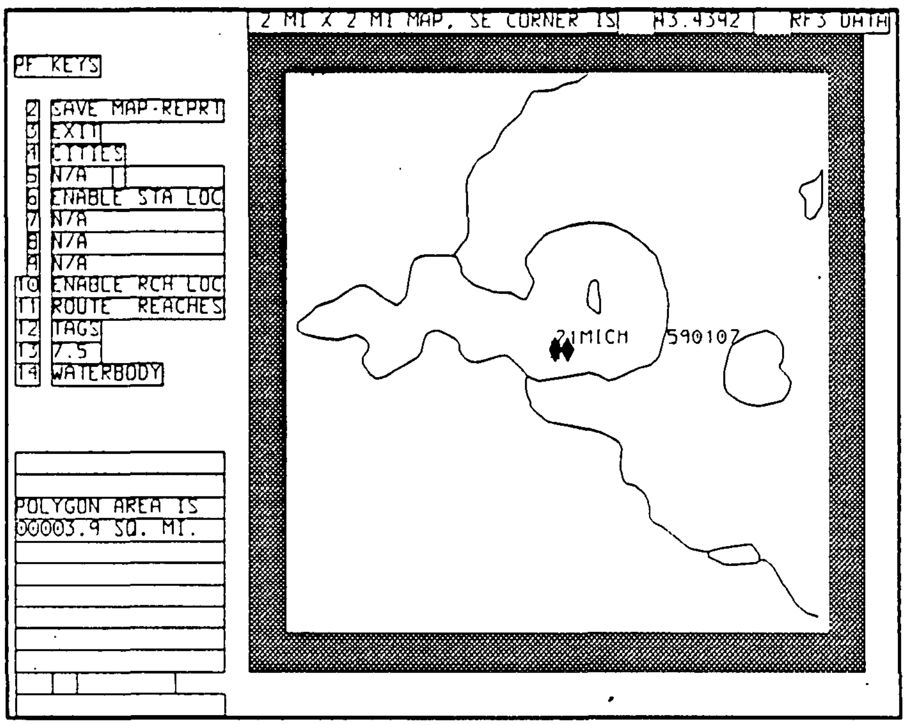

Figure A.9. Two-mile window

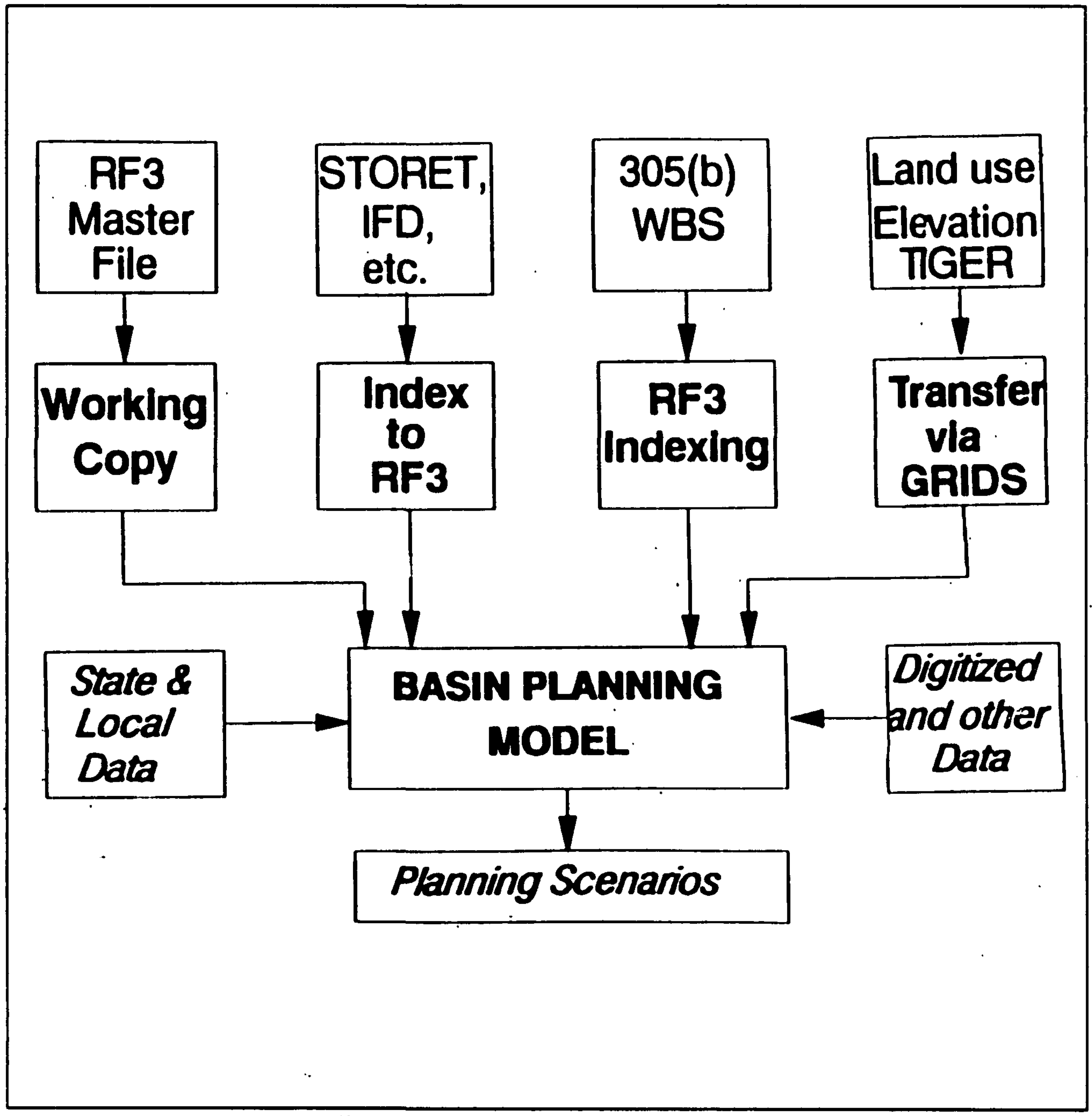

Figure A.10. Basin-wide planning with RF3

<u>Trend Analysis with STORET</u>

National (or watershed) level trend analyses are also possible on the mainframe. In less than 20 minutes at a work station, we performed a crude trend test on dieldrin at all USGS NASQAN monitoring stations. (Crude in the sense that there are more powerful and robust trend tests available in the literature; however, they have not been incorporated on the mainframe to date.) Figure A.10 depicts the locations of all NASQAN monitoring stations and Figure A.11 shows increasing or decreasing trends (corresponding to the plotted arrow direction) in the 85th percentile dieldrin concentration.

