Draft

Report to Congress on the Great Lakes Ecosystem

U.S. Environmental Protection Agency

Second Report
July 1991

Note: an illustration will be added to this cover

This report is prepared pursuant to Sections 118(c)(6) and 118(f) of the Clean Water Act, which state:

118(c)(6) Comprehensive Report. — Within 90 days after the end of each fiscal year, the Administrator shall submit to Congress a comprehensive report which —

(A) describes the achievements in the preceding fiscal year in implementing the Great Lakes Water Quality Agreement of 1978 and shows by categories (including judicial enforcement, research, State cooperative efforts, and general administration) the amounts expended on Great Lakes water quality initiatives in such preceding fiscal year;

(B) describes the progress made in such preceding fiscal year in implementing the system of surveillance of the water quality in the Great Lakes System, including the monitoring of groundwater and sediment, with particular reference to toxic pollutants;

(C) describes the long-term prospects for improving the condition of the Great Lakes; and

(D) provides a comprehensive assessment of the planned efforts to be pursued in the succeeding fiscal year for implementing the Great Lakes Water Quality Agreement of 1978, which assessment shall —

(i) show by categories (including judicial enforcement, research, State cooperative efforts, and general administration) the amount anticipated to be expended on Great Lakes water quality initiatives in the fiscal year to which the assessment relates; and

(ii) include a report of current programs administered by other Federal agencies which make available resources to the Great Lakes water quality management efforts.

118(f) Interagency Cooperation. — The head of each department, agency, or other instrumentality of the Federal Government which is engaged in, is concerned with, or has authority over programs relating to research, monitoring, and planning to maintain, enhance, preserve, or rehabilitate the environmental quality and natural resources of the Great Lakes, including the Chief of Engineers of the Army, the Chief of the Soil Conservation Service, the Commandant of the Coast Guard, the Director of the Fish and Wildlife Service, and the Administrator of the National Oceanic and Atmospheric Administration, shall submit an annual report to the Administrator with respect to the activities of that agency or office affecting compliance with the Great Lakes Water Quality Agreement of 1978.

Letterhead

Dear Mr. President:
Dear Mr. Speaker:

Over the past two decades, the United States and Canada have achieved a world-class success in abating nutrient-related algae problems in Lake Erie. They have likewise reduced dramatically the numbers of sea lampreys, a parasitic eel-like invader that by the 1950s had devastated lake trout populations. Levels of many targeted contaminants have declined drastically in fish and wildlife, resulting in clear improvements in the health of many species.

These successes have been obtained by substituting away from high phosphate detergents, restrictions on targeted contaminants, and huge public and private investments in pollution treatment and abatement. The United States alone has invested more than $8 billion in municipal wastewater treatment facilities in the Great Lakes watershed since 1971. The governors of the eight Great Lakes States have signed a historic charter to protect their vital ecosystem and have begun to endow a trust fund to help finance the elimination of toxic substances from the lakes. EPA and States, through hazardous waste programs, are pursuing major cleanups around the Great Lakes.

We should not allow this heartening progress to make us complacent. The health of the ecosystem remains a matter of concern. Unacceptable levels of persistent toxic substances continue to show up in the tissues of fish and wildlife. These substances are associated with a number of health problems in fish and wildlife, including tumors and impaired reproduction. Humans who ingest these substances by consuming fish face increased risk of cancer. Moreover, there is some disturbing evidence that children of mothers who have eaten Great Lakes fish may suffer small but detectable developmental deficits.

Two additional concerns are the loss of fish and wildlife habitat and the introduction of harmful exotic (non-native) species. It has been estimated that since 1800, two-thirds of Great Lakes wetlands, which perform vital ecological functions, have been lost. There are development pressures on the remainder. A second impaired habitat is nearshore bottom sediment that in many locations has been poisoned by past or continuing loadings of toxicants. One recent exotic intruder to the Great Lakes, likely via the ballast water of a transoceanic vessel, is the zebra mussel. A prolific breeder, this mollusc may cause catastrophic ecological effects. It devours microscopic plants at the foundation of the food web and may create a food shortage, threatening top predators such as walleye, salmon, and lake trout.

At my behest, EPA's Science Advisory Board (SAB), a distinguished panel of independent scientists, engineers, and other technical experts, reviewed the Agency's ability to identify and solve our most serious environmental issues. Released in September 1990, the SAB report, Reducing Risk: Setting Priorities and Strategies for Environmental Protection, cited EPA's relative neglect of natural ecosystems. The SAB noted that both environmental statutes and EPA have focused on risks to human health, less so on ecological degradation. The SAB urged EPA to give increased emphasis to ecological protection.

During its first two decades, EPA became highly compartmental, organized to treat and retroactively cleanup pollution, medium-by-medium, chemical-by-chemical—not to prevent it. As a result, we sometimes have cycled problems through the environment, rather than solved them. For instance, we redirected contaminants from pipes into sludge, spread the nutrient-rich sludge on farm land, and then witnessed the inevitable runoff contaminate surface waters. Treatment regulations have brought us a long way in protecting the environment. But they are not sufficient and in some cases can actually be counterproductive, serving to inhibit innovation and discourage regulated industries from going beyond minimum legal requirements.

To protect ecosystems, we need to go beyond treatment and prudent handling of contaminants. This is not to say that EPA will in any way abandon its regulatory responsibilities. It is to say that EPA also needs to seek out the best opportunities to reduce environmental risks, in toto, and to do this by harnessing the innovatory energy of our entire society in the search for the most efficient, cost-effective ways to do this. We need change of a fundamental nature—generators must prevent pollutants by adopting processes that are more environmentally kind. Pollution prevention can take many forms. It is the product of everyday industrial, agricultural, governmental, and personal decisions in favor of choices that generate the least pollution. Industries can use a substance more efficiently, or substitute one substance or process for another, as has been demonstrated so successfully in the Great Lakes by the switch to low phosphorus detergents. One means for farmers to prevent pollution is through conservation tillage to reduce the erosion of soil particles by wind and water. Governments can practice pollution prevention by providing environmental education or ensuring accurate ecological labeling of consumer products. Individuals hold the key to much further environmental progress in their choices of lifestyle and purchases of products.

To solve current problems facing the Great Lakes, environmental protection agencies need to invent new ways to protect an ecosystem. States, EPA, and other Federal agencies are now joined in pioneering such a holistic approach for the Great Lakes. Our broad agenda is to prevent, abate, and remediate toxic pollution, and to inventory, protect, and restore damaged habitat and native species. To accomplish this agenda efficiently, we will set priorities based on comparative assessment of risks to the ecosystem. Pollution prevention will be a preferred means to reduce risks; we want to work with industries to cut their toxic emissions voluntarily, sharply, rapidly. At the same time, we will better integrate our enforcement of environmental laws to address the overall pollution problem at a facility. We will aggressively inform the public about environmental issues, out of the related convictions that it is their right to know and that an informed public is the ultimate guardian of the Great Lakes. Local stakeholders are integral to successful solutions; we will invite both citizens and industries to participate in planning the restoration of Great Lakes toxic hotspots. We will apply appropriate measures from our suite of air, water, and waste programs to fit the needs of these areas. And we will judge our progress in tangible, ecological terms, as in the health of sensitive fish and wildlife species. In all this, we will take the utmost advantage of opportunities for cooperative actions with Canada.

The two nations will know that they have succeeded when their citizens can safely consume Great Lakes fish and wildlife in unlimited quantities, and when a vulnerable species like the bald eagle, our proud national symbol, can thrive in its traditional domain along the shores of the Great Lakes.

The world is at a historic crossroads with respect to the environment. Environmental concerns are sweeping the globe in conjunction with humankind's burgeoning numbers and the spread of industrialization. In environmental affairs, as in our championing of democracy, human rights, and a market economy, the United States is an example for much of the world. Many nations will look to the successes of our shared stewardship of the Great Lakes for encouragement in protecting and restoring their own living resources. As I look ahead, I feel confident that the United States and Canada will continue to reverse many decades of environmental abuse to the Great Lakes. It is our responsibility, both to our own and to future generations.

Sincerely,

William K. Reilly

Honorable J. Danforth Quayle
President of the Senate
Washington, DC 20510

Honorable Thomas Foley
Speaker of the House of Representatives
Washington, DC 20515

Draft

Report to Congress on the Great Lakes Ecosystem

Second Report
July 1991

Great Lakes National Program Office
U.S. Environmental Protection Agency
Chicago, Illinois

A Progress Report

This is the second report by the Environmental Protection Agency on United States actions to implement the Great Lakes Water Quality Agreement with Canada and, more broadly, on Great Lakes ecosystem trends and programs. It is developed pursuant to Sections 118(c)(6) and 118(f) of the Clean Water Act and is organized into the following chapters:

Introduction: Chapter One helps to place today's Great Lakes ecological issues in perspective. It sketches some aspects of the physical features of the lakes, economic development in the region over the last three centuries, and ecological outcomes associated with this development.

The State of the Lakes: Chapter Two discusses five broad problems currently facing the Great Lakes: contamination of fish and wildlife; contaminated bottom sediments; lost, degraded, and threatened wetlands; damage to native species from exotic (non-native) ones; and undesirable effects from excessive nutrients.

The Great Lakes Program in 1991: Chapter Three describes a model, holistic approach to ecosystem protection that EPA is pioneering on the Great Lakes. This approach will seek to cut loadings of toxic pollution to the Lakes and to protect and restore habitats necessary for healthy plant and animal communities. It will pursue these broad goals by promoting pollution prevention as the preferred means to reduce environmental damage and by focusing the Agency's programs around an ecosystem. EPA will direct its activities on the basis of ecological needs and measure progress by ecological yardsticks.

Actions to Implement the Water Quality Agreement: Chapter Four presents achievements for Fiscal Years 1989 and 1990 and plans for FY 1991 under the Agreement with Canada. The chapter focuses on the three major approaches under the Agreement for improving the Great Lakes ecosystem: Remedial Action Plans for Areas of Concern; Lakewide Management Plans for Critical Pollutants; and the Phosphorus Load Reduction Plan.

Actions By Federal Partners: Chapter Five provides highlights from five other agencies on their programs relating to the Great Lakes. These agencies are the Army Corps of Engineers; the Coast Guard; the Fish and Wildlife Service; the National Oceanic and Atmospheric Administration; and the Soil Conservation Service.

Great Lakes Science: Chapter Six discusses surveillance of the Great Lakes system, including 3 EPA initiatives relating to persistent toxic contaminants. These are a binational network to monitor atmospheric deposition of trace organic substances; a multi-year study of the sources and fates of several contaminants in Green Bay; and the outfitting of a new research vessel to monitor trace organics in open-lake waters.

Expenditures: Chapter Seven provides Federal expenditures on Great Lakes water quality over 3 fiscal years.

Except where noted otherwise, this report is written as of the start of Federal Fiscal Year 1991 (October 1, 1990).

THE STATE OF THE LAKES

Contamination of Fish and Wildlife: The Great Lakes food web is contaminated by a variety of persistent toxic substances, causing unacceptable levels in certain fish and wildlife. Due to use restrictions and major investments in pollution treatment and abatement, levels of some contaminants are much lower than in the early 1970s and continue to decline, but still justify the issuance of public health advisories regarding fish consumption. Contaminants have been associated with reproductive and other health problems in fish and wildlife, though with the sharp decline of targeted pollutants many species seem to be recovering. Problems persist for fish and wildlife in certain locations, particularly in harbors and rivers with highly contaminated bottom sediments and for predators high in the food web like lake trout, mink, herring gulls, and bald eagles.

Contaminated Bottom Sediments: Bottom sediments of many harbors and rivers are poisoned by a variety of persistent toxic substances. Contaminated sediments are of ecological concern because they are associated with tumors in bottom fish; they serve as a reservoir of contaminants that recycle into the food web through resuspension or uptake by benthic (bottom-dwelling) organisms; and they injure sensitive benthic organisms. Contaminated sediments also increase the costs of navigational dredging, because they require special measures during dredging and disposal. In various locations, sediment contamination has delayed navigational dredging for years.

Lost, Degraded, and Threatened Wetlands: Wetlands are invaluable habitat for a variety of birds, fish, and other wildlife. It has been estimated that since 1800 about two-thirds of Great Lakes wetlands have been lost, primarily because of conversion to what landowners regard as more useful purposes. The present rate of destruction is much less than in prior eras, but development continues to pressure remaining wetlands.

Damage to Native Species from Exotics: About 100 exotic (non-native) species have been introduced to the Great Lakes since 1800, one-third carried by ships. The rate of introduction of exotics has sharply increased over the last 30 years, since completion of the St. Lawrence Seaway in 1959 allowed more transoceanic shipping. Some exotics have profoundly damaged native species. A threatening recent invader, the zebra mussel, probably entered the Great Lakes about 1988 via ballast water discharge from an ocean-going vessel. Ecological effects of the mussel are as yet unknown, but potentially catastrophic. A prolific breeder, the striped mollusc devours microscopic plants at the foundation of the food web and may create a food shortage for other phytoplankton eaters, ultimately threatening predator fish such as walleye, salmon, and lake trout. Some other introduced species of concern are the sea lamprey (although a program of lampricide application controls its numbers), the river ruffe, and the spiny water flea.

Undesirable Effects from Excessive Nutrients: Shallow waters that receive agricultural runoff of fertilizers or have high surrounding populations—such as Lake Erie, Lake Ontario, Saginaw Bay, and Green Bay—are overenriched with nutrients, notably phosphorus. The situation has improved since the late 1960s, when Erie was clogged by mats of algae that depleted dissolved oxygen from bottom waters. Phosphorus concentrations are approaching those predicted to end undesirable effects. Partly as a result, the walleye population of Lake Erie has increased and the numbers of plankton-grazing fish have diminished. Erie has a much reduced mass of algae and the mix between types of algae has improved. In 1989, the rate of depletion of dissolved oxygen in the bottom waters of Erie's central basin was at a twenty year low and the duration of the period of oxygen depletion in these waters was shorter than in the mid-1980s. Nevertheless, the bottom waters of central Lake Erie continue to suffer oxygen depletion in late summer.

THE GREAT LAKES PROGRAM IN 1991: A MODEL, ECOSYSTEM APPROACH

To attack current Great Lakes problems, EPA will launch a new, holistic approach to ecosystem protection. In general, this approach will aim to reduce toxic pollutant loadings to the Lakes and to protect and restore habitats necessary for healthy plant and animal communities. In pursuing these broad goals, EPA will examine ecological and human health risks facing the Great Lakes region; target priority problems and geographic areas; promote pollution prevention as the preferred, efficient means to reduce risks; integrate regulatory and enforcement actions in order to address the overall pollution problem at a given facility; meet local needs with an appropriate blend of solutions from across the entire range of the Agency's programs; encourage public participation; and evaluate progress using ecological indicators. In all these elements, the Agency will take advantage of opportunities for cooperative actions with Canada.

EPA has successfully used many individual elements of this approach in the past. The fundamental changes being pioneered on the Great Lakes are to promote innovative pollution prevention measures and to focus and integrate the Agency's programs around an ecosystem, setting goals on the basis of environmental needs and measuring progress by ecological yardsticks.

Setting a Risk Based Agenda

EPA will invite other stakeholders to join in the development of a 5-year strategy for the Great Lakes, to kick-off in FY 1992. Stakeholders include Federal, State, Tribal, and local governments, representatives from industry, agriculture, and environmental groups, and other concerned members of the public. The strategy will emphasize the ecosystem approach, strongly rely on pollution prevention methods, and seek to reduce loadings of toxic substances and to protect and restore healthy plant and animal communities.

To support development of this strategy, EPA will conduct its first risk-based comparative examination of human health and ecological hazards facing the Great Lakes region. The study will look at the available evidence on 23 different types or sources of problems including those addressed by the Agency's various air, waste, and water programs, and other problems of import to the Great Lakes like the introduction of exotic species, changing lake levels, and contaminated fresh water bottom sediments. This study will help the Agency to target the most pressing sources of Great Lakes problems.

Promoting Pollution Prevention

EPA will use the Great Lakes as a proving ground for promoting pollution prevention. Pollution prevention is the adoption of "greener" technologies or practices. It entails everyday decisions by industry, agriculture, governments, universities, individuals – in short, by everyone – that cause the least environmental harm. Pollution prevention heads-off environmental injury at its origins. Buttressed by other Agency activities, pollution prevention will be the preferred means to reduce risks to the Great Lakes ecosystem. EPA will weave pollution prevention into the fabric of all its Great Lakes activities and encourage all sectors of society to contribute their energies and ideas to the ecological imperative to reduce the quantity and harmfulness of resources used to satisfy human needs.

In concert with the eight Governors of Great Lakes States, EPA will launch a Great Lakes Pollution Prevention Action Plan aimed at reducing toxic substances found in the Great Lakes food web. The Action Plan will augment State pollution prevention programs. During recent years, the Great Lakes States have launched various prevention initiatives, involving education, research, technical assistance, and recognition of prevention successes via awards. Some States are also exploring ideas such as issuing one permit to cover all the emissions from a facility; incorporating pollution prevention into enforcement settlements; and linking permit fees to toxic generation.

The Action Plan will also complement EPA's national Pollution Prevention Strategy that includes the 33/50 Program. EPA has identified 17 high risk chemicals that offer strong opportunities for prevention. During 1991, EPA will announce a goal of encouraging firms to voluntarily cut their nationwide releases of these substances 33 percent by the end of 1992 and 50 percent by the end of 1995. Large manufacturing firms report their annual releases or transfers of over 300 toxic substances. On a national basis these firms released or transferred over 1.4 billion pounds of the 17 chemicals in 1988. EPA will ask firms who have reported releases of the target chemicals to voluntarily reduce these through pollution prevention. EPA expects widespread cooperation because pollution prevention offers economic benefits and is good corporate citizenship.

The Action Plan will be predicated on challenging all sectors of society to prevent pollution; focusing on high risk pollutants and areas; and measuring progress. It will launch five initiatives dedicated to the Great Lakes:

- **The Challenge**: The Governors of the Great Lakes States will challenge all sectors of society to voluntarily reduce releases of pollutants harmful to the Great Lakes. They will develop a regional award program to recognize excellence in pollution prevention, and also examine technical and/or regulatory disincentives to prevention.

- **Lake Superior**: Superior has not experienced surrounding development as intensely as other lakes, and remains relatively pristine. As the fountainhead of the Great Lakes system, it is important that it remain so. EPA and the Lake Superior States will agree on common procedures to prevent degradation; agree on key pollutants; and establish air deposition monitoring sites to measure loadings of air pollution to the lake.

- **Auto Manufacturing and Related Industries**: EPA and States will work with Chrysler, Ford, and General Motors to promote prevention of persistent toxic substances, which they or their suppliers may use, that could injure the Great Lakes ecosystem.

- **Urban Non-point Pollution**: EPA and New York will support educational programs to prevent urban non-point source pollution from households. These will target the public around Buffalo, Niagara Falls, Rochester, and Watertown.

- **Binational Symposium**: In the fall of 1991, EPA will co-sponsor with Environment Canada a symposium to share information on pollution prevention.

Geographic Targeting

A hallmark of the ecosystem approach will be to focus on priority ecological problems and geographic areas. This will be achieved through implementation of ecosystem restoration plans – Remedial Action Plans (RAPs) for Areas of Concern and Lakewide Management Plans (LAMPs) for Critical Pollutants on a whole-lake basis. Related efforts include geographic enforcement initiatives; development of guidance regarding water quality criteria for the Great Lakes; and the ARCS program to demonstrate technologies for the treatment of contaminated sediments.

During FY 1991, EPA and States will especially target two locations encompassing Areas of Concern, because of their profiles of high ecological risk and non-compliance with permits and regulations. The Agency and States will focus remediation, inspection and enforcement, and prevention activities on Southeast Chicago-Northwest Indiana and along the Niagara River.

The Agency believes that in some cases criteria specific for the Great Lakes are necessary to protect aquatic biota and wildlife, and human health – primarily from fish consumption risks – on a long-term basis. In FY 1989, EPA and States began a "Great Lakes Water Quality Initiative" to develop EPA guidance to States regarding water quality criteria for the Great Lakes, a Great Lakes antidegradation policy, implementation procedures, and pollution prevention measures. EPA is responsible for developing national water quality criteria that numerically define maximum allowable concentrations of certain pollutants in surface waters across the nation. These criteria are used by States as a basis for their water quality standards and water quality-based regulation under the National Pollutant Discharge Elimination System (NPDES). The initiative will continue in FY 1991. EPA envisions that the guidance will be completed in time to be incorporated into the next triennial State water quality standard review process (1991 to 1993).

During 1989-90, the ARCS program assessed the nature of sediment contamination in several areas: Ashtabula River, Ohio; Buffalo River, New York; Grand Calumet River, Indiana; Saginaw River, Michigan; and Sheboygan River, Wisconsin. The program also began comprehensive hazard evaluations of the Buffalo and Saginaw Rivers to assess risks under various remedial alternatives that are continuing. Beginning in 1991 and continuing into 1992, ARCS will undertake pilot-scale, field demonstrations of sediment treatment technologies in each of the study areas. By December 1993, the ARCS program will develop guidance on remedial alternatives to assist local decision-makers in addressing the different sediment situations in Areas of Concern.

Integrated Enforcement

Another aspect of EPA's integration will be to follow a "multi-media" enforcement strategy. Traditionally, EPA has relied on enforcement under a single statute, addressing a single medium (air, waste, or water). This may have sometimes had the effect of allowing a polluter to transfer an environmental problem from one medium to another (e.g., soil to air). On a national basis, EPA will seek to make 25% of all enforcement actions in 199 "multi-media" cases so as to address the overall pollution problem at a given facility. During 1989-90, EPA took several multi-media enforcement actions in the Great Lakes region for alleged violations of environmental permits and regulations in Northwest Indiana.

Assessing Progress

Another hallmark of EPA's approach to the Great Lakes will be to set goals and assess progress towards them, using demonstrable measures. In 1987, EPA, the New York State Department of Environmental Conservation and counterpart Canadian agencies dedicated themselves to cut in half loadings of priority toxic chemicals to the Niagara River by 1996. Progress towards this goal is ascertained by monitoring water quality at both ends of the river. Ecosystem indicators will be established for each lake as part of the Lakewide Management Planning process. EPA will develop a better understanding of the significance of atmospheric deposition of pollutants by establishing a monitoring network.

ACTIONS TO IMPLEMENT THE WATER QUALITY AGREEMENT

The Great Lakes Water Quality Agreement is a joint commitment by the United States and Canada to protect and restore the Great Lakes. Its three major approaches for doing this are Remedial Action Plans for Areas of Concern, Lakewide Management Plans for Critical Pollutants, and the Phosphorus Load Reduction Plan.

Remedial Action Planning

In 1987, the U.S. formally committed to develop and implement ecosystem cleanup plans for the most impaired areas around the lakes, called Areas of Concern. These tend to be bays, harbors, and river mouths with damaged fish and wildlife populations, contaminated bottom sediments, or ongoing loadings of toxic or bacterial pollutants. Though they are still impaired, there have been notable improvements in many of these areas since the 1960s. Improved water quality in the Cuyahoga, Black, and Ashtabula Rivers in Ohio and the Buffalo River in New York have allowed fish to return. However, contaminants remain in these areas, rendering some fish species unsafe for human consumption and causing an increased incidence of tumors or other abnormalities in some fish.

With the addition of Presque Isle Bay during 1991, the U. S. has 31 Areas of Concern, including 5 shared with Canada. RAPs are principally developed and implemented by States with support from EPA, consistent with the Federal/State partnership in national environmental legislation. Other Federal agencies are also supporting the RAP process in valuable ways.

Another notable feature of the RAP process is that community stakeholder groups are strongly involved in working with local and State governments on many RAPs. This grass roots participation has molded the goals of RAPs and strengthened the sense of local "ownership" of both problems and their solutions. These groups have also provided a valuable channel for local industries to join in the restoration process and to look for ways to prevent pollution. The RAPs developed to date have also served to inform the public and to justify needed investments in Great Lakes restoration (e.g., Great Lakes Governors launched a $100 million Great Lakes Protection Fund in 1988).

An indicator of progress toward the restoration of Areas of Concern is completion of editions of Remedial Action Plans. States have committed to completing 9 Stage One (problem definition) and 2 Stage Two (remedial action definition) during FY 1991. This will bring their cumulative totals thus far to 22 Stage One and 12 Stage Two RAPs. Many other RAPs are under development.

RAPs will be continually improved as more is learned about the problems of Areas of Concern, and as warranted by the results of preventive and remedial measures. EPA views Remedial Action Planning as a valuable ongoing management process to identify priority environmental problems, steps needed to solve these, and ecological progress.

Actions to Restore Areas of Concern

EPA, States, and other participants do not wait for the completion of plans before taking warranted actions to reduce toxic loadings or protect habitat. Some highlights of recent accomplishments:

- The cleanup process is continuing through various stages at 13 Superfund sites that are integral to restoring 7 Areas of Concern – Ashtabula River, Kalamazoo River, Niagara River, St. Lawrence River, Sheboygan River, Torch Lake, and Waukegan Harbor. This process is also continuing at another 4 Superfund sites that are significant, though generally to a lesser degree, to restoring 3 other Areas of Concern – the Clinton River, St. Louis River, and Saginaw River. Over the course of these multi-year remediations, hundreds of millions of dollars will be invested, by potentially responsible parties and EPA, in redressing environmental problems.

- Multi-year programs to eliminate combined sewer overflows of untreated waste water are underway in many communities around the Great Lakes. These are of particular importance to 8 Areas of Concern – the Detroit River, Maumee River, Menominee River, Milwaukee Harbor, Rochester Embayment, Rouge River, St. Clair River, and St. Marys River.

- Major long-term investments in municipal wastewater treatment plants are improving 3 Areas of Concern – the Black River, Cuyahoga River, and Green Bay.

- The Federal government has filed suit to enforce the pretreatment of industrial effluent in a case relating to two Areas of Concern – the Rouge River and Detroit River.

- Pursuant to RCRA, EPA and States have taken measures that are significant to two Areas of Concern – the Menominee River and River Raisin.

Actions to Restore Areas of Concern

Lake Michigan

Contamination of sport fish with PCBs is the principal basis for the issuance of health advisories regarding Great Lakes fish. Various actions ringing Lake Michigan attack this priority problem.

- The largest known reservoir of PCBs in the Great Lakes is Waukegan Harbor. Under a Superfund remedial plan being carried out through 1993, 99 percent of the PCBs in the harbor will be removed.
- Another important source of PCBs has been the Sheboygan River; it is the subject of a Superfund remedial investigation and feasibility study. On the eastern side of the lake, the Kalamazoo River has PCB-contaminated bottom sediments. In 1989, EPA and Michigan proposed a 35 mile stretch of the river as a Superfund site and a remedial investigation is beginning in 1991.
- The Fox River and Green Bay have suffered high levels of PCBs; EPA and Wisconsin are studying the sources and fates of PCBs in this area.
- At the base of Lake Michigan, various enforcement actions have been taken and the area remains the focus of EPA and State activities. Under a recent innovative settlement, USX Corporation will dredge sediments from a stretch of the Grand Calumet River to prevent movement of contaminants, including PCBs, to the lake.

The Niagara River

The other most contaminated lake is Ontario. The U.S. side of the Niagara River, which after World War II attracted a cluster of chemical companies, has been a leading source of toxic pollutants, including 10 of the 15 most troublesome in the Lake Ontario food web. Studies indicate that non-point loadings, such as leachate and runoff from waste sites, are the dominant source of priority pollutants to the Niagara. There are many hazardous waste sites near the river, the most infamous of which may be a former landfill called Love Canal which became a residential area.

The Niagara Frontier has been a sustained emphasis of EPA and New York over many years. A major binational study of the river was completed in 1985. In 1987, EPA and the State joined Canadian counterparts in a declaration dedicated to halving toxic loadings to the Niagara by 1996. They have taken many actions related to remediating waste sites, including five Superfund sites and others addressed by the State's waste program. Some of the residential areas near Love Canal that were once deemed unsafe have recently been judged to be habitable. EPA and the State have announced schedules to remediate, by 1996, the 20 waste sites considered responsible for 99 percent of U.S. waste site loadings to the Niagara.

The St. Lawrence River

EPA and State actions are also aimed at profound local problems. One of the most pressing is the St. Lawrence River Area of Concern. Largely during the 1960s and 1970s, U.S. and Canadian industries poured wastes including PCBs and mercury into riverside landfills, even the St. Lawrence River itself. Aluminum smelters emitted fluroide into the air. This pollution damaged the traditional fishing, farming, and hunting economy of Mohawks living on the Akwesasne Indian Reservation in New York State. Fish, ducks, and turtles, long principal sources of protein for the Mohawks, became contaminated with PCBs or mercury.

In 1983, EPA added a General Motors site on the St. Lawrence to its Superfund NPL list. In 1990, EPA selected a remedial plan for part of this site that is estimated to cost $78 million. In 1991, EPA also issued Superfund Administrative Orders to the Aluminum Company of America (ALCOA) and the Reynolds Metal Company to perform remedial investigations, designs, and cleanups of PCB-contaminated bottom sediments in the St. Lawrence River system.

- Agricultural nonpoint pollution control measures, many including Department of Agriculture participation, are focusing on Areas of Concern where this type of pollutant source is notably significant – Green Bay, Maumee River, and Saginaw Bay.
- Regulation of point source water dischargers is especially helping 2 Areas of Concern – the Grand Calumet River and Manistique River.

Lakewide Management Planning

The second major restoration approach under the Water Quality Agreement is the development of Lakewide Management Plans for Critical Pollutants to address whole-lake problems that extend beyond Areas of Concern. While EPA has the lead responsibility for developing these plans, participation by other Federal agencies, States, and local communities is integral to their success. During 1991, EPA and the States will develop LAMPs for Lakes Ontario and Michigan, as accumulations of persistent toxic substances in fish and wildlife are highest in these lakes. In FY 1992, the Agency will begin work on a LAMP for Lake Superior.

Phosphorus Load Reduction Plan

In 1983, the U. S. and Canada agreed to develop and implement Phosphorus Load Reduction Plans to reduce phosphorus loadings to the two lower lakes and Saginaw Bay. Implementation of the U.S. Plan relies on programs aimed at increasing the use of best management practices in agricultural areas, including increased adoption of conservation tillage practices, better management of livestock waste, and better management of fertilizers. Through 1988, the apparent rate of adoption of conservation tillage was about a quarter of that targeted for the Lake Erie watershed.

However, phosphorus levels in Lake Erie have continued to decline and are approaching target concentrations, though this success may be partly attributable to several recent years of below average rainfall. In 1989, the rate of depletion of dissolved oxygen in the bottom waters of central Lake Erie was at a twenty year low. Phosphorus concentrations in Lake Erie are significantly affected by both weather and agricultural land use. Better agricultural land use practices will continue to be important to improving waters vulnerable to nutrient overenrichment.

FEDERAL PARTNERS

Five other Federal agencies have provided information on their programs as these affect the Great Lakes ecosystem. These agencies are the Army Corps of Engineers; the Coast Guard; the Fish and Wildlife Service; the National Oceanic and Atmospheric Administration; and the Soil Conservation Service.

The Army Corps of Engineers

The Corps maintains navigational channels in authorized harbors and rivers; administers the Federal program that regulates the discharge of dredge or fill materials into U.S. waters; and conducts civil works projects, including flood and shoreline erosion control projects. Some recent highlights and upcoming plans:

- During both FY 1989 and 1990, the Corps analyzed bottom sediments at 19 navigational projects to determine sediment disposal needs.
- To maintain navigation, the Corps removed about 4 million cubic yards of bottom sediments from the Great Lakes during each year, placing about half this volume in confined disposal facilities because of contaminants in the sediments. The Corps also studied potential contaminant loss from 2 CDFs.
- In FY 1990, the Corps issued 6,500 dredge and fill permits within the Great Lakes watershed, and took 343 enforcement actions.
- The Corps worked with EPA and States on technical reviews of several Superfund site plans, on the ARCS program to demonstrate contaminated sediment remediation technologies, and on Remedial Action Planning for several Areas of Concern.
- The Corps began construction of two major flood damage reduction projects in Chicago and northwest Indiana.

- During FY 1991, the Corps will continue the dredge and fill permit and navigational dredging programs. The Corps will begin to construct or modify 6 CDFs and start construction of two small boat harbors. The Corps will also continue to remediate hazardous waste at former defense sites.

The Coast Guard

Through promulgation of regulations and inspections for marine safety and law enforcement, the Coast Guard promotes prevention of pollution from vessels. The Coast Guard is also responsible for responding to spills of oil and hazardous substances into the Great Lakes. As the Federal On-Scene Coordinator for spills from ships, the Coast Guard monitors cleanup activities and conducts the cleanup when responsible parties do not do so effectively. A further Coast Guard activity that is important to the Great Lakes ecosystem is prevention of the introduction of exotic species from ships. Some recent highlights and upcoming plans:

- In May 1989, the Coast Guard collaborated with the Canadian Coast Guard to establish voluntary guidelines to protect the Great Lakes from further introduction of exotic species through discharge of ship ballast water. Under these guidelines, ships scheduled to enter the Great Lakes system are advised to exchange their ballast water beyond the continental shelf, or if this is not possible, in the Gulf of St. Lawrence. These guidelines were distributed by the International Maritime Organization to its 133 member governments and organizations. The St. Lawrence Seaway Authority is monitoring compliance with the guidelines, and the Canadian Coast Guard plans to evaluate the effectiveness of the guidelines, with assistance from the U.S. Coast Guard as necessary. The Authority reported 85 percent compliance with the guidelines during the 1989 shipping season. Ballast water was not sampled to verify that it had been exchanged.

- In April 1989, the Coast Guard promulgated regulations to implement Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). These regulations prohibit the discharge of garbage into the navigable waters of the United States, and apply to all ships, including recreational boats.

- The Coast Guard continued to verify pollution incidents in the U.S. waters of the Great Lakes. During calendar year 1989, the Coast Guard recorded 262 such incidents. Of these, 13 involved hazardous materials, the remainder involved oil. The Federal government funded cleanups for 17 incidents.

The Fish and Wildlife Service

The Service maintains fish and wildlife resources and provides access to them for the public. The Service collects and interprets information on fish and wildlife species, populations, and habitats to assist resource managers in making decisions about the protection and restoration of the Great Lakes ecosystem. Many of its activities fall into three functional areas: fisheries; refuges and wildlife; and fish and wildlife enhancement. Activities include permit reviews; land acquisition and habitat management; management of migratory birds, anadromous fish, and endangered species, including the surveillance and stocking of lake trout and the control of a leading trout predator, sea lamprey; and research on the causes and effects of habitat change and chemical contaminants.

Fisheries

- During 1989 and 1990, the Service stocked 9.8 million lake trout into the Great Lakes. Many of these were stocked offshore over traditional spawning reefs to increase the likelihood of their survival.

- The Service applied lampricides to tributaries where sea lamprey spawn; 31 rivers were treated in 1989, 28 the next year, and 39 will be targeted in 1991.

