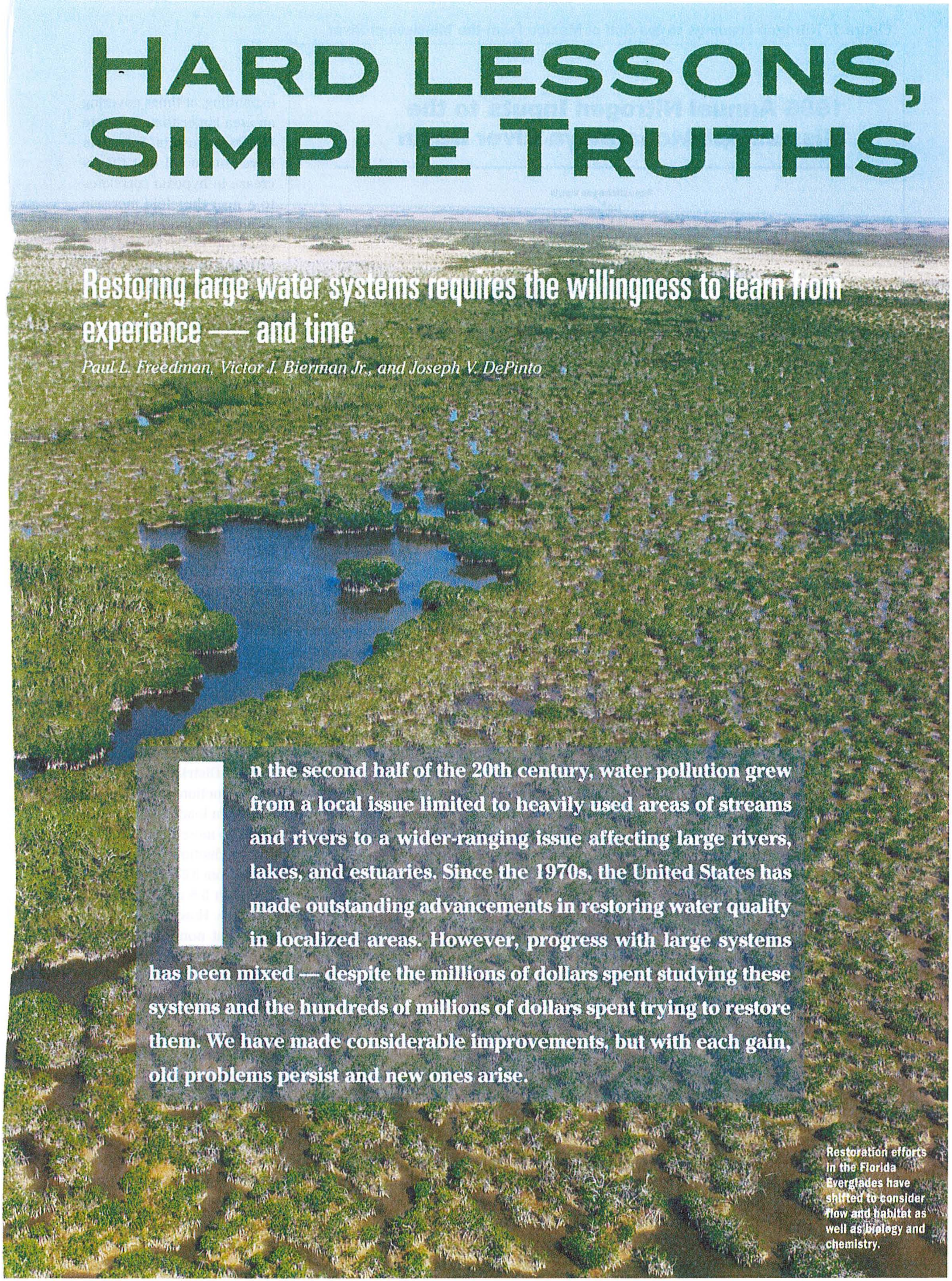
Hard Lessons, Simple Truths

Restoring large water systems requires the willingness to learn from experience — and time