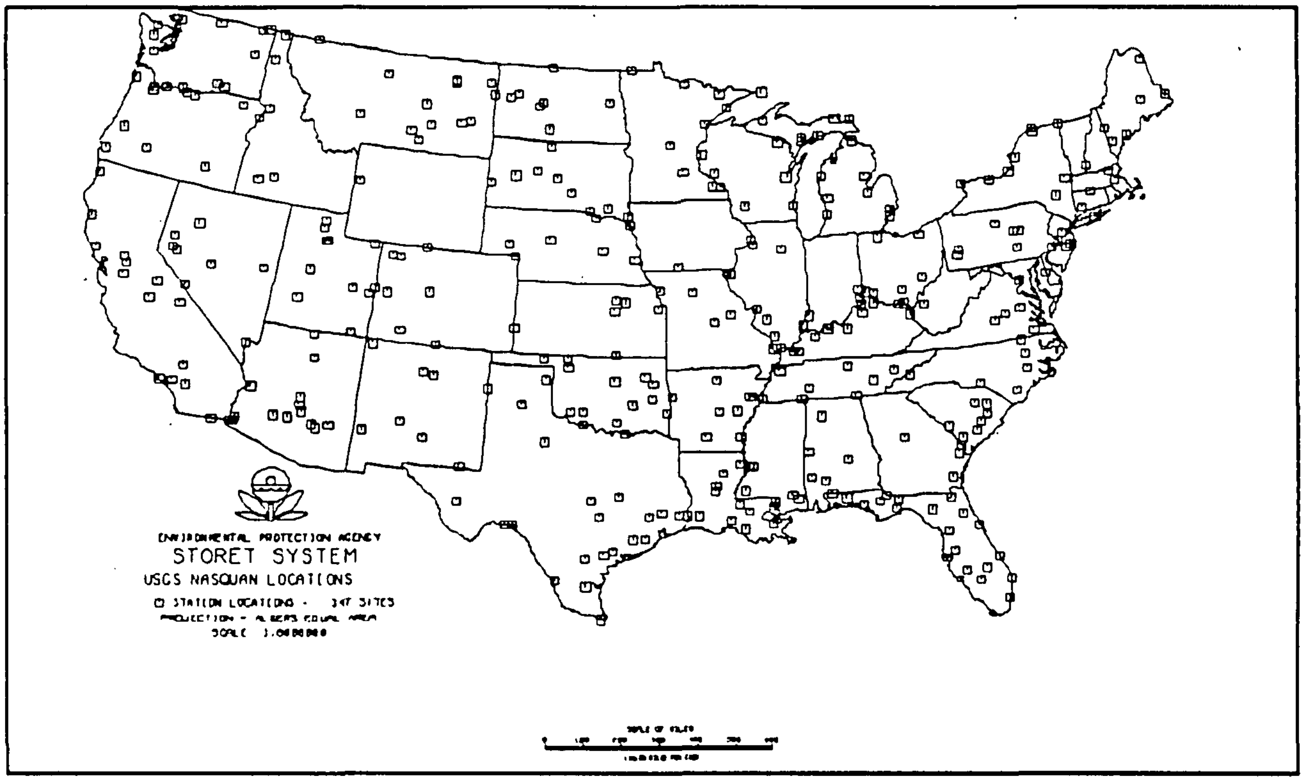

Figure A.11. Location of USGS NASQUAN water quality monitoring stations

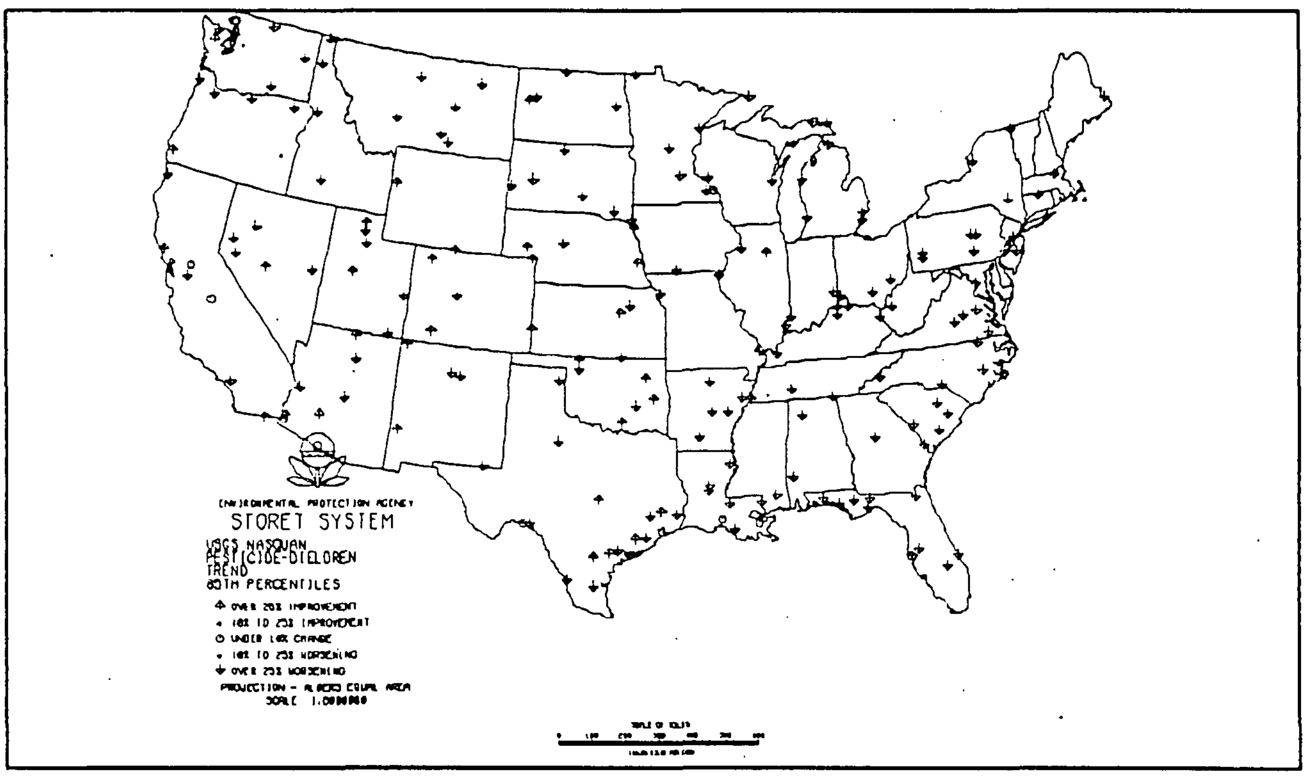

Figure A.12. Trends in the 85th percentile dieldrin concentration

Screening and Prioritization of River Basins

The upper Mississippi river drainage area was divided into 14 basins as summarized in Table A.3 and Figure A.13. STORET was used to retrieve and summarize all mercury, PCB, phosphorus, and nitrogen data for each basin. Figures A.14 through A.19 are LOTUS 1-2-3 plots that were created from the downloaded STORET reports. For the purposes of finding "hot-spots," we elected to plot the 85th percentile concentration for each river basin. (Other summary statistics can be as easily plotted; however, the 85th percentile tends to avoid the problems of erroneously high values [outliers] as well as detection levels.) More than 10,000 observations are represented by each nutrient figure. By reviewing these figures, one may hope to find basins that require more thorough evaluation. For our example, we arbitrarily elected to review phosphorus concentrations in Rock River with more detail. Figure A.20 is a plot of total phosphorus as a function of river mile above the confluence with the Mississippi River.

Table A.3. River basin code

1	Mississippi Headwaters
2	Minnesota River
3	St. Croix
4	Black-Root
5	Chippewa River
6	Maquoketa
7	Wisconsin
8	Iowa-Skunk-Wapsipinicon
9	Rock River
10	Des Moines River
11	Salt
12	Upper Illinois River
13	Lower Illinois River
14	Kaskaskia-Meramec
15	All Rivers

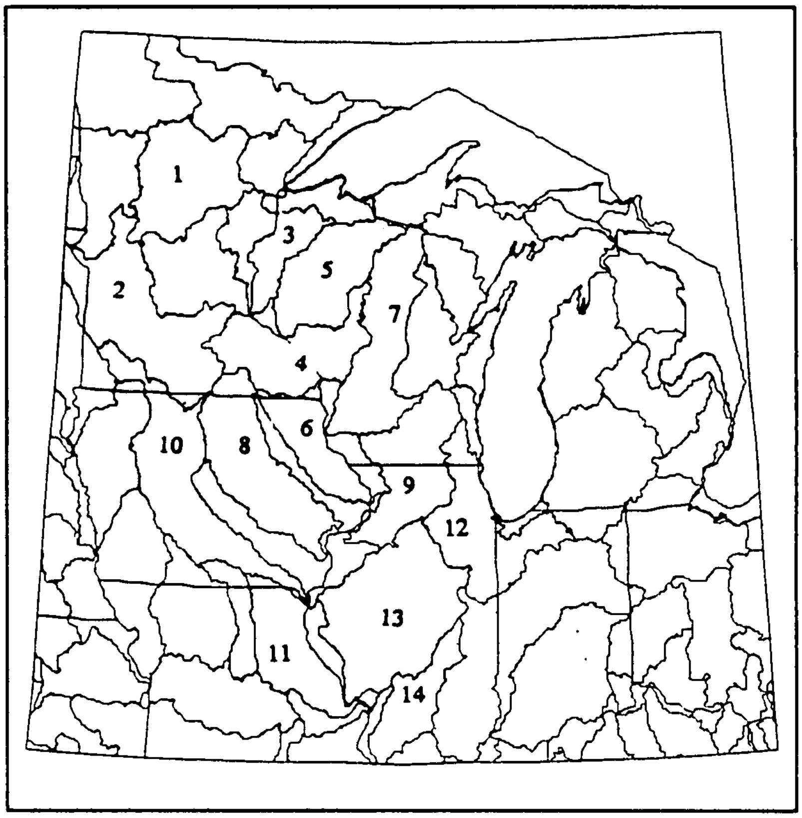

Figure A.13. River basins for comparison of mercury, PCBs, phosphorus, and nitrogen