- The Service continued to monitor contaminants in Lake Michigan bloater chubs, a program that has been maintained since 1969.

Refuges and Wildlife

- During 1990, the Service continued to support wetland restorations through cooperative agreements with landowners; two national wildlife refuges supported the restoration of 971 acres of wetlands, including 109 acres in counties bordering Lake Erie.
- The Service is supporting a survey of colonial waterbirds of the Great Lakes; this three year study, begun in 1989, will update a survey from the late 1970s and indicate where the Service should direct future management efforts.
- The Service is working with Ohio in monitoring bald eagles near Lake Erie; active eagle nests have risen from 2 to 16 over the past 8 years.
- During 1991, the Service will finish a preliminary study, begun in 1990, to identify lands within 10 miles of Lake Erie that have potential for wildlife habitat and public recreation, and that have unique natural, historic, or scenic features.

Fish and Wildlife Enhancement

- In 1989, the Service prepared natural resource damage surveys for two Superfund sites (General Motors Central Foundry located along the St. Lawrence River and Hooker Chemical along the Niagara River). In 1990, the Service continued a pre-assessment of natural resource damages for Waukegan Harbor, Illinois, and began a natural resources damage assessment for Saginaw Bay. In 1991, the Service will begin a natural resource damage assessment for the Grand Calumet River.
- To support EPA's ARCS program, the Service conducted surveys of fish (bullheads) and sediments in Saginaw, Grand Calumet, and Buffalo River for tumors and abnormalities. The sediment collected will be used to study bioaccumulation of chemicals in fish collected at these three locations.
- During 1990, the Service reviewed bald eagle population and productivity data as a review of the species' endangered status.
- In cooperation with States and duck hunter organizations, the Service continued efforts to restore beds of wild celery along the Great Lakes. Wild celery provides foraging opportunities for fish and the vegetation is eaten by waterfowl. In the spring of 1988, celery was planted at 2 locations in the lower Detroit River. While the celery failed at one site, about 5,000 plants took hold at the other. This work indicates that restoration of wild celery in the lower Detroit River is possible under proper conditions.
- The Service studied gulls and bald eagles around the Torch Lake, Michigan, Area of Concern to determine if the high copper level in the lake was hurting their reproductive success. Initial indications were that the productivity of the species was normal. A companion study looked at yellow perch reproduction in Torch Lake, finding impaired hatchability of perch eggs.
- The Service plans to propose the Lake Erie water snake for threatened status and Hungerford's crawling water beetle for endangered status. The snake is found only on several Ohio and Ontario islands, while the beetle is found in only 2 Michigan sites and 1 in Ontario.
- The Service will support the advanced identification of important wetland resources in northwest Ohio that are unsuitable for the discharge of dredged or filled materials. This is a joint activity with EPA, OEPA, Ohio DNR, and the Army Corps of Engineers. The Service will also continue to support a similar advanced identification of wetlands near Green Bay.

The Soil Conservation Service

The Soil Conservation Service of the Department of Agriculture (USDA) provides technical and financial assistance to land users including farmers, ranchers, and foresters, and to other government agencies on a variety of natural resource issues. The Service contributes to conserving the Nation's soil, water, plant, and animal resources by informing land users of management practices that control erosion, protect the quality of surface water, and reduce the contamination of groundwater by agricultural chemicals.

Through its nationwide network of conservation specialists, the Service provides assistance on topics such as pesticide and nutrient management, reduced tillage practices, fish and wildlife habitat development, soil mapping and interpretation, and watershed protection. It also conducts natural resource inventories and maintains data on soil erosion and land use. To assist land users in protecting natural resources, the USDA also administers cost-sharing programs to pay land users for following conservation practices, protecting wetlands, and improving water quality.

The Service is participating in 10 major USDA projects that are underway or planned in the Great Lakes watershed. Some recent highlights and upcoming plans:

- The Service is participating in five Water Quality Special Projects that seek to reduce agricultural releases of nutrients and sediment to surface waters: Cattaraugus Creek, New York; LaGrange County Lake Enhancement Program, Indiana; Vermillion River and the West Branch of the Black River, Ohio; and the Clam River, Michigan.

- USDA is also conducting two long-term demonstration projects, within the Green Bay and Saginaw Bay watersheds. These seek to demonstrate crop management systems that reduce the quantities of nutrients and pesticides needed to produce acceptable crop yields, and the Saginaw project will also implement Integrated Pest Management practices to prevent groundwater contamination. The two projects provide land users up to 70 percent cost-sharing for improving their land management.

- The Service is participating in the Saline Valley Water Project that is aimed at reducing the loadings of phosphorus from southeastern Michigan to Lake Erie.

- The Service is also participating in two hydrologic unit projects, one for Sycamore Creek, Michigan, that is attempting to prevent pesticide and sediment contamination. The other, in the Wolf Creek watershed of Michigan is working to protect Lake Adrian from sediment, phosphorus, and pesticides.

Note to Reviewers: The Executive Summary of the next draft will address chapters 6 and 7 of this report on, respectively, Great Lakes science and expenditures.

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Chapter 1

Introduction

The Great Lakes basin is a region where America's inventive and productive genius has been amply realized. Early in the last century, steamships and the Erie Canal helped to open a 2,200 mile waterway into the heart of a continent. From this corridor, poured forth timber to build a growing nation, and ores to feed the successive industrial ages of iron, then steel. America's first oil refineries were within the Great Lakes basin, helping to spark the region's automobile industry that grew into the preeminent industry of 20th century America. The connection of railroads and canals to the lakes contributed to unprecedented agricultural development in the Midwest and Great Plains.

And the tradition continues, vigorously, today. Forest products, shipping, agriculture, food processing, chemicals, mining, metals, and heavy manufacturing remain important to both the regional economy and America's.

Before its development, the Great Lakes basin was also a region of extraordinary natural abundance – oceans of freshwater, vast and splendid stands of timber, plentiful fur-bearing animals, rich soil, immense wetlands, multitudes of waterfowl. The waters teemed with fish. Sturgeon up to 9 feet long were common. Fisherman using hand-held dipnets could reap many hundreds of whitefish in a day.

Much of the natural beauty and abundance of the Great Lakes remain, although development has often changed or damaged the ecosystem. The blue pike is extinct, Atlantic salmon long gone from Lake Ontario. The numbers of surviving sturgeon are few. Lake trout populations are not self-sustaining and must be stocked. A sensitive top predator, the bald eagle, finds it relatively more difficult to reproduce along the shores of the Great Lakes than inland. The extent of habitat available to fish and wildlife is much reduced, as are their populations.

To help place today's Great Lakes environmental issues in context, this chapter discusses some aspects of the physical features of the lakes, their economic development during the past three centuries, and ecological outcomes associated with this development.

THE GREAT LAKES

By many measures, the five Great Lakes are freshwater seas. Formed by the melting retreat of mile-thick glaciers 10 to 12 thousand years ago, the Great Lakes water system represents about 18 percent of the world's surface freshwater and 95 percent of the surface freshwater of the United States. If poured over the continental United States, the 6 quadrillion gallons of the Great Lakes would immerse the "lower 48" States to a depth of almost 10 feet. The breadth of the lakes, between eastern and western extremes, is about 800 miles. The Great Lakes and their connecting channels have 7,437 miles of shoreline within eight States and the Province of Ontario. Their surface area is 96,394 square miles, an area about that of the State of Oregon. Their 201,000 square mile watershed holds nearly 80,000 small lakes – one-third within the United States – that would collectively cover an area larger than Lake Erie.

By virtue of their size, the Great Lakes have pronounced effects upon the climate of their region. Heat stored in the surface waters of the lakes during the summer warms adjacent land in the fall and winter. As a result, areas of Michigan, southern Ontario, and western New York have warmer winters than some other parts of North America at similar latitudes. However, these same areas receive heavy snowfalls as prevailing winds from the west pick up moisture over the lakes. In the spring and summer, the lakes are slow to warm, cooling near-shore land.

As would be expected across such a large geographical area, the physical characteristics of the Great Lakes watershed are varied. In the north, the land is heavily forested, particularly by conifers. The soil is generally thin and acidic, covering a hard, ancient bedrock called the Laurentian Shield. The climate is cold. Principal industries are timber, mining, and hydroelectric power. In the south, soils are deeper and fertile, rocks sedimentary and nutrient rich, temperatures warmer, the density of human population greater. Vast wetlands and deciduous forests have generally been replaced by agricultural, industrial, and residential uses.

By surface area, Lake Superior is the largest freshwater lake in the world. It is the second largest in terms of water volume, trailing only the immensely deep Lake Baikal in Siberia. Superior holds just over one-half of the water in the Great Lakes system. It is the coldest and deepest of the lakes. About 90 percent of the Superior watershed is forested; only 3 percent is used for agriculture. Due to its huge volume, Lake Superior has the longest water retention time of any of the Great Lakes – 191 years. Superior's outlet is the St. Marys River that flows south-easterly into Lake Huron.

Lake Michigan is the only Great Lake that lies wholly within the United States. It is the second largest in terms of water volume, holding about 21 percent of the water in the Great Lakes system. With the exception of Wisconsin's Fox River Valley, the northern part of Lake Michigan's watershed is sparsely populated. The southern end of the lake is ringed by lakefront cities, including Milwaukee, Chicago, and Gary. Lake Michigan's watershed holds the largest human population of all of the Great Lakes – about 14 million. Lake Michigan's water retention time is 99 years, the second longest of the lakes. Water from Lake Michigan primarily flows out through the Straits of Mackinac into Lake Huron. A much smaller outflow is artificially diverted into the

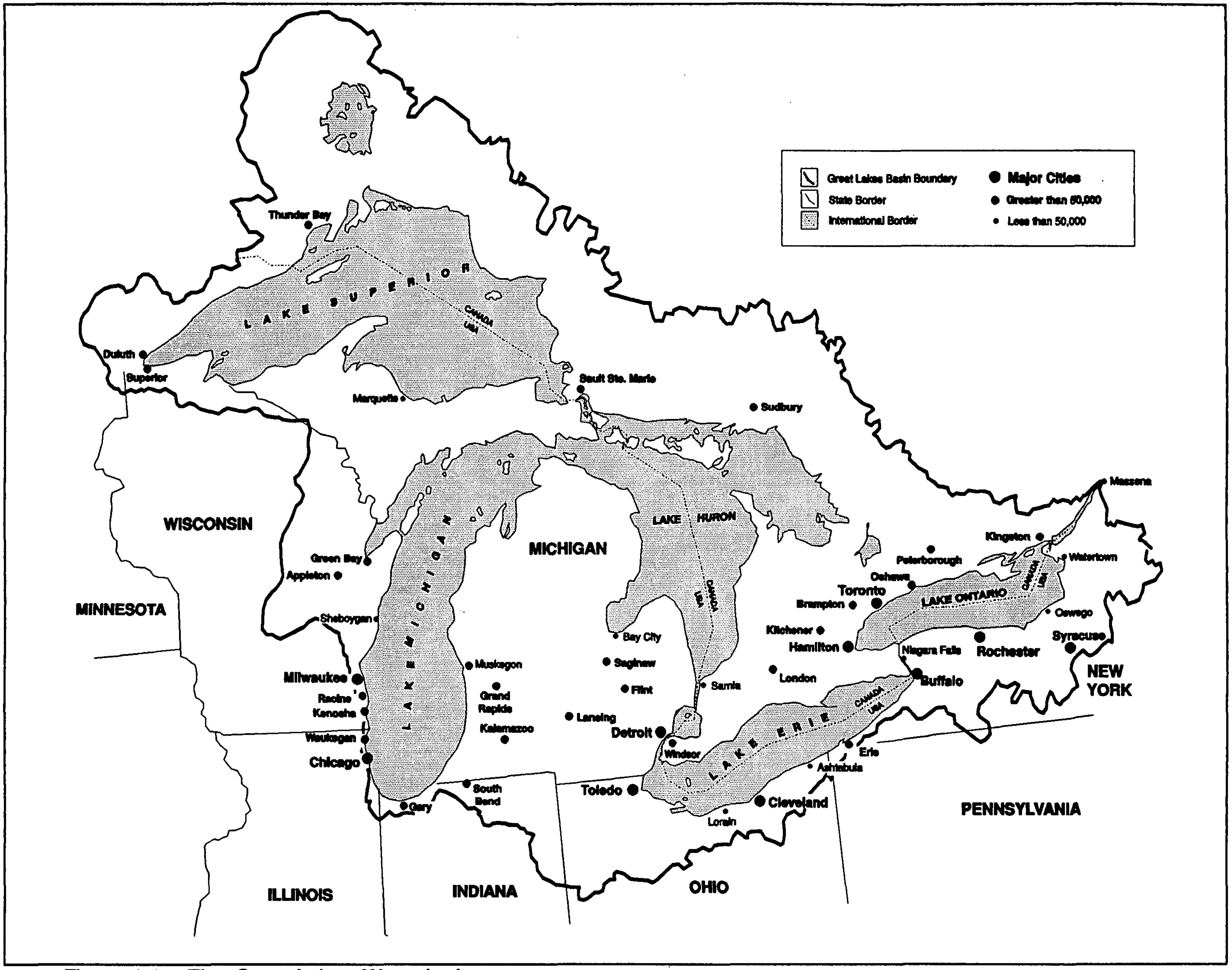


Figure 1-1. The Great Lakes Watershed

Mississippi River system via the Chicago Sanitary and Ship Canal.

More than 100 rivers flow into Lake Michigan. Just nine of these have an average flow in excess of 1,000 cubic feet per second (cfs). The four largest—the Fox, St. Joseph, Grand (Michigan), and Menominee—have flows of around 4,000 cfs. To put these flows into some perspective, the natural flow of the Niagara River over Niagara Falls averages about 200,000 cfs.

Lake Huron is the second largest in terms of surface area, slightly larger than Lake Michigan in this regard. Lake Huron receives both the outflow of Lake Superior and a net outflow from Lake Michigan through the Straits of Mackinac. Lake Huron holds about 16 percent of the water of the Great Lakes. About two-thirds of Huron's watershed is forested; another quarter is devoted to agriculture, particularly around Saginaw Bay. Lake Huron's water retention time is 22 years. The lake's outlet is the St. Clair River that flows into Lake St. Clair, a shallow lake (average depth 11 feet) northeast of Detroit.

Lake Erie is the smallest of the Great Lakes in water volume, with an average depth of only 62 feet. Lake Erie has three distinct basins that are defined by water depth and underwater ridges. The western basin is shallow, with an average depth of 24 feet; its waters are well mixed. The central basin is deeper; its waters stratify by temperature, and its narrow bottom layer is vulnerable to oxygen depletion. The eastern basin is the deepest of the three. Its bottom layer is thicker than that of the central basin, making it much less vulnerable to oxygen depletion. Lake Erie has the shortest water retention time, 2.6 years, making it the lake most responsive to both environmental abuse and cleanup.

Lake Erie is the southernmost of the Great Lakes. Its waters are the warmest in summer and the most productive biologically, supporting abundant fisheries. Because of its shallowness, Erie is the lake most affected by air temperature. As a result, Lake Erie regularly has 95 percent ice cover in the winter in contrast to the deeper Lake Ontario that has an average cover of only 15 percent. Lake Erie's watershed is the most agricultural, most urban, and least forested; about two-thirds of it is used for farming. Erie has the highest rate of sedimentation of the five lakes, receiving soil particles from the rich farmlands of its watershed. Erie's western basin receives water from the upper lakes via the Detroit River and from the Maumee River that joins the lake near Toledo. The Niagara River, flowing north into Lake Ontario, is Erie's primary outlet.

Lake Ontario is the smallest of the lakes in surface area, but contains more than three times the water volume of Lake Erie. About one-quarter of the Lake Ontario watershed is used for agriculture; dairy and cattle farms are the most common types of agriculture. The Canadian population within Lake Ontario's watershed is about twice that of the United States and has increased significantly through the 1970s and 1980s, whereas the U. S. population has remained stable. Canada's largest industrial region lies along the western and northwestern shores of Lake Ontario, and includes Toronto, a city of 3 million people. The southern portion of the Lake Ontario watershed contains Buffalo, Niagara Falls, Rochester, and Syracuse, New York.

The major source of water into Lake Ontario is the Niagara River flowing from Lake Erie. The Niagara provides about three-quarters of the estimated net inflow to the lake. Water from the Niagara River circulates rapidly; any contaminant borne by the Niagara is well distributed around the lake in 1 or 2 years. A smaller inflow is artificially diverted into Lake Ontario via Canada's Welland Canal that provides a navigable connection to Erie. Stretches of the Niagara River are industrialized, principally on the U.S. side. Lake Ontario is about 325 feet lower in elevation than Lake Erie, causing the Niagara River to cascade spectacularly at the famous Niagara Falls. Lake Ontario's water retention time is 6 years. Its outlet is the St. Lawrence River, which has an annual flow that represents less than one-half of 1 percent of the water volume of the entire Great Lakes system.

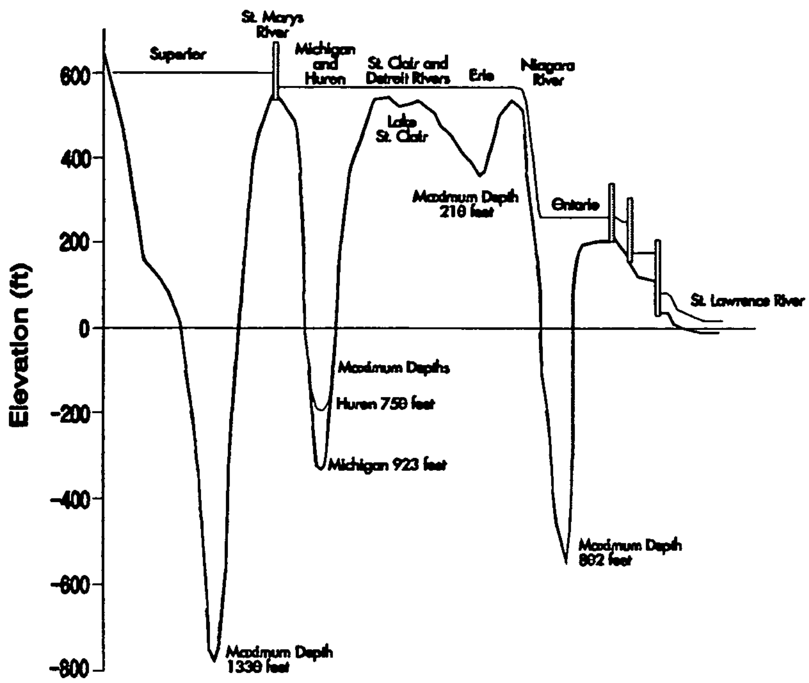
This relatively small outflow is an important characteristic of the Great Lakes. The lakes are a nearly closed system. Persistent pollutants introduced into the lakes, especially into Superior and Michigan with their long water retention times, are primarily removed from the water column by evaporation, burial, or induction into the food web. The system does not flush contaminants quickly. This attribute makes the Great Lakes ecosystem sensitive to environmental stresses.

Another important characteristic of the Great Lakes is their clarity. Before intense European settlement of the region began around 1800, the Great Lakes contained little phosphorus, were rich in oxygen, and, with the exception of western Lake Erie and shallow bays, were very clear (oligotrophic or poorly nourished). One reason for these phenomena was that the lakes' shorelines were for the most part rimmed by forests and wetlands, providing little nutrient runoff to stimulate the production of microscopic plants (i.e., phytoplankton, such as algae). While phytoplankton are a necessary building block of the Great Lakes food web, overenrichment and excessive algal growth cloud water and decay, depleting oxygen. Today, most of Superior and Huron remain oligotrophic, as do parts of the northern basin of Lake Michigan.

The most biologically productive waters are those of shallow embayments, such as Green Bay, Saginaw Bay, and western Lake Erie that are fed by the Fox, Saginaw, and Maumee Rivers, respectively, and that have warmer waters than the open lakes. Green Bay was so named by early settlers because of the hue imparted by its phytoplankton.

Before 1800, there were about 170 native fish species in the Great Lakes. Nearshore species included smallmouth and largemouth bass, muskellunge, northern pike, channel catfish and sturgeon. Lake herring, blue pike, lake whitefish, grayling, walleye, sauger, freshwater drum, lake trout and white bass inhabited deeper waters. Sturgeon lived to 150 years, reaching 9 feet in length and 400 pounds, whereas lake trout lived to 75 years.

The species mix varied between lakes. A large population of Atlantic salmon was confined to Lake Ontario. The deep eastern basin of Lake Erie supported lake trout, whereas the shallower and warmer western basin did not. Lake Erie sustained the most inshore species,



Feature	Superior	Michigan	Huron	Erie	Ontario
Average Depth (feet)	483	279	195	62	283
Volume (cubic miles)	2,900	1,180	850	116	393
Area:Water (sq. mi.)	31,700	22,300	23,000	9,910	7,340

Figure 1-2: Depth Profile of the Great Lakes and Summary of Their Physical Features

whereas cold Superior was the least productive. Superior, however, provided the best habitat for the whitefish. Atlantic salmon, grayling, blue pike, whitefish, and lake trout were top predators among fish. These species were staples in the diet of Native Americans.

The composition of fish populations in the Great Lakes is very different today. Fish are generally smaller than two centuries ago, and many non-native fish have been introduced, increasing the number of species to about 190. Fish populations have changed for a variety of reasons, including alterations to the food web; deliberate introduction of sport-fish, notably Pacific salmon; inadvertent introduction of non-native species, such as alewife, smelt, and sea lamprey; habitat loss or disruption; overfishing; and the effects of pollutants on fish reproduction.

Grayling are now extinct in the Great Lakes. By 1900, Atlantic salmon disappeared from Lake Ontario. Blue pike vanished from Lake Erie, and thus from the world, in the 1950s. Lake trout, sturgeon, and lake herring survive in decreased numbers. Even in relatively pristine Superior, hatchery-reared lake trout must be stocked to bolster the population. Populations of some native species, such as walleye and white bass, are more robust, and the whitefish populations in Superior and parts of Michigan and Huron are sufficient to support commercial fishing. Stocked, non-native Pacific salmon – coho and chinook – are the most abundant top predators in the open lakes, except in western Lake Erie, where the top predator is walleye.

The Great Lakes region also sustains a rich diversity of birds and other wildlife. Following the Atlantic and Mississippi flyways, an estimated 3 million waterfowl migrate through the Great Lakes each year, using the lakes for food and shelter. During their spring and fall migrations, up to 25,000 raptors (birds of prey) can be observed each day from Whitefish Point in eastern Lake Superior. The lakes are home to multitudes of terns, herons, gulls, egrets, and cormorants. Native animals include moose, deer, fox, wolves, and fur-bearing mammals – mink, muskrats, and beaver – that fueled the early development of the region by European settlers.

ECONOMY IN HISTORICAL PERSPECTIVE

During the past 300 years, various industries have boomed in the Great Lakes region. Fur trapping, especially of beavers, thrived from the last half of the 17th century until the early 19th century. As trapping depleted beaver populations in the region, the fur trade expanded throughout the continent, to California, Oregon, the Arctic Ocean. Even after trapping had moved to the west, the Great Lakes remained vital to the industry as a transportation system. The Great Lakes and St. Lawrence River provided a 2,200 mile waterway to the Atlantic coast whence furs were shipped to customers in Europe. Many early settlements on the Great Lakes were fur-trading posts, among them Detroit, Chicago, Green Bay, and Duluth. Chicago's first non-Indian settler, Jean Baptiste Pointe du Sable, a Haitian of African and French descent, was a fur trader who built a cabin on the north shore of the Chicago River in 1779.

About the time the beaver industry ended because of the scarcity of beavers and the whims of fashion, early settlers to the Great Lakes region began a massive harvest of trees. There were three principal types of forests surrounding the lakes. Spruce and fir trees grew in the north, on the Laurentian Shield above Superior and down to the eastern shore of Huron. The second forest of birch, hemlock, and pines ranged from south of Lake Superior, to northern Michigan, to the north shore of Lake Erie, and encircled Lake Ontario. South of this region were hardwoods: ash, oak, maple, and dogwood. The first deforestation was by local settlers clearing land for agriculture and buildings. Commercial logging began in the 1830s after the opening of the Erie Canal and the advent of steamships provided access to eastern markets. Logging began in Michigan and soon extended to Minnesota and Wisconsin. Loggers cut softwoods first, chiefly white pine, often hundreds of years old and more than 100 feet high. Softwood timber framed homes and ships. Hardwoods became barrels and furniture.

The heyday of Great Lakes lumbering was 1850 to 1900. Grand Rapids, today Michigan's second largest city, was a sawmill boom town in the 1850s that used the rapids for power; later it became a center for furniture making. During the 1890s, there were 100 sawmills adjacent to the Saginaw River; by tonnage shipped, Saginaw was the largest port on the Great Lakes. Tugboats pulled enormous floating trains of trees from Canada to the Saginaw mills. Around Muskegon Lake, beside Lake Michigan, there were 50 active sawmills in 1900. By 1910, there were none.

The Great Lakes lumber industry ran out of trees early in the 20th century. The soils of the North Woods and the Laurentian Shield are generally not conducive to farming. With the passage of time, forests have now returned to much of their former domain in the northern half of the Great Lakes region, though the trees are much younger and smaller than their predecessors. Today, these woods are harvested for paper. The paper-making industry, begun in the 1860s, remains important in both the United States and Canada. In 1982, the forest industry of Michigan, Minnesota, and Wisconsin employed about 150,000 people with sales of $15 billion. An additional 80,000 persons were employed in forest recreation.

The mining industry grew concurrently with the lumber industry and remains important. In 1845, rich iron ore was found in the Marquette Range of Michigan's upper peninsula. Additional iron ranges were later discovered near Lake Superior – the Cuyuna, Mesabi, and Vermillion Ranges in Minnesota, the Menominee Range in Michigan's upper peninsula, and the Gogebic Range on the Wisconsin and Michigan border. In 1855, completion of the Sault Canal opened Superior to shipping and permitted mining of these ranges.

Iron ore from the mineral-rich Lake Superior watershed subsequently helped to make the Great Lakes a center of iron-making, steel-making, and heavy manufacturing. The Great Lakes provided an efficient waterway for ore to be shipped to lakeside cities, like Buffalo, Detroit, Cleveland, Gary, Sault-Sainte Marie, and Hamilton. Another key ingredient for steel-making, limestone, was quarried near the northeast shore of Michigan's lower peninsula. Coal from Illinois, Ohio, and Pennsylvania fired industrial hearths.

Oil became another significant industry. The world's first oil well was tapped in the northwestern Pennsylvania town of Titusville in 1859. Oil was later found near such locations as Midland, Michigan; Toledo, Ohio; and north-east of Lake St. Clair around Petrolia and London, Ontario. Cleveland, Ohio, already an industrial hub in part owing to being the terminus of a canal that linked the Great Lakes to the Ohio River, became the nation's oil-refining center. In 1863, a 23-year old bookkeeper, John D. Rockefeller, invested $4,000 in a Cleveland oil refinery. By 1880, his Standard Oil Company refined 95 percent of the nation's oil. Ten years later, Cleveland had a population of 260,000.

Chicago, too, grew rapidly after becoming a canal terminus. The canal was completed in the 1830s, connecting Lake Michigan and the Mississippi River system. Chicago's first railroad, to northwest Illinois' lead mining district, was completed in 1853. Other railroads followed, to establish the city as the midwest's transportation center by the time of the Civil War. Chicago grew 800-fold from 350 inhabitants in 1833 to 300,000 by 1870, receiving waves of Irish, German, and other European immigrants.

Owing to the easy confluence of iron ore, limestone, coal, oil, and water transportation, the Great Lakes region became an industrial heartland of both the United States and Canada. The automotive industry was born in a Michigan triangle bounded by Lansing, Flint, and Detroit, drawing on and supplanting the carriage industry that had been thriving there. Detroit's population soared by almost 400 percent between 1890 to 1920 as Ford Motor Company began mass production of automobiles. The Ford, Chrysler, and General Motors corporations were producing eight million cars and trucks a year by 1950.

Industries associated with the automobile business, such as tool and die, machining, aluminum, and rubber, were drawn to the area. By the 1920s, Akron, Ohio, where Benjamin Goodrich had opened a rubber factory in 1871, was processing almost half the world's rubber. Proximity to the steel industry helped to attract agricultural equipment and appliance manufacturers. Proximity to industrial and agricultural customers helped to attract chemical manufacturers. Chemical companies were further encouraged by the brine wells of southeastern Michigan. To draw on these wells, Herbert Dow founded what became one of America's largest chemical firms, Dow Chemical Company, in Midland, Michigan, in 1891.

During the 1970s and early 1980s, foreign competition and rising energy costs caused red-ink and job losses in Great Lakes heavy industry, especially in the United States. By that time, foreign economies devastated by the Second World War had developed into strong competitors to Detroit's automobile manufacturers. The demand for fuel-efficient cars made lighter materials, such as plastics and aluminum, desirable alternatives to steel. During the 1970s, Detroit lost 20 percent of its residents. About one million manufacturing jobs were eliminated in the early 1980s in just five Great Lakes States.

Yet heavy industries, including mining, steel, and auto-making, have adjusted, reducing production to meet demand and investing in new facilities. Today, manufacturing remains the largest single sector in the economy of most Great Lakes States, although the steel industry in particular will face increasing competition from higher strength, lighter weight composite materials.

Mining and manufacturing are likewise major elements in the economy of the Province of Ontario. The Sudbury area produces the largest quantity of nickel in the world. Ontario is a major producer of gold, silver, platinum, uranium, zinc, iron, copper, salt, and gypsum. The province produces nearly 50 percent of Canada's manufactured goods.

Agriculture is another productive element of the Great Lakes economy. During the 19th century, cheap land with ample top soil, flat terrain, horse-drawn harvesting machines, and railroads that brought crops to distant markets contributed to extraordinary agricultural productivity in the American Midwest. After 1914, combustion engines supplanted horses in powering farm machinery. Since 1950, farm yields have soared further, owing to advances in biology, chemistry, and engineering. Breeding of plants has provided varieties with higher yields. Fertilizers, especially nitrogen, have raised soil productivity, and pesticides have abated crop losses to weeds, fungi, and insects. Farm machines have become vastly more effective.

As a result of these improvements, agricultural output within the U. S. Great Lakes watershed has increased over the last 40 years, although farm acreage has actually shrunk by one-third. Cropland accounts for 18 percent of the lands in the U. S. counties of the Great Lakes watershed, predominantly in the south. Major cropland areas include east-central Wisconsin, the Saginaw Bay watershed, and northwest Ohio. The largest crop is corn (42 percent of farm acreage), followed by soybeans (24 percent), and small grains, especially wheat (17 percent). Dairy products, fruits, vegetables, and tobacco are other important crops. Wisconsin ranks first among States in milk output; Michigan leads the nation in production of blueberries, tart cherries, and navy beans.

Convenient waterways have abetted the economic successes of the region. The Erie Canal was completed in 1825, connecting Buffalo to the Hudson River at Albany. (Rebuilt, it still operates today as the New York State Barge Canal.) About the same time, Canada constructed the Lachine Canal to bypass rapids on the St. Lawrence and the first Welland Canal between Ontario and Erie to bypass Niagara Falls. The 27-mile long Welland has been enlarged a number of times. Its locks are now 30 feet deep and 859 feet long.

These dimensions set size limits on transoceanic vessels that enter the Great Lakes. There are about 300 "lakers" that ply the Great Lakes. Long and narrow, they tend to be 650 to 730 feet long with a maximum width of 75 feet and a cargo capacity of 20,000 tons. The most recent lock at Sault-Sainte Marie, completed in 1969, permits larger ships on the upper lakes. About 25 vessels, up to 1,100 feet in length with a capacity of 60,000 tons, traverse the lakes west of Buffalo.

The five parallel locks at Sault-Sainte Marie, connecting Superior and Huron, are among the busiest in the world. In 1990, five thousand vessels carrying 90 million tons of cargo (including 50 million tons of iron ore) passed through these locks. Many of these vessels are headed to or from the port of Duluth/Superior, which ranked 14th in the United States by tonnage shipped in 1987. Among its products, Duluth ships low-sulfur coal from the American west. Thunder Bay, Ontario, is the port of embarkation for about one-half of Canada's total grain production.

The St. Lawrence Seaway connects Lake Ontario to Montreal and provides the final link in a 2,200 mile commercial waterway between Duluth and Montreal. Completed in 1959, the Seaway is 27 feet deep, as are the shipping channels that cut through the St. Marys, St. Clair, and Detroit Rivers, and through shallow Lake St. Clair. This inland waterway is navigable by about three-quarters of the world's saltwater fleet. In 1986, 40 million tons of cargo passed through the St. Lawrence Seaway.

The waters of the Great Lakes confer other economic benefits, as well. They provide abundant drinking water to millions. Industries use water as an ingredient (as in the beer for which Milwaukee is famous) and as a coolant for manufacturing processes. Some rivers are harnessed to generate electricity; up to one-half of the natural flow of the Niagara River is diverted for electrical generation. Another connecting channel, the St. Marys River, is also harnessed for electricity.

Another large element of the Great Lakes economy is recreation, including sight-seeing, fishing, boating, camping, hiking, and lodging. In 1987, Michigan had more registered boat owners than any other State. The Great Lakes sustain both sport and commercial fisheries, although recreational fishing is the more important of the two today. As the value of recreational fishing has increased in comparison with commercial fisheries, some jurisdictions have established policies that favor sport fishing. The Great Lakes Fisheries Commission has estimated that five million sport fisherman on the Great Lakes spent $2 billion in 1985; during the same year, the value of the commercial fish catch was just $41 million. The largest recorded commercial fish harvests were in 1889 and 1899. By weight, the commercial yield in recent years has been about two-thirds of these peak years, yet the value is small since the size and species harvested are less desirable. The economic potential of Great Lakes fisheries is much higher than their recent value.

At the onset of the 20th century, the human population of the Great Lakes watershed was just over 10 million. According to 1986 census data, the region has 35 million residents—27.5 million U.S. citizens and 7.5 million Canadians. The Lake Superior and Lake Huron basins are sparsely inhabited. The south and southwestern shorelines of Lake Michigan, the Canadian shore of Lake Ontario, and the U.S. side of Lake Erie are far more heavily populated. The third and fourth highest populated U.S. metropolitan areas (Chicago and Detroit) and the largest Canadian one (Toronto) are situated by lakes or a connecting channel. Among the inhabitants of the Great Lakes region are Indian Tribes. Five Indian reservations within the United States touch upon the shores of the Great Lakes; 14 do so on the Canadian side.

SOME ECOLOGICAL IMPACTS OF DEVELOPMENT

Intense development of the Great Lakes region has wrought vast changes to the ecosystem. Humans have altered habitat, introduced exotic (non-native) species, and cast a wide range of contaminants into the lakes.