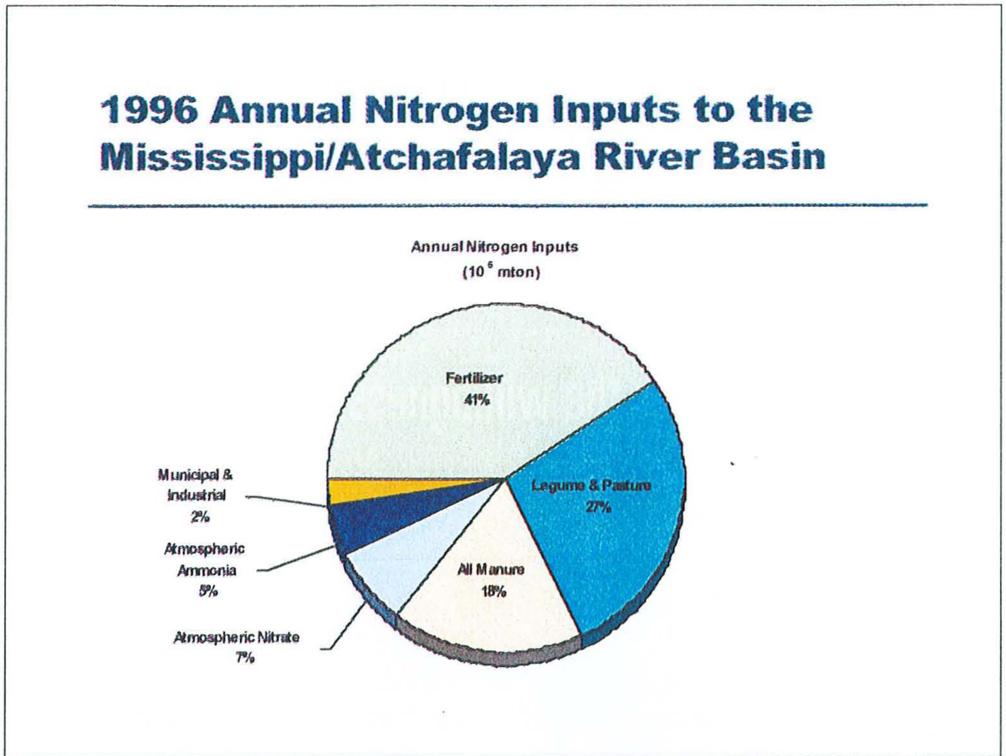
Paul L. Freedman, Victor J. Bierman Jr., and Joseph V. DePinto



In the second half of the 20th century, water pollution grew from a local issue limited to heavily used areas of streams and rivers to a wider-ranging issue affecting large rivers, lakes, and estuaries. Since the 1970s, the United States has made outstanding advancements in restoring water quality in localized areas. However, progress with large systems has been mixed — despite the millions of dollars spent studying these systems and the hundreds of millions of dollars spent trying to restore them. We have made considerable improvements, but with each gain, old problems persist and new ones arise.

Restoration efforts in the Florida Everglades have shifted to consider flow and habitat as well as biology and chemistry.

Figure 1. Nitrogen Loadings to the Gulf of Mexico From the Mississippi River



Source: D. A. Goolsby et al (1999). *Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico*, National Oceanic and Atmospheric Administration.

This article explores some simple truths learned from this long and difficult history. Hopefully, these lessons will help us make better decisions in the future as we work to protect and restore large water systems.

To Restore the Water, Focus on the Land

The initial focus of pollution controls was on wastewater point sources, which the Clean Water Act (CWA) successfully has controlled through National Pollutant Discharge Elimination System permit requirements. However, nonpoint source pollution from land uses is growing and has become a regional and national issue. Long-term success in restoring large waterbodies now depends on controlling pollution sources from the entire watershed.

A 2000 national assessment by the U.S. Environmental Protection Agency (EPA) found that 90% of impaired waters are impaired at least in part because of nonpoint pollution sources. Approximately half are impaired solely by nonpoint or land use sources of pollution. Similarly, in large regional waterbodies, we have observed that nonpoint sources are a growing contributor to pollution. Controlling these sources is key to protecting and restoring water quality.

This truth is apparent when looking for solutions to the hypoxic zone in the northern Gulf of Mexico. An area of low dissolved oxygen — a "dead zone" — forms off the coast of Louisiana each summer. This dead zone is expanding, at times covering an area larger than the state of Massachusetts. Scientists have concluded that the increase in hypoxia correlates to a near-threefold increase in nitrogen load to the gulf since the 1950s. Most of this nitrogen load results from fertilizer application and agricultural practices in the Mississippi River Basin.

The Federal–State–Tribal Action Plan issued by EPA in 2001 for reducing hypoxia in the northern Gulf of Mexico included a goal to reduce the average size of the hypoxic zone to less than 5000 km^2 by 2015. Results from three different models suggest that a 40% to 45% percent reduction in nitrogen loads from the Mississippi River Basin may be necessary to achieve this goal. Unfortunately, CWA regulates only 2% of these loads, whereas 86% comes from agricultural sources (see Figure 1, above). Any significant reduction in gulf hypoxia will require us to focus on agricultural land uses and fertilizer practices.