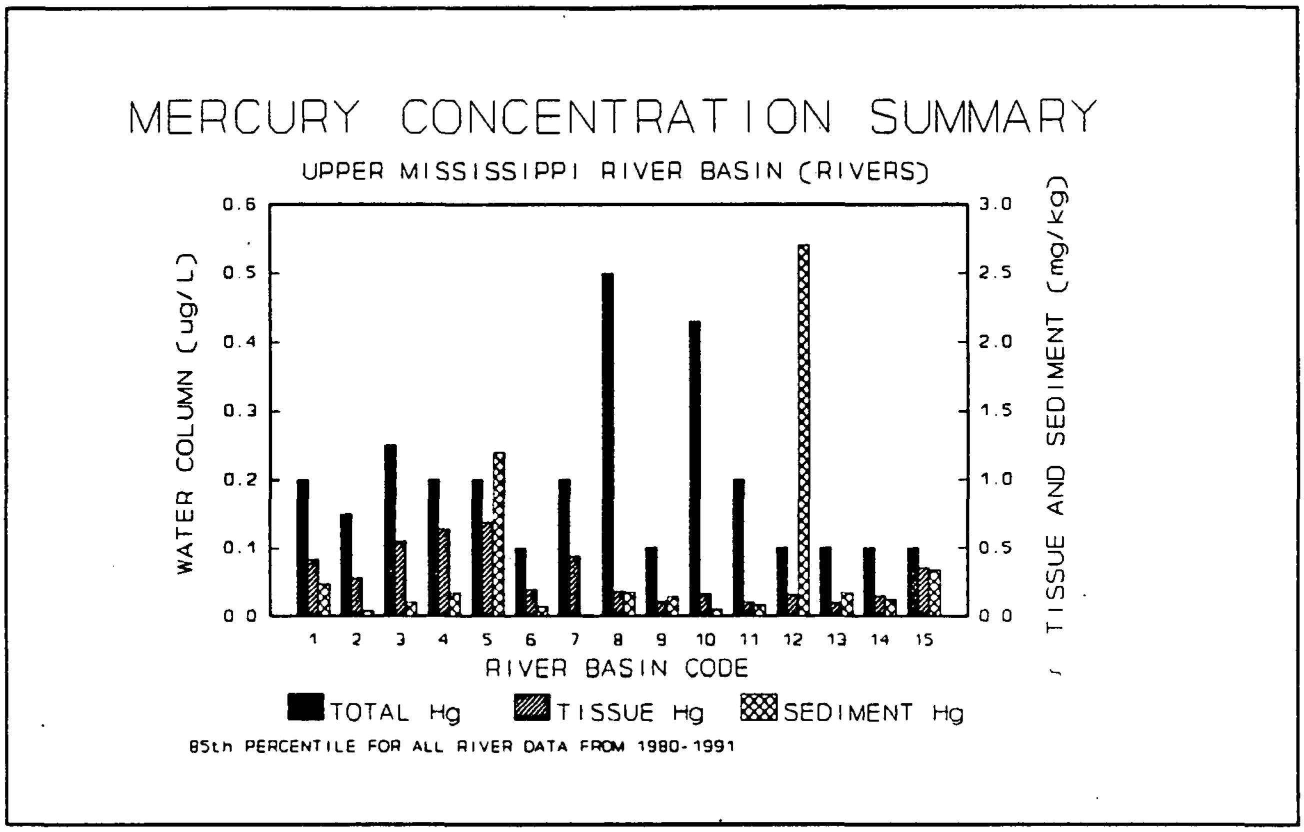

Figure A.14. Mercury concentration summary (rivers)

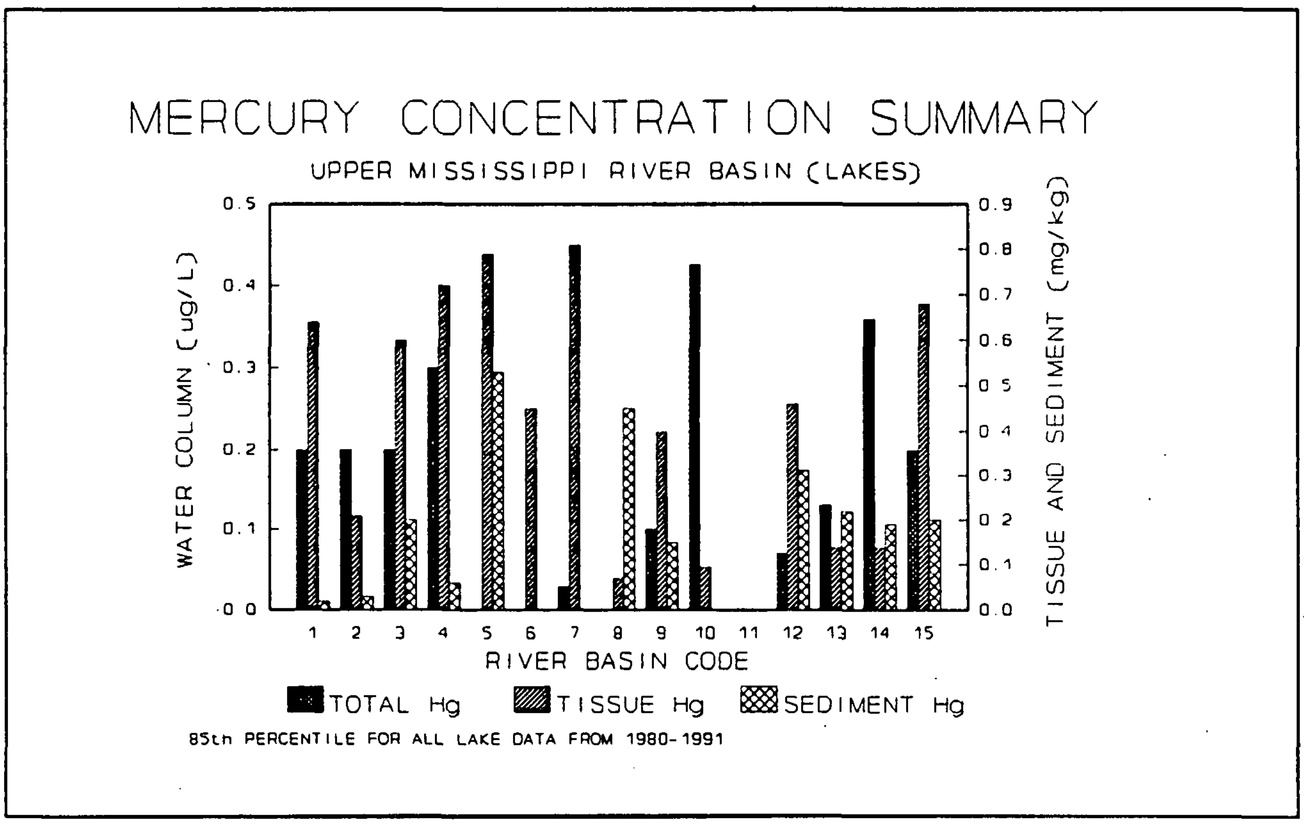

Figure A.15. Mercury concentration summary (lakes)

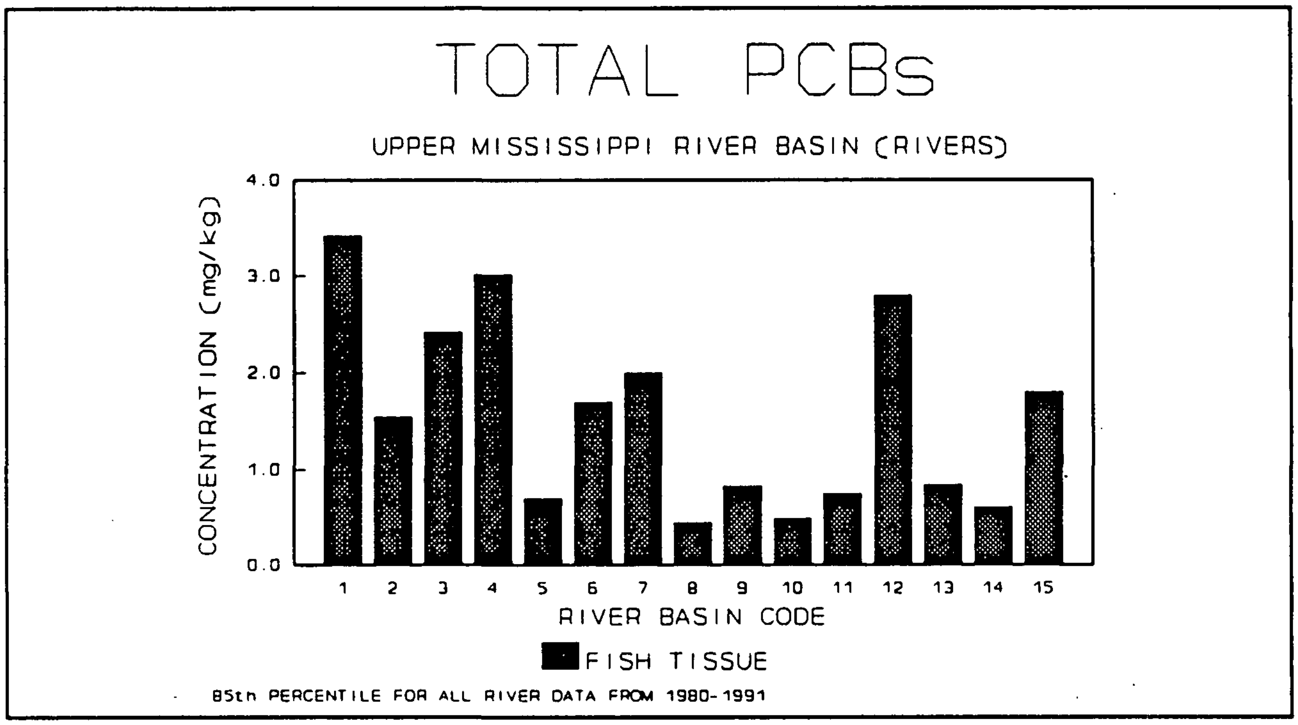

Figure A.16. PCB concentration summary (rivers)