Some effects have been dramatic. Through discharge of raw sewage into the lakes, cities infected their water supplies with typhoid and cholera during the late 19th and early 20th centuries. By the mid-1950s, non-native sea lampreys (small, parasitic eel-like fish) decimated lake trout to the extent that commercial catches in Lakes Huron and Michigan fell to 1 percent of the yield obtained 20 years before. By the 1960s, the overenrichment of Lake Erie was infamous; mats of algae fouled beaches and water intakes. In 1967, millions of another exotic fish, alewife, a member of the herring family, washed up on the Lake Michigan shore, victims of the combined effects of cold weather and starvation. Overpopulation, related to the decline of alewife predators such as lake trout, contributed to the massive die-off. In 1969, a stretch of the Cuyahoga River in Cleveland was so laden with oil products, chemicals, and debris that it caught fire. During the 1970s, researchers began to note tragic birth defects, probably caused by persistent toxic chemicals, in birds such as double-crested cormorants, born with grotesquely crossed beaks.

Many of these once acute problems have abated. Treatment of both drinking water and sewage ended water-related epidemics. Application of a toxicant to spawning grounds has slashed the population of sea lampreys, though this exotic is firmly established as a resident of the Great Lakes. Stocking of lake trout have bolstered their numbers, though the species generally continues to be unable to sustain itself. Reductions in loadings of phosphorus have lessened many of the problems associated with nutrient overenrichment, like excessive algae. Stocking of salmon and trout have controlled alewife numbers. Since the passage of the Clean Water Act in 1972, the reduction in pollutant loadings from dischargers has generally and greatly improved water quality, allowing fish to return to many harbors from which they had disappeared. The health of many populations of fish and wildlife has improved after their body burdens of some contaminants have declined.

Yet the Great Lakes ecosystem has been pervasively changed in other, less dramatic fashions, many permanent. The decline in the beaver population resulted in fewer beaver dams, which had impeded tributaries and helped to create wetlands. In their absence, river flows increased; faster rivers captured and carried more silt, burying the spawning grounds of fish.

The reaping of forests had profound ecological consequences. Forests were cleared, exposing soil to drying by direct sunlight and to erosion by wind and water, increasing the silting of rivers. Loggers floated trees down tributaries, gouging soil from river banks to cover gravel bottoms where fish spawned and fed. Debris from sawmills heaped upon spawning grounds and, through decay, depleted oxygen from the water. Forests had provided shade along tributaries. In their absence, the temperature of streams increased, further modifying the habitat of fish. Forest clearance also increased seasonal variation in tributary flow. Low wintertime flows exposed streambeds, freezing the eggs of fish.

Agriculture also increased soil erosion. Erosion of soil from tilled fields is often imperceptible, yet inexorable. It has been estimated that by 1910 between a quarter to a half of the deep original topsoil of the great Missouri and Mississippi river drainage basins had been washed away, largely through profligate agricultural practices. Since 1950, eroding soil particles and rainfall runoff have carried agricultural chemicals—pesticides and fertilizers. The overenrichment of Lake Erie by the 1960s was partly the result of increased nutrient use by farmers.

The growth of human population around the Great Lakes has imposed further ecological change. Roads and sidewalks, roofs, and parking lots distort natural infiltration of water into the ground. Rain that would otherwise seep into the soil is caught by drainage systems and discharged to streams. As a result, tributaries have become more variable in their flow and less hospitable to fish.

The Great Lakes have been vastly altered for shipping and flood control. River mouths, critical habitat for fish and wildlife, have especially attracted development. Hundreds of them have been dredged and surrounded by breakwaters. Dredging and the wash from ship propellers injure organisms in bottom sediments upon which fish feed. Canals and ships have introduced non-native species. Unchecked by natural predators, some of these have wreaked profound damage to native species. One canal has notably diverted pollution from the Great Lakes. The Chicago Sanitary and Ship Canal, completed in 1900, reversed the flow of the Chicago River, flushing Chicago's wastewater into the Illinois River and protecting Chicago's beaches and water supply, at a cost of tapping Lake Michigan's water volume.

Wetlands and sand dunes are other habitats that humans have profoundly modified. Wetlands have vital ecological functions, acting as buffers against floods and erosion, and serving as nursery, resting, and breeding habitat for fish and wildlife. It is thought that wetlands once constituted 60 percent of southwest Ontario and 30 percent of Michigan. Perhaps two-thirds of region's wetlands have been drained or filled since 1800, including the huge Black Swamp of northwest Ohio, almost entirely converted to rich farmland. The downtown areas of Milwaukee and Chicago largely rest on filled-in wetlands. In fact, Chicago takes its name from an Indian word for the wild onions that once grew in marshlands beside Lake Michigan.

Before parks were established to preserve the remainder, a vast array of sand dunes at the base of Lake Michigan, home to a rich diversity of wildlife, was mined for glass production and for railway bed fill. Cheap lakefront land and a large nearby labor force in Chicago also made the dunes and adjacent wild rice swamps attractive to heavy industry. Standard Oil Company (now Amoco) established a refinery in Whiting, Indiana, in 1889; Inland Steel Company opened in East Chicago in 1901; and the city of Gary took its name from the surname of the chairman of United States Steel when America's first billion dollar corporation opened a huge works there in 1906. Bethlehem, National, and LTV steel companies followed. Today, northwestern Indiana is an American Ruhr of metal, oil, and petrochemical facilities. In places, large amounts of oil float on the groundwater; during rainfall, the rising water table lifts oil into municipal drainage systems. Through this region meanders the Grand Calumet River that receives most of its waters from industrial and municipal dischargers. Its river bed holds contaminants of extraordinary toxicity.

Manufacturing firms have contributed a broad range of contaminants to the lakes. One of the most ecologically injurious is the family of organic chemical compounds called polychlorinated biphenyls (PCBs). PCBs were widely used from 1929 until banned by EPA in 1977. They are highly stable, which made them useful as hydraulic fluids and lubricants in high temperature or pressure processes. They were also used in paint, ink, plastics, caulking compounds, and metals. Tests have shown that PCBs may cause reproductive disorders, birth defects, and cancers in laboratory animals. The stability that made PCBs desirable in commercial applications has undesirable environmental consequences; they magnify up the Great Lakes food web and do not degrade. PCB contamination is the most frequent grounds for health advisories regarding consumption of Great Lakes fish. PCB contamination is greatest in Waukegan Harbor, Illinois, from where it is estimated that hundreds of thousands of pounds of PCBs have entered Lake Michigan.

Though the practice ceased in the U.S. during the 1970s, some pulp and paper mills released mercury, a persistent toxic substance that magnified in concentration up the Great Lakes food web. Mercury was found in fish from Lake Huron, Lake St. Clair, western Lake Erie, eastern Lake Ontario, and the St. Lawrence River at levels that required the closing of some commercial fisheries. In the 1980s, EPA recognized that pulp and paper mills, particularly those using the bleached kraft process, discharge very low concentrations of chlorinated dibenzodioxins and dibenzofurans as byproducts of pulp and paper bleaching with chlorine. Dioxins and furans represent a family of 210 structurally related chemical compounds. The most infamous of the dioxin compounds—2,3,7,8-TCDD—produces a variety of toxic effects in laboratory animals at very low doses.

The pulp and paper industry also continues to be a significant source of conventional pollutants to the Great Lakes, particularly to Lake Superior. According to a 1989 report by the International Joint Commission, pulp and paper mills in the Province of Ontario generally do not use secondary (biological) processes to treat their wastewater. Secondary treatments, usually practiced by U. S. mills, decrease conventional pollutants and can reduce 25 to 60 percent of the toxic organic byproducts of papermaking.

Chemical companies have left a toxic heritage in the ground water, bottom sediments, and soils of the Great Lakes region. EPA's Superfund program to clean-up abandoned hazardous waste sites in large measure had its origin in the Great Lakes, being in part a response to the widely-publicized 1978 discovery of toxicants in the infamous Love Canal, near the Niagara River. Chemical companies attracted by hydroelectric power generated from the Niagara, situated near its banks. Canadian chemical companies similarly clustered along the St. Clair River, around Sarnia, Ontario. Waste sites along the U.S. side of the Niagara have been a major source of contamination to Lake Ontario, which with Lake Michigan are the two most contaminated lakes. Since its inception, these sites have been a major focus of the Superfund program, with the result that their loadings to the Niagara are being substantially reduced.

Metals-based industries, including mining and steel-making, have been a significant source of pollutants to the Great Lakes. Torch Lake, a tributary to Lake Superior near the base of the Keweenaw Peninsula, received copper tailings for more than 100 years before mining ceased in 1969. Two hundred million tons of tailings fill more than 20 percent of the lake's original volume. Many steel-making technologies that are presently in use generate such byproducts as ammonia, cyanide, coal tar, zinc, lead, and a range of air pollutants, including fly ash, sulfur compounds, and the gases benzene, toluene, and xylene. Steel mills are a source of benzo(a)pyrene, the most toxic member of the family of polyaromatic hydrocarbons (PAHs). Like other PAHs, benzo(a)pyrene is a product of incomplete combustion of fossil fuels and is suspected of causing lip and liver tumors in bottom-dwelling fish. PAHs are common in nearshore bottom sediments.

The intent of this chapter has not been to attribute environmental damage solely and simplistically to a few leading industries. Degradation of the Great Lakes ecosystem over the past three centuries has been the collective result of actions throughout society, by individuals and the governments they elect, as well as by industry and agriculture. And the prominent industries mentioned in this chapter, especially productive sectors like farming, forest products, metals, and manufacturing, have made a vital contribution to a steady rise in the national standard of living. Their heritage of economic achievement has been of national importance. The future promise of the U.S. economy will continue to rely on such productive industries.

Rather it has been the intent of this chapter to suggest, however sketchily, the vastness of the changes to the Great Lakes ecosystem over the last three centuries. Without a long-term perspective, one has little appreciation for the magnitude of some damage, such as that to fish populations. Whereas the drastic decline during the 1980s in striped bass populations off the eastern seaboard of the United States has been a relatively recent and well known phenomena, the steep declines of sturgeon and lake trout in the Great Lakes occurred earlier and the passage of time has accustomed many people to these ecological disasters.

Chapter 2 focuses on some ecological problems in the Great Lakes that are the object of government programs discussed thereafter in this report.

Chapter 2

The State of the Ecosystem

This chapter discusses five broad problems facing the Great Lakes ecosystem:

- Contamination of fish and wildlife with persistent toxic substances,
- Contaminated bottom sediments,
- Lost, degraded, and threatened wetlands,
- Damage to native species from exotic ones, and
- Undesirable effects from excessive nutrients.

PERSISTENT TOXIC SUBSTANCES

Persistent toxic substances do not pose a problem for humans drinking Great Lakes water. Their concentrations in the Great Lakes water column are extremely low, because they tend to quickly bind to particles – sediment or phytoplankton – and fall to the bottom or enter the food web. They also volatilize into the atmosphere. Open lake concentrations of contaminants are measured in parts per billion or trillion. A part per trillion represents a teaspoon in 1.3 billion gallons of water. A person would have to drink two or three million gallons of water to be exposed to a quantity of contaminants equivalent to that ingested by eating a single mature lake trout (1).

Low levels of contaminants in water concentrate in the tissues of predators through the phenomena of bioaccumulation and biomagnification up the food web. At the base of the food web, microscopic plants – called phytoplankton – use sunlight and mineral nutrients for nourishment. Microscopic animals, known as zooplankton, feed on such vegetation and are in turn eaten by fish. Tiny sediment-dwelling insects and crustaceans are another source of food for some small fish. Higher predators, fish and birds, consume smaller fish. A simplified view of the Great Lakes food web is shown by Figure 2-1. It does not show many different species of phytoplankton, zooplankton, benthic animals, fish, and wildlife, but displays the food web concept.

Phytoplankton and zooplankton continually bathed in contaminants and benthic organisms living in contaminated bottom sediments adsorb and bioaccumulate persistent toxic substances. As higher organisms in the food web graze on large quantities of plants and other organisms, they accumulate higher quantities of contaminants. The increasing concentration of contaminants at upper levels of the food web is known as biomagnification.

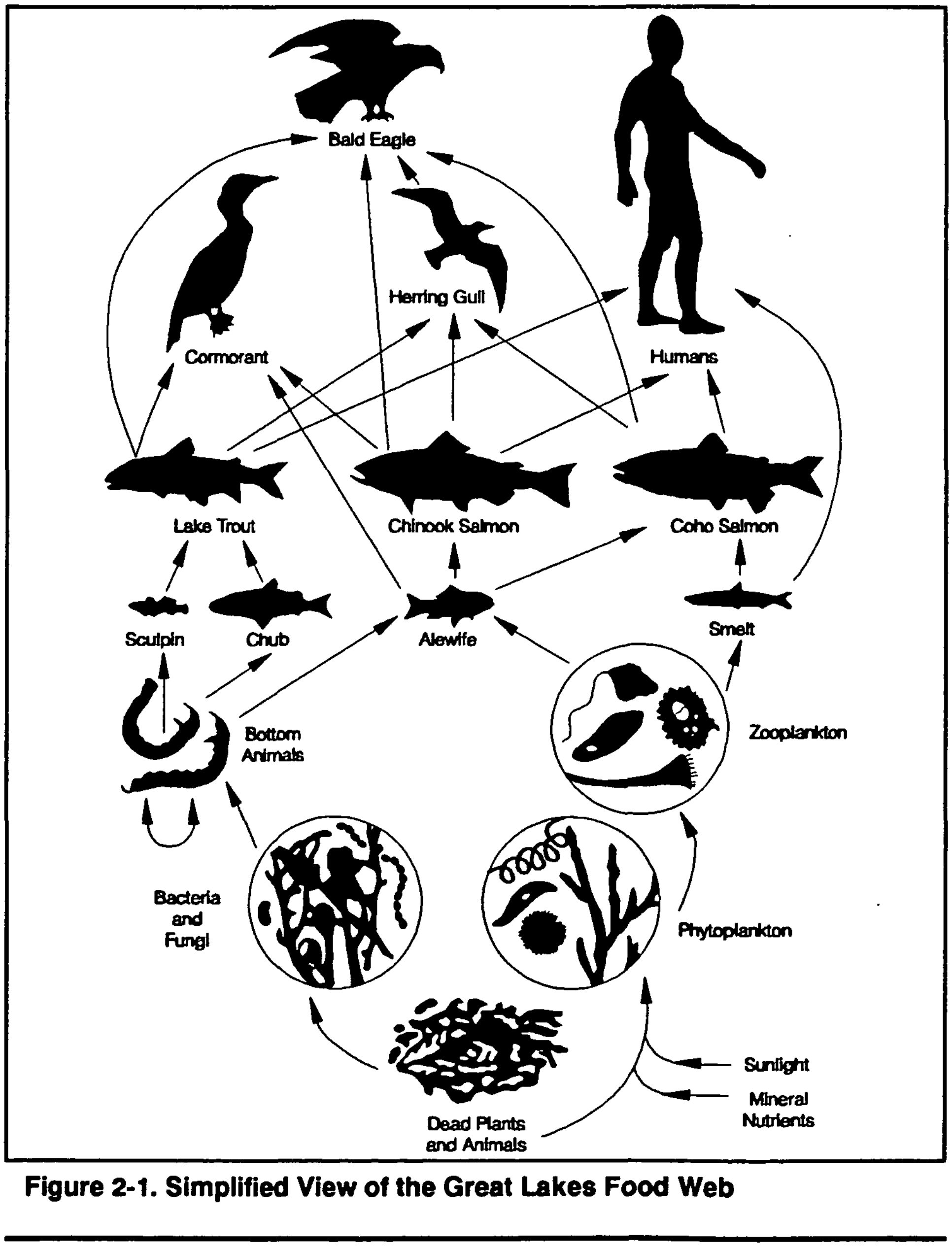


Figure 2-1. Simplified View of the Great Lakes Food Web

Fish and birds living in or around Lake Michigan and Lake Ontario tend to have markedly higher levels of contaminants than those of the other three lakes. The relatively low levels in Lake Erie biota are a bit surprising, since that lake has a high surrounding population and is known to receive high loadings of toxic substances. Scientists offer two possible explanations. First, Erie's relatively high sedimentation may adsorb and remove toxic substances from the water column, making them less available to the food web. Second, Erie's abundance of phytoplankton may result in a lower contaminant concentration at the bottom of the food web than in Lakes Michigan and Ontario, resulting in lower concentration higher up the web.

There have been striking declines in levels of some targeted substances over the last two decades. Figures 2-3 and 2-4 show declines in two substances, PCBs and the pesticide DDT, in Lake Michigan herring gulls and bloater chubs. Further evidence of the decline in PCBs across several Lake Michigan fish species is provided in Figure 6-2 in Chapter 6.

Despite these marked declines, levels of contaminants remain unacceptably high. State public health authorities issue fish consumption advisories for some species in each lake and in various rivers and bays. These tend to be based on risks from PCBs, mercury, and the pesticide chlordane. Table 2-1 summarizes advisories issued for 1989.

EPA has no formal role in setting sport fish consumption advisories, although the Agency shares responsibilities with States, under the Clean Water Act, to protect the quality of surface waters through establishment of State Water Quality Standards and the regulation of water dischargers under the National Pollutant Discharge Elimination System (NPDES). State standards are sometimes governed by the risks posed by human consumption of fish that bear bioaccumulative pollutants. In September 1989, EPA's Office of Water Regulations and Standards released a guidance manual, entitled Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish, which provides the Agency's recommended procedures for assessing risks related to the consumption of fish. States have

Some persistent toxic substances concentrate up the food web. Top predators, such as herring gulls and lake trout, can accumulate PCB levels that are, respectively, 51,000 and 5,600 times greater than those found in plankton.

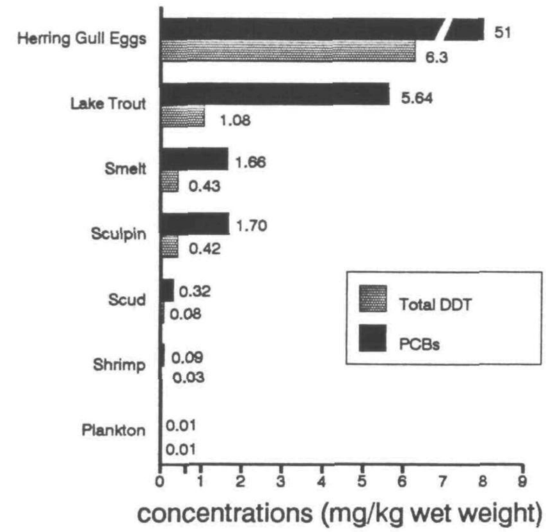


Figure 2-2. Lake Ontario Food Web Biomagnification

Fish-eating birds like the herring gull are near the top of the food web. Only top predators such as the bald eagle, that eats gulls and other foods, builds up higher concentrations of contaminants. Herring gulls' diet is about three quarters fish and the remainder includes mammals, insects, birds and bird eggs, amphibians, earthworms and crayfish, as well as garbage. Herring gulls remain on the Great Lakes all year around rather than migrating. Thus, they are good indicators of local levels of contamination. Herring gulls nest in established colonies, making it easy to collect egg samples regularly from the same colony. By collecting eggs, birds do not have to be killed to be sampled. The gulls usually lay more eggs to replace ones lost early in the nesting season, so this kind of sampling does not threaten their populations.

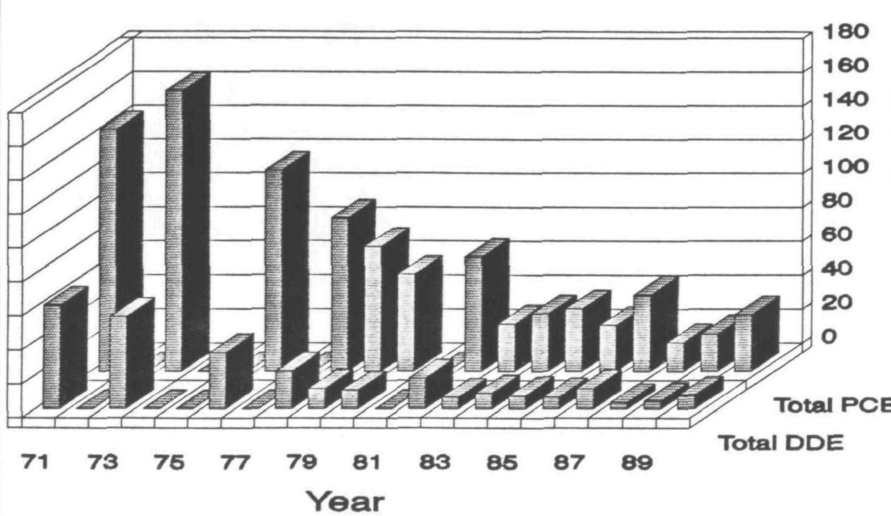


Figure 2-3. Contaminants in Herring Gull Eggs on Sister Island (Green Bay), Wisconsin

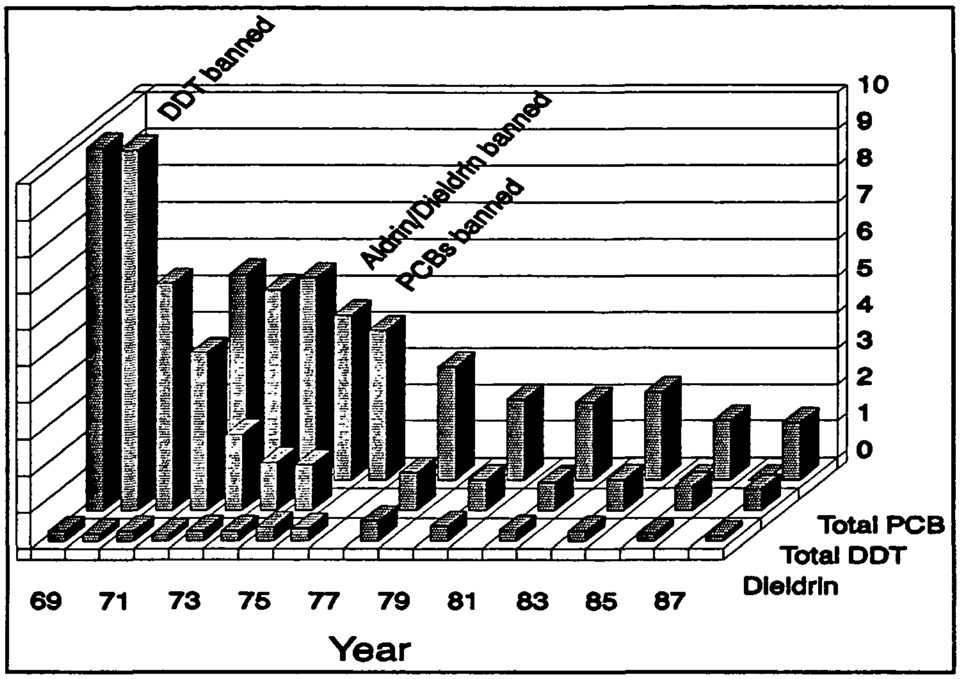


Figure 2-4. Pesticides and PCBs in Lake Michigan Bloater Chubs
(analyses of whole fish – mg/kg wet weight.)

traditionally used grounds for fish advisories that have often not been based on estimates of human health risks.

Effects on Wildlife

Over the last few decades, researchers have observed population declines and health problems in excess of 15 Great Lakes fish and wildlife species that have seemed to be associated with exposure to various persistent toxic substances. Effects have usually been most pronounced at the top of the food web and across generations, as expressed in birth defects. Other problems, seemingly associated with exposure to toxicants, that have been noted in Great Lakes species include: loss of appetite and weight; hormonal changes; poor reproductive success; tumors; increased susceptibility to disease; and behavioral changes. With the reduction of many targeted pollutants in the food web, the populations of affected species generally seem to be improving.

The bald eagle, a top predator, began to decline in population across the nation during the 1940s. Since EPA banned and restricted the persistent pesticides DDT and dieldrin in the 1970s, improved bald eagle reproductive success has led to a recovery in the national population. However, bald eagles have not recovered so vigorously along the shores of the Great Lakes. Researchers have noted that eagles do not reproduce as successfully along the lakes as they do further inland. Great Lakes fish may provide too toxic a diet for bald eagles to raise viable young.

During the 1970s, herring gulls around the Great Lakes were also found to have reproductive problems (2). Changes in behavior were a contributing factor – herring gulls neglected their nests, which caused low hatching success. Herring gull populations have increased as PCBs and pesticides have decreased in the food web.

Also during the 1970s, scientists observed deformities in various bird species, such as double crested cormorants, common terns, caspian terns, ring-billed terns, and herring gulls. Birds were found with crossed bills, jaw defects, and malformed feet and joints. Although the incidence of these deformities has declined in conjunction with contaminant levels, such problems remain in relatively contaminated areas.

Mink have proved extremely sensitive to a diet of Great Lakes fish. In the mid-1960s, mink breeders found that their animals were experiencing high mortality rates and almost complete reproductive failure. The ranch animals were being fed fish from Lake Michigan tributaries. Laboratory toxicology experiments determined that mink are highly susceptible to such contaminants as PCBs. As with bald eagles, it is thought that wild mink populations are larger inland than along the shores of the Great Lakes.

Great Lakes contaminants may also have contributed to a sharp decline since the 19th century in the population of beluga whales in the St. Lawrence estuary. The whales are burdened by many contaminants, including mirex, a persistent toxic substance known to be present in Lake Ontario. Though beluga do not enter the Great Lakes, they eat Atlantic eels that migrate from Lake Ontario and that are suspected to contain mirex.

Another suspected impact of persistent toxic substances on fish has been

Contamination of Fish and Wildlife

The Great Lakes food web is contaminated by a variety of persistent toxic substances, leading to unacceptably high levels in certain fish and wildlife. Due to use restrictions and major investments in pollution treatment and abatement, levels of some contaminants are much lower than in the early 1970s and continue to decline, but still justify the issuance of public health advisories regarding fish consumption. Consumption of some fish present risks to human health, though the degree of risk is contingent on the species and location of fish, the amount consumed, the method of cleaning and cooking, and the gender and age of the consumer, among other factors. Fish contamination detracts from the potential value of sport and commercial fisheries. Contaminants have been associated with reproductive and other health problems in Great Lakes fish and wildlife; however, with the sharp decline of targeted pollutants, many species seem to be recovering. Problems persist for fish and wildlife in certain locations, particularly in harbors

Are Great Lakes Fish Safe to Eat?

A person who eats Great Lakes fish ingests potentially carcinogenic substances. As to whether eating these fish is "safe" is a matter of personal judgment for an informed individual.

Fish of different species, locations, and size, different potential carcinogens; fish that bear the largest burdens tend to be large, bottom-dwelling, high in the food web, and high in fat content. Modern risk assessment methods generally assume that the probability of cancer is proportional to dose, so that there is zero probability at zero dosage. Because risk is based on cumulative exposure, high consumption of "low risk" fish can actually pose greater risk than less consumption of "high risk" fish. It is valuable to inform the public about which fish species tend to carry the highest burdens of contaminants. State health authorities usually follow this approach when issuing fish advisories (see Table 2-1).

Some clarifications should be made about estimates of risk. First, risk assessments have substantial uncertainty in that they are usually based on estimates of carcinogenic potency obtained by tests on animals; actual human effects are likely to be different. Second, assessments produce a range of risk; health authorities commonly use the high end of the range. Third, some methods of cleaning and cooking fish can lower the dose of potential carcinogens. Fourth, not all potential carcinogens may have been detected, which would cause an assessment to underestimate actual risk. And fifth, risk assessments tend to be based on estimates of cancer incidence and do not consider other harmful health effects.

This last point is important, since some research over the last decade suggests that there may be non-cancer, transgenerational effects associated with contaminants found in the tissues of Great Lakes fish. A series of studies of human health effects from eating Lake Michigan fish containing PCBs began in 1980 (3). The studies have focused on children whose mothers had regularly eaten Lake Michigan fish, examining them at birth, at 7 months, and at 4 years of age. The studies concluded that infants whose mothers consumed Lake Michigan fish showed lower birth weights, smaller head circumference, and slower responsiveness than infants whose mothers had not consumed such fish. At 4 years, these same children had poorer short-term memory. The deficits noted were small in magnitude and were not evident outside the testing situation. There was no indication that the long-term memory of young children was affected. Since short-term memory is important in the acquisition of reading and arithmetic skills, however, the deficits may augur later impacts on academic performance. One implication of these studies is that a woman's lifetime exposure to PCBs may adversely affect her children. Eliminating exposure during pregnancy or lactation may not prevent adverse affects.

Because of the Lake Michigan study and other research, public health authorities consider children and women who anticipate bearing children to be the most vulnerable consumers of Great Lakes fish. Fish advisories recommend that these populations avoid eating the fish species cited in Table 2-1.

noted in bottom-dwelling or bottom-feeding fish, such as bullheads and suckers. These fish have been found to suffer a high incidence of dermal and liver tumors at a number of Great Lakes locations (3). The causes of these tumors are difficult to determine because of the broad suite of substances to which these fish are exposed. However, the incidence of tumors is strongly correlated with polluted conditions, especially with the presence of polyaromatic hydrocarbon (PAH) contamination in bottom sediments (4). Several PAH compounds are known or suspected carcinogens. Although little is known about the significance of tumors on either the health of fish or on the health of humans who might eat these fish, visible abnormalities reduce the commercial and recreational value of fish.

While scientists have noted associations between contaminants and impaired fish and wildlife health, they have thus far only established one cause and effect relationship. DDE (a decay product of DDT) accumulates in some species of birds, including double-crested cormorants and black-crowned night heron, and inhibits enzymes that are responsible for incorporating calcium carbonate into eggshells. As a result, their eggs are too fragile for incubation.

Contaminants

EPA has established water quality criteria for about 130 substances that are known or suspected to be harmful to humans, fish, or wildlife. Criteria numerically define maximum allowable concentrations of a contaminant in water and serve as a basis for the development of enforceable State Water Quality Standards.

EPA and States have identified a set of pollutants deemed especially injurious and often present in the Great Lakes ecosystem. Table 2-2 summarizes some priority pollutants. All pollutants listed in this table are thought to biomagnify up the food web. Several are the most toxic members of groups of related chemicals.

Pathways

Persistent toxic substances reach the Great Lakes from a broad range of human activities. Some sources are readily visible, such as discharges from sewage systems and industry and spills from ships and shore. Other sources are much less obvious: transport and deposition of contaminants through the atmosphere, movement of contaminants through groundwater, and urban and agricultural runoff. Even substances that are no longer used in this country continue to reach the Great Lakes, albeit in smaller quantities, by incineration and runoff or volatilization of terrestrial contamination. Also, substances like DDT are still used outside the U.S. and are borne to the Great Lakes through the atmosphere.

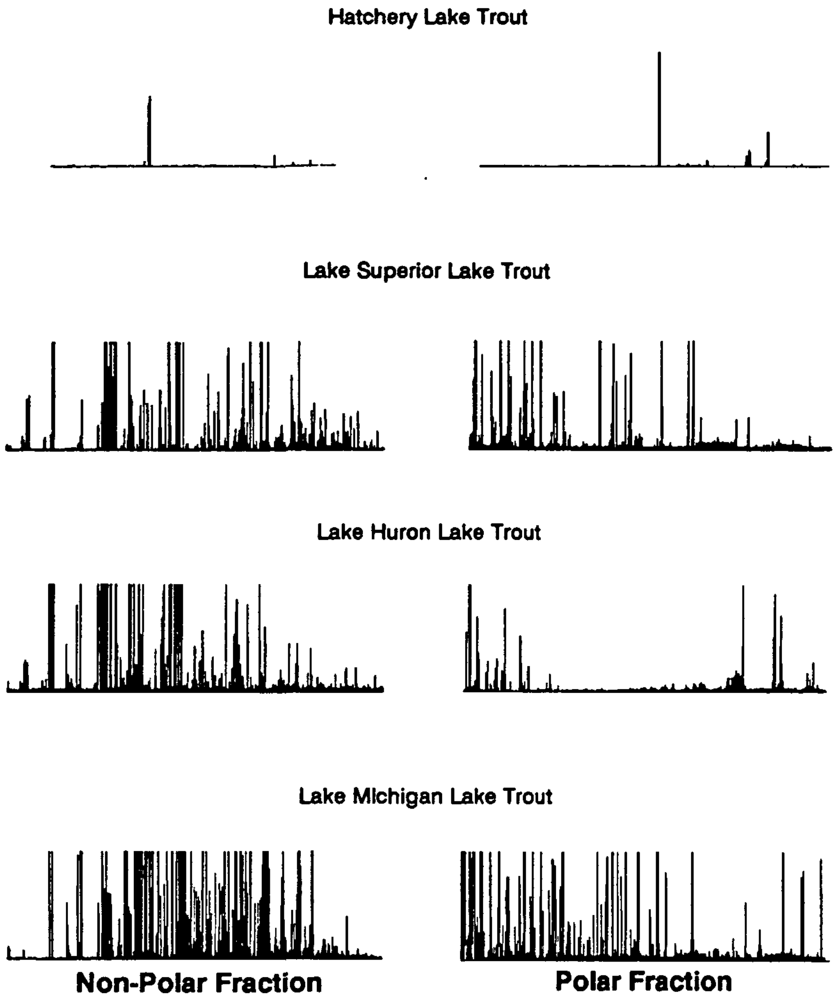
Table 2-1. Great Lakes Fish Consumption Advisories (1989)*

Location (States)	Pollutant of Concern	Restrictions**	Do Not Eat
Lake Superior Michigan Minnesota Wisconsin	PCBs (MI)	Lake Trout 20"-30"	Lake Trout over 30"
Lake Michigan Illinois Indiana Michigan Wisconsin	PCBs (MI, IL, WI) Chlordane (IL)	Lake Trout 20"-23" Coho Salmon over 26" Chinook Salmon 21"-32" Brown Trout over 23"	Lake Trout over 23 " Chinook Salmon over 32" Brown Trout over 22" Carp (any size) Catfish (any size)
Lake Huron Michigan	PCBs (MI)	Brown Trout up to 21" Lake Trout Rainbow Trout	Brown Trout over 21"
Lake Erie Michigan New York Ohio Pennsylvania	PCBs (MI,NY,OH, and PA) Chlordane (PA)		Carp (any size) Catfish (any size)
Lake Ontario New York	PCBs, mirex, and Dioxin (NY)	Carp, White Perch, smaller Coho Salmon, Rainbow Trout, and Brown Trout	American Eel, Catfish, Lake Trout, Chinook Salmon, Coho Salmon over 21", Rainbow Trout over 25", Brown Trout over 20"
Lake St. Clair Michigan	PCBs and mercury (MI)	Walleye over 18", White Bass over 13", Smallmouth Bass over 18", White Perch over 16", Carp over 22", Rock Bass over 8", Largemouth Bass over 14", Bluegill over 8", Freshwater Drum over 14", Carpsucker over 18", Brown Bullhead over 14", Northern Pike over 22"	Muskie (any size) Sturgeon (any size) Catfish (any size)
Saginaw Bay Michigan	PCBs (MI)	Rainbow Trout Brown Trout	Carp (any size) Catfish (any size)
Detroit River Michigan	PCBs and dioxin (MI)	Freshwater Drum over 14"	Carp (any size)
St. Marys River Michigan	Mercury (MI)	Walleye over 19"	
Green Bay Michigan Wisconsin	PCBs (MI)	Splake up to 16 "	Rainbow Trout over 22", Chinook over 25", Brown Trout over 12", Splake over 16", Northern Pike over 28", Walleye over 20", White Bass, Carp
Niagara River New York			Any fish taken between Hyde Park Lake Dam and the river mouth
St. Louis River Minnesota Wisconsin	PCBs, Dioxins (MN) Mercury (WI)	All species Walleye 18"-26"	Walleye over 26"
All Inland Lakes Michigan	Mercury	Rock Bass, Perch, and Croppie over 9", and any Largemouth Bass, Smallmouth Bass, Northern Pike, Muskie, and Walleye	

* Advisories also pertain to tributaries into which migratory species enter.