The importance of nonpoint load sources of pollution is apparent in another prominent example, Chesapeake Bay. In 2003 the six bay watershed states and the District of Columbia agreed to new nutrient reduction goals that call for reducing annual nitrogen loads from 129 million kg (285 million lb) to no more than 79 million kg (175 million lb), a 39% reduction; and reducing annual phosphorus loads from 8.6 million kg (19.1 million lb) to no more than 5.8 million kg (12.8 million lb), a 33% reduction. However, extensive monitoring has shown that nonpoint sources, primarily from agriculture and urban runoff, contributed approximately two-thirds of the existing loads. Total elimination of all wastewater sources would only provide a little more than 20% reduction; hence, control of watershed land sources is key to ultimate restoration in the bay.

It is also evident we must control land sources in large inland waterbodies. For example, in the 1980s, Lake Erie was restored by both reducing municipal wastewater phosphorus and implementing best management practices on agricultural lands. Achieving the target phosphorus load of 11,000 tonne/yr required not only reducing the total phosphorus concentration in wastewater treatment plant effluents but also reducing nonpoint sources by 50%. Most nonpoint source reductions were achieved by implementing voluntary low-till and no-till practices on agricultural lands. As a result of these efforts, Lake Erie was transformed from the pollution poster child with hypoxia and noxious algal blooms to a magnet for tourism with a world-class walleye fishery. This remarkable success story was realized only because we focused beyond CWA and focused on the land, as well as point sources. This needs to be the general paradigm for the future if we expect to make progress in restoring large water systems.

Figure 2. Zebra Mussels Along Great Lakes Shorelines

Source: *Bay City Times* (courtesy of the Great Lakes Environmental Research Lab).

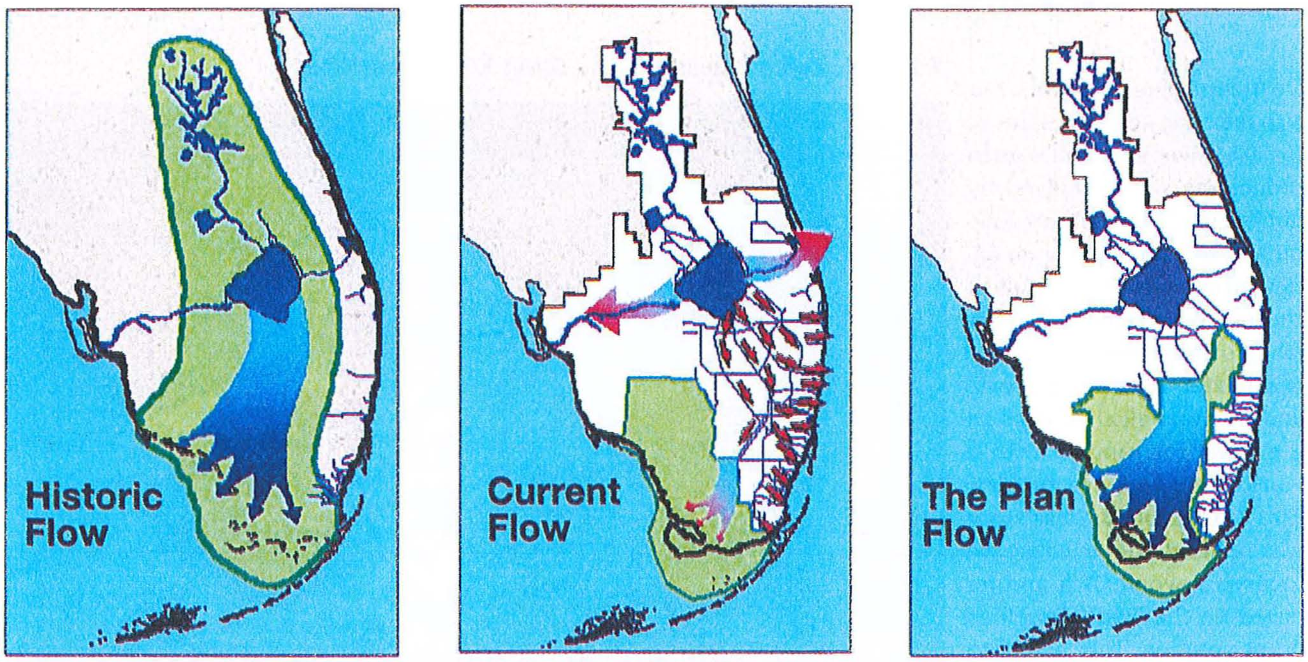
To Control Pollution, Look Beyond Chemistry

Although the objective of CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," regulatory efforts focused on controlling sources of chemical pollutants. As progress has been made in controlling pollutant sources, we now see the importance of biological and physical elements to fully restoring uses.