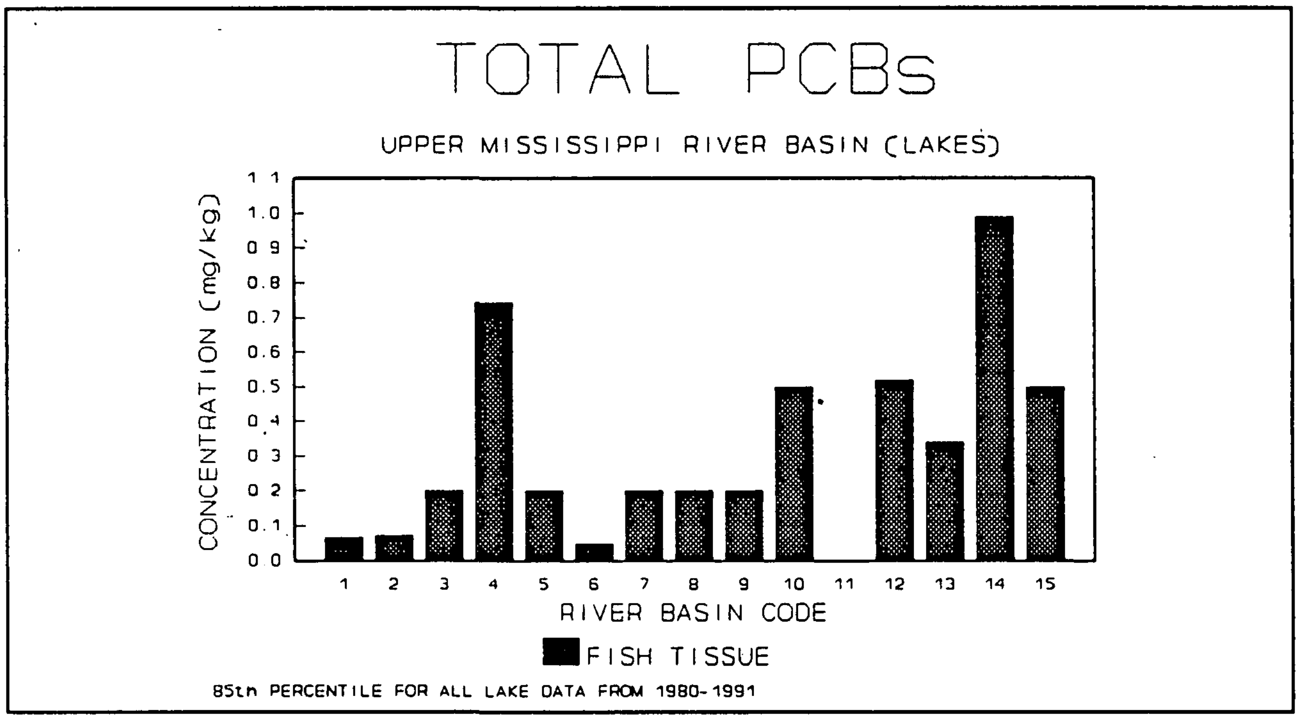

Figure A.17. PCB concentration summary (lakes)

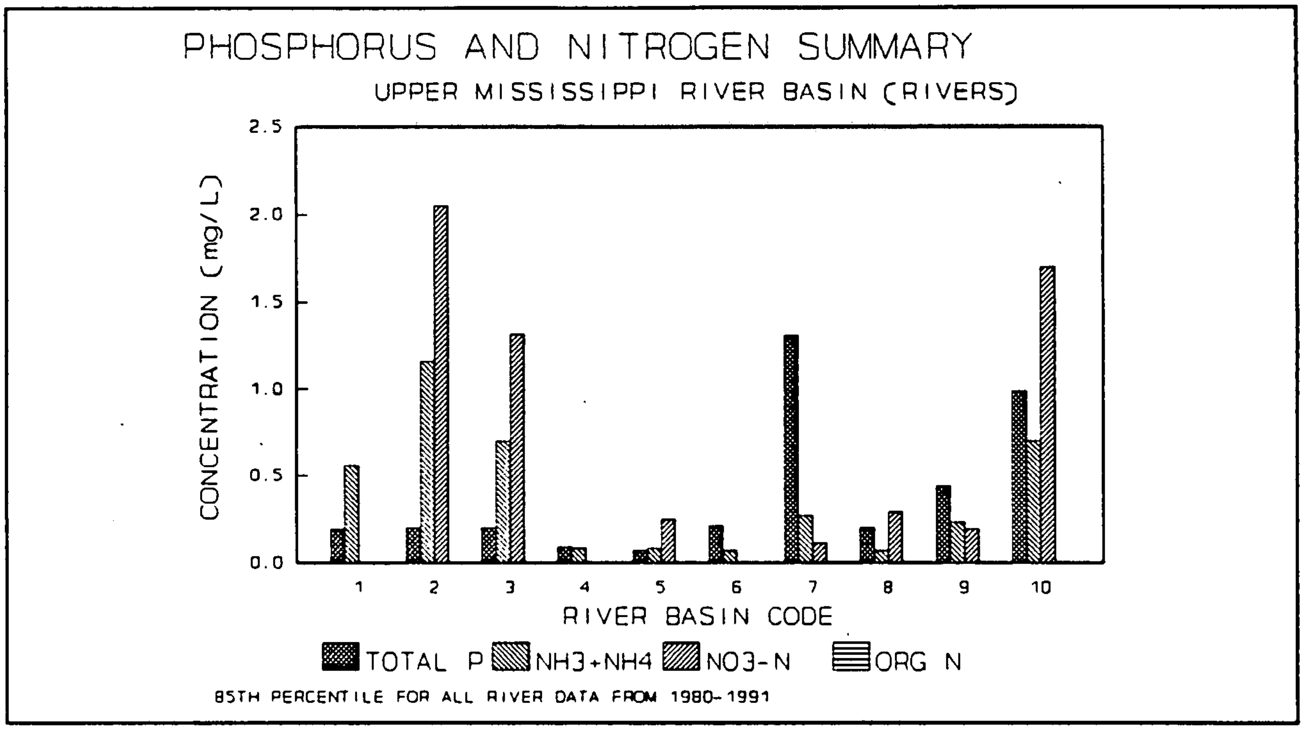

Figure A.18. Phosphorus and nitrogen concentration summary (rivers)

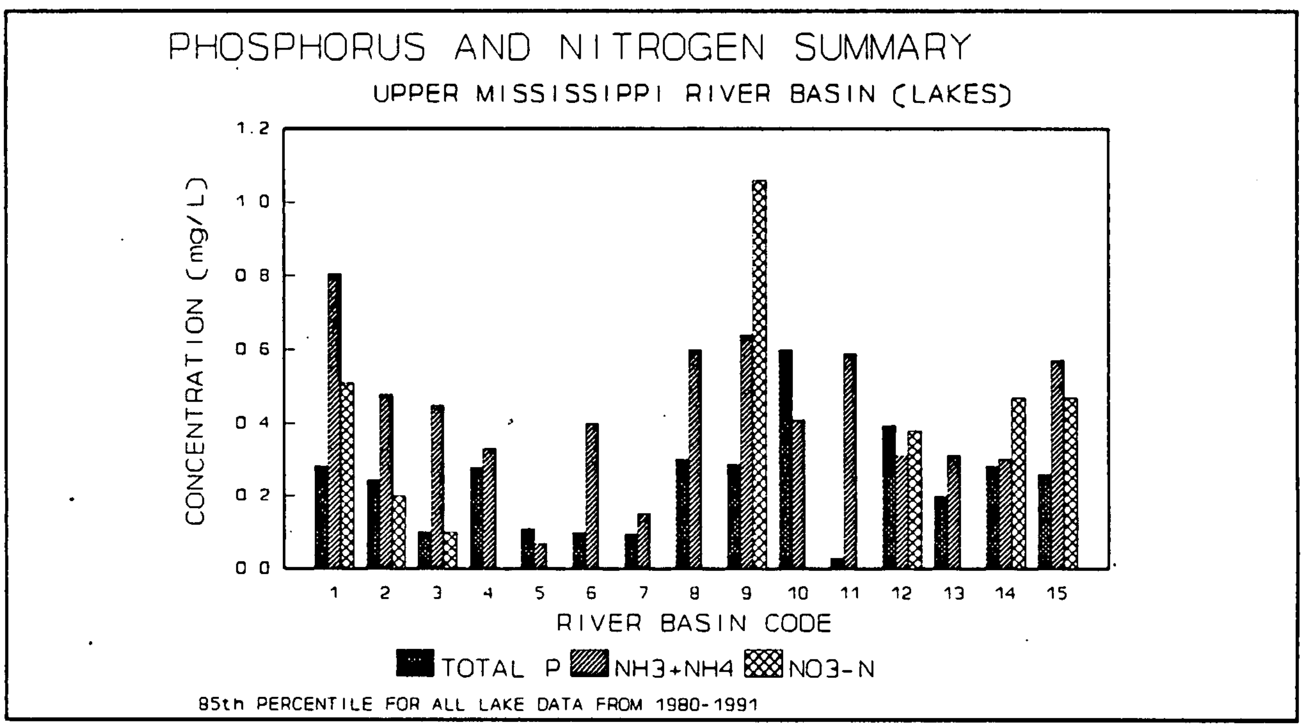

Figure A.19. Phosphorus and nitrogen concentration summary (lakes)