** Nursing mother, pregnant women, women who anticipate bearing children, female children of any age, and male children age 15 or under should not eat these fish. Other persons should limit their consumption to one meal per week and follow preparation and cooking recommendations.

Preparation and cooking recommendations: Sport fish can be prepared and cooked in ways that will reduce contaminants in the edible portion. These techniques include removal of the skin and fatty tissue associated with the belly lateral line and dorsal area of large fish and cooking by baking, broiling on a rack, or barbecuing so that fatty oil can drip away from the finished meal.



Great Lakes fish and wildlife are exposed to a wide variety of substances. This is clearly illustrated in the figure (left), which juxtaposes GC/MS (gas chromatography/mass spectroscopy) readings of chemical compounds detected in the tissues of hatchery fish with readings of fish obtained in 1977 from several of the lakes. Fish raised in the protected environment of a hatchery registered only eight compounds in their tissues. A total of 476 different compounds were found in the tissues of fish taken from the Lakes. More than half of these compounds are believed to be man-made. An interesting finding from these analyses is that many compounds are unique to the fish of one lake, suggesting that many contaminants are local problems and are not spread through the entire system either via the atmosphere or by water currents.

Figure 2-5. Chemical Compounds in Hatchery Versus Great Lakes Lake Trout (1977)

Many older urban areas have combined sewer and stormwater systems that deliver rain runoff as well as industrial and household effluents to municipal wastewater treatment facilities. During rainstorms, water flow often exceeds the capacity of these systems, leading to releases of untreated water. The significance of combined sewer overflows (CSOs) varies around the Great Lakes. Whereas Wisconsin does not consider CSOs to have a major impact on any of its rivers, Michigan regards CSOs as a major source of impairment to 317 miles of its rivers, making this the second leading source of impairments to the State's waters. Michigan estimates that the 170 CSO outfalls that empty to the Rouge River release an annual volume of 7.8 billion gallons of untreated water. Figure 2-6 shows the locations of another 75 Canadian and U.S. overflow points that discharge directly to the Detroit River. Overflows from the Detroit and Windsor sewer systems represent a major continuing source of pollution to the Great Lakes.

Accidental spills can be a significant, temporary source of toxic substances as well. The Coast Guard recorded 5,003 spills of oil or toxic substances into the U.S. waters of the Great Lakes from January 1980 through September 1989. About 80 percent of these spills came from land facilities, such as oil storage tanks and pipelines; the balance came from ships. Most were oil spills of small volume. However, there have been oil spills up to a million gallons and toxic substance spills up to 200,000 gallons.

Transport of contaminants by groundwater is known to be a problem in some places, notably along the Niagara River, owing to the coincidence of certain geological features and leaking adjacent landfills. Rain runoff from farms and urban areas brings with it pesticides and surface contamination.

The atmosphere is another pollutant pathway. Contaminants reach the atmosphere from combustion and volatilization. They exist in the atmosphere attached to particles, associated with water droplets, and in their gaseous state. They leave the atmosphere via dry deposition of particles, rain and snow, and gas exchange to water.

In the late 1970s, studies on Isle Royale, a relatively isolated island in Lake Superior, reported PCBs, DDT, and

Table 2-2. Some Key Toxic Contaminants in the Great Lakes

Pollutant	Sources	Effects
Polychlorinated biphenyls (PCBs)	PCBs were widely used in the U.S. from 1929 until 1976 when banned from use except by special permit. Still used in electrical equipment because of high heat resistance and stability. PCBs continue to enter the environment through accidental releases from transformers and capacitors and volatilization of soil contamination.	PCBs are highly persistent and bioaccumulative. All five of the Great Lakes have fish consumption advisories based on PCBs. A series of studies has related maternal lifetime consumption of Lake Michigan fish with delays in neurobehavioral development in infants. PCBs are suspected human carcinogens.
Mercury	A toxic metal and natural element, mercury was once used widely by the pulp and paper industry and in the manufacture of chlorine and caustic soda. There are high accumulations in sediments near old industrial discharges. Coal burning power plants and waste incinerators may be active sources.	Methyl mercury (the organic form of mercury) is highly bioaccumulative and is a known cause of brain damage and birth defects in humans. Human exposures are greatest through fish consumption. Fish advisories based on mercury are in effect for the St. Marys River and Lake St. Clair, 10,000 inland lakes in Michigan, and 400 others in Minnesota and Wisconsin.
Dioxins 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	Dioxins are contained in herbicides and are generated by chlorine bleaching in pulp and paper manufacture. They are also a byproduct of combustion of fossil fuels (leaded gasoline) and waste incineration. Dioxins are widely present in the environment.	Dioxins are highly persistent and bioacumulative. 2,3,7,8-TCDD, the most toxic of a chemical family of 75, is an animal carcinogen. It has been linked in humans to a skin disease. A recent epidemiological study found greater incidence of cancer among highly exposed persons.
Furans - 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF)	Byproduct of similar processes that produce 2,3,7,8-TCDD. Furans were also an inadvertent contaminant to some PCB products.	2,3,7,8-TCDF is one-tenth as toxic as 2,3,7,8-TCDD, but it has similar toxicoloical properties and is present in the environment at much greater concentrations.
Benzo(a)pyrene (B(a)P)	One of several polynuclear aromatic hydrocarbons formed by the incomplete combustion of fossil fuels, wood, and tobacco, B(a)P is also a byproduct of steel and coke production, coal liquification and gasification, and waste incineration. B(a)P is present at high concentrations in the sediments of some Great Lakes harbors.	B(a)P is persistent and bioaccumulative. High concentrations in river and lake sediments have been associated with liver tumors in fish. B(a)P is an animal carcinogen. B(a)P is not associated with increased cancer in humans.
Mirex	An insecticide, Mirex was not applied in the Great Lakes region. However, its manufacture in the area lead to its introduction into the Lake Ontario food web. Use was banned in the U.S. in 1978.	Mirex is highly persistent and bioaccumulative. Levels in most fish have decreased since its control, but levels in herring gull eggs have not decreased much during the same period.
DDT and metabolites (DDE)	DDT, an insecticide introduced in 1946, was used widely until banned in the U.S. in 1970. Environmental concentrations have fallen significantly but seem to have stabilized. DDT is carried atmospherically from other countries where it is still used.	DDT is converted to DDE and retained within the tissues of organisms. DDE is highly bioaccumulative. It has caused eggshell thinning in birds.
Alkylated lead	Alkylated lead compounds are used as additives for leaded gasolines, solder, and paints. Levels have decreased since 1981 and continue to decrease as the use of leaded gasoline has declined.	Alkylated lead can cause anemia, fatigue, and brain damage, especially in children. Lead compounds should not pose a human health risk as long as fish consumption advisories are followed.
Dieldrin	An insecticide once used extensively on fruit, dieldrin is now restricted and is no longer manufactured in the U.S. Dieldrin is highly persistent, and levels in the environment have decreased little over time. Dieldrin accumulates in soil and sediment.	Dieldrin is persistent and bioaccumulative.
Toxaphene	Toxaphene was widely used on cotton crops in the south until the late 1970s; its production in the U.S. was banned in 1982. Lake Superior contains the highest levels of toxaphene in fish apparently due to atmospheric deposition.	Toxaphene is persistent and bioaccumulative. Toxaphene levels in Great Lakes fish are not considered a significant human health risk.
Hexachlorobenzene (HCB)	Originally manufactured as a fungicide, HCB is a by-product of pesticides in current use and can be formed during the combustion of substances containing chlorine.	Hexachlorobenzene is bioaccumulative. It may cause skin rash, nausea, and headaches in humans and is a suspected carcinogen.

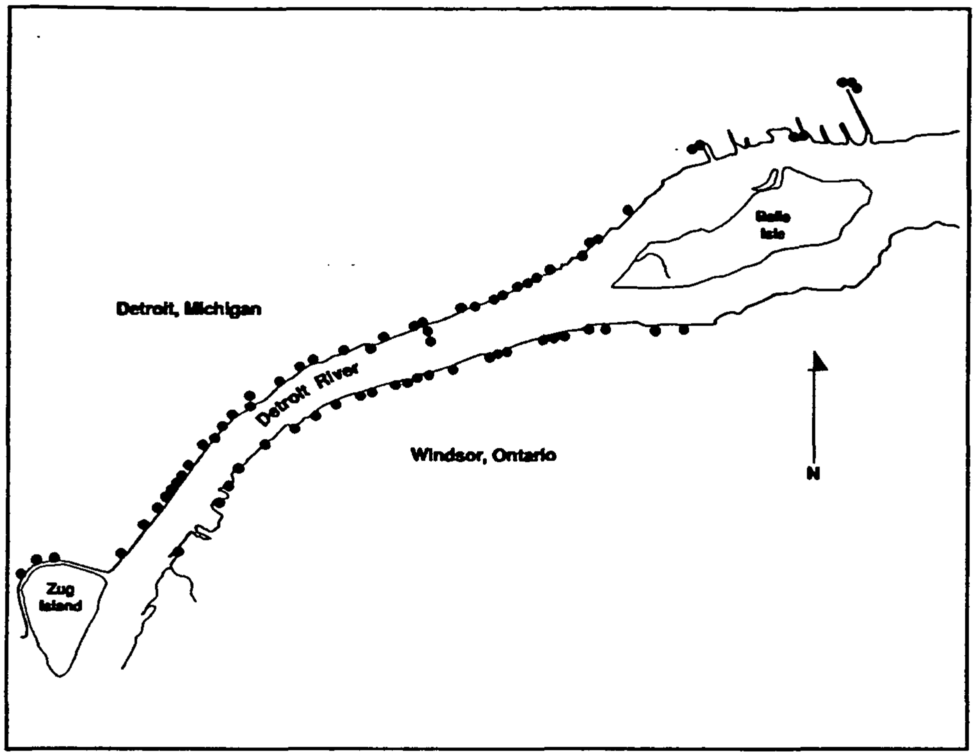


Figure 2-6. Combined Sewer Overflows Along the Detroit River

toxaphene in the waters of its lakes. Researchers theorized that such pollution must have been the result of deposition from the air. Since toxaphene was principally used to reduce insects on cotton crops in the American south, there was an implication that it had been transported a great distance through the atmosphere.

Researchers have subsequently tried to estimate the extent of atmospheric deposition of contaminants to the Great Lakes. Atmospheric deposition may be the largest path for some contaminants – such as PCBs – to enter Lake Superior, for instance, because of the Lake's relative lack of adjacent development and its large surface area. Yet there are great uncertainties surrounding such estimates because: there is not routine lakewide monitoring of airborne deposition of organic toxicants such as PCBs, and there is some evidence to suggest that atmospheric deposition near urban areas may be high, but understanding of its extent is at an early point.

Recent research in Minnesota and Wisconsin has concluded that the atmosphere is a significant pathway for mercury, potentially emitted by garbage incinerators and coal-burning power plants, among various sources. In the last several years, Michigan has issued advisories regarding fish consumption for thousands of its inland lakes based on levels of mercury, while Minnesota and Wisconsin have issued advisories for hundreds of such lakes. The issuance of these advisories is partly a reflection of expanded fish monitoring programs of inland lakes to include mercury. Though there are atmospheric loadings of mercury across the entire region, differences in water chemistry and bacteria between waterbodies causes mercury levels to be more of a problem in the fish of some lakes than in others. Mercury levels in walleye and lake trout have sharply fallen in areas of the Great Lakes where they were highest two decades ago following the modification or closure of pulp and paper mills that were then the major source of loadings. In general, there are not indications that mercury levels are rising in Great Lakes fish, although the evidence of atmospheric loadings to the region may help account for present levels of this contaminant in fish and warrants continued monitoring.

Sources

Some evidence of the magnitude of contaminants used, released, and transferred by industry is reported to the public by large U.S. manufacturing firms. Since 1987, these firms have reported annual releases or transfers of more than 300 toxic substances under the Emergency Planning and Community Right-to-Know Act. EPA compiles this information into a data base called the Toxics Release Inventory (TRI). As shown in Figure 2-7, during 1988, firms in the counties of the Great Lakes watershed reported that they released or transferred more than 1 million pounds of toxic substances. Relatively little of this quantity was directly released to surface water; additional quantities may reach the Great Lakes indirectly by pathways such as atmospheric deposition. Many of these substances do not biomagnify in the food web. The distribution of releases and transfers is mapped in Figure 2-8. Figure 2-9 shows releases and transfers by industrial groups.

The TRI does not directly indicate the amounts of toxicants to which humans or the environment are exposed, nor does it directly measure the risks that these substances pose to either. TRI data do not necessarily indicate regulatory violations, in part because manufacturers report transfers offsite to authorized disposal facilities. Not all toxic substances are included under TRI, nor are all sources of their release to the environment; the TRI does not, for example, include releases from small manufacturing firms and from non-manufacturing firms.

CONTAMINATED BOTTOM SEDIMENTS

Bottom sediments that hold such substances as PCBs and DDT are probably the principal cause of the continuing contamination of fish and wildlife with these now banned chemicals. The transfer of sediment-bound contaminants to the base of the food web takes place both directly, through accumulation of contaminants in bottom-dwelling organisms, and indirectly, through resuspension of contaminants to the water column and their ensuing adsorption by phytoplankton. Contaminated sediments are also toxic to bottom-dwelling organisms, either killing them or impairing their normal functioning. Sublethal effects include tumors in bottom fish. Brown bullheads, a variety of bottom-feeding catfish, have been found

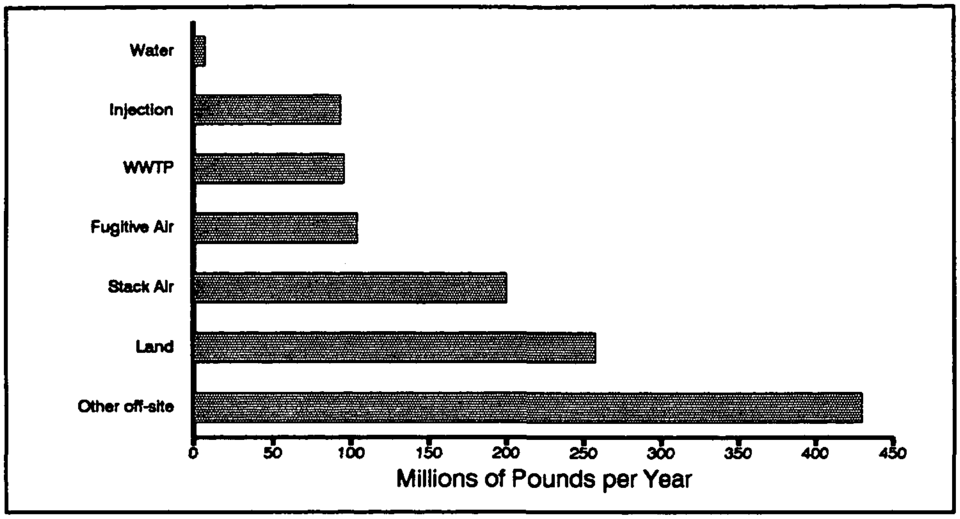


Figure 2-7. Routes of Releases of Toxic Substances around the Great Lakes (1988)

with a high incidence of ugly facial tumors in the Buffalo River in New York and the Black River in Ohio where they are exposed to contaminated sediments.

Contaminated sediments also impose economic costs. Special steps are required to dredge and dispose of contaminated sediments, which increase the cost of maintaining waterways for navigation. In a number of locations, including Indiana Harbor, Indiana, Ashtabula River, Ohio, Sheboygan Harbor, Wisconsin, and Menominee River, Michigan, navigational dredging has been delayed for years because of concerns over disposal of dredged sediments. Reduced dredging increases transportation costs because industries must find alternative transportation methods or reduce their loading of ships.

Yet, the sedimentation process also covers old sediments with new. In this way, it may bury past contamination and be an important natural means for the recovery of the ecosystem. The rate of burial differs from location to location and lake to lake, with Lake Erie having a relatively high rate of sedimentation, Lakes Michigan and Superior low rates.

EPA and States have designated 31 harbors and rivers in the region, all of which have contaminated bottom sediments, as Areas of Concern. Bottom

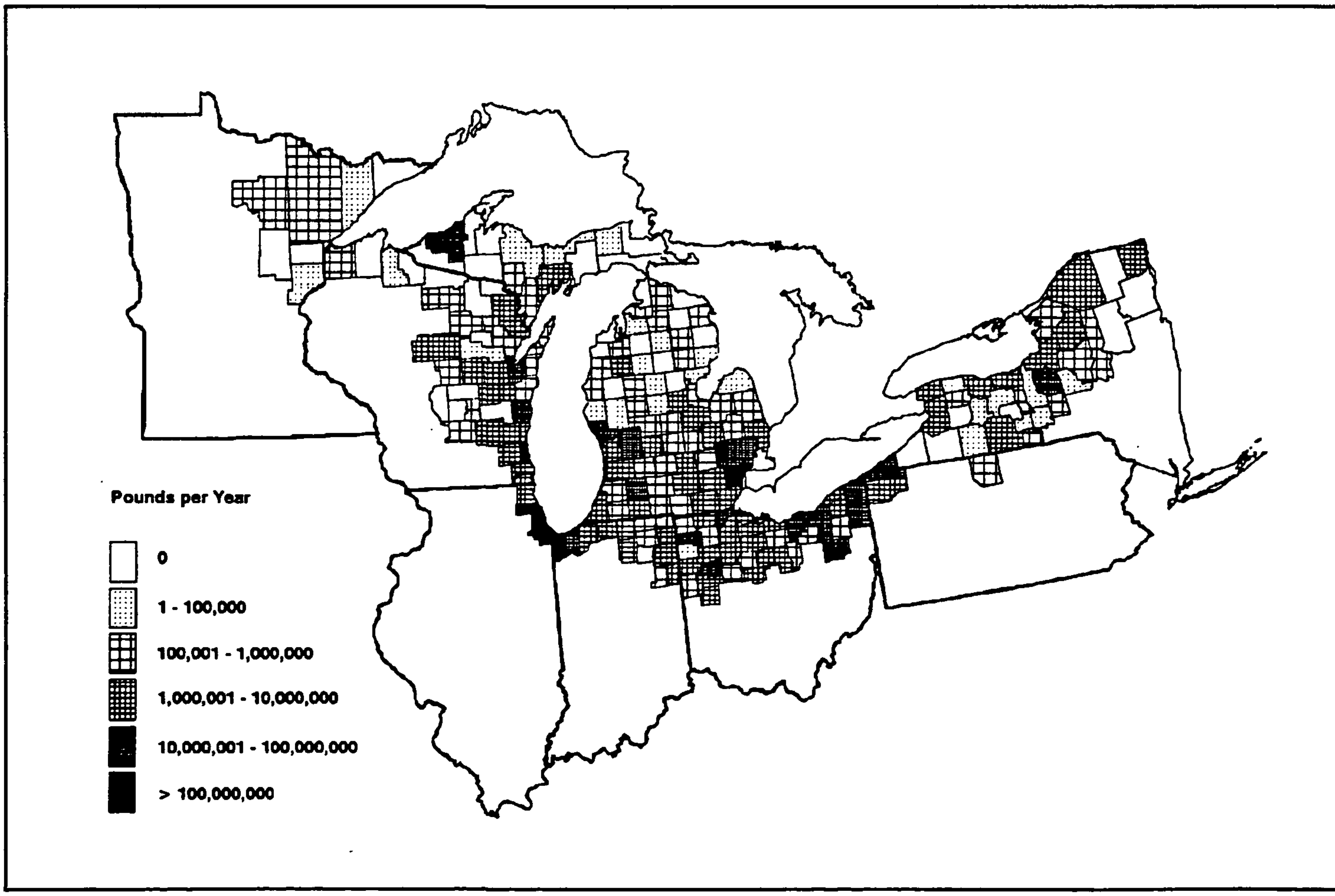


Figure 2-8. Releases of Toxic Substances in Great Lakes Counties (1988)

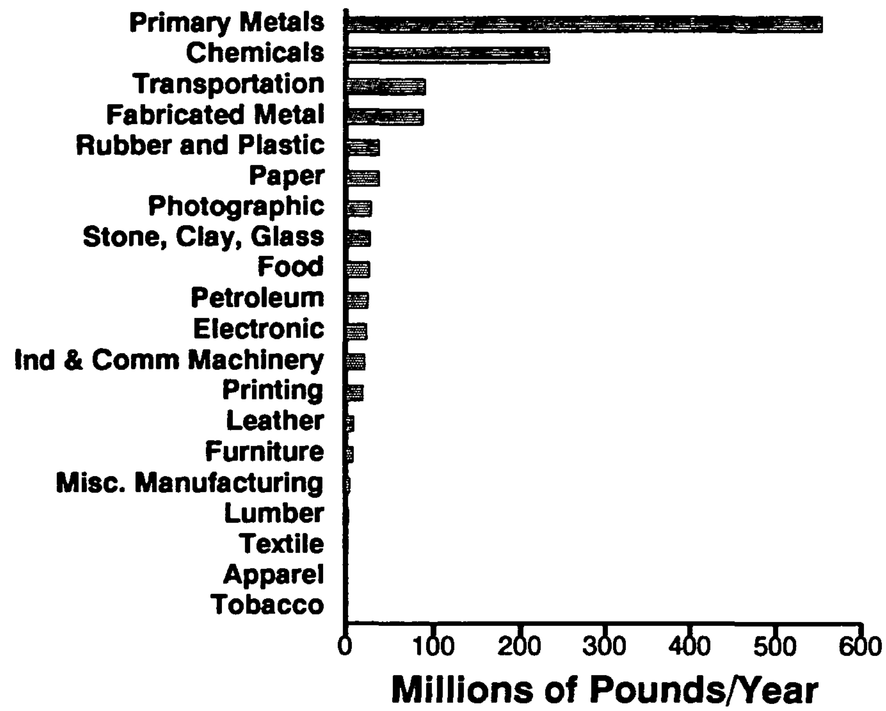


Figure 2-9. Releases of Toxic Substances around the Great Lakes by Industrial Group (1988)

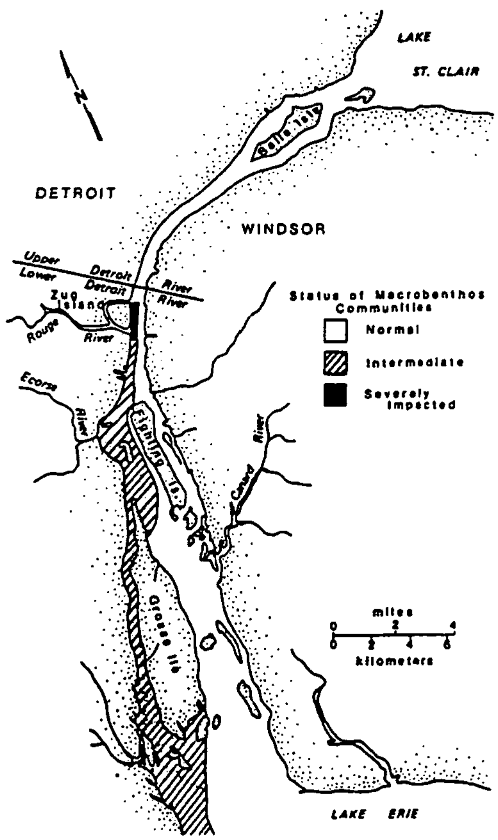


Figure 2-10. Sediment Contamination in the Detroit River as Suggested by Impacts on Benthic Macroinvertebrate Communities

sediments in these areas contain a wide range of contaminants, including toxic metals such as copper, lead, nickel, and zinc as well as chemicals. Figure 2-10 illustrates the geographical zone of highest sediment contamination in one Area of Concern, the Detroit River, the international channel that suffers the most sediment pollution.

Another indication of the scope of the contaminated sediment problem is that in recent years, to maintain navigation channels, the Army Corps of Engineers has dredged a large volume of sediment from the lakes that is too contaminated for open-lake disposal. As directed by the Water Resources Development Act, the Corps places such material in confined disposal facilities (CDFs), which are manmade islands designed to hold and isolate toxic substances. There are 38 CDFs, completed or under construction, in U.S. waters. Many of these are not yet full and the Corps adds about two million cubic yards of sediments to them annually. When filled to capacity, the contents of a CDF are covered by a layer of clean soil.

CDFs are an imperfect solution, although they may lower the transfer of contaminants to the Great Lakes food web that would otherwise take place if contaminated bottom sediments remained in place. CDFs encroach on the lakes and require ongoing monitoring and periodic maintenance. Some also develop dense populations of vegetation and insects, and sizable fish communities. One CDF at the mouth of the Buffalo River had a fish population estimated at 20 thousand in an 8 hectare pool during 1988. A survey of its brown bullhead population found that 89 percent had external abnormalities such as tumors.

DEGRADED WETLANDS

A wetland is an area, such as a marsh, swamp, bog, or fen with a predominance of hydric soils that are inundated or saturated by surface or ground water at sufficient frequency to support vegetation that is adapted to an aquatic or very wet environment.

A vital component of the Great Lakes ecosystem, wetlands serve a variety of important functions—providing nursery, resting, feeding, and breeding grounds for a rich diversity of birds, fish,

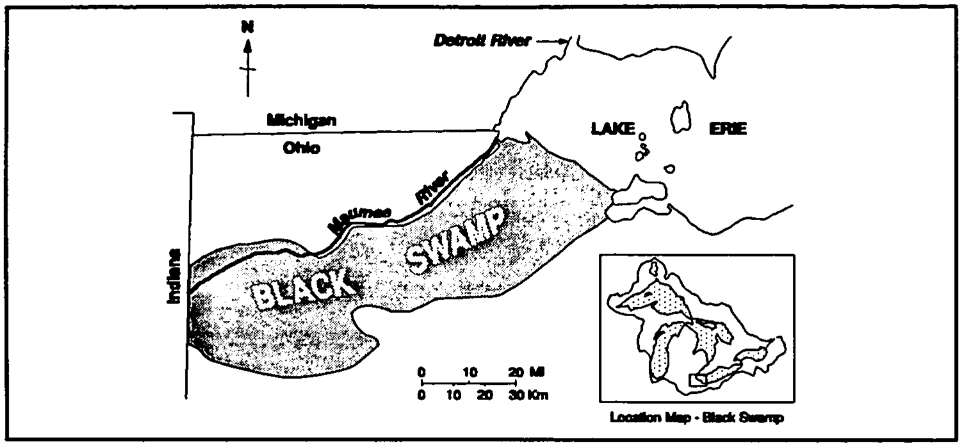


Figure 2-11. Presettlement Extent of the Black Swamp in Northwestern Ohio

and wildlife. These areas protect a variety of fish species from waves and predators. Coastal wetlands offer warmer temperatures than open lake waters, and their high biological productivity provides an abundant food supply. The submerged plants of wetlands support bacteria, phytoplankton, and zooplankton. Larval and juvenile fish harbored by wetlands are an important food source for waterfowl. Ducks consume plants that extend above the water and submerged ones, while geese graze on the former. Wetlands also protect shorelines from erosion; store flood waters with their dense vegetation; and trap sediments that can pollute waterways. Natural fluctuations in lake water levels rejuvenate coastal marshes by keeping plant life at an early successional stage and by releasing nutrients from sediments and decaying vegetation (5).

Many of the wetland areas of the Great Lakes watershed have been lost over the last two centuries. On the Canadian side, it is estimated that between 1800 and 1982, more than 60 percent of the wetlands in southern Ontario were lost. In southwestern Ontario, more than 90 percent have been converted to other uses (6). Similar losses have occurred in the U.S. On a statewide basis, Illinois and Indiana have each lost more than 80 percent of their original wetland acreage. Ohio is believed to have lost 90 percent of its wetlands, with the 1,500 square mile Black Swamp of northwest Ohio almost entirely converted to farmland by the 1920s (Figure 2-11).

The most extensive wetland losses took place in the 19th and early 20th centuries when many wetlands were drained to become suitable for agriculture. Remaining wetlands continue to be threatened by such purposes as building construction, waste disposal, and mining of sand and gravel. Consumption of groundwater has diminished recharge of certain wetlands. There are also indications that wetlands have been disrupted by non-native plants, such as purple loosestrife, and fish, such as carp.

EXOTIC SPECIES

Over the past two hundred years, humans have introduced about 100 exotic (non-native) species to the Great Lakes, many of which have profoundly hurt the populations of native species. Exotics damage native populations through direct competition for food, displacement from physical environments, direct attack, and through alteration of the chemical or physical conditions needed by other species.

Some introductions have been intentional, such as those of carp and Pacific salmon. Pacific (chinook and coho) salmon were introduced to the lakes in the 1960s and are regularly stocked by States and the Province of Ontario in order to provide an additional predator to control the numbers of smelt and alewife. Salmon also provide sport fishing alternatives to greatly diminished lake trout populations. Many other introductions of exotics have been unintended, such as those of sea lamprey, alewife, zebra mussel, and smelt.

The pace of the introductions of exotics has accelerated over the last 30 years, as shown by Figure 2-12. Of the just over 100 species introduced to the Great Lakes since 1810, one third have appeared since 1960. This increased pace is largely due to greater transoceanic shipping traffic on the Great Lakes since completion of the St. Lawrence Seaway in 1959. Such vessels have often taken-on ballast water in a distant port that they have later discharged into the Great Lakes to compensate for the on or off-loading of cargo or to allow a vessel to accommodate the 27 foot maximum draft of Great Lakes navigation chan-

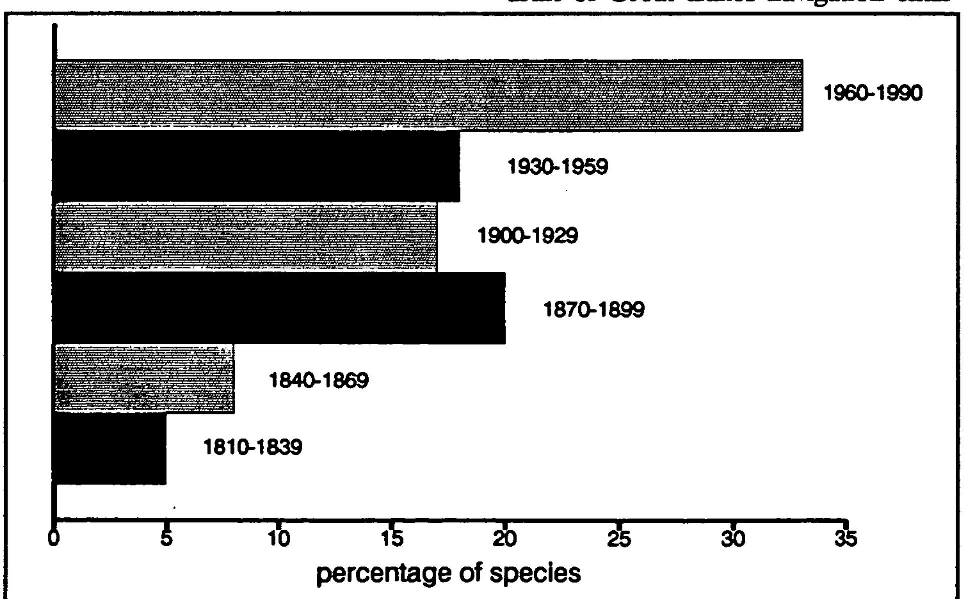


Figure 2-12. Timing of the Entry of Exotic Species into the Great Lakes

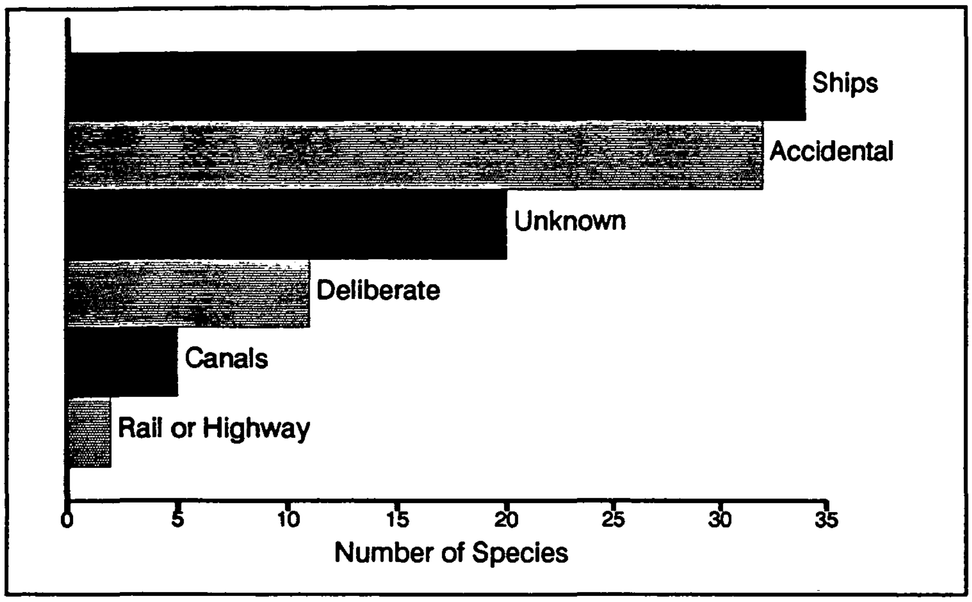


Figure 2-13. Entry Routes of Exotic Species

nels. This water can bring and sustain exotic organisms until it and they are together released into the lakes. Thus, ocean-going vessels have often spanned saltwater barriers to freshwater species from other continents.

The relative frequencies of the routes by which exotic species are believed to have entered the Great Lakes are shown in Figure 2-13. More than one-third of exotics have been stowaways by ships. Organisms that can survive in ship ballast tanks are frequently very adaptable and aggressive; when released to an ecosystem in which they have few natural predators, they can proliferate and severely affect the existing balance between native species. The transfer of exotics through ballast water can be prevented if ships take-on ballast water at sea before entering the Great Lakes. Saltwater organisms are unlikely to survive in the Great Lakes. Exotics have also made their way into the Great Lakes via canals. Species that had been barred from the upper lakes by Niagara Falls were able to enter them after the Welland Canal was completed or enlarged.

Fish species are among the best known of the exotics. Yet, numerous other exotics have also been introduced. Plants represent about 40 percent of exotics, fish 20 percent, and algae 18 percent.