Biological invaders can be a more significant stressor to waterbodies than pollutant sources.

The Great Lakes have been a perfect example

Figure 3. Restoration of the Everglades



Source: Comprehensive Everglades Restoration Plan (www.evergladesplan.org/index.aspx).

of this shift to other issues. In the 1970s and 1980s, we focused largely on controlling phosphorus loads, and then toxics. However, in the mid-1990s concurrent research revealed that the most significant factors affecting the overall ecological health of the Great Lakes were not wastewater pollutant sources but lost habitat and invasive species. This shook the conventional wisdom of many scientists and Great Lakes managers but now is well-recognized and a growing focus. Today, there are nearly 200 invasive species, many creating havoc to the ecosystem. Also, land use changes in favor of urbanization continue to threaten natural habitats, especially coastal habitat and wetlands, along much of the Great Lakes shoreline.

Biologic invaders have been a significant stressor in the Great Lakes. Although eutrophication in much of the Great Lakes was reversed in the 1980s by nutrient controls, today this problem is re-emerging, in large part because of the late-1980s invasion of zebra (*Dreissena polymorpha*) and quagga (*Dreissena bugensis*) mussels (see Figure 2, p. 59). Through extremely efficient particle filtration, these invaders have altered the ecological balance by

- outcompeting zooplankton and disrupting the food web;
- selective feeding that rejects most blue-green algae species, and hence has contributed to a re-emergence of late summer blue-green algal blooms in shallow areas;
- dominating bottom sediment habitat, causing declines in ecologically important benthic organisms, such as *Diporeia*, and limiting benthic diversity; and
- mobilizing phosphorus in the nearshore, leading to a re-emergence of benthic algal mats (*e.g.*, *Chladaphora*) in many areas.

There even is speculation that *Dreissena* has promoted the return and worsening of hypoxia in the central basin of Lake Erie by leading to an increase in sediment oxygen demand.

On the physical side of restoration, flow and physical habitat are also equally important as biology and chemistry to our national goals of restoring waters. For example, in the efforts to restore the Florida Everglades, initial efforts focused on reducing phosphorus loads for wetlands converted to agricultural uses. However, scientists soon realized that flow alterations were equally important. Current efforts are focused on "replumbing" the Everglades to restore the natural hydrologic cycles and habitat (see Figure 3, above).

In another example, protecting the Truckee River and Pyramid Lake in Nevada, modeling has shown that flow diversions from the Truckee River out of the basin have a greater impact than pollutant loads from the Reno area wastewater treatment plant. It is common in arid Western waters for water diversions to have a greater impact on water quality than wastewater pollutant inputs.

In a third example, the restoration efforts on Chesapeake Bay initially focused on nutrient and chlorophyll goals as targets. However, as research evolved, scientists and managers soon realized the importance of setting goals for improving water clarity and the re-establishment of shallow area plants. In 2003, the six bay watershed states and the District of Columbia agreed to reduce baywide sediment loads and shoreline erosion in order to meet the 2010 goal of increasing bay grasses by two-thirds. Scientists believe this increased grass coverage will result in dramatic improvements throughout the entire bay ecosystem.

So, true to the CWA goal, to protect and restore large waterbodies, we need to focus on biology and physics, as well as on controlling pollutant loads to improve the chemistry.

Integrate Monitoring and Modeling

There often is a tension between empiricists who want to collect data to help understand how to restore large waterbodies and modelers who want to simulate the responses mathematically. The simple truth is that both monitoring and modeling are needed, since both are merely approximations of nature.