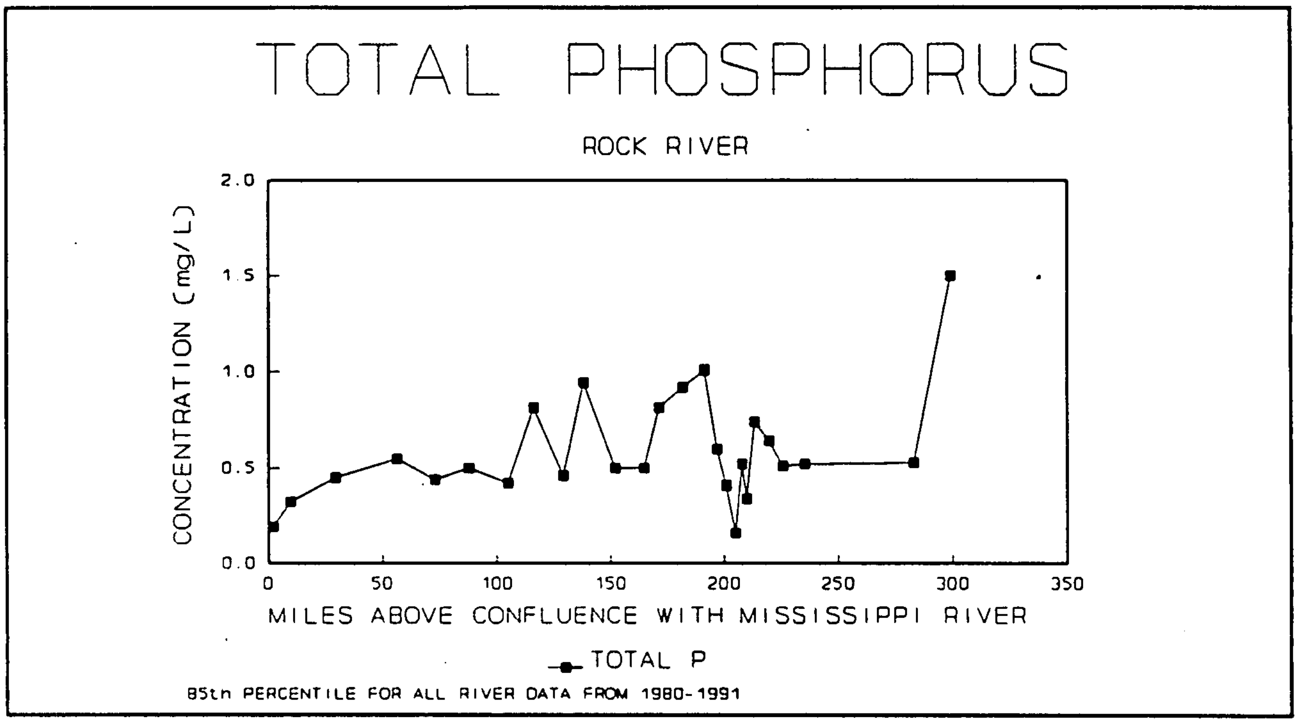

Figure A.20. Phosphorus concentration profile for Rock River

Facility Information

In addition to identifying problem areas based on receiving water quality, it may also be necessary to examine individual dischargers. In Figure A.21, STORET was used to retrieve and plot all facility locations from the Industrial Facilities Discharge (IFD) file that discharge to major rivers in the upper Mississippi River drainage area.

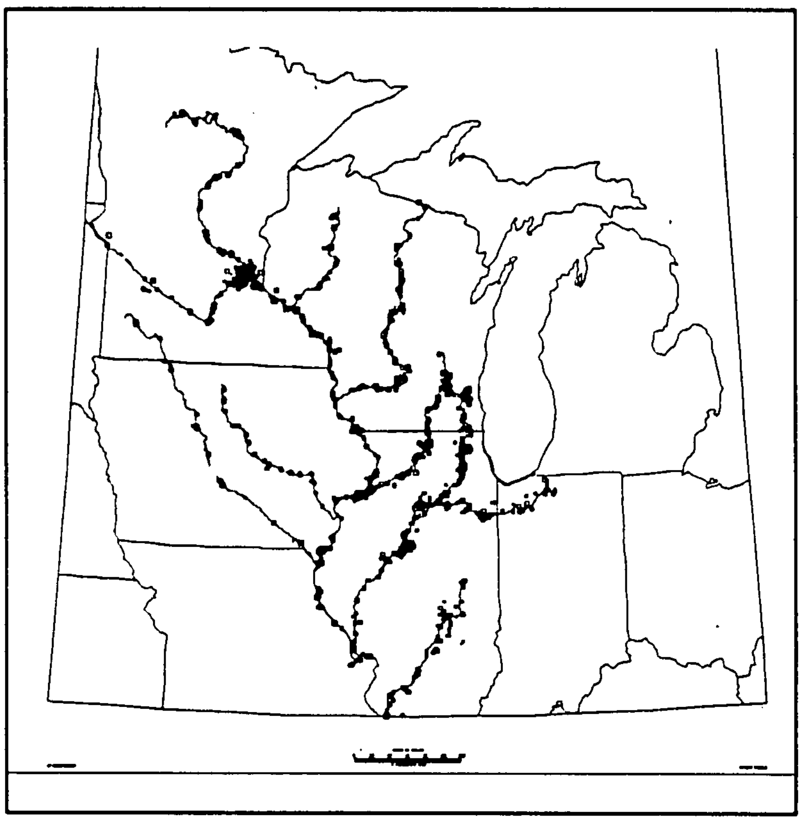

Figure A.21. NPDES facilities

In some cases, the information in Figure A.21 is more than what is needed. For example, the water quality analyst may already know which discharge to examine. In this case, MDDM is used to display a two mile by two mile window of a facility on the Wisconsin River (Figure A.22).

Figure A.22. Specific facility

Using EDDM, one may then interactively plot data from a facility's discharge monitoring report (DMR). Figure A.23 is a plot of flow, total nonfilterable residue, BOD_5, and total ammonia nitrogen accessed from the Permit Compliance System (PCS) via EDDM. (Not all mainframe users have clearance for this option.)

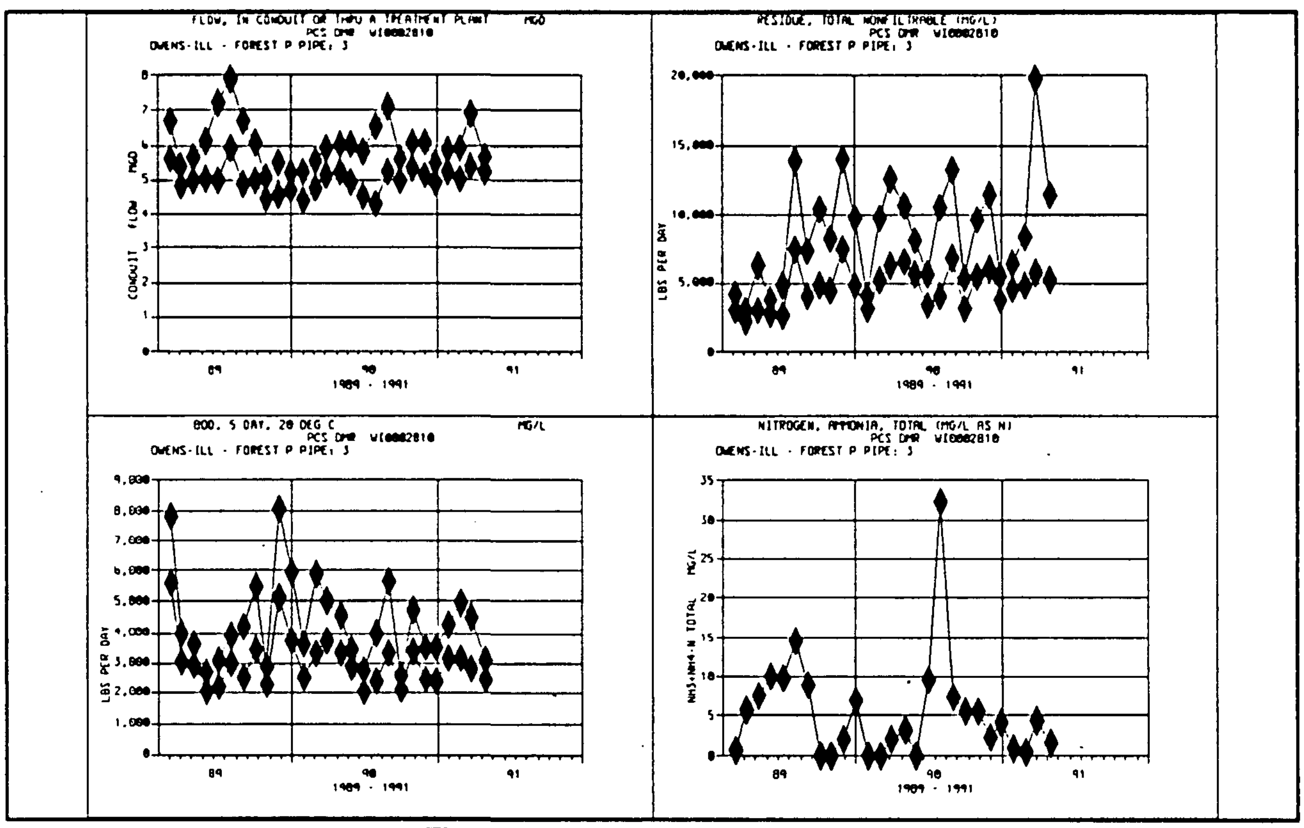

Figure A.23. Data retrieved from PCS

Spatial Analysis of Selected Coastal Areas

In a similar analysis to the upper Mississippi River drainage basin example, six coastal areas were selected for nutrient screening analysis. Table A.4 and Figure A.24 summarize the selected areas.