Zebra Mussel

Zebra mussels may prove to be the most harmful exotic ever introduced to the Great Lakes. Named for their distinctive black and yellow bands, this tiny barnacle-like shellfish (up to 2 inches long) are found throughout Europe. Zebra mussels are prolific breeders; female mussels produce as many as 400 surviving offspring each year. They were first noted in Lake St. Clair in 1988.

Since then, they have been found in numerous locations, from Duluth to the entrance of the St. Lawrence River. They have infested Lake Erie to an astounding degree and with equally impressive speed, colonizing nearly every available surface in just two years. It is expected that the species will occupy most of its suitable living environments within the Lakes over the next several years. It also seems inevitable that the zebra mussel will in time spread through much of America, through pathways such as the Chicago River to the Mississippi River system and carried by ships and recreational boats. The species was found in the Hudson River in 1990.

Zebra mussels cement themselves to hard surfaces, building grape-like clusters six and more inches thick; densities up to 700,000 to the square meter have been found in Lake Erie. The lifespan of the species is 3 to 5 years. They favor relatively warm, nutrient-rich, shallow water (6 to 30 feet deep). Microscopic mussel larvae float freely for 10 to 15 days, carried by lake currents before finding a suitable hard surface to which to attach themselves and mature into the more familiar mussel form. The mobility of the mussel larvae accounts for the rapid spread of the species through the Great Lakes.

The zebra mussel may pose many ecological problems. One adult mussel filters the suspended phytoplankton from one liter of water per day. A vast population of zebra mussels can devour a vast quantity of phytoplankton, the foundation of the Great Lakes food web, and may in time create a food shortage for other phytoplankton grazers and ultimately threaten the food supply of predators such as lake trout, salmon, walleye, and bass. Zebra mussels may also threaten the spawning sites of native fish. Many species, such as walleye, prefer rocky shoals for spawning. Zebra mussels prefer this habitat for colonization. Zebra mussels also coat crayfish and clams, making it difficult for them to open or move.

The mussels have economic impacts as well, clogging municipal and industrial water intakes. Many hundreds of millions of dollars will have to be invested in construction of new intakes, redesign of present ones to reduce their vulnerability to mussel fouling, extension of pipes into deeper water, and periodic mussel removal. The mussels also encrust and slow ships, and infiltrate and clog their ballast and cooling systems. Beaches can be fouled by the odor of decaying zebra mussels and bathers at some beaches will have to wear foot protection to prevent cuts from the sharp shells of the mussels. Dead mussels also give off methane gas, imparting a foul taste and smell to adjacent water. The mussel also attaches to navigational buoys, breakwater rocks, piers, and fish nets.

Freshwater drum, also known as the sheepshead, is a fish species present in the Great Lakes that feed on zebra mussels. Scaup, a diving duck that migrates through the Great Lakes, is another mussel predator. Yet, scientists consider that these natural predators will be unable to curtail the explosive growth in numbers of zebra mussels.

Damage to native fish populations from exotic species

More than 100 exotic (non-native) species have been introduced to the Great Lakes since 1800, one-third carried by ships. Only about 21 percent of the exotics have been fish species; the majority have been plants, plankton, and benthic organisms. The pace of the introductions of exotic species has steadily accelerated over the past 30 years since the opening of the St. Lawrence Seaway spurred an increase in transoceanic shipping. Exotics have profoundly damaged the populations of some desirable native species. The sea lamprey, a parasitic, eel-like fish, entered the upper lakes via the Welland Canal in the 1930s; within 20 years, it decimated lake trout populations that to this day are not self-sustaining, though a program of lampricide application has reduced the sea lamprey population. A notable recent invader, likely via the ballast water of an ocean vessel, is the zebra mussel. A prolific breeder, this mollusc forms dense colonies on hard surfaces like water intake pipes, imposing immediate economic costs. Ecological effects of the zebra mussel are as yet unknown, but potentially catastrophic. The zebra mussel devours microscopic plants at the foundation of the food web and may create a

Sea Lamprey

The sea lamprey was one of the first exotic species to devastate native populations. This small, parasitic, eel-like fish attaches to larger fish and lives off their bodily fluids, often killing the host. Sea lamprey are native to the Atlantic Ocean. They may have made their way into Lake Ontario via the St. Lawrence River or the species may have entered the Lake through the Erie Canal. By whichever path, sea lamprey were present in Lake Ontario by the mid-19th century but were barred from the other lakes by Niagara Falls. In the 1920s after enlargement of the Welland Canal, they escaped into the upper lakes and over the next three decades spread throughout them.

Partly as a result of sea lamprey depredations, lake trout populations in Lakes Huron, Michigan, and Superior collapsed; commercial catches in the 1950s were only 1 percent of those 20 years earlier. Whitefish and burbot populations were likewise decimated, and walleye and suckers attacked. As large prey disappeared, lamprey turned to forage fish, virtually extinguishing several of the larger species of cisco in the three upper lakes.

The sea lamprey has wreaked less destruction on Lake Erie fish populations. This may be because Erie is warmer and the lamprey prefers the cold environment of the upper lakes. Or it may be that the lamprey has lacked spawning areas in Lake Erie.

In 1961, the U. S. and Canada began to apply a chemical to sea lamprey spawning grounds. This lampricide application program has slashed numbers of lampreys by about 90 percent. However, complete eradication of the lamprey is probably not feasible and the control program will need to continue indefinitely to keep the lamprey's predations in check. Today, the lamprey is concentrated in northern Lakes Huron and Michigan, and in Lake Superior. The strong currents of the St. Marys River have lessened the effectiveness of lampricide application. As a result, a large population of lampreys live in the river and in nearby reaches of Lake Huron.

River Ruffe

The river ruffe, a small (typically 6 to 8 inches) perch-like fish from northern Eurasian fresh waters, entered the Duluth harbor around 1986, probably from the discharge of ballast water from an ocean-going vessel. The ruffe is hardy and a rapid breeder. A growing population has been noted in the relatively warm and nutrient-rich St. Louis River estuary. In 1989, the ruffe's population was estimated at 300,000. A year later, its population was estimated to have doubled.

Scientists doubt that the temperature or food supply of Lake Superior will be a barrier to the ruffe. They think the ruffe will spread in time, although its pace will not rival that of the zebra mussel. If the ruffe spreads, it may injure desirable native species. It competes for food with native fish, such as yellow perch, and feeds on the eggs of whitefish.

As a first attempt to control the ruffe population in Duluth harbor, fisheries managers stocked walleye and northern pike to assess their predation of ruffe. Early indications are that walleye are not effective in controlling ruffe, if alternative prey is available. Of 400 walleye obtained from Duluth harbor, none were found to have recently eaten ruffe. Walleye also have not eaten ruffe in laboratory feeding studies. Limited sampling of burbot, a voracious member of the cod family, and northern pike show that some had eaten ruffe, and further work is underway to assess the potential of these predators to control the ruffe population in the harbor.

Spiny Water Flea

Another recent invader to the Great Lakes is the large zooplankton, *Bythotrephes cederstroemii* or spiny water flea. At up to one-half inch in length, it derives its name from a long spiny tail. First noted in Lake Huron in 1984, the spiny water flea is native to Eurasian freshwaters.

It is not yet apparent what impacts the spiny water flea may have on the Great Lakes ecosystem. One concern is that it may not be palatable to potential predators, which could lead to its unconstrained population growth. It feeds on a few species of Daphnia, another form of zooplankton that grazes on phytoplankton. Daphnia are an important food source for young fish such as the bloater chub and its decline might also bring about an increase in algae on which it feeds. Some recent evidence indicates that alewife may consume the spiny water flea, providing a constraint on its population (7).

Alewife

The sardine-like alewife is a 4- to 11-inch long member of the herring family. Alewife are native to northeastern U.S. salt waters and entered Lake Ontario, presumably through the Erie Canal, in the mid-1800s. Alewife spread to the other lakes during 1931 to 1954, after enlargement of the Welland Canal allowed the species a pathway to bypass Niagara Falls.

Undesirable Effects From Excessive Nutrients

In some shallow waters that receive agricultural runoff of fertilizers and/or in areas having a high surrounding population, such as Lake Erie, Lake Ontario, Saginaw Bay, and Green Bay, water is over-enriched with nutrients, particularly phosphorus. The situation has improved since the late 1960s when Lake Erie was infamously clogged by foul-smelling mats of algae that depleted dissolved oxygen from bottom waters by its seasonal die-off and decay. Nevertheless, the bottom waters of central Lake Erie continue to suffer periods of oxygen depletion. Phosphorus concentrations in the water column of Lake Erie are approaching those predicted to achieve desired water quality, although this success may be partly attributable to several recent years of below average rainfall. Conservation tillage and other farming practices that reduce runoff remain important to achieving desired concentrations of phosphorus. Zebra mussels are expected to reduce

Alewife have become a favored food of lake trout and salmon. With the precipitous decline of lake trout populations, alewife populations exploded. In 1967, millions of alewife in Lake Michigan died and washed ashore, owing to the twin effects of cold temperatures and starvation. Another notable alewife die-off occurred in southern Lake Huron.

Stocking of salmon and lake trout have subsequently helped to control alewife numbers, and the species has been harvested commercially for fertilizer and pet food. Alewife are believed to have damaged the populations of several native species through competition for food. Among these are lake herring and emerald shiner whose numbers have not recovered since the control of alewife.

EXCESSIVE NUTRIENTS

By the late 1960s, various areas of the Great Lakes exhibited eutrophic conditions, marked by thick algal blooms, unpleasant odor from and taste to the water, and depletion of dissolved oxygen from the water due to the decay of algae following their seasonal die-off. These conditions were most pronounced in Lake Erie, which as the shallowest, warmest, and biologically most productive lake is most susceptible to nuisance levels of algae. Lake Erie has also been vulnerable because it surpasses other lakes in receipt of effluent from sewage treatment plants and of sediment from the rich farmland in its watershed. Both effluent and sediment carried nutrients to the Lake, notably phosphorus, altering its chemistry and, as a result, its algae populations. To a lesser degree, eutrophic conditions were also evident in Lake Ontario and in shallow, naturally productive embayments including Saginaw Bay, Green Bay, and the Bay of Quinte.

Over the last two decades, the U.S. and Canada have generally improved water quality across the Great Lakes by reducing phosphorus levels. Lake Erie's improvement, in particular, has been visible and dramatic. Scientists determined that lowering phosphorus concentrations would have the greatest limiting effect on algal productivity. The U.S. and Canada passed laws limiting phosphorus content in household detergents and constructed more effective municipal sewage treatment plants, cutting their phosphorus discharges. As a result, open-lake phosphorus concentrations have declined. As seen in Figure 2-14, phosphorus concentrations in Lakes Michigan, Superior, and Huron continue to be below levels that scientists regard as the highest that will still allow desirable biological conditions. Phosphorus concentrations in Lakes Ontario and Erie have declined markedly, approaching their target levels.

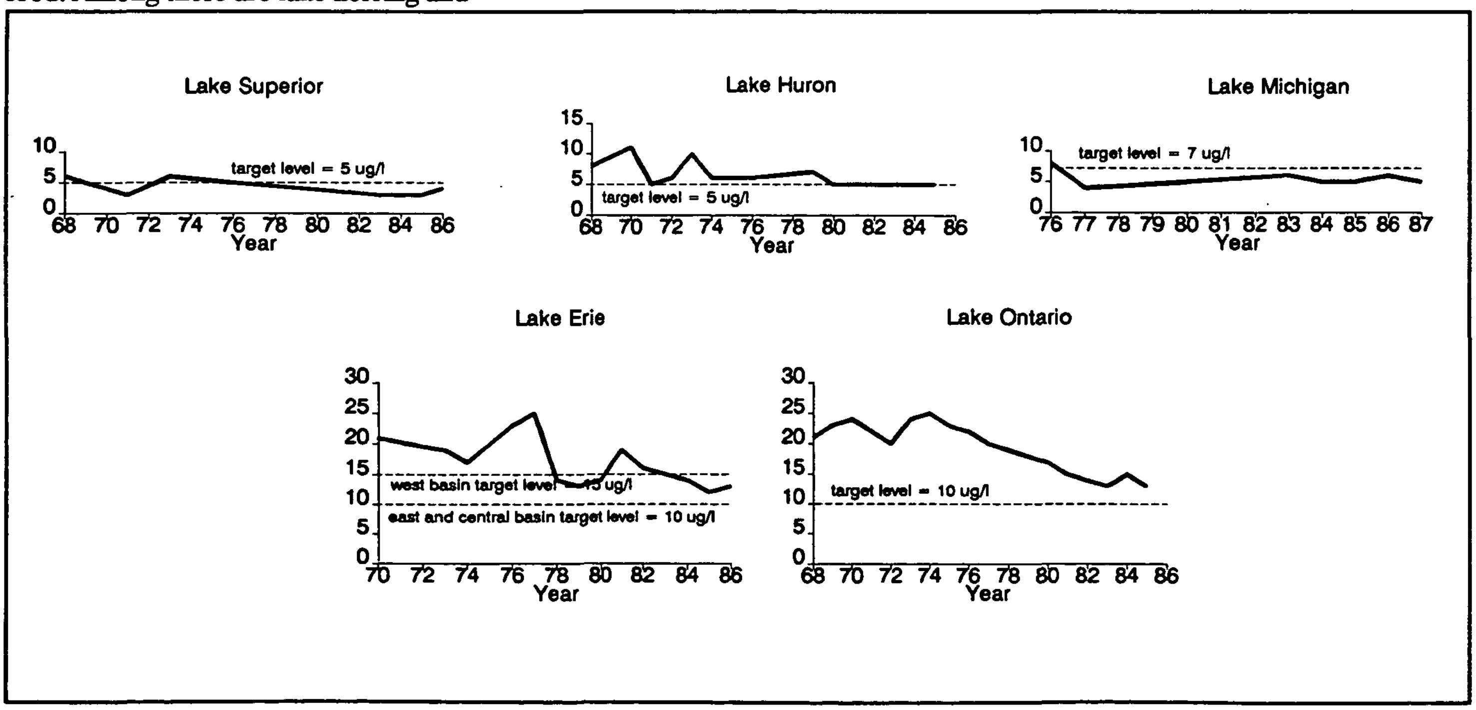


Figure 2-14. Phosphorus Concentrations in the Great Lakes

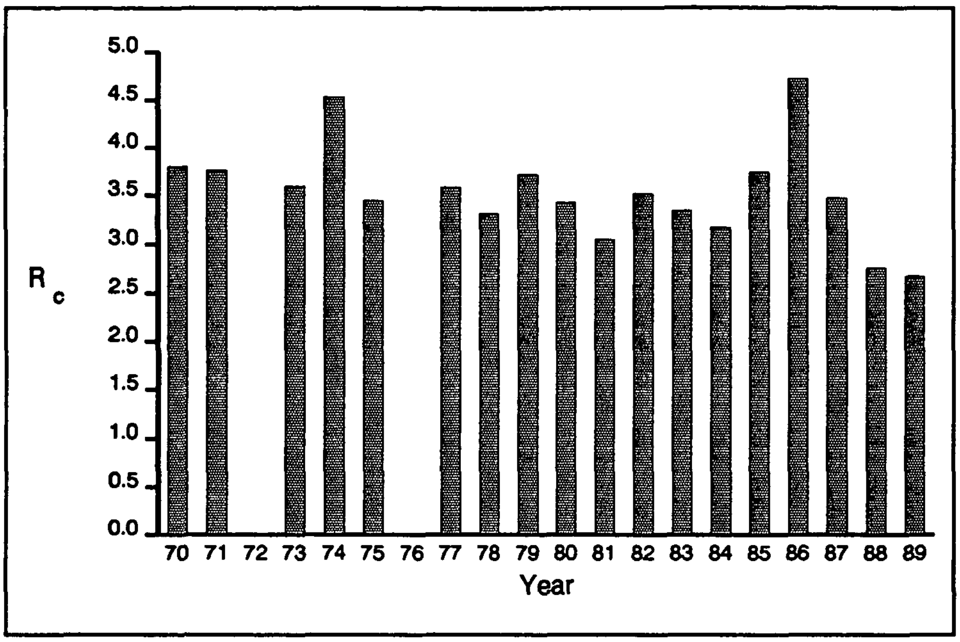


Figure 2-15. Annual Average Corrected Oxygen Depletion Rate, R_c, for the bottom waters of the Central Basin of Lake Erie (mg O_2/L/month)

Phosphorus levels have also declined in Saginaw Bay and Green Bay. A facility that draws drinking water from Saginaw Bay has not found taste or odor problems since 1980. This same facility had 56 days of such problems in 1974. Michigan also reports that phosphorus concentrations in the Saginaw River have fallen 73 percent since 1970 (8). During the 1980s, phosphorus levels in lower Green Bay fell by about 25 percent from the average during the 1970s (9). Wisconsin has set a goal of reducing phosphorus levels in Green Bay to under 125 micrograms per liter by the year 2000.

The bottom waters of Lake Erie's central basin continue to suffer depletion of dissolved oxygen during late summer. During the summer, the central basin stratifies by temperature, forming a thin bottom layer. When algae die and sink to the bottom, their decay exhausts the limited supply of dissolved oxygen in that layer, creating for several months a zone that cannot support bottom dwelling fish. However, an indication of Lake Erie's improved water quality is that the rate of oxygen depletion in the bottom layer of the central basin has steadily declined and in 1989 was at its lowest rate in twenty years. This reduction means that the bottom layer is depleted of oxygen later in the summer and the period of oxygen depletion is shorter than in the past (see Figure 2-15).

Levels of another nutrient, nitrogen, found in the water as nitrate-plus-nitrite, have been steadily rising throughout the Great Lakes for many years. The likely sources of this increase are atmospheric deposition of combustion byproducts and runoff of nitrogen fertilizers used on farms and lawns. The rise in nitrate-plus-nitrite concentrations may affect phytoplankton communities, causing ripples up the food web.

Chapter 3

The Great Lakes Program in FY 1991: A Model, Ecosystem Approach

This chapter presents the holistic approach to ecosystem protection that EPA will launch during FY 1991 to attack current Great Lakes environmental problems. In general, this approach will aim to reduce toxic pollutant loadings to the Lakes and to protect and restore habitats necessary for healthy plant and animal communities. In pursuing these broad goals, EPA will examine ecological and human health risks facing the Great Lakes region; target priority problems and geographic areas; promote pollution prevention as the preferred, efficient means to reduce risks; integrate regulatory and enforcement actions in order to address the overall pollution problem at a given facility; meet local needs with an appropriate blend of solutions from across the entire range of the Agency's programs; encourage public participation; and evaluate progress using ecological indicators. In all these elements, the Agency will take advantage of opportunities for cooperative actions with Canada.

EPA has successfully used many individual elements of this approach in the past. The fundamental changes now being pioneered on the Great Lakes are to promote innovative pollution prevention measures and to focus and integrate the Agency's programs around an ecosystem, setting goals on the basis of environmental needs and measuring progress by ecological yardsticks.

A RISK-BASED AGENDA

The previous chapter discussed some leading problems facing the Great Lakes ecosystem – continuing unacceptable levels of persistent toxic substances in fish and wildlife; damaged, lost, or threatened habitat; damage to native fish populations from the accelerating introduction of exotic species; and remaining undesirable effects owing to excessive levels of phosphorus. To attack these problems, EPA will focus on slashing levels of persistent toxicants, and on protecting and restoring habitat and native species. The Agency will also continue activities to lower loadings of phosphorus and join other Federal and State agencies in efforts to control and prevent exotic species. These are interim steps towards EPA's long-term goal of a healthy Great Lakes ecosystem which contains fish that humans can safely consume in unlimited quantities and thriving populations of vulnerable species like bald eagle and lake trout.

To address this agenda, EPA will invite other stakeholders to join in the development of a five year strategy, that will begin in FY 1992. Stakeholders include Federal, State, Tribal, and local governments, representatives from industry, agriculture, and environmental groups, and other concerned members of the public. The strategy will emphasize the ecosystem approach, rely strongly on pollution prevention methods, and seek to reduce loadings of toxic substances and to protect and restore healthy plant and animal communities.

To support development of this strategy, EPA will also conduct its first risk-based comparative examination of human health and ecological hazards facing the Great Lakes region. The study will look at the available evidence on 23 different types or sources of problems, including those addressed by the Agency's various air, waste, and water programs, and other problems of import to the Great Lakes such as the introduction of exotic species, changing lake levels, and contaminated fresh water bottom sediments. This study will help the Agency target the most pressing sources of Great Lakes problems.

PROMOTE POLLUTION PREVENTION

EPA will use the Great Lakes as a proving ground for pollution prevention efforts. While buttressed by other Agency activities, pollution prevention will be the preferred means to reduce risks to the Great Lakes ecosystem. EPA will weave pollution prevention into the fabric of all its Great Lakes activities and encourage all sectors of society to contribute their inspiration to the ecological imperative to reduce the quantity and harmfulness of resources used to satisfy human needs.

In concert with the eight Governors of Great Lakes States, EPA will launch a Pollution Prevention Action Plan for the Great Lakes. This will aim to reduce levels of toxic substances found in the Great Lakes food web by promoting pollution prevention. The Action Plan will augment State pollution prevention programs. During recent years, the Great Lakes States have launched various prevention initiatives, involving education, research, technical assistance, and recognition of prevention successes via awards. Some States are also exploring ideas such as issuing one permit to cover all the emissions from a facility; incorporating pollution prevention into enforcement settlements; and linking permit fees to toxic generation. EPA will continue to work closely with States and support their pollution prevention programs.

The Action Plan will also complement EPA's national Pollution Prevention strategy, which includes the 33/50 Program. EPA has identified 17 high risk chemicals that offer strong opportunities for prevention. During 1991, EPA will announce a goal of encouraging firms to cut their nationwide releases of these substances 33 percent by the end of 1992 and 50 percent by the end of

1995. Among the 17 are three metals — cadmium, lead, and mercury — that biomagnify in the aquatic food web and are thus of special concern to the Great Lakes ecosystem. Large manufacturing firms report their annual releases or transfers of over 300 toxic substances. On a national basis these firms released or transferred over 1.4 billion pounds of the 17 chemicals in 1988. EPA will ask firms who have reported releases of the target chemicals to voluntarily reduce these through pollution prevention. Many of the 17 substances will be subject to more stringent regulation under the newly amended Clean Air Act. Under that law's "early reductions" provisions, a company may receive a six-year deferral from meeting a maximum achievable control technology (MACT) standard if it voluntarily reduces its toxic emissions by 90 percent before a MACT is proposed. EPA also expects widespread cooperation because pollution prevention offers economic benefits and is good corporate citizenship.

Great Lakes Pollution Prevention Action Plan

The Pollution Prevention Action Plan will launch five initiatives dedicated to the Great Lakes and incorporate prevention into all environmental programs. It will be predicated on challenging all sectors of society; focusing on high risk pollutants, sources, and areas; and measuring progress. The five initiatives will be:

- **The Challenge:** The Governors of the Great Lakes States, in cooperation with EPA, will challenge all sectors of society to voluntarily reduce releases of pollutants harmful to the Great Lakes. They will develop a regional award program to recognize excellence in pollution prevention, and also examine technical and/or regulatory disincentives to prevention.
- **Lake Superior:** Superior has not experienced surrounding development as intensely as other lakes, and remains relatively pristine. As the fountainhead of the Great Lakes system, it is important that it remain so. Among other measures, EPA and the Lake Superior States will: agree on common procedures to prevent degradation; agree on key pollutants; and establish air deposition sites to monitor loadings of air pollution to the lake.
- **Auto Manufacturing and Related Industries:** EPA and States will work with Chrysler, Ford, and General Motors to promote prevention of persistent toxic substances that injure the Great Lakes ecosystem. These com-

Pollution Prevention: Some Whats, Whys, and Hows

Pollution prevention is the adoption of "greener" technologies or practices. It entails everyday decisions by industry, agriculture, governments, universities, individuals — in short, by everyone — that cause the least environmental harm. Pollution prevention heads-off environmental injury at its origins.

Pollution prevention takes innumerable forms. In the manufacturing context, pollution prevention involves forethought about the ultimate disposal of a product at the stages of its conception and design; firms prevent pollution by such methods as product reformulation, changes in processes, and equipment redesign. Farmers prevent pollution by sound tillage practices and handling of pesticides and fertilizers. Universities conduct research on promising preventive technologies. Individuals hold a key to environmental progress in their purchases of consumer products and in their lifestyles.

For many manufacturing firms, pollution prevention has compelling attractions. It can reduce worker exposure to toxic substances, lowering medical and insurance costs. It can lower the cost of compliance with environmental regulations regarding treatment, cleanup, or disposal of hazardous substances. And can save raw materials wasted as pollutant byproducts and lower the disposal costs of non-hazardous rubbish.

Pollution prevention also adds luster to a firm's reputation with its customers, surrounding community, and employees. Increasingly, consumers stop buying products that they regard as environmentally unkind in their generation or disposal, presenting profit opportunities for firms clever enough to provide green products. Firms with green records may find it easier to earn community support for new facilities, and to recruit and motivate employees.

For such reasons, many U.S. firms have well-established pollution prevention programs. This welcome development harnesses their innovatory energies to go beyond EPA's traditional standards for treatment technologies. In some cases, such standards have served to freeze technology within industries, forestalling cleaner products and processes.

EPA will encourage and assist firms in preventing pollution and is examining innovative ways to do so. The Agency will continue to release information on polluters, bringing companies that need to prevent pollution to public notice. EPA will support the sharing of pollution prevention information, and sponsor research into preventive technologies. Also, regulatory barriers to development of cleaner technologies will be identified. Other potential means of fostering prevention are market incentives for firms that reduce their use of virgin materials, their toxic emissions, or energy consumption. Government regulation of advertisements can help consumers receive accurate green information on which to base purchases.

EPA also places a high priority on encouraging all sectors of society to prevent pollution. Education is one vital means to engage the public. The Agency is providing educational materials on prevention opportunities. Educational campaigns can help homeowners deal with household hazardous products or help farmers protect wells from pesticide contamination.

panies will join with EPA and States to determine the substances of greatest concern and evaluate which may be used in their operations. The companies will seek to reduce both their own use of such substances and that by their suppliers. They will also participate in technology transfer forums to share non-proprietary information on prevention techniques.

- **Urban Non-point Pollution:** EPA and New York will support three pilot programs to prevent urban non-point source pollution from households. In conjunction with county and municipal governments, New York will launch a consumer education campaign around Buffalo, Niagara Falls, Rochester, and Watertown, on the use and disposal of hazardous waste by households. Also, fact sheets will be used to inform the public of the potential risks associated with lawn chemicals and suggest lawn care procedures.
- **Binational Symposium:** In the fall of 1991, EPA will co-sponsor with Environment Canada a symposium to share information on pollution prevention.

Under the Action Plan, EPA and States will also weave prevention into the fabric of all their activities, including permits, enforcement, and educational programs. For instance, they will attempt to arrange settlements of enforcement actions under which a polluter will, in lieu of merely a fine, invest in pollution prevention or clean-up past contamination. Pollution prevention measures will also be incorporated into clean-up plans—Remedial Action and Lakewide Management Plans—for geographical problem areas.

GEOGRAPHIC TARGETING

A hallmark of the ecosystem approach will be to focus on priority ecological problems and geographic areas. As problems abate in areas that have been targeted, EPA's focus will shift to other geographic areas. This targeting will be shaped by the development, implementation, and continual improvement of Remedial Action and Lakewide Management Plans. Related efforts include development of guidance regarding water quality criteria for the Great Lakes, and various measures to redress leading ecological risks like degraded habitat, the invasion of non-native species, and excessive nutrients.

Remedial Action Planning

In 1987, the United States and Canada each formally committed to develop and implement plans—termed Remedial Action Plans (RAPs)—to restore the most impaired areas around the Great Lakes. In general, these so called "Areas of Concern" are bays, harbors, and river mouths with damaged fish and wildlife populations, contaminated bottom sediments, and past or continuing loadings of toxic and bacterial pollutants. Including 5 shared with Canada, the U.S. has 31 Areas of Concern. The Remedial Action Planning process is intended to define ecological problems, apply appropriate solutions, and assess progress towards ecological goals. RAPs are principally developed and implemented by States with EPA support, consistent with the Federal/State partnership in national environmental legislation.

One measure of RAP progress is the completion of editions of these planning documents. States have committed to completing initial versions of 9 Stage One (problem definition) and 2 Stage Two (remedial action definition) RAPs during FY 1991. This will bring the cumulative totals thus far to 22 Stage One and 12 Stage Two RAPs.

While RAPs are being developed, EPA and States concurrently take many warranted actions to protect and restore Areas of Concern. Such actions to restore Areas of Concern will be discussed in the next chapter.

During FY 1991, EPA and States will especially target two locations encompassing Areas of Concern, because of their profiles of high ecological risk and non-compliance with permits and regulations. EPA and States will focus remediation, inspection and enforcement, and prevention activities on Southeast Chicago-Northwest Indiana and along the Niagara River.

In further support of Remedial Action Plans, EPA will also continue its ARCS program (see chapter 4) that has assessed contaminated sediment problems in five Areas of Concern and will demonstrate pilot scale treatment technologies in the Buffalo, Saginaw, and Grand Calumet Rivers during 1991. In FY 1992, this program will test additional technologies in the other two Areas of Concern—the Ashtabula and Sheboygan Rivers. The ARCS program will develop guidance on assessment methods and on remedial alternatives to assist local decision-makers in addressing the contaminated sediment situations of Areas of Concern.

Lakewide Management Planning

Also in 1987, the United States and Canada committed to develop and implement plans, called Lakewide Management Plans (LAMPs), to address whole-lake problems that extend beyond Areas of Concern. While EPA has the lead responsibility for developing these plans, participation by other Federal agencies, States, and local communities is fundamental to their success. A joint Federal-State policy committee has been established to guide the LAMP process and to incorporate participation by the interested public.

During FY 1991, EPA will focus on completing Stage One LAMPs for the lakes that have experienced the greatest contamination—Michigan and Ontario. The objectives of Stage One LAMPs are to identify key pollutants and their sources, and to schedule reduction measures. In FY 1992, the Agency will begin work on a LAMP for Lake Superior; Lakes Erie and Huron will follow. EPA and State LAMP activities will be treated more fully in the next chapter.

EPA regards the completion of an initial version of a RAP or LAMP to be an important, though interim, achievement. These plans must, of course, be implemented to obtain desired results. RAPs and LAMPs will also be continually improved as more is learned about problems and their sources, and as the results of preventive and remedial measures warrant.

Water Quality Initiative

In view of the unique features of the Great Lakes system, EPA and States believe that in some cases criteria specific for the Great Lakes are necessary to protect aquatic biota and wildlife, and human health—primarily from fish consumption risks—on a long-term basis. In FY 1989, EPA and States began a "Great Lakes Water Quality Initiative" to develop EPA guidance to States regarding water quality criteria for the Great Lakes, a Great Lakes antidegradation policy, implementation procedures, and pollution prevention measures. EPA is responsible for developing national water quality criteria that numerically define maximum allowable concentrations of certain pollutants in surface waters across the nation. These criteria are used by States as a basis for their water quality standards and water quality-based regulation under the National Pollutant Discharge Elimination System (NPDES). The initiative will continue in FY 1991. EPA envisions that the guidance will be completed in time to be incorporated into the next triennial State water quality standard review process (1991 to 1993).

The Initiative will fulfill a number of purposes. It will help ensure that Great Lakes environmental needs are incorporated into State water quality programs, thereby providing a sound scientific basis for water quality-based protection of the Great Lakes under the Clean Water Act. It will support greater consistency among States in their standards and implementation procedures for the Great Lakes. And it will help to define water quality objectives for Lakewide Management Plans; compliance with standards will provide an opportunity to adopt pollution prevention technologies and methods.

Water quality guidance developed under the Initiative will represent an interim accomplishment. Over the long-term, EPA and States will seek to prevent loadings of toxic substances, with a goal of virtual elimination. Technology-based regulatory requirements will supplement water-quality requirements.

Habitat Protection and Restoration

EPA will work with other Federal agencies, State, and local governments on protection of wetlands and critical plant communities. This will entail development of a joint Great Lakes wetlands strategy. Also, critical plant communities will be inventoried and assessed for their ability to sustain fish and wildlife populations.

Prevention and Mitigation of Exotic Species

EPA will research the impact of zebra mussels on the health of the Great Lakes, identify areas susceptible to the spread of this exotic species, and evaluate the environmental risks posed by possible control options. In conjunction with the Coast Guard, EPA will also study the effectiveness of ballast water exchange by transoceanic vessels before they enter the Great Lakes at preventing the introduction of exotic species. The Fish and Wildlife Service will also continue to apply lampricides to sea lamprey spawning grounds and to stock lake trout in order to mitigate the effects of this exotic.

Excessive Nutrients

Through its base programs, EPA will continue working with the Department of Agriculture and with States on assorted programs to reduce the non-point loadings of agricultural nutrients like phosphorus and nitrogen to the Great Lakes.

INTEGRATED REGULATION AND ENFORCEMENT

EPA will increasingly transcend statutory and organizational seams in its development and enforcement of regulations and permits. One instance of the integration of regulations, with implications for the Great Lakes, is the revision of pulp and paper industry regulations. EPA will develop integrated regulations for pulp and paper mills so that technology-based effluent treatment standards under the Clean Water Act and requirements under the Clean Air Act are considered together for optimal environmental results and for incorporation of pollution prevention opportunities. One aim will be to further reduce the discharge of dioxins from this industrial sector. Mills throughout the nation will be required to install the best available effluent treatment technology by 1995. The Agency will also establish guidelines for managing landfills that receive dioxin-contaminated wastewater treatment sludge from pulp and paper mills.

Another aspect of EPA's integration will be to follow a "multi-media" enforcement strategy. Traditionally, EPA has relied on enforcement under a single statute, addressing a single medium (air, waste, or water). This may have sometimes had the effect of encouraging a polluter to transfer an environmental problem from one medium to another (e.g., soil to air). On a national basis, EPA will seek to make 25 percent of all enforcement actions in 1991 "multi-media" cases so as to address the overall pollution problem at a given facility. During 1989-90, EPA filed several multi-media suits for alleged violations of environmental permits and regulations in Northwest Indiana.

ENGAGE THE PUBLIC

EPA and States will also continue to encourage involvement by interested members of the public in many aspects of their Great Lakes activities:

- Local community "stakeholders" are strongly involved in the development, and in overseeing the implementation, of many RAPs. This grass-roots participation has molded the goals of these planning efforts, strengthened the sense of local ownership of both problems and their solutions, and is helping governments be more responsive to local concerns.
- Public participation will also be encouraged as part of the LAMP process and in the formation of a 5-year Great Lakes strategy.
- EPA and the Governors of the Great Lakes States will encourage public involvement in pollution prevention by such means as recognition for excellence in pollution prevention.
- Representatives from environmental groups, business associations, and municipalities have been invited to comment during the development of the Water Quality Initiative. A public record on the Initiative is being developed and public hearings will be held once findings and recommendations are reached. Proposed guidance will be available in the Federal Register for public review and comment.

- EPA's ARCS program has held public meetings to inform residents living near the areas of study about its activities and results.