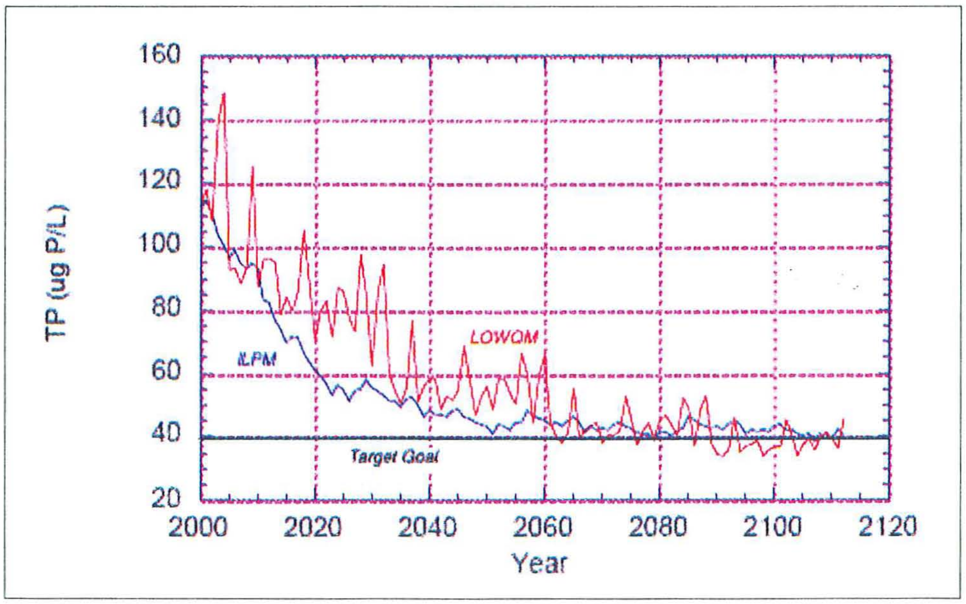
In any restoration study, it is necessary first to ask the management questions and then to design complementary monitoring and modeling programs that together provide the answers. Developing models early helps guide priorities for sampling and research, as well as being useful in screening alternative approaches for restoration. After some time, data become the foundation of reliable models, because only through data collection can the model be effectively validated, refined, and improved. However, a common theme in both monitoring and modeling is to start simple and progress in complexity and scope as understanding progresses and the nature of questions become more specific.

In every successful large-scale restoration effort, management decisions have been based on insights gained by integrating both monitoring and modeling programs. Ultimately, models validated with strong data were the tools that transformed unproductive debate about needed controls into effective negotiation and real action. This approach worked successfully in restoration efforts in the Great Lakes, Puget Sound, Chesapeake Bay, Neuse River Estuary, and Lake Okeechobee.

Models based on good data also are effective tools for clarifying unrealistic expectations. We all desire fully restored waters that are safe for all uses, but sometimes these expectations are unrealistic. Models are perfect tools for testing these realities. For example, in the Delaware River Estuary, levels of PCBs in fish exceed consumption guidelines, and a total maximum daily load was undertaken to help restore levels to safe concentrations. Initial expectations were that controlling point sources of PCBs would restore safe levels. However, models clearly showed that nonpoint, atmospheric, and sediment contributions that cannot be quickly controlled will confound attainment. As a result, stakeholders altered their expectations to more realistic schedules and goals.

The Potomac River Estuary serves as another example of effectively integrating models and data. In the 1970s, an aggressive phosphorus control program was undertaken based on modeling analysis that indicated reductions were required to eliminate noxious algal blooms. However, in 1983, a massive bloom occurred, and data suggested to some that the modeling and phosphorus control strategy were flawed and that controls were needed to decrease nitrogen instead of phosphorus. However, an integrated monitoring and modeling program demonstrated that the bloom was a result of peculiar environmental conditions that year and a massive sediment release of phosphorus. The phosphorus control strategy was deemed sound and proved

Figure 4. Phosphorus Levels in Lake Okeechobee



ILPM = internal loading phosphorus model.

LOWQM = Lake Okeechobee water quality model.

Adapted from Blasland, Bouck & Lee (2003). *Evaluation of Alternatives, Lake Okeechobee Sediment Management Feasibility Study, South Florida Water Management District* (C-11650).

For More Information

Chesapeake Bay Program
www.chesapeakebay.net

Delaware River
www.state.nj.us/drbc

Florida Everglades and Lake Okeechobee
www.evergladesplan.org/index.aspx and www.dep.state.fl.us/water/tmdl

Great Lakes Regional Collaboration
www.glrc.us

Hudson River
www.epa.gov/hudson

Mississippi River and Gulf of Mexico Hypoxia
www.epa.gov/msbasin

State of the Lakes Ecosystem Conference
www.epa.gov/glnpo/solec

U.S. EPA Water Quality Assessment
www.epa.gov/305b

ultimately successful for the Potomac. Neither modeling nor data alone were sufficient to answer this critical management query confidently. (Nitrogen controls ultimately were added more than a decade later, but only because modeling showed they were needed mainly to protect Chesapeake Bay, not the Potomac itself.)