Table A.4. Coastal code

109	Boston Harbor/Bay
204	Delaware Bay
206	Norfolk, VA
206	Norfolk, VA
301	Pamlico Sound, NC
302	Pamlico Sound, NC
310	Tampa Bay, FL
1203	Galveston Bay, TX
1204	Galveston Bay, TX

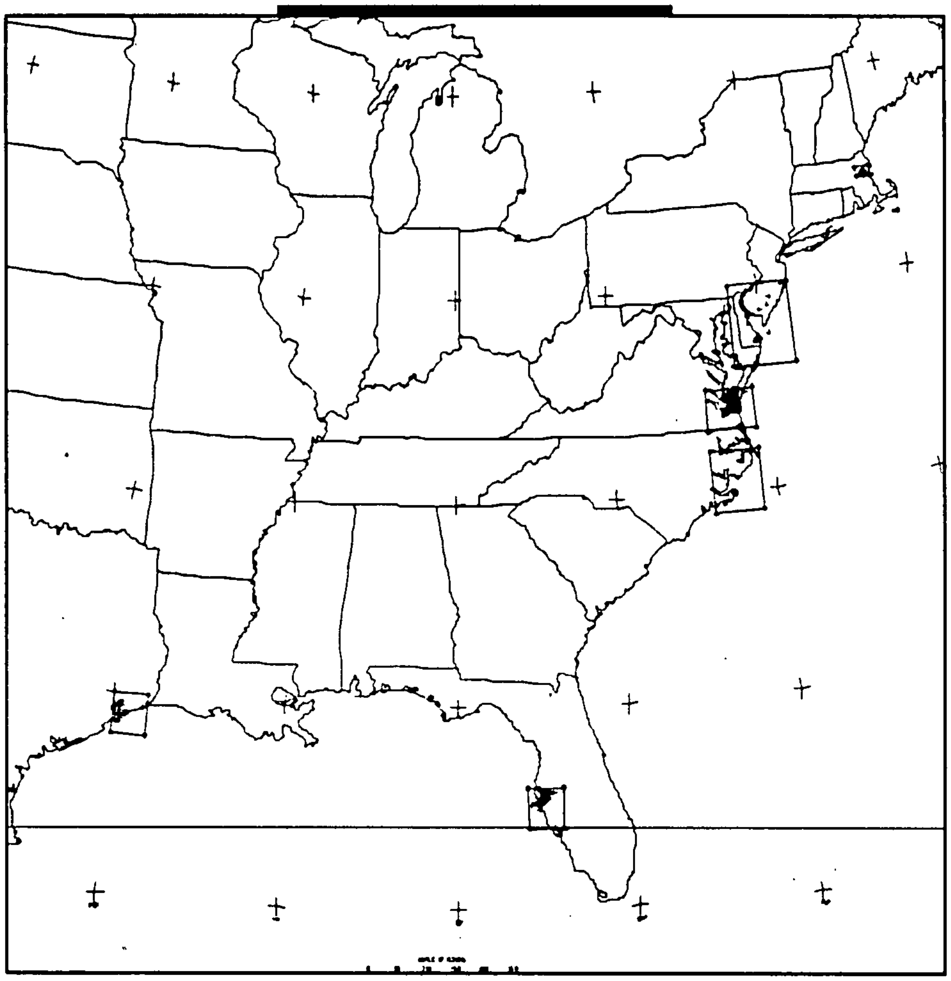

Figure A.24. Coastal map

In this case, polygons defining the boundary of the selected coastal zones were entered by the user. The phosphorus and nitrogen 85th percentile concentration for each zone is summarized in Figure A.25. Figure A.26 is a monitoring location map for Galveston Bay, Texas and was generated by STORET. Figure A.27 is a two dimensional plot of pH and a surface plot of chlorophyll *a* for Galveston Bay using UNIMAP. (It looked a whole lot better in color -- trust us.)