ASSESS PROGRESS

Another hallmark of EPA's approach to the Great Lakes will be to set goals and assess progress towards them, using demonstrable measures. The national 33/50 program sets goals to reduce releases of 17 target substances by 1992 and 1995, respectively, and will track progress through Toxic Release Inventory reporting. In 1987, EPA, the New York State Department of Environmental Conservation and counterpart Canadian agencies dedicated themselves to cut in half loadings of priority toxic chemicals to the Niagara River by 1996. Progress towards this goal is ascertained by monitoring water quality at both ends of the river.

EPA and States will pursue a variety of other activities to assess the health of the ecosystem and the efficacy of preventive and remedial actions:

- During FY 1991, EPA will join States and other Federal agencies in the first of what will be annual comprehensive reviews of research and monitoring priorities to ensure that scientific work supports program management needs.
- As part of LAMP processes, proposed ecosystem objectives for Lake Ontario will be presented for public comment, and ecosystem objectives for Lake Michigan will also be begun.
- EPA will develop a better understanding of the extent and significance of atmospheric deposition of pollutants by establishing three stations to monitor this pollutant pathway. When these are added to two stations that Canada will establish, each lake will have one master station.
- EPA, the Fish and Wildlife Service, and States will continue to monitor contaminant levels in different fish and wildlife species to judge the health of the ecosystem.
- During 1991, EPA will begin to sample open lake water column concentrations of priority pollutants on Lakes Ontario and Michigan.
- EPA and Wisconsin will conclude the analytic aspects of their multi-year study of the sources, paths, and fates of several persistent toxic substances in Green Bay. Lessons from this study will be transferred to whole-lake analyses in support of LAMPs.

COOPERATION WITH CANADA

EPA and States will look for all opportunities to work with counterparts in Canada. Canadian representatives have been invited to ARCS program meetings so as to keep apprised of U.S. findings regarding technologies to address contaminated sediments. Canadian observers have also been invited to attend meetings of the Great Lakes Water Quality Initiative work groups, since this initiative will provide a basis for the revision of binational "specific objectives" under the Great Lakes Water Quality Agreement. EPA and States will also continue to work with Canadian counterparts on RAPs for shared Areas of Concern and on LAMPs for shared lakes. They will also work with Canada to coordinate pollution prevention activities for the Great Lakes.

Chapter 4

Actions to Implement the Water Quality Agreement

This chapter reports recent actions by EPA and States to cut pollutant loadings to the Great Lakes and to protect fish and wildlife habitats. Many of these actions support the three major approaches of the Water Quality Agreement with Canada: Remedial Action Plans, Lakewide Management Plans, and the Phosphorus Load Reduction Plan. This chapter also discusses EPA's ARCS Program that is testing remedial technologies and will develop guidance on addressing contaminated bottom sediments.

FRAMEWORK

The United States and Canada have a long history of cooperation on issues pertaining to their joint stewardship of the Great Lakes. In 1905, the two nations formed an International Waterways Commission to advise them about Great Lakes water levels and flows. Created under the Boundary Waters Treaty of 1909, the International Joint Commission (IJC) superseded this commission and continues to function today.

The IJC has six members, three appointed by each nation. It has limited authority to approve diversions, obstructions, and uses of Great Lakes waters that affect water flow or levels on the other side of the international boundary. A major activity of the IJC has been to advise the two Federal governments about Great Lakes water issues and to conduct studies at the request of the governments. Since 1972, the IJC has had the additional function of reviewing progress of the two nations under their Great Lakes Water Quality Agreement.

The IJC has two advisory boards to assist it. The Great Lakes Water Quality Board, comprising members from Federal, State, and Provincial environmental agencies, promotes coordination of programs and the sharing of environmental information. The Science Advisory Board consists of government and academic experts who advise the IJC concerning scientific findings and needs. Many of the committees and work groups of these boards convene at the IJC's Great Lakes Regional Office in Windsor, Ontario.

Widespread public concern over the health of the Great Lakes led the United States and Canada to sign the first Great Lakes Water Quality Agreement in 1972. The primary thrust of the first Agreement was to reduce excessive levels of phosphorus in the Great Lakes that were causing nuisance levels of aquatic plant life, particularly undesirable algae. The Agreement also called for coordinated international environmental research and surveillance of Great Lakes conditions.

In 1978, the two nations signed a new Agreement. By that time, there had been clear progress in reducing phosphorus loadings to the Great Lakes. There was also a growing appreciation of a subtler risk to fish, wildlife, and human health—persistent toxic substances. Certain species of fish in many locations through the Great Lakes had been found to contain unsafe levels of persistent toxic substances, such as polychlorinated biphenyls (PCBs), mercury, chlordane, and mirex. The second Agreement added commitments to prohibit the discharge of toxic substances in toxic amounts into the Great Lakes, virtually eliminate all persistent toxic substances, and restore the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem. In 1983, the two nations added provisions under which they pledged to develop phosphorus reduction plans to reduce excessive plant life in areas of the Great Lakes.

In November 1987, the nations revised the Agreement again. Under this revision, they committed to preparing and executing ecosystem cleanup plans for Areas of Concern and for whole-lake problems associated with certain critical pollutants. The two types of cleanup plans are respectively called Remedial Action Plans (RAPs) and Lakewide Management Plans (LAMPs). The Agreement stated that these plans would be submitted to the IJC for review and comment at various stages. The 1987 revision also added some management commitments. The two nations formally agreed to meet twice a year to coordinate their respective work and to evaluate progress. They also agreed to report to the IJC on a biennial basis concerning progress on certain activities.

The Great Lakes Water Quality Agreement sets forth a joint agenda for international stewardship of the Great Lakes ecosystem. To carry out this agenda, Canada and the United States each control pollution and protect natural resources under their respective national, state, and local laws. Implementation of the Agreement relies on the full range of U.S. environmental programs. Most U.S. environmental legislation is administered by EPA and States in partnership. In addition, other Federal agencies play important roles in protecting the Great Lakes: the Army Corps of Engineers, the Coast Guard, the Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the Soil Conservation Service.

EPA is the lead Federal agency for carrying out the Agreement. EPA's Great Lakes National Program Office coordinates within the Agency and with appropriate Federal, State, Tribal, and international agencies to implement the Agreement. The Program Office also administers a system-wide surveillance network to monitor the water quality of the Great Lakes, with emphasis on the monitoring of toxic pollutants. In addition, it serves as liaison with and provides information to the IJC and to EPA's Canadian counterpart, Environment Canada. The Program Office conducts studies pertaining to the Great Lakes ecosystem, demonstrates cleanup technologies and methods, works with States to develop cleanup plans, and develops this comprehensive report that discusses Federal programs and the long-term prospects for improving the condition of the Great Lakes.

Areas of Concern

Since 1973, the U.S. and Canada have identified geographic problem areas in the Great Lakes. Over time, the number of areas has increased or decreased as more environmental data have become available, environmental conditions have changed, and definitions of impairments have evolved. In 1976, the two nations identified 47 "problem areas." In 1981, they identified 39 "Areas of Concern," grouping them into two classes according to their severity of impairment: 18 Areas of Concern were classified as "significantly degraded" and 21 others as "exhibiting degradation." Of the 18 significantly degraded areas, 13 were wholly in the United States, 4 were shared by the two nations, and 1 was in Canada. In 1985, the U.S. added 3 Areas of Concern: the Kalamazoo River in the Lake Michigan basin and Torch Lake and Deer Lake/Carp River in the Lake Superior basin.

In 1991, the United States will add Presque Isle Bay in the Lake Erie basin. With this addition, there will be 43 Areas of Concern. The U.S. has 31 Areas of Concern – 26 located wholly in the U.S. and 5 shared with Canada. Figure 4-1 shows their locations.

A problem common to all U.S. Areas of Concern is the presence of sediments contaminated by toxic substances. Even though the problem of contaminated sediments is common, solutions are likely to be varied and site-specific, depending on such factors as the nature of the contamination, the type of sediment particle, whether the source of the contamination has stopped, and the degree of risk posed by the sediments to the ecosystem.

Other common problems within Areas of Concern include fish with tumors and human health advisories for consumption of fish. As of 1987, there were advisories regarding consumption of fish within 26 of 30 U.S. Areas of Concern. In addition, 12 U.S. Areas of Concern were known to contain fish with clearly evident problems, such as tumors.

REMEDIAL ACTION PLANNING

In 1985, EPA and the Great Lakes States agreed to develop and implement RAPs for Areas of Concern. They recognized that many lakewide problems originate in certain nearshore areas, so that addressing these through RAPs would also reduce lakewide impairments. The U.S. and Canada formally added provisions concerning RAPs to the Great Lakes Water Quality Agreement in November 1987.

One of the Agreement's general principles regarding RAPs calls for the use of an ecosystem approach to restoring Areas of Concern. Each RAP is to identify the nature and causes of problems, remedial actions, and responsible organizations. Pursuant to the Agreement, RAPs will be submitted to the IJC for independent review and comment at three stages – after definition of problems, after development of appropriate remedial measures, and after monitoring indicates that beneficial uses have been restored.

Another important provision of the Agreement is that the public, particularly from communities adjacent to the Area of Concern, be involved in RAP planning and implementation. The two nations realize that cleanup of many Areas of Concern will be a lengthy, costly process. Continuing public interest is integral to the success of this process.

RAPs are developed and implemented by States, consistent with the Federal/State partnership in national environmental legislation. To supplement State funding, EPA provides annual grants to States for administering national water, waste, and air programs. Some of these funds are applied to remedial measures in Areas of Concern. In addition, EPA gives grants specifically for RAP development and provides technical assistance. EPA has joined States in supporting a series of major studies on a number of Areas of Concern, including the Niagara River (completed 1985); the St. Marys, St. Clair, and Detroit Rivers (completed 1988); and Green Bay (in progress). The Agency is also conducting a major study on contaminated bottom sediments in five Areas of Concern. All these studies have developed information that is useful in understanding the problems of Areas of Concern.

Progress

One administrative measure of RAP progress is the completion of editions of these planning documents. Through FY 1990, States had developed 13 Stage One (problem definition) and 10 Stage Two (proposal of remedial actions) RAPs to the point of submission to the IJC. States have committed to completing initial versions of 9 additional Stage One and 2 Stage Two RAPs during FY 1991. This will bring the cumulative totals thus far to 22 Stage One and 12 Stage Two RAPs. Many other RAPs are under development. Table A-1 in the Appendix summarizes RAP submission status, past and planned.

RAPs will be continually improved as more is learned about the problems of Areas of Concern, and as warranted by the results of preventive and remedial measures. EPA views Remedial Action Planning as a valuable ongoing management process to identify priority environmental problems, steps needed to solve these, and resulting demonstrable ecological progress.

Yet, EPA, States, and other participants do not wait for the completion of editions of these plans before taking warranted actions to reduce toxic loadings or protect habitat. Table A-2 in the Appendix provides some recent accomplishments and planned activities in U.S. Areas of Concern. Some highlights of recent accomplishments:

- The cleanup process is continuing through various stages at 13 Superfund sites which are integral to restoring 7 Areas of Concern – Ashtabula River, Kalamazoo River, Niagara River, St. Lawrence River, Sheboygan River, Torch Lake, and Waukegan Harbor. This process is also continuing at another 4 Superfund sites that are clearly significant, though generally to a lesser degree, to restoring 3 other Areas of Concern – the Clinton River, St. Louis River, and Saginaw River (its Shiawasee River tributary). Over the course of these multi-year Superfund program

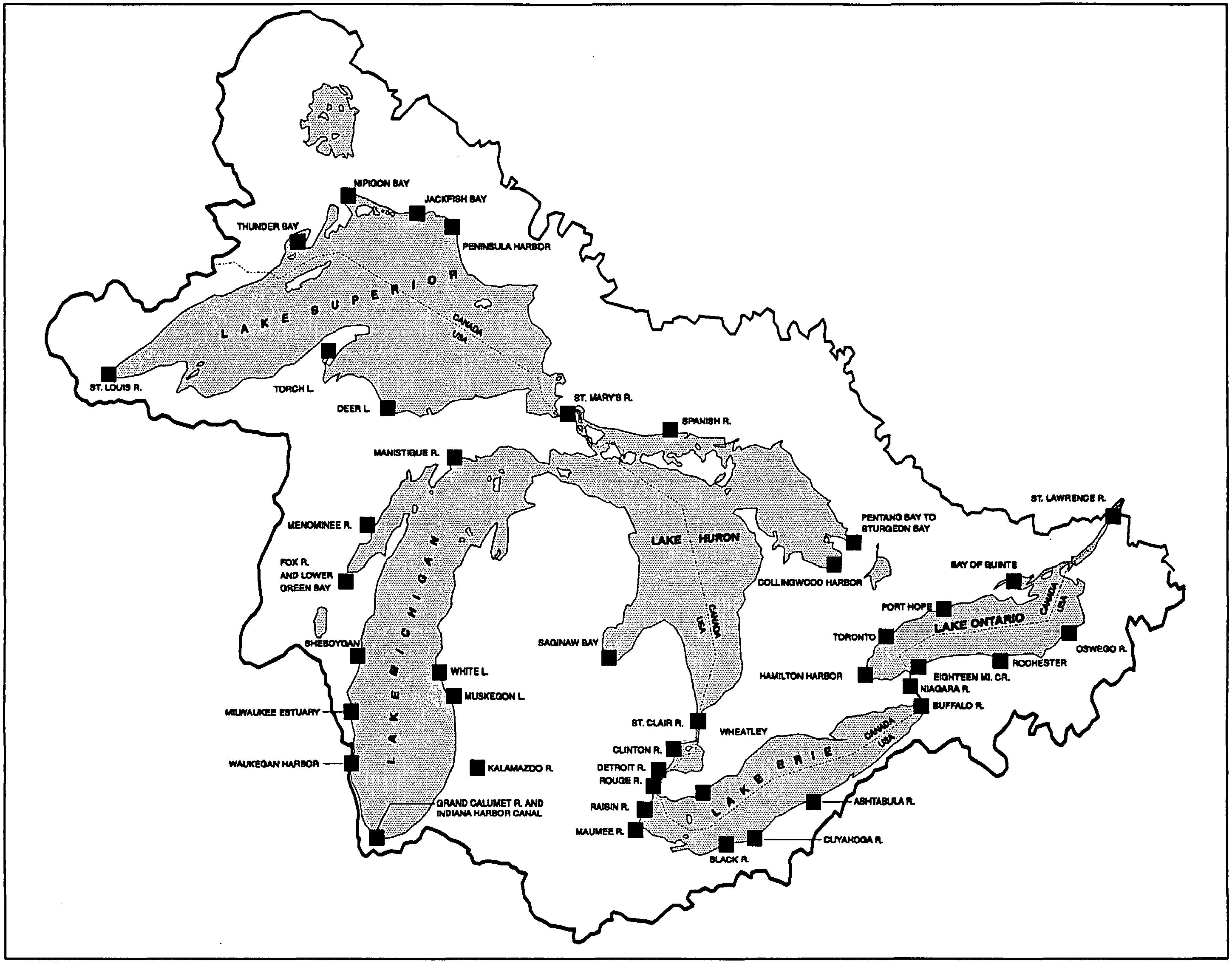


Figure 4-1. Areas of Concern

remediations, hundreds of millions of dollars will be invested, by potentially responsible parties and EPA together, in redressing environmental problems.

- Multi-year programs to eliminate combined sewer overflows of untreated waste water are underway in many communities around the Great Lakes. These are of particular importance to 8 Areas of Concern—the Detroit River, Maumee River, Menominee River, Milwaukee Harbor, Rochester Embayment, Rouge River, St. Clair River, and St. Marys River.
- Major long-term investments in municipal wastewater treatment plants are improving 3 Areas of Concern—the Black River, Cuyahoga River, and Green Bay.
- The Federal government has sued to enforce the pretreatment of industrial effluent in a case relating to two Areas of Concern—the Rouge River and Detroit River.
- Pursuant to RCRA, EPA and States have taken measures that are significant to two Areas of Concern—the Menominee River and River Raisin.
- Agricultural nonpoint pollution control measures are focusing on Areas of Concern where this type of pollutant source is notably significant—Green Bay, Maumee River, and Saginaw Bay.
- Regulation of point source water dischargers is especially helping 2 Areas of Concern—the Grand Calumet River and Manistique River.

Although the U.S. has identified Areas of Concern for over a decade, it should be noted that, generally, there have been substantial environmental improvements in these areas as a result of pollution abatement. Improved water quality in areas such as the Cuyahoga, Black, and Ashtabula Rivers in Ohio and the Buffalo River in New York have allowed fish to return, though contaminants remain in those areas, causing the fish to develop tumors or other abnormalities and to be unsafe for human consumption.

Another Area of Concern where there are strong biological responses to improved water quality is the Fox River and Green Bay. A recent report on the area noted that the number of different bottom-dwelling species doubled in the 10 years after 1978. Wild celery, a favored food of waterfowl, has been recovering. The reproductive success of Forster's terns in Green Bay improved during the 1980s, and the number of nesting pairs increased about 500 percent from 1986 through 1988 (10).

RAP Process Lessons

Some successes of the RAP process to date:

- Local community "stakeholder" groups are strongly involved in many RAPs. This grass roots participation has molded the goals of RAPs and strengthened the sense of local "ownership" of both problems and their solutions.
- Stakeholder participation has helped to increase public awareness of environmental issues.
- Stakeholder groups have provided an opportunity for industrial firms to join in restoration planning. One State environmental agency participant has noted: "In the RAP process, we work with firms to prevent pollution, talking to their engineers rather than their lawyers."
- The development of some RAPs has brought together nearby municipalities in addressing common regional problems (e.g., Green Bay, Rouge, and Maumee RAPs).
- RAPs developed to date represent an impressive assemblage of information on environmental problems and solutions. They serve to inform the public, guide government actions, and justify investments in Great Lakes restoration (e.g., the Great Lakes Governors launched a $100 million Great Lakes protection fund in 1988).
- RAPs have called upon a broad range of environmental programs to meet ecological needs. For instance, they rely on nonpoint source measures (Saginaw and Green Bays), industrial pretreatment (Rouge River), groundwater remediation (Niagara River), better sewage treatment, and wetlands restoration (Green Bay), among other measures.

Some general lessons that have been learned from the Remedial Action Planning process include the following:

- The development of a strong RAP can be complex and protracted. The Rouge River RAP became seven separate volumes.
- Some RAP development efforts encounter a host of questions about the extent and causes of ecosystem impairments. Establishing "causality" between known sources of pollution and impaired fish and wildlife may entail years of study.
- The RAP process will be iterative and incremental. The first generation of the Rouge River RAP, for instance, is a superb achievement, resulting from exemplary involvement by many communities. It addresses the most immediate problems of the Area of Concern—overflows from combined sewers and bacteria problems. In the future, the Rouge River RAP will be updated to address the problem of toxic substances.
- There can be a considerable asymmetry of information available to different RAP teams. Sometimes there is extensive information about an Area of Concern upon which the RAP may draw (e.g., Green Bay). In other cases, the development effort must include analyses of water, fish, and sediment samples to fully define use impairments and their causes (e.g., Cuyahoga and Maumee Rivers).
- Some communities have citizens with a strong knowledge of local environmental conditions that has helped their stakeholder groups (e.g., Duluth, Green Bay, and Milwaukee).
- The RAP development process can be greatly helped by information

Actions to Restore Areas of Concern

Lake Michigan

Contamination of sport fish with PCBs is the principal basis for the issuance of health advisories regarding Great Lakes fish. Various actions ringing Lake Michigan attack this priority problem.

- The largest known reservoir of PCBs in the Great Lakes is Waukegan Harbor. Under a Superfund remedial plan being carried out through 1993, 99 percent of the PCBs in the harbor will be removed.
- Another important source of PCBs has been the Sheboygan River; it is the subject of a Superfund remedial investigation and feasibility study. On the eastern side of the lake, the Kalamazoo River has PCB-contaminated bottom sediments. In 1989, EPA and Michigan proposed a 35 mile stretch of the river as a Superfund site and a remedial investigation is beginning in 1991.
- The Fox River and Green Bay have suffered high levels of PCBs; EPA and Wisconsin are studying the sources and fates of PCBs in this area.
- At the base of Lake Michigan, various enforcement actions have been taken and the area remains the focus of EPA and State activities. Under a recent innovative settlement, USX Corporation will dredge sediments from a stretch of the Grand Calumet River to prevent movement of contaminants, including PCBs, to the lake.

The Niagara River

The other most contaminated lake is Ontario. The U.S. side of the Niagara River, which after World War II attracted a cluster of chemical companies, has been a leading source of toxic pollutants, including 10 of the 15 most troublesome in the Lake Ontario food web. Studies indicate that nonpoint loadings, such as leachate and runoff from waste sites, are the dominant source of priority pollutants to the Niagara. There are many hazardous waste sites near the river, the most infamous of which may be a former landfill called Love Canal which became a residential area.

The Niagara Frontier has been a sustained emphasis of EPA and New York over many years. A major binational study of the river was completed in 1985. In 1987, EPA and the State joined Canadian counterparts in a declaration dedicated to halving toxic loadings to the Niagara by 1996. They have taken many actions related to remediating waste sites, including five Superfund sites and others addressed by the State's waste program. Some of the residential areas near Love Canal that were once deemed unsafe have recently been judged to be habitable. EPA and the State have announced schedules to remediate, by 1996, the 20 waste sites considered responsible for 99 percent of U.S. waste site loadings to the Niagara.

The St. Lawrence River

EPA and State actions are also aimed at profound local problems. One of the most pressing is the St. Lawrence River Area of Concern. Largely during the 1960s and 1970s, U.S. and Canadian industries poured wastes including PCBs and mercury into riverside landfills, even the St. Lawrence River itself. Aluminum smelters emitted fluroide into the air. This pollution damaged the traditional fishing, farming, and hunting economy of Mohawks living on the Akwesasne Indian Reservation in New York State. Fish, ducks, and turtles, long principal sources of protein for the Mohawks, became contaminated with PCBs or mercury.

In 1983, EPA added a General Motors site on the St. Lawrence to its Superfund NPL list. In 1990, EPA selected a remedial plan for part of this site that is estimated to cost $78 million. In 1991, EPA also issued Superfund Administrative Orders to the Aluminum Company of America (ALCOA) and the Reynolds Metal Company to perform remedial investigations, designs, and cleanups of PCB-contaminated bottom sediments in the St. Lawrence River system.

provided by potentially responsible parties pursuant to enforcement actions (e.g., Ashtabula, Kalamazoo, and Sheboygan).

- Major investments will be required to restore some Areas of Concern. Large sewage system and treatment facility improvements are underway or will be needed in many Areas of Concern (e.g., Maumee, Rouge, and Detroit Rivers, and Milwaukee Harbor). Michigan estimates that the total cost of all improvements for CSOs that discharge into the Rouge River to be $1 billion and for those that discharge into the Detroit River to be $2.6 billion.
- It is often unclear how to address the common problem of contaminated bottom sediments in rivers and harbors. EPA is testing technologies and will develop guidance to assist local decision-makers.

ARCS PROGRAM

During FYs 1989-90, EPA continued its sponsorship of a study and demonstration program – the Assessment and Remediation of Contaminated Sediments (ARCS) Program – to assess contaminated Great Lakes bottom sediments, test remedial technologies, and develop guidance on addressing bottom sediment contamination in the Great Lakes. Five areas are receiving priority consideration: Ashtabula River (Ohio), Buffalo River (New York), Grand

Calumet River (Indiana), Saginaw Bay (Michigan), and Sheboygan Harbor (Wisconsin). EPA is joined in the ARCS program by various federal and State agencies, including the Army Corps of Engineers; Bureau of Mines; Fish and Wildlife Service; National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory; Indiana Department of Environmental Management; Michigan Department of Natural Resources; New York State Department of Environmental Conservation; Ohio Environmental Protection Agency; Wisconsin Department of Natural Resources; and a number of universities.

All 31 U. S. Areas of Concern, including the 5 given priority by ARCS, have contaminated bottom sediments. Developing scientific grounds and improved technologies for addressing contaminated sediments will be critical to restoring the Great Lakes ecosystem. Many existing technologies for removing contaminated sediments have unwanted environmental side effects. Many present methods of dredging bottom sediments, for instance, release and resuspend some contaminants from sediments.

The ARCS program assesses the scope and nature of contamination in the study areas, assesses human and ecological health impacts of the contamination and of alternative remedial measures, and tests the efficacy of new remedial technologies. Another aspect of ARCS is to inform and solicit comments from interested citizens in communities adjacent to the study areas about the intent and findings of the program.

A final report on the ARCS program will be available in December 1993. It will include guidance on how to assess freshwater contaminated sediment problems (i.e., models and risk assessment tools), and guidance on remedial alternatives.

Assessment

During FYs 1989-90, the ARCS program sampled bottom sediments at different depths in the Indiana Harbor/Grand Calumet River, Buffalo River, and Saginaw River. ARCS started analyses of sample chemistry, toxicity (both acute and chronic) to aquatic organisms exposed to the sediment, and identification of benthic organisms. These analyses will be completed in FY 1991, and three-dimensional maps of the extent and nature of contamination will be prepared.

Preliminary data from Indiana Harbor samples indicate their acute toxicity to test organisms; they are among the most toxic Great Lakes sediments ever analyzed. Since this is true of samples from the surface of bottom sediment, there is the implication that contamination is continuing from sources in the area. In the Grand Calumet River, surface sediments were also found to be highly toxic. Preliminary analytic results of surface samples from the Buffalo River indicate their toxicity was generally lower than those of samples from Indiana, though sediments from one Buffalo River site were found to be acutely toxic to some organisms. In November 1989, ARCS took surficial samples in the Saginaw River. Preliminary analysis of these generally indicates less toxicity than in the Buffalo River, though two Saginaw sites had notably higher toxicity than others.

Benthic organisms found living in the Indiana Harbor Canal were mainly pollution tolerant species, whereas more pollution sensitive species were found in the Saginaw and Buffalo Rivers.

The Fish and Wildlife Service surveyed fish (bullheads) for tumors and abnormalities in the Ashtabula, Saginaw, Grand Calumet, and Buffalo Rivers. No bullheads or white suckers could be found in the Grand Calumet. The Service also began studying, in the Saginaw and Buffalo Rivers, the transfer of contaminants from sediment to fish.

ARCS is drawing on Superfund activities in the Ashtabula River to obtain samples and chemical analyses, both surficial and with depth. Sheboygan Harbor also contains a Superfund site, allowing ARCS to obtain its bioassays and chemistry analyses.

Hazard Evaluations

As contaminants in sediments are identified, an important element of ARCS is to evaluate the risks from them under current conditions and under various remedial alternatives. During FYs 1989-90, ARCS continued to assess human and ecological health impacts of sediment contamination and of remedial alternatives. ARCS continued evaluations, begun in FY 1989, of current hazards at each of the five priority locations.

In the Buffalo and Saginaw Rivers, ARCS began comprehensive hazard evaluations to assess risks under various remedial alternatives. Many industrial firms along the Buffalo River have closed since the 1970s or directed their discharges to municipal treatment facilities; thus, the Buffalo River analysis may prove to be less complex than that of the Saginaw River, which contains a larger watershed and likely a greater number of current sources of pollutants.

A FY 1991 aspect of these comprehensive evaluations will be to study the sources and fates of contaminants in the Buffalo and Saginaw Rivers over a six week time span. Water column, fish, and sediment samples will be collected to analyze for selected pollutants. Contaminants being studied in the Buffalo River are PCBs, DDT, dieldrin, chlordane, lead, copper, benzo(a)anthracene, benzo(a)pyrene, benz(b/k)fluoranthene, and chrysene. Contaminants being studied in the Saginaw River are PCBs, zinc, copper, and lead.

Once models of the sources and fates of these pollutants are refined, ARCS will predict risks under various remedial alternatives, including: the no-action alternative or leaving sediments undisturbed; dredging only the two or three worst hot spots; capping stretches of river with clean material rather than dredging them; and complete removal of contaminated sediment. ARCS is looking at the complete picture of risks associated with each option, including dredging, treatment, and ultimate disposal of contaminated sediments.

Technology Evaluations

During FYs 1989-90, ARCS began small-scale laboratory tests of treatment technologies on sediments from the five priority locations. These tests use between a few grams to a few kilograms of sediment, and provide data for ensuing, larger field demonstrations. Treatment technologies being evaluated in a laboratory setting include solidification/stabilization, thermal extraction, chemical treatment, and biological treatment. ARCS also sponsored a binational research conference on biological treatment of sediments contaminated by PCBs, PAHs, and some metals.

To date, ARCS has chosen 16 technologies for testing consideration. Each was selected based on a number of criteria, including effectiveness and cost, the latter an important consideration given the large volume of contaminated sediments across the Great Lakes. The innovative technologies fall into five general categories: thermal technologies (including incineration, but more often the use of high temperatures short of combustion); chemical destruction (using chemical reactions to break down contaminants); biological treatment (using bacteria or fungi to break down contaminants); extraction technologies (using solvents to separate contaminants from sediments); and immobilization (such as processes that mix cement with sediments to reduce the availability of contaminants to the Great Lakes food web).

ARCS plans pilot-scale, field demonstrations in all five priority locations during FYs 1991-92:

- On the Ashtabula River, ARCS will demonstrate a thermal stripping process to desorb semivolatile organic contaminants (such as PAHs) from sediment.
- On the Buffalo River, ARCS will demonstrate a thermal extraction process to remove organic contaminants from sediment. Like the low temperature thermal stripping, this process is also a thermal desorption process that removes semivolatile organic contaminants. Under it, sediments are heated to temperatures high enough to volatilize contaminants, but beneath temperatures used during incineration.
- On the Grand Calumet River/Indiana Harbor, ARCS will demonstrate the application of a solvent extraction process to separate organic contaminants.
- On the Saginaw River, ARCS will demonstrate physical separation of sediments by particle size using a hydrocyclone or another physical separation technology. Since contaminants tend to adhere to a certain size of sediment particle, this demonstration is expected to reduce the overall volume of heavily contaminated sediment by separating sediment of one size that bears relatively less contamination from another size holds more contaminants. Thereafter, using the more heavily contaminated product of the physical separation demonstration, ARCS will also consider demonstrating two further technologies: a solvent extraction process to remove organic contaminants; and a bioremediation process to break down contaminants into less harmful substances.
- On the Sheboygan River, ARCS will provide technical assistance to Superfund remediation activities, through EPA's Environmental Research Laboratory-Athens. This will entail a scientific review of the Sheboygan bioremediation pilot project already underway, including design and statistical recommendations.

Public Communication

During FYs 1989-90, a work group including citizens living near the study areas was formed to promote information exchange with the public. The work group established repositories in libraries near each of the five areas. ARCS also developed a slide-show presentation and sponsored public meetings to inform residents living near the priority areas about program activities and results.

LAKEWIDE MANAGEMENT PLANNING

The second major restoration approach under the Agreement is the development of Lakewide Management Plans (LAMPs) for critical pollutants to address whole-lake problems that extend beyond Areas of Concern. As with the RAP process, LAMPs are intended to follow a comprehensive ecosystem approach, drawing on the full range of Federal, State, and local environmental programs, as needed. Again like the RAP process, EPA views Lakewide Management Planning as an ongoing management process to identify priority environmental problems, steps needed to solve these, and ecological outcomes.

EPA and States are giving priority to completing Stage One LAMPs for Lakes Michigan and Ontario in FY 1991. The objectives of Stage One LAMPs are to identify key pollutants and their sources, and to schedule reduction measures. In FY 1992, the Agency will begin work on a LAMP for Lake Superior. LAMPs for Lakes Erie and Huron will follow.

Lake Ontario

The LAMP will build upon the existing Lake Ontario Toxics Management Plan. In 1987, EPA, the New York State Department of Environmental Conservation (NYSDEC), and counterpart agencies in Canada (Environment Canada and the Ontario Ministry of the Environment) agreed to develop such a plan. Its first generation was adopted in February 1989. The goal of the Toxics Management Plan is a lake that provides drinking water and fish that are safe for unlimited human consumption and allows natural reproduction of the most sensitive native species, such as bald eagles, ospreys, mink, and otters.

Under the plan, the four agencies have compared concentrations of toxic substances in fish and in the Lake Ontario water column with water quality standards for the protection of fish and human health. No exceedences were found for drinking water standards. However, fish tissue concentrations exceeded human health protection levels for such substances as dioxin, PCBs, chlordane, mirex, mercury, dieldrin, DDT and its metabolites, octachlorostyrene, and hexachlorobenzene. DDT and its metabolites, hexachlorobenzene, and dieldrin were also found in the water column at levels above EPA guidance values for the protection of human health from fish consumption.

The plan uses four elements to eliminate these exceedences. First, it relies on reduction of toxic inputs by regulation of industrial and municipal dischargers. Second, it calls for obtaining further reductions through special focus on the three New York Areas of Concern and two others shared with the Province of Ontario. Third, future reductions will be obtained based on lakewide analyses of pollutant fate to provide grounds for water quality-based regulation. Fourth, the plan calls for zero discharge of toxic substances into Lake Ontario.

During FY 1989, the four agencies completed initial characterization of toxics in Lake Ontario. Differences in chemical-specific standards were identified and commitments made for their resolution. Ontario Ministry of the Environment and Environment Canada committed to work with Health and Welfare Canada to develop Canada's first water quality criteria for the protection of human health from contaminants in fish. During FY 1990, work continued on a model of steady-state exposure and bioaccumulation for toxic chemicals in Lake Ontario, including development of a time-response model of exposure and bioaccumulation of toxic substances. FY 1991 activities will include a comprehensive estimation of loadings from groundwater, air, and sediment to test the bioaccumulation model. Also in 1991, EPA and NYSDEC will start to incorporate pollution prevention measures into their lakewide efforts. Such measures include: targeting the Rochester and Buffalo areas for urban non-point source prevention; targeting facilities that emit any of the priority lakewide pollutants; and implementation of a New York regulation for 50 percent reduction of fugitive air emissions.

During FY 1990, a binational team from EPA, NYSDEC, New York State Department of Health, Fish and Wildlife Service, and counterpart Canadian agencies developed ecosystem objectives for Lake Ontario. The team will develop measurable ecosystem objectives during FY 1991 for nearshore and open-lake water quality (trophic condition), human health, wildlife health, and habitat.

Lake Michigan

During 1991, EPA will work with the States of Illinois, Indiana, Michigan, and Wisconsin to develop a Stage One LAMP for Lake Michigan. This entails identification of critical pollutants, their sources, and the scheduling of reduction measures. The two broad objectives of the Lake Michigan plan are:

- to reduce the release and deposition of pollutants into the ecosystem and to isolate, treat, or remove contaminated sediments to provide: water quality and sediments capable of supporting natural reproduction of the most sensitive native species; and drinking water and fish that are safe for unlimited human and wildlife consumption.
- to eliminate the release or deposition of persistent or bioaccumulative pollutants, whenever possible through pollution prevention measures at pollutant sources.