So the adage is, in order to develop effective restoration plans, ask your questions first, then use an integrated program of modeling and monitoring that directly addresses those key questions in a progressive fashion.

Keep an Eye on the Long Term

In the environmental field, we were able to accomplish quick restorations in small systems, but larger systems typically have much longer response times. Additionally, the precision of our forecasts is limited. Given the natural variability in the environment and the long response times, it is not uncommon to see things get worse before they get better.

Many of these large systems took decades to pollute and likely will take decades to restore. For example, PCB contamination in the Upper Hudson River, even under aggressive dredging plans, will take more than 35 years to achieve restoration goals. A Lake Ontario PCB model has determined that even after eliminating all loads to the lake, feedback from historically contaminated sediments in the system will slow its recovery such that it will take approximately 30 years for PCBs in fish to be reduced to acceptable levels.

To meet phosphorus standards under a proposed total maximum daily load scenario, it will take Lake Okeechobee as long as 50 years, during which time conditions in any given year are predicted to get worse due to annual variations (see Figure 4, p. 61). These annual variations also can create misleading trends, as is evident in the Gulf of Mexico, where the areal extent of hypoxia has varied tenfold and more due to droughts, high flows, and storm events — not because of restoration progress or worsening trends.

In large systems such as these with large annual variations, long-term trends can be assessed only by examining long-term data sets, coupled with modeling interpretation.

Replace Impatience With Persistence

We live in an impatient society that wants answers and results fast. We all want to see our large waters restored to swimmable, fishable conditions quickly, but the simple truth is that success requires putting aside our impatience and replacing it with persistence by making progressive steps towards improvement.

With all the advances in science and computers, the public has come to believe that answers to all our environmental challenges can be obtained and achieved easily. However, the simple truth is that we often are uncertain what goals to set and what steps will help us reach them.

It is difficult to understand, let alone control, all factors affecting progress in the restorations of large systems. Therefore, the key to success is to take incremental steps coupled with scientific evaluation and then additional steps. This adaptive management approach is the best path toward successful restoration.

The adaptive approach is used widely in resource management and now is being called for as a new paradigm in water quality management. If we are committed to restoring these large waterbodies, the simple truth is that we need persistence, patience, and an adaptive approach — because there are no simple answers.

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It Takes a Watershed

When friends and family ask me about water quality, I find myself in a bind: How do I do justice to a complex topic while keeping them engaged in the conversation? Since I usually don't have a diagram of a wastewater treatment plant handy, I often turn to a subject already familiar to them: the local watershed.

Everyone lives in a watershed, and anyone can make a difference in one. Here in the Washington, D.C., region, storm sewers are stenciled with the message, "Don't Dump — Chesapeake Bay Drainage." Campaigns such as these raise awareness about water quality issues and remind citizens that watersheds are our shared responsibility.

For water quality professionals, the watershed approach requires taking a holistic view, recognizing all inhibitors to water quality, and working collaboratively on restoration efforts. This is a tall order, but we continue to see examples of how it can be done. For instance, just last month the U.S. Department of Agriculture and Environmental Protection Agency announced they will work cooperatively to reduce nutrients in the Chesapeake Bay watershed. Since farmlands account for approximately one-fourth of this watershed, according to the Natural Resources Conservation Service, controlling agricultural runoff will be an integral part of restoring the bay.

In this issue we highlight various viewpoints on watershed management: goals that have been set, partnerships that make sense, and what more needs to be done to sustain water quality for the long term.

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Water Environment & Technology [ISSN 1044-9493; IPM 0658294] is published 12 times per year, monthly.

Correspondence should be sent to Water Environment Federation executive and editorial offices: 601 Wythe St., Alexandria, VA 22314-1994, USA.

Subscriptions: (703) 684-2400. Individual subscriptions included with Federation membership for those choosing Water Environment & Technology; other member subscriptions $55. Nonmember subscriptions: $178 in the U.S., $225 elsewhere. Single issues (including shipping and handling): $14 members, $16 nonmembers. Orders under $50 and orders outside the U.S. must be prepaid.

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Canada mailed under IPM Agreement Number 0658294.

POSTMASTER: Send change of address forms to Water Environment & Technology, Water Environment Federation, 601 Wythe St., Alexandria, VA 22314-1994, USA.

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Publisher William J. Bertera

VOL. 19, NO. 6 • JUNE 2007

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