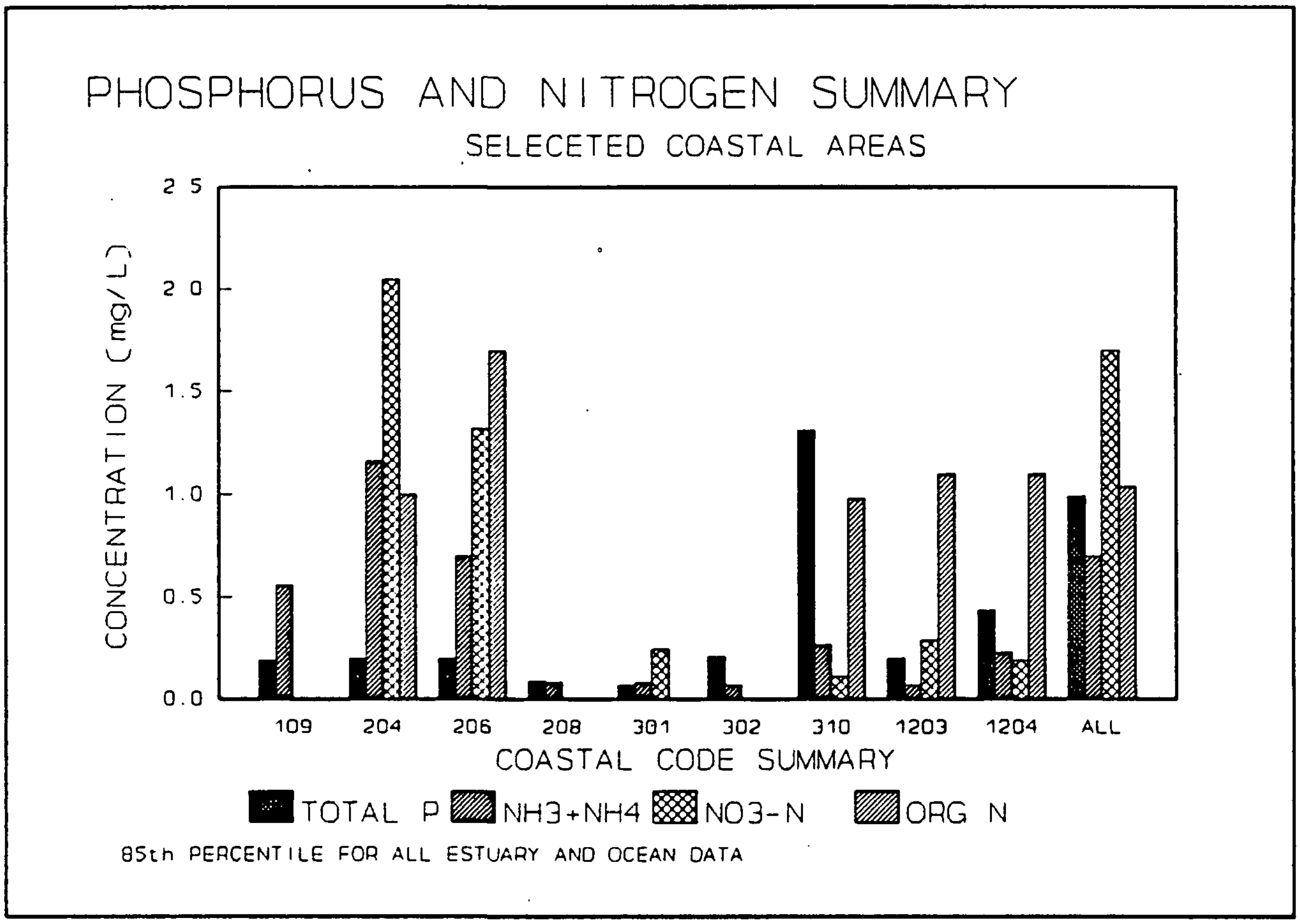

Figure A.25. Phosphorus and nitrogen concentration summary

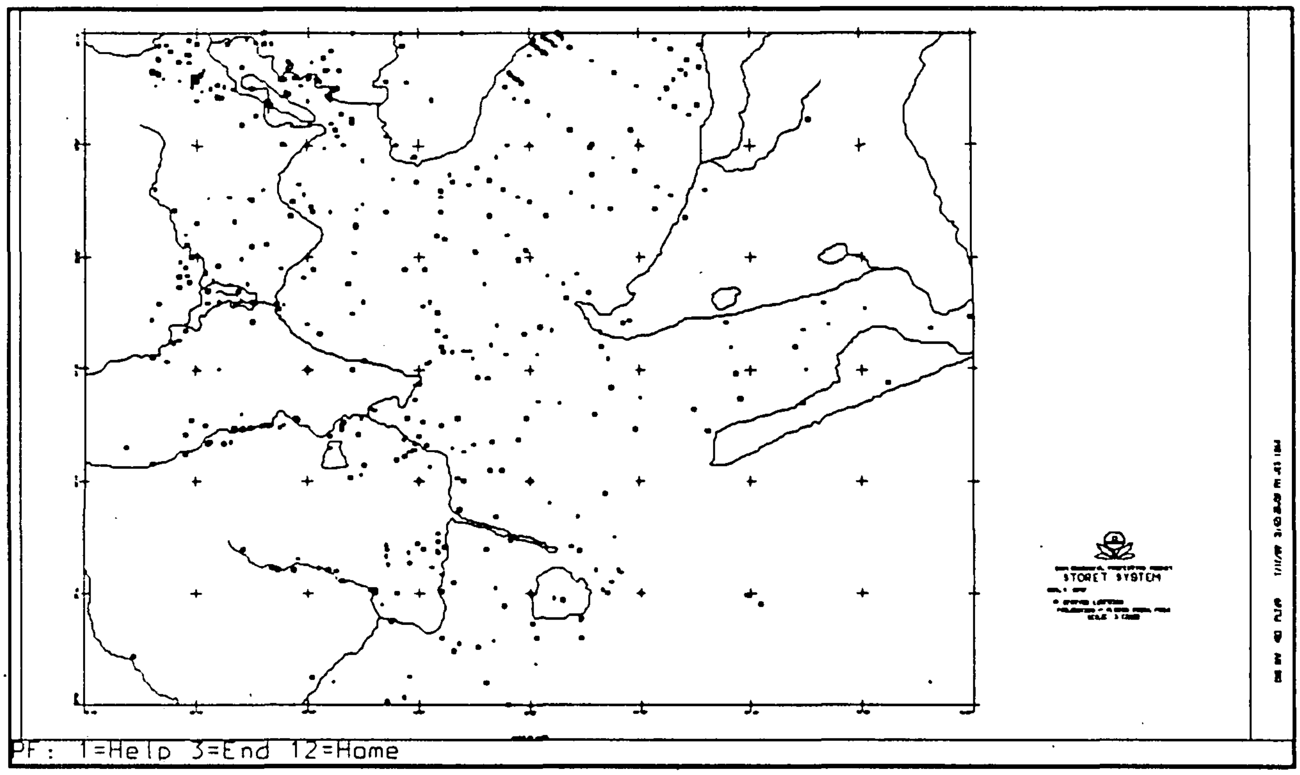

Figure A.26. Monitoring locations in Galveston Bay

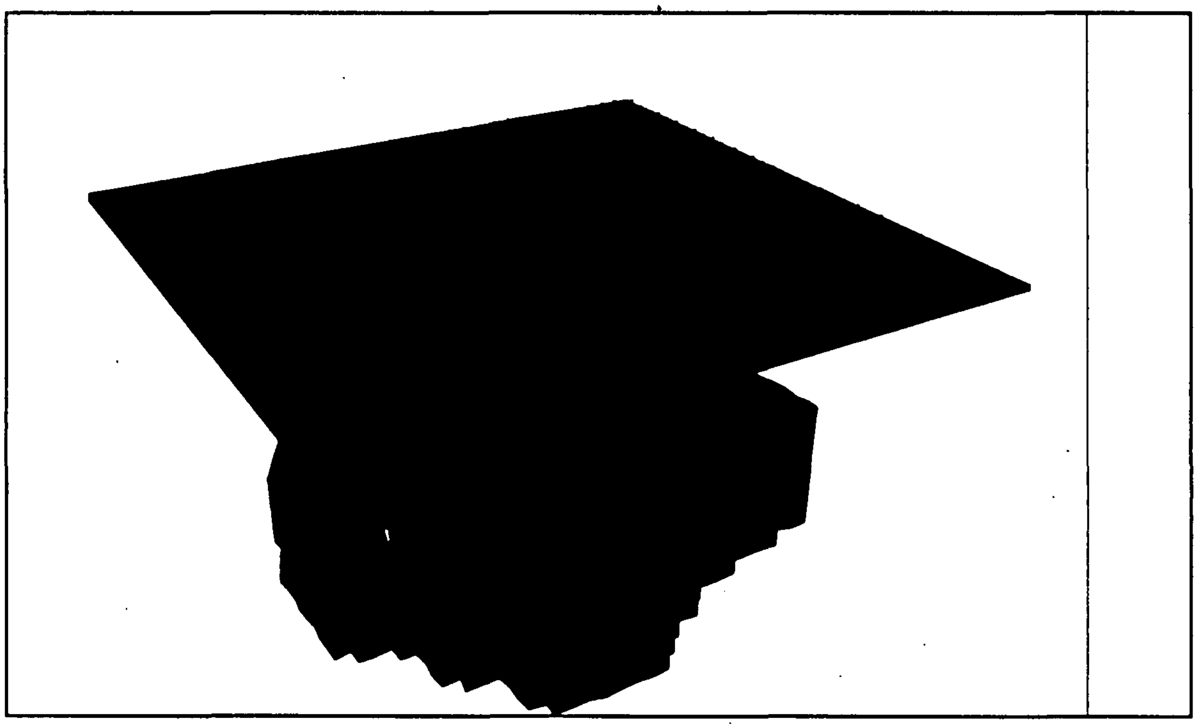

Figure A.27. Example UNIMAP output

OWOW/AWPD Data Files

Drinking Water Supply File - The Drinking Water Supply File contains information on 8,000 water supplies that utilize surface waters. Data covers FRDS number, utility name, city, state, basin, latitude and longitude, stream reach, population served, water volume used, and locations for plant, intakes, and sources.

Gage - The Stream Gage Data File contains information on approximately 36,000 stream gaging locations throughout the United States. Information stored includes locations of gaging streams, stream reach identification, types of data collected, frequency of data collection, media in which the data are stored, identification of the collection agency, mean annual flow and 7 day/10 year flow.

City - This file contains data on 53,000 cities, towns, and villages located in the United States and its possessions.l Information on each city includes the city's unique identification code; the county, state, major and minor river basin, and congressional district within which it is geographically located; stream reaches associated with the city; its latitude and longitude; and its census population data.

Dam - Inventory of 68,000 dams produced y U.S. Army Corps of Engineers which provides type, ownership, purpose, height, volume, surface area, latitude-longitude, stream reach.

Industrial Facilities - The Industrial Facilities Discharge File contains information on 128,000 NPDES industrial and municipal facilities (active and inactive) useful for environmental analyses. Data consists of NPDES, DUNS, and Needs A/F numbers with name, address, basin latitude and longitude, stream reach, flow, SIC codes, discharges type for facility and pipe level, and industrial category. Indirect discharges to POTW systems are also included.

CETIS - The Complex Effluent and Toxicity Information System contains Bioassay results for NPDES discharges toxicity tests.

ASIWPCA - Streams reported in the Americas' Clean Water - STEP report by the Associations of State and Interstate Water Pollution Control Administrators (ASIWPCA) covering water quality impairments for 1'972, 1982, and 1984 and indexed to the version 1 reach file.

ICAT - Industrial categories used in effluent guidelines studies are grouped with standard industrial classification (SCI) indexes.

STORET PARM - Information on 13,000 STORET parameters indicating reporting units, media, CAS registry number, and chemical/biological type.

ODES - The Ocean Data Evaluation System is an extensive system of software for managing and analyzing marine environmental monitoring data.

PCS - The Permit Compliance System contains NPDES permit compliance, tracking and discharge monitoring reports for active permitted facilities.

Reach File - The River Reach File provides hydrologic connectivity between geographic locations and historical data created for the express purpose of performing hydrologic routing for modeling programs. The Reach File, Version 1, contains 68,000 stream reaches covering 100% of the continental U.S. and is indexed with STORET, IFD, drinking water supplies, stream gages, and fishkills, Version 3 covers 80% of the U.S. and provides hydrologic linkages for 3.5 million reaches based ion the USGSW DLG data.

STORET-BIOS - A component of STORET containing distribution, abundance, physical condition, and habitat description of aquatic organisms. These are integrated with the water quality file and linked to the reach file, PCS, IFD, and Gage files.

STORET-USGS Flow - Contains daily stream observations of stream flow and miscellaneous water quality at USGS gaging stations. These data represent more than 695,000 water years for over 29,000 gages.

STORET - WQ - The agency's water quality system containing physical, chemical and biological parameters. More than 800 monitoring organizations have provided 175 million parametric observations from 700,000 sampling locations for surface water, ground water, fish tissue, and sediment. The sample locations are indexed to the reach file IFD, GAGE, and drinking water file with a PCS interface.

STORET - Tissue - Tissue sample results cover over 530 parameters including metals, organics, and pesticides specific to species, tissue types, length, weight, and sex. These data and stations are integrated with the water quality file and indexed to the reach file with indexes to IFD, Gage, drinking water files and the PCS interface.

STORET Form 2C - Priority pollutant data reported by NPDES second round permits are in STORET referenced by the permit number and can be integrated with the water quality data and PCS data with the PCS/STORET interface.

WBS - The Waterbody System data base contains water quality assessment information collected by states for 305(b) reporting. These data serve as an inventory of each state's navigable waters that have been assessed.