EPA will model loadings of target pollutants based on evidence of their levels in the water column and in fish and wildlife. The Agency will also join States and other Federal agencies in a review of Great Lakes ecosystem monitoring needs and programs. This will support starting whole-lake sampling for critical Lake Michigan pollutants in FY 1992.

EPA will also invite public participation in the Lake Michigan LAMP. The Agency will notify the public of the proposed Lake Michigan LAMP through the Federal Register and conduct public meetings on the plan.

PHOSPHORUS LOAD REDUCTION PLAN

This section discusses progress under the U.S. Phosphorus Load Reduction Plan. It focuses on and illustrates the adoption of conservation tillage in the Great Lakes watershed, since this practice is a key element of the plan.

By the 1960s, eutrophic conditions in the lower lakes provoked wide public concern. Lake Erie in particular suffered from thick blooms of algae, unpleasant odor and taste in water supplies, and depletion of dissolved oxygen from the water due to the decay of algae following their seasonal die-off. Erie was the first of the lakes to show eutrophic conditions, because it is the shallowest, warmest, and most biologically productive. Its drainage basin contains intense agricultural and urban uses. About one-third of the Great Lakes basin population lives within Erie's watershed, and Erie surpasses other lakes in receipt of effluent from sewage treatment plants.

Loadings of phosphorus were the primary cause of eutrophic conditions. The U.S. and Canada have taken a number of measures over the past 20 years that have reduced phosphorus concentrations to near desired levels. Among these measures have been construction and improvement of municipal wastewater treatment plants and enactment of State laws limiting the content of phosphorus in laundry detergents. EPA and States have estimated that in 1972 phosphorus loadings to Lake Erie from U.S. municipal dischargers amounted to almost 14,000 tons; similar loadings were estimated to be 2,400 tons in 1986. All States now limit the phosphorus content of laundry detergents sold within the Great Lakes watershed to 0.5 percent.

In 1983, the U.S. and Canada agreed to develop and implement "Phosphorus Load Reduction Plans" to reduce phosphorus loadings by 2,000 tons for Lake Erie, 430 tons for Lake Ontario, and 220 tons for Saginaw Bay. These reductions were calculated from an estimate of loadings during 1982. They represented about a 15 percent reduction in total phosphorus loadings to Lake Erie and a 6 percent reduction in Lake Ontario loadings. Under the U.S. Phosphorus Load Reduction Plan, begun in 1986, target open-lake phosphorus concentration levels are 15 micrograms per liter (or parts per billion) in the western basin of Lake Erie and in Saginaw Bay, and 10 micrograms per liter in the deeper waters of Lake Ontario and the central and eastern basins of Lake Erie.

Agricultural runoff is a major source of phosphorus to the Great Lakes. The Phosphorus Load Reduction Plan relies on programs aimed at increasing the practice of conservation tillage, better management of livestock waste, and better management of nutrients used in crop production. Many of these programs are administered by Soil and Water Conservation Districts, with support from the U.S. Department of Agriculture (USDA) and States.

Progress

The U.S. Great Lakes Phosphorus Task Force, including members from EPA, USDA (i.e., Soil Conservation

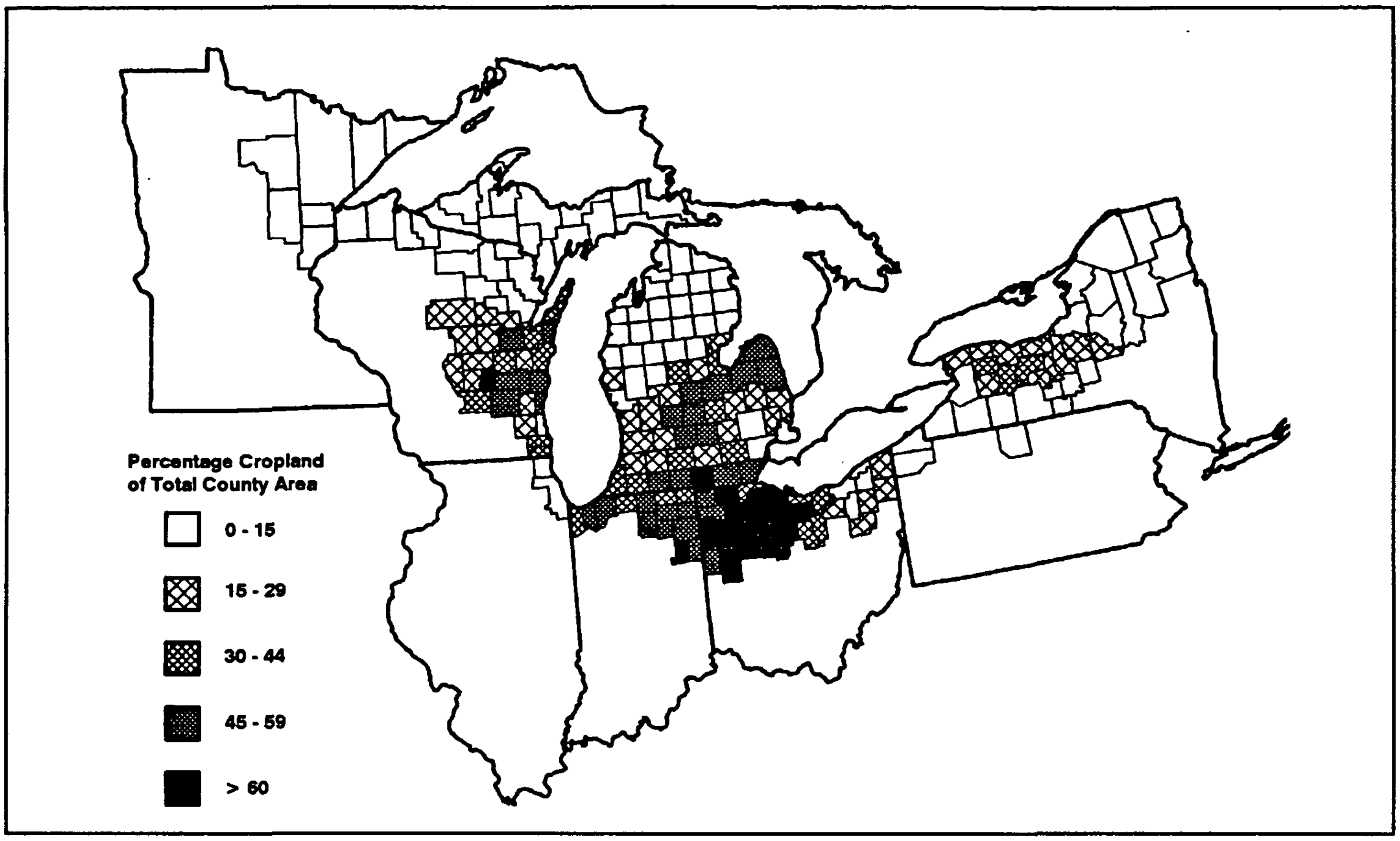


Figure 4-2. Cropland in the Great Lakes Watershed (1988)

Service, Agricultural Stabilization and Conservation Service, and Cooperative Extension Service), and agricultural and environmental agencies in Indiana, Michigan, New York, Ohio, and Pennsylvania, has evaluated plan implementation through 1988. Methods of estimating phosphorus reductions vary by State. In most cases, estimates of agricultural loadings are derived from assessments of conservation tillage adoption, fertilizer and animal waste management practices, and structural improvements (e.g., drainage systems and fertilizer storage facilities). Progress is measured in reductions from estimated 1982 loadings.

New York State has estimated phosphorus load reductions through 1988 represent 46 percent of plan targets for Lake Ontario.

Michigan estimates that it has achieved about 78 percent of its target for Saginaw Bay.

Indiana estimates that it has exceeded its target reduction for Lake Erie.

However, Lake Erie requires substantial further reductions in phosphorus loadings from the agricultural sector in Michigan and Ohio. Ohio estimates that its farmers have reduced phosphorus loadings by 198 metric tons; an additional 1,032 tons in reductions are still sought. Through 1988, only 24 percent of the phosphorus load reduction target for Lake Erie had been collectively achieved by the five States bordering on it.

Yet, States also noted a partially offsetting reduction in phosphorus loadings from municipal wastewater treatment facilities. They estimate that in 1987 municipal dischargers reduced phosphorus discharge to Lake Erie by 502 tons and to Lake Ontario by 216 tons from 1982 levels. These estimated reductions achieve about one half of the reductions sought from the agricultural sector that were not met through 1988.

Conservation Tillage

Conservation tillage entails reduced plowing and leaving crop residue on the surface of fields. In relation to conventional tillage, it reduces soil erosion by water and wind. To meet the Soil Conservation Service's definition of conservation tillage, at least 30 percent residue must remain on the surface after planting to reduce water erosion, or at least 1, 000 pounds of flat small grain residue must be on the surface during the critical period for wind erosion.

There are four main types of conservation tillage practices: no till, mulch till, ridge till, and strip till. These tillage practices differ in degree of soil disturbance. No till is the most effective in preventing erosion, as it entails elimination of mechanical cultivation. The other practices are known collectively as "reduced till." The tillage system selected by a farmer depends on physical circumstances, including soil type, crops, availability of equipment, and upon his/her understanding of the benefits of conservation tillage.

Estimates of farm acreage under conservation tillage are an important basis for evaluating progress under the Phosphorus Reduction Plan. Figures 4-2 and 4-3 illustrate, as of 1988, the distribution of farmlands within the Great Lakes

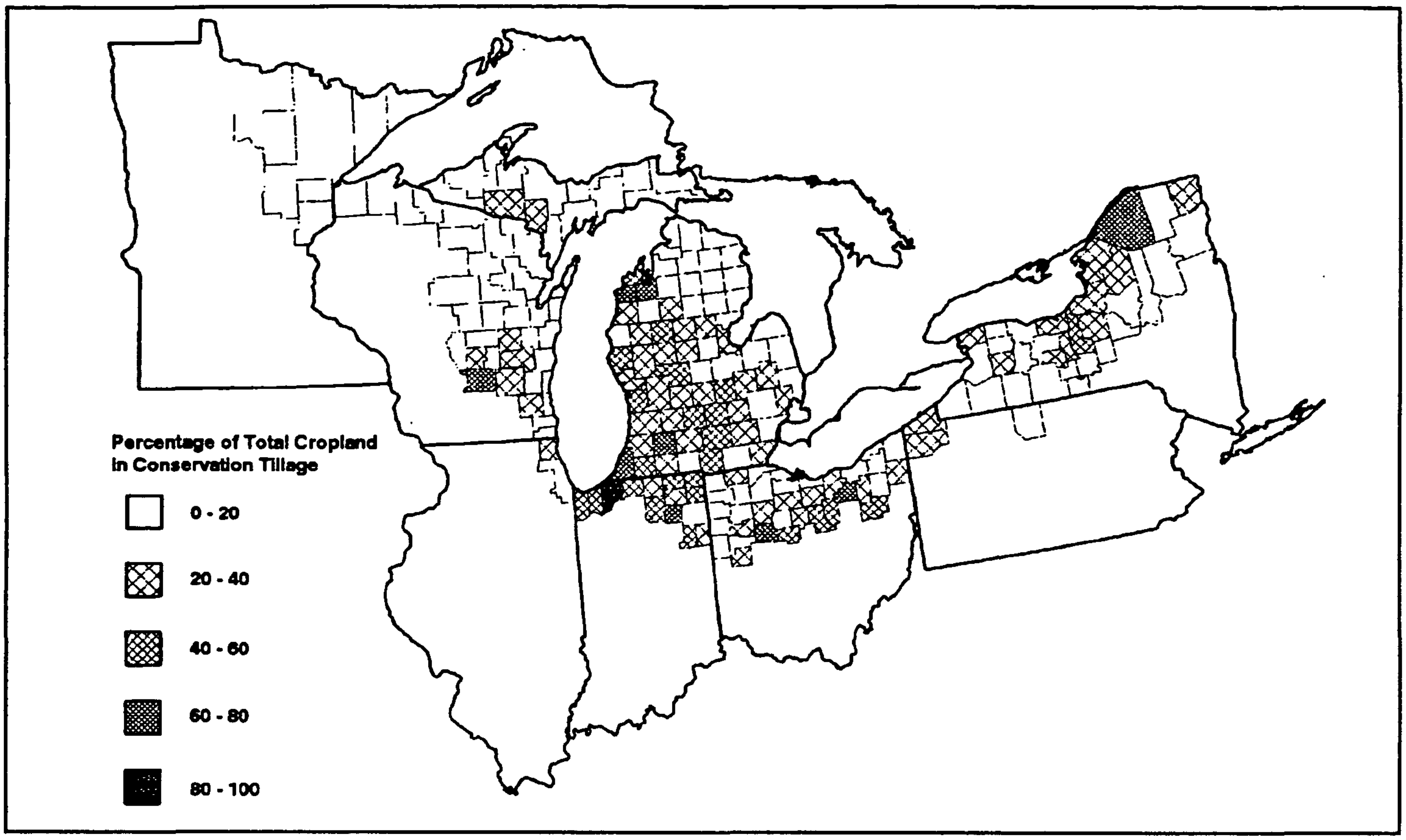


Figure 4-3. Conservation Tillage in the Great Lakes Watershed (1988)

watershed and of the rate of adoption of conservation tillage. These maps use data from the Conservation Technology Information Center (CTIC), part of the National Association of Conservation Districts, located in West Lafayette, Indiana. CTIC compiles agricultural and tillage data provided by the Soil Conservation Service on a county level nationwide.

As may be seen from Figure 4-2, cropland accounts for 18 percent of the total area of counties lying fully or partly within the Great Lakes watershed. Major farming areas are northwest Ohio, west-central Wisconsin, and adjacent to Saginaw River and Bay. Corn is the largest crop (4 percent of farm acres), followed by soybeans (24 percent) and small grains, especially wheat (17 percent). About 30 to 50 percent of the corn and soybean acreage are in a corn/soybean rotation. Major corn-growing areas are located in east-central and south-east Michigan, northwest Ohio, and central Wisconsin.

As shown in Figure 4-3, conventional tillage is much more common than conservation tillage, which is used on 21.6 percent of cropland. Mulch till is the most frequently used method of conservation tillage, accounting for 68 percent of all conservation tillage acres. No till practices are used on 24 percent of conservation tillage acres. Farmers who grow corn use conservation tillage more than those who grow other crops. Conservation tillage is used for about 38 percent of the corn, 21 percent of the soybean, and 16 percent of the small grain crops.

In corn production areas, conservation tillage practices are most prevalent in northwest Indiana, central Wisconsin, and central Michigan. In 1988, LaPorte and Porter Counties in northwest Indiana had the two highest rates of conservation tillage in corn production, averaging 92 percent of acres producing corn. However, the top 11 counties in the Great Lakes watershed having the highest proportion of cropland devoted to corn, all in northwest Ohio, have relatively low rates of conservation tillage, averaging about 23.7 percent in 1988.

Higher rates of conservation tillage have subsequently been reported from 5 Ohio counties participating in USDA's Conservation Action Project (CAP). This program involves farmers, agricultural suppliers, and company representatives in a joint effort to improve water quality by promoting conservation tillage. CAP sponsors field days, seminars, demonstrations, field comparisons, tours, and other educational and information opportunities. In 1990, two CAP counties, Defiance and Fulton, reported an average of 40.5 percent of their corn acreage under conservation tillage.

Varying rates of conservation tillage are partly attributable to differences in soil types. Some soils with clay content limit conservation tillage practices, since the soil becomes too tight to permit drainage, thereby drowning seed or denying sufficient moisture to near surface soil. During the early 1980s, EPA helped to support demonstrations of conservation tillage in part of the Maumee River watershed. One outcome of these studies was to show that high farm yields were obtainable under conservation tillage in certain high clay soils, given sufficient drainage systems. Construction of such systems (e.g., parallel tile outlet terraces) is expensive, however, and the drainage systems require the availability of outlet streams. Although Figure 4-3 does not adjust for soil types, it is useful for displaying the absolute rates of conservation tillage among counties.

Long-Term Prospect

Over the past 20 years, the U.S. and Canada have significantly decreased phosphorus levels where they had been excessive. Partly as a result, the walleye population of Lake Erie has increased, and the numbers of plankton-grazing fish like alewife have diminished. Erie also has a much reduced mass of algae, and the mix between types of algae has improved. In 1989, the rate of depletion of dissolved oxygen in the bottom waters of the central basin of Lake Erie was at a 20-year low, and the duration of the period of oxygen depletion in these waters was shorter than in the mid-1980s.

Scientific models of Lake Erie suggest that restoration of year-round aerobic conditions in the bottom waters of Lake Erie will take up to 5 years beyond the attainment of targeted levels of phosphorus. EPA will continue to survey water quality indicators to monitor the recovery of the lake to assess if further reductions in phosphorus concentrations are warranted.

Phosphorus concentrations in the lakes are significantly affected by both weather and agricultural land use. Lower precipitation and tributary flows during 1985-87 than in prior years contributed to reduced nonpoint loadings of phosphorus to Lake Erie from agriculture. Without improved agricultural land uses as called for under the Phosphorus Load Reduction Plan, Lake Erie phosphorus concentrations may rise again with increased rain storm activity, higher tributary flows, and associated higher loads of phosphorus.

Agricultural practices will continue to be important for Great Lakes water quality, especially around Lake Erie, Saginaw Bay, and Green Bay. In addition to conservation tillage, measures that improve fertilizer management, protect or restore wetlands, pay farmers not to farm highly erodible land, establish vegetative filter-strips along stream and ditch banks, and reduce direct access to streams by livestock help to prevent phosphorus loadings. Better agricultural land use practices offer the most promise for protection of Great Lakes waters that are vulnerable to overenrichment.

Chapter 5

Actions By Federal Partners

This chapter presents FY 1989 and 1990 accomplishments and FY 1991 plans pertaining to the Great Lakes, as reported by 5 Federal agencies: the Army Corps of Engineers, the Coast Guard, the Fish and Wildlife Service, the Great Lakes Environmental Research Laboratory of the National Oceanic and Atmospheric Administration (NOAA), and the Soil Conservation Service.

THE ARMY CORPS OF ENGINEERS

Under the Rivers and Harbors and Flood Control Acts, the Corps maintains navigational channels in authorized harbors and rivers of the Great Lakes, necessitating periodic dredging of bottom sediments. In recent years, the Corps has dredged four million cubic yards of sediments annually from the Great Lakes. Since half of this volume is contaminated and unsuitable for disposal in open-lake waters, the Corps builds confined disposal facilities (CDFs), manmade islands designed to hold and isolate these sediments. There are 38 CDFs, completed or under construction, within the Great Lakes.

The following Corps activities also relate to the Great Lakes:

- Administration of the Federal program under the Clean Water Act that regulates the discharge of dredge or fill materials into U.S. waters, including most wetlands
- Flood control and shoreline erosion projects
- Technical support to EPA and States on Superfund site cleanups
- Technical support to EPA and States in construction of municipal wastewater treatment plants
- Technical support to environmental agencies on Great Lakes Remedial Action Plans (RAPs)
- Technical support to EPA's Assessment and Remediation of Contaminated Sediments (ARCS) program
- Cleanup of hazardous materials at formerly used defense sites, through the Defense Environmental Restoration Program (DERP)
- Participation on various International Joint Commission boards that regulate lake water levels

FY 1989 Accomplishments

- The Corps administered the dredge and fill permit program. Applications were reviewed in cooperation with Federal and State agencies, public comments were reviewed, environmental impacts assessed, and mitigation requirements determined.
- The Corps analyzed bottom sediments at 19 navigational projects in the Great Lakes: Ashtabula, Cleveland, and West Harbors in Ohio; the Saginaw, Rouge, and St. Clair Rivers, Manistique Harbor, Keweenaw Waterway, and Lake St. Clair in Michigan; Buffalo and Olcott Harbors in New York; Chicago River and Waukegan Harbor in Illinois; Erie Harbor in Pennsylvania; Indiana Harbor in Indiana; Milwaukee and Sheboygan Harbors, and Green Bay in Wisconsin; and Duluth/Superior Harbor in Minnesota-Wisconsin. Sediment analyses included physical, chemical, and biological testing. The results of Corps' sediment analyses represent the largest data base of its kind on the Great Lakes. Results have been made available to Federal and State agencies, and have been widely used for Remedial Action Planning (RAP). These analyses are applicable to a wide range of water quality issues, including bench-top investigations of advanced treatment technologies for contaminated sediments at Indiana Harbor, studies of microbiological degradation of polynuclear aromatic hydrocarbons (PAHs) in sediments, and comparative analysis of sediment bioassays.
- Navigational dredging and confined disposal removed nearly two million cubic yards of polluted sediments from the Great Lakes. Navigation projects where polluted sediments were removed and placed in a CDF included the Calumet River and Harbor in Illinois; Cleveland and Toledo Harbors in Ohio; the Rouge and Saginaw Rivers, Monroe Harbor, and Keweenaw Waterway in Michigan; Milwaukee and Green Bay Harbors in Wisconsin; and Duluth/Superior Harbor in Minnesota-Wisconsin.
- A new CDF was completed at Clinton River, Michigan.
- The Corps participated in the development of RAPs for several Areas of Concern, including Ashtabula, Buffalo, Cleveland, Grand Calumet River, and Milwaukee.

FY 1990 Accomplishments

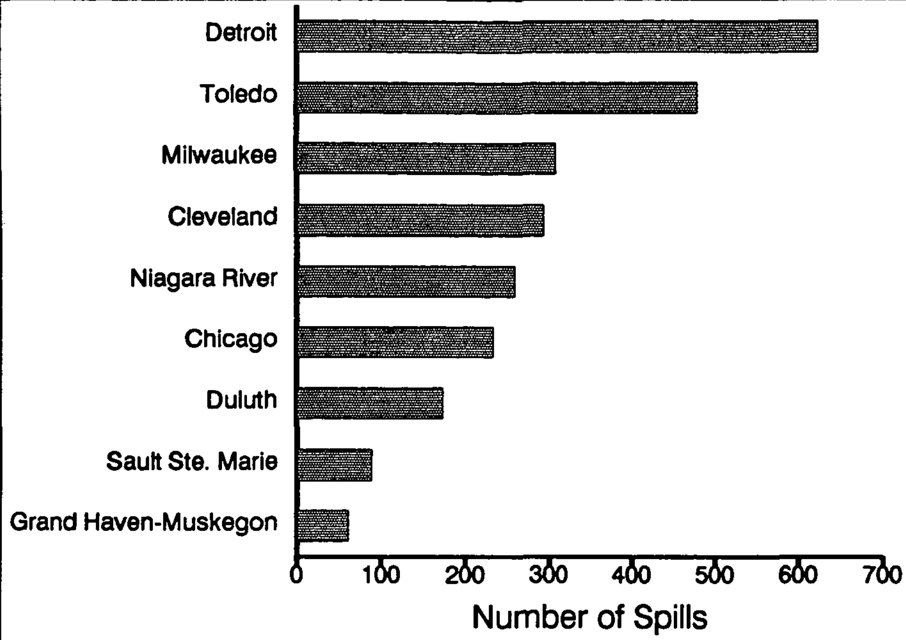
- The Corps continued to administer the dredge and fill permit program. Approximately 6,500 permits were issued and 343 enforcement actions were taken by Corps districts within the Great Lakes watershed.
- The Corps analyzed bottom sediments from 19 Great Lakes navigation projects: Waukegan Harbor in Illinois; Cleveland, Conneaut, and Sandusky Harbors, and Rocky River in Ohio; Grand Traverse Bay, Manistique, and Ontonagon Harbors, and the Saginaw and Black Rivers in Michigan; Ashland, Bayfield, Cor-

nucopia, LaPointe, Manitowoc, and Milwaukee Harbors in Wisconsin; Duluth-Superior Harbor in Minnesota/Wisconsin; Oswego Harbor and Rochester Harbor in New York.

- Navigational dredging removed about 4.1 million cubic yards of bottom sediments. About 2 million cubic yards were determined to be unsuitable for open-water disposal and were placed in CDFs. Dredging projects were conducted in Buffalo Harbor, New York; Cleveland, Huron, Lorain, and Toledo Harbors in Ohio; the Detroit River, Saginaw, and St. Clair Rivers, Keweenaw Waterway, and Holland and Monroe Harbors in Michigan; Duluth-Superior Harbor in Minnesota/Wisconsin; and Green Bay and Milwaukee Harbors in Wisconsin. These projects included CDF operation, maintenance, and water quality monitoring.
- Support was provided to EPA's ARCS program. The Corps provided technical support, bench-scale testing of treatment technologies, development of plans for pilot-scale demonstrations, development of procedures for estimating contaminant losses, development of concept plans for full-scale remediation, and participation in five ARCS work groups.
- The Corps assessed contaminant loss and bioaccumulation in fish at the Saginaw CDF, and polychlorinated biphenyls (PCB) bioaccumulation and volatilization at the Chicago CDF. No biologically significant amounts of PCBs were found to be leaving the Saginaw CDF.
- Construction of the Maumee Bay Shoreline Erosion and Beach Restoration and Reno Beach-Howard Farms Flood control projects were started in Ohio.
- The Corps began a study of sediment and water quality in Onondaga Lake, Syracuse, New York.
- Construction of two major flood damage reduction projects was started. The Chicagoland Underflow Plan is the reservoir portion of Chicago's Tunnel and Reservoir Project (TARP). The TARP will reduce the backflow of stormwater and sewage from Chicago area rivers into Lake Michigan. Construction was also started on the Little Calumet River Flood Protection and Recreation Project in northwest Indiana. This project includes significant wetland mitigation and enhancement and will provide a recreational corridor along the river.
- The Corps removed underground storage tanks and transformers from a site near Sault St. Marie, Michigan under the DERP program. Remedial investigations and feasibility studies are ongoing at this and other sites.
- Water level impacts on wetlands along the St. Marys River were evaluated in support of the IJC Levels of Reference Study.
- The Corps provided technical support to EPA's Superfund project at the Sinclair Oil Site in Wellsville, New York.
- Technical review of a sediment sampling plan was conducted for the Fields Brook Superfund site in Ashtabula, Ohio.
- Technical review of remediation designs was conducted for the Superfund site at Waukegan, Illinois.
- The Corps provided support to Wisconsin in the development of management alternatives for contaminated sediments.
- The Corps studied wetland mitigation, restoration projects, and environmental management of CDFs for the State of Michigan.
- The Corps assisted States in the development and implementation of RAPs at a number of the Areas of Concern of the Great Lakes (e.g., Milwaukee, St. Louis River, and Manistique).
- A study of the movement of dredged material placed in Sandusky Bay, Ohio was started under the Dredging Research Program.

FY 1991 Plans

- The Corps will continue to administer the dredge and fill permit program.
- A EPA/Corps task group on Clean Water Act Section 404(b)(1) implementation will meet to develop guidance on dredged material testing and decision-making.
- Continuing support to the ARCS program, the Corps will demonstrate pilot-scale sediment remediation technologies, and support an EPA project to remove contaminated sediments from the Buffalo River.
- Testing of bottom sediment will be conducted at 21 navigation projects: Arcadia, Au Sable, Caseville, Holland, Lexington, Ludington, Manistee, Manistique, and Port Sanilac Harbors, and the Detroit and St. Clair Rivers in Michigan; Waukegan Harbor in Illinois; Burns Waterway and Michigan City Harbors in Indiana; Dunkirk Harbor in New York; Erie Harbor in Pennsylvania; Fairport, Huron, Port Clinton, and West Harbors in Ohio; and Sheboygan Harbor in Wisconsin.
- Dredging of polluted sediments and confined disposal is planned for the following sites: the Clinton, Detroit, Rouge, and Saginaw Rivers, and Lake St. Clair and Bolles Harbor in Michigan; Buffalo Harbor in New York; Cleveland, Huron, Lorain, and Toledo Harbors in Ohio; Duluth-Superior Harbor in Minnesota/Wisconsin; Green Bay and Manitowoc Harbors in Wisconsin.
- The Corps will construct new CDFs, offloading facilities, or major modifications to existing confined disposal facilities are planned at: Erie Harbor in Pennsylvania; Duluth-Superior Harbor in Minnesota/Wisconsin; Green Bay Harbor and Sturgeon Bay in Wisconsin; St. Joseph Harbor in Michigan; and Toledo Harbor in Ohio. Routine maintenance and water quality monitoring will be performed at other CDFs.



Most spills occur in port areas. According to the Coast Guard, the harbors with the most recorded spills during the 1980s were Detroit, Toledo, and Milwaukee.

Figure 5-1. Great Lakes Harbors with Most Recorded Oil and Chemical Spill, January 1980 - September 1989

- The Corps will start construction of small boat harbors in Buffalo, New York, and in Little Calumet River, Indiana, and continue the Chicagoland Underflow Plan flood damage reduction project.
- The Corps will continue to identify and remediate hazardous wastes at former defense sites. An analysis of a sample of barrels from more than 1400 dumped into Lake Superior more than 30 years ago will be completed.
- Through participation on boards and committees, the Corps will continue to support the IJC.
- The Corps will continue support to EPA and State wastewater treatment plant and Superfund activities.
- The Corps will participate in a Fish and Wildlife Service assessment of the management and restoration needs of Great Lakes fisheries resources.
- The Corps will finish its assistance to Wisconsin in the development of management alternatives for contaminated sediments.
- The Corps will make grants to States for programs aimed at reducing zebra mussels at public facilities.

THE COAST GUARD

Through promulgation of regulations and marine safety and law enforcement inspections, the Coast Guard promotes prevention of pollution from vessels. The Coast Guard is also responsible for responding to spills of oil and hazardous substances into the Great Lakes. As the Federal On-Scene Coordinator for spills from ships, the Coast Guard monitors cleanup activities and conducts the cleanup when responsible parties do not do so effectively. The Coast Guard operates 9 marine safety units on the Great Lakes to perform pollution response and investigation functions. A further Coast Guard activity that is important to the Great Lakes ecosystem is prevention of the introduction of exotic species from ships.

Recent Accomplishments

- In May 1989, the Coast Guard collaborated with the Canadian Coast Guard to establish voluntary guidelines to protect the Great Lakes from further introduction of exotic species through discharge of ship ballast water. Under these guidelines, ships scheduled to enter the Great Lakes system are advised to exchange their ballast water beyond the continental shelf, or if this is not possible, in the Gulf of St. Lawrence. These guidelines were distributed by the International Maritime Organization to its 133 member governments and organizations. The St. Lawrence Seaway Authority is monitoring compliance with the guidelines, and the Canadian Coast Guard plans to evaluate the effectiveness of the guidelines, with assistance from the U.S. Coast Guard as necessary. The Authority reported 85 percent compliance with the guidelines during the 1989 shipping season. Ballast water was not sampled to verify that it had been exchanged.
- In April 1989, the Coast Guard promulgated regulations to implement Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). These regulations prohibit the discharge of garbage into the navigable waters of the United States, and apply to all ships, including recreational boats.
- In May 1990, these regulations were amended to require maintenance of waste management plans and display of MARPOL Annex V placards on all oceangoing vessels greater than 26 feet in length. This amendment is to ensure that all persons on board are aware of garbage pollution laws and to promote proper disposal.
- The Coast Guard continued to verify pollution incidents in the U.S. waters of the Great Lakes. During calendar year 1989, the Coast Guard recorded 262 such incidents. Of these, 13 involved hazardous materials, the remainder involved oil. The Federal

government funded cleanups for 17 incidents.

- The U.S.-Canada Joint Marine Pollution Contingency Plan (JCP) was amended to include provisions for periodic meetings and exercises of the Joint Response Team and On-Scene Coordinator organizations. A binational exercise of the JCP took place at St. Catherine's, Ontario, in February 1989.
- The Coast Guard reviewed all its oil contingency plans, including those for the Great Lakes. In conducting the review, Coast Guard on-scene coordinators considered preparedness to respond to the average, largest, and most complex oil spills that have occurred in their zones. In addition, they considered the most catastrophic potential incidents, given shipping patterns and cargos. The on-scene coordinators have amended their local contingency plans accordingly.

THE FISH AND WILDLIFE SERVICE

The Fish and Wildlife Service maintains fish and wildlife resources and provides access to them for the public. The Service collects and interprets diverse information on fish and wildlife species, populations, and habitats to assist resource managers in making decisions about the protection and restoration of the Great Lakes ecosystem. The Service's activities generally fall into five functional categories: fisheries, refuges and wildlife, law enforcement, fish and wildlife enhancement, and public affairs. Major activities include permit review; land acquisition and habitat management; management of migratory birds, anadromous fish (fish that spend their adult life in the sea but swim up rivers to reproduce) and endangered species; and research. As part of the permit review process, the Service reviews Federal Energy Regulatory Commission hydroelectric projects, Army Corps of Engineers dredge and fill permits, Farm Bill habitat easements, and wetland restorations. The Service's research activities address both needs of the Service and, when feasible, the needs of other Federal agencies, Indian tribes, State agencies, and international groups, such as the IJC and the Great Lakes Fisheries Commission.

The Service manages the National Fishery Center-Great Lakes; five National Fish Hatcheries that support Great Lakes lake trout restoration efforts; and six National Wildlife Refuges within the Great Lakes watershed – Iroquois and Montezuma in New York, Erie in Pennsylvania, Ottawa in Ohio, and Seney and Shiawassee in Michigan. In addition, the Service conducts surveys of wetlands to support the National Wetlands Inventory Program.

Some recent accomplishments and FY 1991 plans are provided below by functional area.

Fisheries

FY 1989 Accomplishments

- The Service stocked the Great Lakes with about 6.4 million lake trout. This native species serves as a valuable biological indicator of water quality, because of its need for clean water and long life span.
- An offshore stocking vessel (the M/V *Togue*) was used to stock fish over traditional offshore spawning reefs to enhance fish survival.
- The Service continued monitoring bloater chubs from Lake Michigan. The National Fisheries Research Center-Great Lakes has analyzed Lake Michigan bloater chubs for DDT congeners and dieldrin since 1969 and added analysis for PCBs in 1972 and for chlordane in 1982.
- As part of its sea lamprey control program, the Service applied lampricides to 31 Great Lakes tributaries. Parasitic and spawning adult populations, larval populations, and non-target organism populations were also evaluated. Operational fishery research was conducted on alternate control techniques, registration of lampricides, and special problems encountered by field crews.
- Fishery assistance biologists continued to study exotic aquatic organisms that appear in the Great Lakes.

FY 1990 Accomplishments

- The Service stocked the Great Lakes with 3.4 million lake trout. More than 2 million were stocked by ship over traditional off-shore spawning reefs to increase their survival rate. Also, more than 300 thousand were stocked by airplane.
- The Service applied lampricides to 28 Great Lakes tributaries.
- The Service developed an interactive computer program ("expert system") that uses the structure of an organic molecule to predict acute toxicity to aquatic life. The system is being used to estimate toxicity of chemicals before starting bioassays.