OW Mainframe Procedures Through TSO

ASIWPCA	Interactive program providing information on stream use impairment
CITY	Interactive program providing overview information on cities
DAMR	Interactive program providing information on dams in the U.S.
DFLOW	Interactive program providing assessing daily flows at gages and providing selected flow statistics
DXLIST	Interactive program providing information on dioxin
EDDM	Interactive program for graphically displaying locations of monitoring activities, PCS and WQ data
FLOW	Interactive program providing information on gage mean flow, 7Q 10 low flows, and daily flows
ICAT	Procedure to list industrial categories and related SIC codes in IFD File used by ITD
IFDPLOT	Interactive program to setup graphical displays of Facility data
IFDRET	Interactive program for generating standard tables of information from IFD
IPS5	Interactive procedure for generating reports from STORET, PCS and IHS files
ISR	Interactive generates selected STORET and IFD reports and D.O. model using PCS DMR data
MDDM	Interactive mapping system for the Reach File, Facility, WQ and WBS data
PARM	Interactive program for providing information on STORET parameters
PATHSCAN	Retrieval of information on hydrological streampaths from NPDES discharge locations
RCHDAT	Interactive program for retrieving reach, streamflow & discharger data
RCHRET	Interactive procedure for generating reach trace Auxfiles for plotting or export
RPA3	Reach pollutant assessment software providing reports using STORET, PCS, TRIS and IHS data
SIC	Interactive program to obtain SIC codes and descriptions used in the IFD File
SITEHELP	Interactive graphical and text retrieval of stream referenced data using IHS, STORET, & PCS files
STRAUX	Procedure which generates a STORET AUXFILE for selected reach number
USE	Interactive program for summarizing WQAB procedure usage for given user

AVAILABILITY/RELATIONSHIP OF OW DATA FILES AND SOFTWARE ON THE MAINFRAME

OW Info. Systems Compendium *	Data File	FILE TYPE	WBS	EDDM	MDDM	IPS5	SITEHELP	PATHSCAN	RCHDAT	CITY	DAMR	IFDPLOT	DFLOW	PARM	RPA	STORET	ODES	IFDRET	GQ	IHS Browse	Flow	ISR	STRAUX	SIC	RCHRET
Drinking Water Supply File	*DRINKS*	IHS		✓		✓	✓	✓				✓				✓			✓	✓		✓			
Gage, City, Dam Files	*GAGE*	IHS		✓		✓	✓	✓	✓			✓				✓			✓	✓	✓				
	CITY	IHS		✓	✓	✓	✓			✓									✓	✓					
	DAM	IHS									✓					✓			✓	✓					
Industrial Facilities Discharge File	*IFD*	IHS		✓	✓	✓	✓	✓	✓			✓			✓	✓		✓	✓	✓			✓		
	CETIS	IHS				✓	✓												✓	✓					
	ASIWPCA	IHS				✓	✓								✓				✓	✓					
	ICAT	IHS													✓									✓	
	ISS	IHS													✓										
	304(I)	D													✓										
	PARM	IHS		✓		✓								✓	✓	✓									
ODES	*ODES*	SAS														✓	✓								
PCS	PCS	ADA		✓		✓									✓	✓									
Reach File	*RF1 Structure*	IHS	✓	✓	✓	✓	✓	✓	✓						✓	✓			✓	✓		✓	✓		✓
	RF1 Trace	IHS	✓	✓			✓					✓			✓	✓			✓	✓		✓	✓		✓
	RF2 Structure	IHS	✓		✓		✓	✓								✓			✓	✓					
	RF3 Structure	VSAM		✓	✓																				
	RF3 Trace	VSAM	✓	✓	✓																				
STORET - BIOS	BIOS	IHS														✓						✓			
- Daily Flow	USGS Flow	W											✓			✓						✓			
- Fish Kill	Fishkill	S					✓									✓									
- WQ	WQ	S		✓	✓	✓	✓								✓	✓						✓	✓		
	Tissue	S		✓											✓	✓									
	FORM2C	S				✓	✓								✓	✓									
	GRAPHICS	IHS			✓							✓			✓	✓						✓	✓		✓
WBS	*WBS*	IHS	✓													✓			✓						
	TRIS	ADA		✓											✓										
	FINDS	ADA					✓																		

* Office of Water Environmental and Program Information Systems Compendium FY1990

Workshop Agenda

WEDNESDAY, JUNE 26

8:00 a.m.	Welcome & Introductory Remarks Carl Myers, U.S. EPA, Deputy Director, Assessment and Watershed Protection Division William Diamond, U.S. EPA, Director, Standards and Applied Science Division
8:30 a.m.	Regional Perspective on Water Quality-based Point Source & NPS Controls Jon Grand, Deputy Director, Water Management Division, U.S. EPA - Region V
8:50 a.m.	Overview of 303(d) & Workshop Objectives Bruce Newton, U.S. EPA, Chief, Watershed Branch
9:10 a.m.	The Watershed Approach from a Point Source Perspective William Brandes, U.S. EPA, Chief, Water Quality and Industrial Permits Branch
9:30 a.m.	**BREAK**

Section 1: Problem Diagnosis

Nelson Thomas, Topic Chair

9:45 a.m.	Top-Down & Bottom-up Approaches for Integrated Assessment of Point & Nonpoint Source Pollution Kenneth L. Dicksen, Institute of Applied Sciences
10:30 a.m.	Diagnosis & Assessment Tools/Models for Determining Nutrient TMDLs Norbert Jaworski, U.S. EPA ERL - Narragansett

Section 2: Watershed Modeling

Lee Mulkey, Topic Chair

11:15 p.m.	Watershed Modeling & TMDL Assessments Anthony S. Donigian, AQUA TERRA Consultants
12 noon	**LUNCH**
1:15 p.m.	Water Quality Diagnosis & Assessment Tools/Models Eugene D. Driscoll, Woodward-Clyde Consultants
2:00 p.m.	Model Capabilities (Agricultural & Urban) Leslie L. Shoemaker, Tetra Tech, Inc.
2:45 p.m.	**BREAK**
3:00 p.m.	Model Capabilities - A User Focus Paul L. Freedman, Limno-Tech, Inc.

3:45 p.m. North Carolina's Basinwide Water Quality Management Approach to Developing TMDLs

Ruth Swanek, North Carolina Department of Environmental Management

4:15 p.m. Modeling Integration & Data Access Tools

Robert B. Ambrose, U.S. EPA ERL - Athens

5:00 p.m. **ADJOURN**

5:30 to 7:00 p.m. **Informal Reception**

THURSDAY, JUNE 27

Section 3: Data Sources, Tools, & Investigations

Ross Lunetta, Topic Chair

8:00 a.m. Multistage Remote Sensing Data Applications for GIS Data Base Development in Support of Nonpoint Watershed Modeling

Ross S. Lunetta, U.S. EPA EMSL - Las Vegas

8:45 a.m. GIS for Nonpoint Source Watershed Modeling Applications

Mason J. Hewitt, III, U.S. EPA EMSL - Las Vegas

9:30 a.m. Grass Waterworks - An Interface Between GIS & Models

Jon F. Bartholic, Institute of Water Research and Center for Remote Sensing

10:15 a.m. **BREAK**

10:30 a.m. Remote Sensing of Agricultural Practices & Downstream Water Quality as Influenced by Sediment from Nonpoint Sources

John G. Lyon, The Ohio State University

11:15 a.m. The Trials, Tribulations, & Successes of Using Remote Sensing, GIS and Modeling

Carol Russell, (formerly with) Arizona Department of Environmental Quality

12 noon **LUNCH**

Section 4: Predictive Modeling of Ecological Restoration

Nelson Thomas, Topic Chair

1:00 p.m. An Overview of Ecological Assessment and Restoration Tools

Carl Richards, Natural Resources Research Institute

1:45 p.m. Application of Tools for Ecological Restoration Predictive Modeling

James A. Gore, Austin Peay State University

2:15 p.m. Ecosystem Assessment & Restoration: The Role of Modeling and Predictability

Michael L. Johnson, Kansas Biological Survey

3:00 p.m. **BREAK**

Workgroup Breakout Sessions

3:15 p.m. All workgroups should address the following:

- the state-of-the-science
- the quality of available tools
- the use of each tool in the TMDL process
- limitations/needed improvements of tools

- recommendations for research and development
- recommendations for technical guidance

1. Watershed Modeling

Chair:	Lee Mulkey, U.S. EPA - Athens
Facilitator:	James Giattina, U.S. EPA - Region V
Recorder:	David Dilks, Limno-Tech

2. Data Sources, Tools, & Investigations

Chair:	Ross Lunetta, U.S. EPA - Las Vegas
Facilitator:	Mason Hewitt, U.S. EPA - Las Vegas
Recorder:	Michael McCarthy, RTI

3. Predictive Modeling of Ecological Restoration

Chair:	Nelson Thomas, U.S. EPA - Duluth
Facilitator:	Ron Carlson, U.S. EPA - Duluth
Recorder:	Amy Sosin, U.S. EPA - HQ

4. Selected Point Source Issues

Chair:	Elizabeth Southerland, U.S. EPA - HQ
Facilitator:	Bruce Zander, U.S. EPA - Region VIII
Recorder:	Paul Freedman, Limno-Tech

5:00 p.m. **ADJOURN**

FRIDAY, JUNE 28

8:00 a.m.	Continuation of Workgroup Breakout Sessions
12 noon	**LUNCH**
1:00 p.m.	Watershed Modeling - Workgroup Summary
1:20 p.m.	Data Sources, Tools, & Investigations - Workgroup Summary

1:40 p.m.	Predictive Modeling of Ecological Restoration - Workgroup Summary
2:00 p.m.	Selected Point Source Issues - Workgroup Summary
2:20 p.m.	**BREAK**
2:30 p.m.	Plenary Discussion - Priorities Bruce Zander, U.S. EPA Region VIII - Moderator
3:15 p.m.	Wrap-up: Where Do We Go From Here? Bruce Newton, U.S. EPA, Chief, Watershed Branch - Moderator
3:30 p.m.	**ADJOURN**

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