FY 1991 Plans

- The Service will implement the Great Lakes Fish and Wildlife Restoration Act of 1990, signed into law in November, that calls for the Service to conduct a comprehensive fishery resources study through FY 1994.
- The Service will continue the lake trout stocking program.
- The Service will apply lampricides to 39 Great Lakes tributaries.
- The Service will continue monitoring bloater chubs from Lake Michigan. In addition, archived fish samples will be analyzed by PCB and chlordane congeners to see historical trends in these contaminants by congener.
- The Service will increase activities with State and Tribal cooperators to assess Great Lakes fish populations.

Refuges and Wildlife

FY 1989 Accomplishments

- The Service increased wetland acreage in the Montezuma National Wildlife Refuge as part of the North American Waterfowl Management Plan, a cooperative effort between the Service and the Forest Service to preserve waterfowl habitats.
- Under the Waterfowl Management Plan, the Service conducted a waterfowl breeding survey and developed a

plan for Fort Drum, New York, that has 12,000 acres of wetlands.

- The Service funded 3 studies that assessed the impacts of contaminants on Great Lakes wildlife. The first study, on St. Lawrence River contaminants, analyzed water and bird eggs for levels of PAHs. The others studied contaminants in two bird species: the double-crested cormorant and black-crowned night heron.
- Samples of water, sediment, and biota were collected in 5 national refuges for analysis of chemical contamination.
- Substantial pump, levee, and dike restorations were made at the Ottawa and Shiawassee Refuges to repair flood damage.

FY 1990 Accomplishments

- The staff of 2 refuges supported wetland restorations through cooperative agreements with landowners. A total of 971 acres of wetlands were restored, including 109 acres in counties adjacent to Lake Erie.
- The Service began a preliminary study to identify lands within 10 miles of Lake Erie that have potential for wildlife habitat and public recreation, and that have unique natural, historic, or scenic features.
- The Service continued to assist the Ohio Department of Natural Resources (ODNR) in monitoring reproductive success of bald eagles nesting near Lake Erie. Over the previous 8 years, active nests have risen from 2 to 16.
- The Service continued to support a survey of colonial waterbirds of the Great Lakes. This 3-year study, begun in 1989, will indicate where the Service should direct future management activities.
- The Service began a study of the physioecology of black ducks in Ohio's Lake Erie marshes. This study should provide information on black duck habitat use, movements, and temporal survival in this critical migration area.

FY 1991 Plans

- In cooperation with Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin, the Service will begin to implement the Upper Mississippi River and Great Lakes Region Joint Venture.
- The Service will continue reintroducing common terns at Ottawa Refuge.
- The Service will continue funding the restoration of wetlands on private lands through challenge grants to landowners.
- The Service will continue to monitor black ducks on Lake Erie and bald eagles.
- The Service will complete its preliminary Lake Erie shoreline study.

Fish and Wildlifé Enhancement

FY 1989 Accomplishments

- The Service participated in the IJC's water levels study that evaluated wetland changes and resulting ecosystem effects during low and high water-level years from 1979 to 1988. The Service examined Kakagon Slough, Wisconsin, on Lake Superior; Cecil Bay Marsh, Michigan, on Lake Michigan; Fish Point, Michigan, on Lake Huron; Dickinson Island, Michigan, on Lake St. Clair; and the St. Lawrence River, Sage Creek, and Campbell marshes, New York.
- Working with EPA, the Service began to develop water quality criteria for wildlife as part of the Great Lakes Water Quality Initiative.
- The Service prepared natural resource damage surveys for two Superfund sites (General Motors Central Foundry located along the St. Lawrence River and Hooker Chemical along the Niagara River) and reviewed a report concerning tumors in fish at the 102nd Street site on the Niagara River.
- To support EPA's ARCS program, the Service conducted surveys of fish (bullheads) and sediments in Saginaw, Grand Calumet, and Buffalo River for tumors and abnormalities. The sediment collected will be used to study bioaccumulation of chemicals in fish collected at these three locations.
- In New York, the Service participated in the licensing effort for 23 hydroelectric projects, recommending changes in operation or shutdown of 3 projects and minimum flow requirements at 6 plants because the projects were causing adverse effects on fish populations. Approximately 26 projects were reviewed by the East Lansing Field Office.
- Also in New York, the Service reviewed about 300 dredge and fill permits, requesting modifications to approximately 100 projects to reduce habitat impacts and recommending denial of 10 projects due to unacceptable impacts.
- Under its Farm Bill activities, in New York the Service obtained easements on about 700 acres of wildlife habitat, transfers of approximately 500 acres of wetlands, and a wetland restoration project on a former farm. In the East Lansing Office, conservation easements were staked for 36 proposals. Twenty-one restorations under the Conservation Reserve Program were inspected – all are filled with water, and wildlife have been observed on most.
- Endangered species consultations were conducted under Section 7 of the Endangered Species Act on about 30 projects in New York.
- The Service began an effort with the Forest Service to reduce beaver pond destruction and to develop small forest ponds to improve black duck breeding habitat.
- The Service supported the development and review of RAPs for the Sheboygan, Marinette, Milwaukee, Oswego, Niagara, and St. Lawrence Rivers, Duluth-Superior Harbor, and Saginaw Bay.

FY 1990 Accomplishments

- The Service reviewed bald eagle population and productivity data as a review of the species' endangered status.
- In cooperation with States and duck hunter organizations, the Service continued efforts to restore beds of wild celery along the Great Lakes. Wild celery provides foraging opportunities for fish and the vegetation is eaten by waterfowl. In the spring of 1988, celery was planted at 2 locations in the lower Detroit River. While the celery failed at one site, about 5,000 plants took hold at the other. This work indicates that restoration of wild celery in the lower Detroit River is possible under proper conditions.
- The Service completed a recovery plan for the lakeside daisy, found only in Ottawa and Erie counties, Ohio, and in Ontario.
- The Service continued involvement in Federal Energy Regulatory Commission hydroelectric projects, Clean Water Act dredge and fill permits, Farm Bill habitat easements and wetland restorations, EPA's ARCS program, and EPA's initiative to develop water quality criteria for wildlife. In New York, the Service participated in the licensing effort for 12 hydroelectric projects, and reported about 30 dredge and fill permit violations to the Corps.
- The Service worked with EPA on a wetlands inventory in the Green Bay watershed. This will be available to planning and regulatory agencies to assist them in decisions on permit issuance, zoning, etc.
- The Service continued a pre-assessment of natural resource damages for Waukegan Harbor, Illinois. The Service began a natural resources damage assessment for Saginaw Bay.
- The Service continued to work with ODNR, Ohio EPA, EPA, and the Army Corps of Engineers on the proposed siting of a CDF for Toledo Harbor dredged materials. The proposed CDF would occupy 176 acres of productive shallow water habitat in Maumee Bay.
- The Service studied gulls and bald eagles around the Torch Lake, Michigan, Area of Concern to determine if the high copper level in the lake was hurting their reproductive success. Initial indications were that the productivity of the species was normal. A companion study looked at yellow perch reproduction in Torch Lake, finding impaired hatchability of perch eggs.
- The Service continued to support Remedial Action Planning for the Cuyahoga, Grand Calumet, Menominee, and Maumee Rivers, and Milwaukee Harbor.

FY 1991 Plans

- The Service will complete recovery plans for Houghton's goldenrod and Pitcher's thistle. Both exclusively inhabit the Great Lakes watershed, primarily in sand dunes and beaches. The Service also will complete a revision to the Eastern Timber Wolf Recovery Plan that addressees wolf populations in Minnesota, northern Wisconsin, and the upper peninsula of Michigan.
- The Service plans to propose the Lake Erie water snake for threatened status and Hungerford's crawling water beetle for endangered status. The snake is found only on several Ohio and Ontario islands, while the beetle is found in only 2 Michigan sites and 1 in Ontario.
- The Service will support the advanced identification of important wetland resources in northwest Ohio (Erie, Lucas, Ottawa, and Sandusky counties) that are unsuitable for the discharge of dredged or filled materials. This is a joint activity with EPA, OEPA, Ohio DNR, and the Army Corps of Engineers. The Service will also continue to support a similar advanced identification of wetlands near Green Bay.
- The Service will continue its support to Remedial Action Planning.
- The Service will begin a natural resource damage assessment for the Indiana Harbor and Grand Calumet River Area of Concern.

Public Affairs

FY 1991 Plans

The Service will develop a volunteer wetland watch program. In addition, the Service will start a public information program to inform the agricultural community and the general public about the fish and wildlife benefits to be derived from the Farm Bill.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

The Laboratory conducts research on Great Lakes ecosystem dynamics and physical processes, conducting integrated, interdisciplinary research in support of resource management and environmental services in coastal and estuarine waters, with special emphasis on the Great Lakes. This program includes both basic and applied studies and combines experimental, theoretical, and empirical approaches. Field, analytical, and laboratory investigations are performed to improve understanding and prediction of environmental interdependencies between atmosphere, land, water, and sediments. The Laboratory emphasizes a systems approach to environmental problems and the development of environmental service tools to assist resource managers and others in the application of scientific findings to specific resource management problems. The Laboratory's work is discussed below under the topics: persistent toxic substances, ecological processes, and benthic populations.

Persistent Toxic Substances

The Laboratory works with EPA, the Fish and Wildlife Service, and various Canadian agencies to improve understanding of the processes that control the distribution, cycling, and fate of organic contaminants, their toxicology, and the kinetics of transfer. A major focus is the association of toxic organics with suspended and deposited sediments. The adsorption of organic contaminants onto sediment particles, followed by settling and eventual burial, commonly controls the residence time and concentration of these compounds in the water column. Understanding the interactions between different types of suspended matter and dissolved organic contaminants is critical to modeling the behavior of such contaminants in the environment. Resuspension of bottom sediments in the Great Lakes is a primary process that introduces nutrients and contaminants into the water. Direct exchanges between bottom sediments and overlying water are also important processes, but are poorly understood.

The Laboratory uses radiotracers to identify and model sediment transport processes because of their relative ease of measurement and dating. These measurements are used to discriminate between resuspended and fresh materials and to study horizontal sediment transport and the movement of sediments into ultimate depositional zones, the seasonal resuspension of sediments, and geochemical changes to sediments over time.

The Laboratory has collected and analyzed sediment cores from all of the Great Lakes during the past 15 years and has deployed sediment traps to obtain samples of suspended sediments from the water column. Sediment traps have been deployed for 10 years, primarily in Lake Michigan and to a lesser extent in Lakes Superior and Huron.

Extensive resuspension of sediments has been found in all three lakes, especially during winter months. Data are being integrated with data obtained by Canada in Lakes Erie and Ontario that will permit a comprehensive view of Great Lakes sediment resuspension.

The Laboratory's various sediment projects provide understanding that can be applied in the development of mass balance models and Remedial Action and Lakewide Management Planning. Better understanding of the physics, toxicology, and availability of Great Lakes sediments can be used to help define the assimilative capacity of the lakes for certain pollutants, the hazards that the reservoir of contaminated sediments pose to aquatic life, and the effects of alternative ways of dealing with sediments. The effects of possible contaminated sediment remediation measures are poorly understood and are one of the fundamental unresolved issues to long-term restoration of the Great Lakes.

FY 1989 Accomplishments

During FY 1989, some of the Laboratory's projects in the area of toxic organics focused on:

- The sediment resuspension process, using radiotracers to identify fundamental sediment transport processes.
- The physics of the bottom 25 meters of the Lake Michigan water column, with focus on bottom currents and resuspension of sediments.
- The toxicology and bioavailability of contaminated Great Lakes sediments.
- A 28-day mortality bioassay using a benthic organism to assess the presence of toxic organic compounds.
- Testing of a gamma scan system to measure the porosity of sediments in a nondestructive manner.
- The development of tolerances to toxic substances by exposing benthic worms collected from offshore sites in Lake Michigan near Grand Haven and Benton Harbor to sediments collected from these two sites. The Benton Harbor sediments were toxic to the organisms from Grand Haven, whereas the same type of organisms from Benton Harbor were unaffected by Grand Haven sediments. These results indicated, but seldom demonstrated, that organisms collected off Benton Harbor have developed tolerance to the generally higher concentrations of contaminants found in their habitat.

In addition, the Laboratory conducted three projects that contribute to the major interagency study of Green Bay, each of which was partially funded by EPA's Great Lakes National Program Office. These projects focused on:

- Water volume movement through the bay and between the bay and Lake Michigan
- The food web of fish in Green Bay to increase understanding of the relative importance of the various food and water pathways of PCB accumulation by fish
- The relationship between current velocity and sediment resuspension in Green Bay.

FY 1990 Accomplishments

- The Laboratory completed the initial examinations of major variables that could affect the bioavailability of sediment associated toxicants to the food chain.
- The Laboratory measured the water volume exchange between the upper and lower parts of Green Bay.
- The Laboratory quantified the seasonal flux of resuspended sediments and estimated particulate and POC settling velocities within Green Bay.

FY 1991 Plans

During FY 1991, the Laboratory plans to analyze trap samples for organic carbon and PCBs; develop empirical sediment resuspension models for Green Bay; and complete projects in support of EPA's Green Bay Study.

Ecological Processes

In addition to physical processes, the Laboratory research focuses on ecological processes and mechanisms. In general, knowledge of many ecosystem processes is at an early stage. Food web processes have a dominant influence on the transfer of energy and contaminants throughout the ecosystem, yet predictive and simulation models of these processes are rudimentary. The Laboratory conducts research on both pelagic (i.e., water column) and benthic ecosystem dynamics to advance understanding of the flow of materials and energy within the food web.

FY 1989 Accomplishments

- A project on the effects of contaminants on the fisheries and water quality of Lake St. Clair. Lake St. Clair food web models indicate that the benthic food chain is twice as important to fish productivity as the pelagic grazing food chain and that four times more carbon is available for aquatic food chains from external particulate sources as from aquatic vegetation and algae.

- A study of the interactions between phosphorus, phytoplankton, and bacteria in Lake Michigan to help develop a better understanding of the seasonal succession of algae.
- A project that studied the feeding dynamics of zooplankton to better understand the seasonal succession of plankton.
- A project addressing benthic ecology and sediment nutrient/energy transformations. Benthic invertebrates feed on material settled from the water column and are in turn consumed by most species of Great Lakes fish.

FY 1990 Accomplishments

- Analysis of two non-indigenous species to the Great Lakes ecosystem: the zebra mussel and the spiny water flea
- A study of phytoplankton, zooplankton, and benthic populations in Saginaw Bay to determine the impact of the zebra mussel on the lower food web
- A study of the seasonal oxygen consumption and nitrogen (ammonia) excretion of zebra mussels collected from Lake St. Clair
- A study, using aquaria and fish-holding tanks, to demonstrate the development of aversion conditioning in perch to attacking the spiny water flea
- Initial analysis of the results of in situ feeding experiments performed during the past 2 years on the selectivity and predation rates of the spiny water flea on zooplankton in Great Lakes, and determination of the effect of the spiny water flea on the food web structure
- Initial observations of ecosystem components to demonstrate the variability in time and space and to improve predictions of food web dynamics that support the Great Lakes salmonid fishery.

FY 1991 Plans

During FY 1991, the Laboratory will continue many studies started in FY 1990, including the identification of causes of ecosystem variability and continued seasonal research on oxygen consumption, nitrogen excretion, and lipid content in zebra mussels of Lake St. Clair and Saginaw Bay. New projects will include examination of toxicokinetics and bioaccumulation analysis of organic contaminants in the zebra mussel and examination of nutrient changes in zebra mussels and the development of eutrophication models.

Benthic Populations

A third area of research by the Laboratory is long-term trends in benthic populations and the relation of these to water quality. Benthic communities are excellent indicators of trophic trends in the Great Lakes. Because of their limited mobility and relatively long life (compared to plankton), benthic fauna form stable communities that reflect the effects of environmental conditions over long periods of time.

FY 1990 Accomplishments

- Identified benthic organisms collected from Saginaw Bay during 1989. Identification of the organisms collected showed a two-fold increase in pollution-tolerant worms since the early 1970s that may be evidence of a degraded habitat since that time.
- Collected additional benthic samples from inside and outside fish enclosures placed in Lake Superior during FY 1986.
- Completed a study of long-term trends in mussel abundance over the past three decades in western Lake Erie.
- Assembled and began to use of a personal computer-based microscope/digitizer system that allows for rapid and reliable completion of body length measurements needed to estimate the energy budget in Great Lakes amphipods.

FY 1991 Plans

During FY 1991, the Laboratory will study whether nutrient sufficient cells are preferred as food by copepods over nutrient deficient cells at high algae concentrations. In addition, the Laboratory plans to observe feeding mechanisms of tethered copepods to make generalizations about appendage use patterns and sensory clues.

THE SOIL CONSERVATION SERVICE

The Soil Conservation Service of the Department of Agriculture (USDA) provides technical and financial assistance to land users, including farmers, ranchers, and foresters, and to other government agencies on a variety of natural resource issues. The Service contributes to conserving the Nation's soil, water, plant, and animal resources by informing land users of best management practices and resource management systems that control erosion, protect the quality of surface water, and reduce the contamination of groundwater by agricultural chemicals.

Through its nationwide network of conservation specialists, the Service provides assistance on topics such as pesticide and nutrient management, reduced tillage practices, fish and wildlife habitat development, soil mapping and interpretation, and watershed protection. It also conducts natural resource inventories and maintains extensive data on soil erosion, land use and cover, conservation practices, and land treatment needs. To assist land users in protecting natural resources, the USDA (through the Agricultural Stabilization and Conservation Service) also administers cost-sharing programs to pay land users for following certain conservation practices, protecting wetlands, and improving water quality. The Service is working with States in their development of Nonpoint Source Management Plans pursuant to Section 319 of the Clean Water Act.

The Service is participating in 10 major USDA projects that are currently underway or planned in the Great Lakes watershed. Five of these projects are

Water Quality Special Projects (WQSP): Cattaraugus Creek, New York; LaGrange County Lake Enhancement Program, Indiana; Vermillion River and the West Branch of the Black River, Ohio; and the Clam River, Michigan. These projects seek to cut agricultural loadings of nutrients (phosphorus and nitrogen) and of sediments to surface waters.

USDA is also conducting two demonstration projects in the Basin. The East River Watershed project in Wisconsin, which affects the Green Bay Area of Concern, seeks to demonstrate crop management systems that reduce the quantities of nitrogen, phosphorus, and pesticides required to produce acceptable crop yields. The goals of the project are to prevent excessive loadings to surface water and groundwater and enhance farm incomes. The 10-year, $50 million project will provide landowners up to 70 percent cost-sharing for installing land management improvements. The Saginaw Bay project in Michigan will not only focus on nutrients and sediment, but will also seek to implement Integrated Pest Management practices to prevent groundwater contamination.

In the Saline Valley Rural Clean Water Project, the emphasis is on reducing the amount of phosphorus entering Lake Erie from southeastern Michigan. Final evaluation of the project, including an analysis of practices to reduce phosphorus in runoff, is underway. A hydrologic unit project related to Sycamore Creek,Michigan, is using fertilizer, pesticide, and crop management techniques to reduce agricultural pesticides and sediment from entering surface waters. Another hydrologic unit project, in the Wolf Creek watershed, is working to protect Lake Adrian from sediment, phosphorus, and pesticides.

FY 1989 Accomplishments

In FY 1989, the Service contributed to the RAP development process in Ohio (Maumee and Cuyahoga Rivers), Minnesota (St. Louis River), Wisconsin (Menominee River and Green Bay), New York (Rochester Embayment, Oswego River, St. Lawrence River, and Buffalo River), and Michigan (multiple sites). The Service assigned one staff person to EPA's Great Lakes National Program Office and another to the IJC's Regional Office in Canada to work on Great Lakes environmental issues. Service personnel also evaluated progress under the Great Lakes Phosphorus Load Reduction Plan. Additional Service accomplishments included:

- Completed transect tillage surveys in the Saginaw Bay and Lake Erie watersheds
- Developed conservation plans for 250,000 acres of highly erodible lands in Wisconsin
- Designed and installed 68 animal waste management systems in Wisconsin
- Completed the first phase of a direct drainage study of Lake Ontario
- Completed inventories of Indiana wetlands within the Great Lakes basin and in 13 Michigan counties
- Completed a stream bank erosion survey for the Au Sable River, Michigan
- Contributed to a Saginaw Bay drainage project to assess the effects of crop production on surface water and groundwater
- Participated in the Lost Creek Experimental Watershed Project in Ohio with Defiance Soil and Water Conservation District and Heidelberg College, that assessed the movement of pesticides, nutrients, and sediments
- Worked with Ottawa County, Ohio, to measure effects of tillage practices on water quality.

FY 1990 Accomplishments

During FY 1990, the Service continued to emphasize water quality benefits in all program delivery elements. All initiatives begun in FY 1989 continued into FY 1990. The Service assigned one staff person to the Michigan Department of Natural Resources for two years to assist in the prioritization of nonpoint source pollution impacted watersheds. Significant accomplishments include the development of standards and specifications for nutrient and pest management, and revision of the standard and specification for waste utilization. Additional Service accomplishments included:

- Completed wetland inventories in five Michigan counties;
- Started a new river basin study for the Menominee River Basin in the Western Upper Peninsula of Michigan and Northeastern Wisconsin
- Started a streambank erosion inventory on the Rifle River in north-central Michigan
- Started implementation of the South Branch Kawkawlin River Watershed Work Plan
- Prepared a watershed work plan for Mud Creek in Barry County, a highly intensified agricultural area with identified sediment and nutrient loadings
- Participated in the preparation and implementation of four non-point source watershed demonstration projects.

FY 1991 Plans

The Service will continue to participate in the 10 major USDA projects in the Great Lakes watershed. It will also increasingly emphasize Integrated Crop Management in all its programs to reduce agricultural use of nutrients and pesticides to improve water quality.

Chapter 6

Great Lakes Science

This chapter discusses U.S. surveillance of the Great Lakes system, including three EPA initiatives on persistent toxic substances:

- Establishment of a binational Integrated Atmospheric Deposition Network (IADN) that will monitor airborne deposition of trace organics on a routine basis
- A multiagency study of the sources and fates of several persistent toxic substances in Green Bay
- Conversion and outfitting of a new ship to establish a capability to monitor trace organics in open-lake waters on a routine basis.

The chapter also discusses accomplishments and plans relating to system-wide surveillance programs, including chemical and biological open-lake limnology, fish monitoring programs, and the Great Lakes Atmospheric Deposition (GLAD) network.

Background

There are three primary elements to the Great Lakes National Program Office's surveillance efforts: open-lake surveys of ambient water quality, monitoring of toxicant levels in fish tissues, and monitoring of atmospheric deposition. The Program Office has conducted open-lake spring and summer surveys of ambient water quality in Lakes Michigan, Huron, and Erie since 1983, and in Lake Ontario since 1986. Prior to these routine surveys, each of the lakes was surveyed intensively in turn. EPA does not survey Superior annually because it does not exhibit eutrophic conditions and its great volume precludes rapid changes in its conditions. The current program includes nutrients (phosphorus, nitrogen, silica), conservative ions, alkalinity (alkali and alkaline earth metals), biological structure (phytoplankton and zooplankton), chlorophyll a, and physical parameters. Surveys measure conditions and trends in the open-waters of the lakes. These waters best indicate long-term trends, because they are less influenced by local discharges of pollutants than shallower, nearshore waters. The productivity measures obtained under the open-lake program enable EPA to assess the response of the lakes to nutrient control measures and trends in plankton populations.

Since 1977, the Program Office, State, and other Federal agencies have monitored toxic organics in the Great Lakes through analyses of chemical residues in fish tissues. Fish are excellent indicators of water quality and ecosystem health because they tend to accumulate many persistent toxic substances, whereas open-water concentrations of toxic organics are generally so low that it is difficult to monitor them directly on a routine basis.

With lake-to-lake variations in the number of collection sites and periodicity, States collect adult resident fish and spot-tail shiners from harbors and tributaries on a 5-to-10-year cycle and open-lake salmon as part of a game fish-monitoring program. The Food and Drug Administration provides analysis of the fish samples. The Fish and Wildlife Service also collects open-lake whole-fish samples of lake trout (walleye on Lake Erie) and smelt on a biennial basis for analysis by EPA. The Service has also analyzed Lake Michigan bloater chubs for DDT and dieldrin since 1968, for PCBs since 1972, and for chlordane since 1982. States conduct additional fish-monitoring programs that are directed towards protecting human health by issuance of fish consumption health advisories.

The third primary element of the Program Office's surveillance activities, also a joint Federal/State endeavor, is monitoring of atmospheric deposition. The United States operates a 20 station Great Lakes Atmospheric Deposition (GLAD) network. GLAD presently addresses nutrients and metals, including lead, cadmium, nitrate/nitrite, and phosphorus, among about 35 parameters.

In addition, States and the U.S. Geological Survey monitor Great Lakes tributaries for pollutants on an ongoing basis, since tributaries are major conveyors of pollutants from both nonpoint and point sources.

INTEGRATED ATMOSPHERIC DEPOSITION NETWORK

Since the late 1970s, the Great Lakes scientific community has been aware of the potential significance of the atmosphere as a pollution pathway. Studies of Isle Royale, a relatively isolated island in Lake Superior, revealed levels of PCBs, toxaphene, and other persistent toxic substances in its lakes. Researchers theorized that such pollutants could only have been the result of deposition from the air.

Since the Isle Royale findings, the Program Office has promoted ways of assessing the absolute and relative magnitude of atmospheric loadings of toxic substances. The Program Office supported conferences in 1980, 1986, and 1987 to assess the state of knowledge of the airborne deposition problem, and developed a strategy in 1987 to monitor these substances. In recognition of the potential importance of air deposition to the Great Lakes, the United States and Canada agreed in 1987 to establish an Integrated Atmospheric Deposition Network (IADN) to monitor both wet and dry atmospheric loadings of toxic substances to the Great Lakes.

It should be noted that the concentrations of toxic organics in precipitation are very minute and, therefore, difficult to collect and analyze. Scientists are developing methods to do this routinely, and it is likely that the feasibility of monitoring atmospheric deposition will differ from parameter to parameter. The Program Office implemented its first master station and two satellite stations for monitoring airborne PCBs and dieldrin in fall 1988. These are located around Green Bay. The two nations plan to build on the experience gained from the Green Bay master station and an initial Canadian site on Lake Ontario in order to design a basin-wide network.

During FYs 1989 and 1990, the United States and Canada coordinated various management, parameter, siting, and methods issues pertaining to establishment of a network to monitor atmospheric deposition of persistent toxic substances. During FYs 1991-1992, the two nations will establish one IADN master station on each of the Great Lakes. The United States will establish master stations on Lake Superior, Lake Erie, and Lake Michigan, while Canada will establish one on Lake Huron to complement the station already on Lake Ontario. Data will be shared by each nation, and the United States will be able to co-locate equipment at the Ontario site. Also in FY 1992, the Program Office will begin to establish six satellite stations, one on each international lake and two on Lake Michigan, while Canada will begin to establish five satellite stations. In FY 1994, based on data obtained to that point, the two nations will consider the need for establishing up to 11 additional satellite stations.

GREEN BAY STUDY

This special study, begun in FY 1987 and to continue through FY 1991, will help EPA develop an understanding of the sources, pathways, and fates of certain pollutants (i.e., cadmium, lead, PCBs, and the pesticide dieldrin) within a large waterbody.

One objective of the Green Bay study is to determine the feasibility of a "mass balance" analysis on one of the Great Lakes. Therefore, the Green Bay study is an important precursor to the surveillance aspects of Lakewide Management Plans. The Wisconsin Department of Natural Resources and EPA's Great Lakes National Program Office are the major sponsors of the study, with aspects supported by EPA's Environmental Research Laboratory-Duluth, Minnesota, and its Large Lakes Research Station at Grosse Ile, Michigan; the Great Lakes

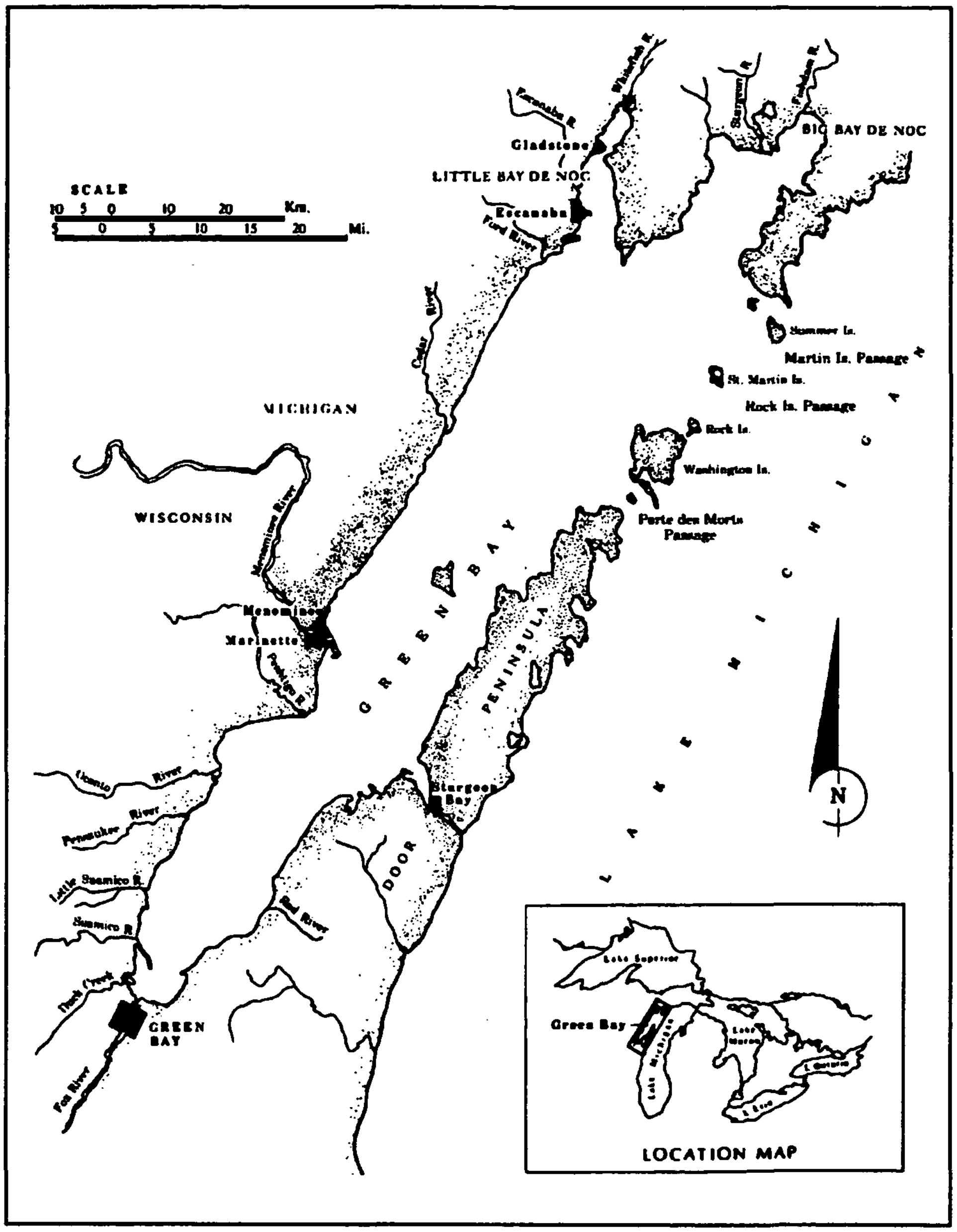


Figure 6-1. Green Bay/Fox River Study Area

Environmental Research Laboratory and Wisconsin Sea Grant of the National Oceanic and Atmospheric Administration; the U.S. Geological Survey; the Michigan Department of Natural Resources; the U.S. Coast Guard; the Illinois State Water Survey; and a number of universities.

Numerous Green Bay Study activities were undertaken during FYs 1989 and 1990. EPA's research vessel, the *Roger Simons*, conducted a field sampling shakedown cruise on Green Bay in October 1988 and conducted five sampling cruises in May, June, July, September, and October 1989. A winter survey was conducted from a U.S. Coast Guard helicopter in February 1989. Another winter survey and a spring survey were conducted in FY 1990. In cooperation with the Wisconsin Department of Natural Resources and the U.S. Geological Survey, tributary monitoring was performed on all important tributaries to Green Bay. Wisconsin also collected fish samples. A master and two routine monitoring stations collected air deposition samples. Other studies underway include water/land/air vapor flux of contaminants, groundwater loadings, and sediment contamination.

The study has refined laboratory methods for handling a large number of samples that must be analyzed for trace organics (i.e., PCB and dieldrin). Detection of these trace contaminants in the water column requires the sampling of large volumes of water. Previously, such analyses were, in essence, small-scale research activities. However, the Green Bay study has developed methods that can be employed on a more routine basis.

The study team is beginning to obtain the results of laboratory analyses on initial samples. Preliminary PCB data indicate, as expected, a gradient in total PCBs, with higher concentrations in the Fox River and southern Green Bay sampling stations. Preliminary results for PCBs in plankton samples show a similar trend, with higher concentrations in the Fox River and southern Green Bay, and a two- to three-fold decrease in northern Green Bay. These data will be used in developing models of contaminant transport and levels in fish. Dieldrin results do not follow the PCB trend. The highest dieldrin concentrations in plankton occur near the Door Peninsula and may reflect the past use of dieldrin in the agricultural practices of that region; concentrations there are higher than those in both the northern and southern portions of the Bay.

In FY 1991, the study team will complete analysis of samples, compile data, and calibrate existing models. A study report will be prepared in FY 1992.

NEW RESEARCH VESSEL

Early in 1990, EPA concluded negotiations with the U.S. Department of Transportation Maritime Administration for purchase of a vessel that is being converted into a replacement research vessel for open-lake water quality monitoring. This vessel was needed because of the age (now more than 50 years old) and size of the current ship, and to expand the capability for routine monitoring of persistent toxic substances in open-lake waters. The larger replacement vessel will have much more space for analytic facilities that will prepare samples for analysis on-board and in land-based laboratories.

The new vessel, which will be christened the *Lake Guardian*, underwent shipyard conversion during the second half of 1990. It will be outfitted with on-board laboratory equipment during FY 1991.

SYSTEM-WIDE SURVEILLANCE

EPA's planned spring 1989 surveys for Lakes Erie, Huron, and Ontario were prevented due to vessel breakdown. The Program Office accomplished all summer 1989 open-lake water quality sampling that was planned for Lakes Erie, Huron, Michigan, and Ontario. During the summer survey in Lake Erie, EPA sampled for 33 parameters at 20 sites. In Lake Huron, EPA sampled for 33 parameters at 20 locations. EPA sampled for 33 parameters at 11 Lake Michigan sites and for 33 parameters at 8 Lake Ontario sites. Spring and summer cruises were also completed in 1990 and are planned during 1991.

During 1989, the Program Office continued studies to examine whether water from certain municipal drinking water intakes is representative of open-lake waters of Lakes Michigan and Ontario and could be used in selected areas in lieu of sampling by ship. Results indicate that the composition of samples collected from intake pipes is generally similar to that of samples collected from offshore waters. Storms and other weather events can affect nearshore water quality, requiring careful analysis of data before they can be used reliably.

Through an agreement with the Fish and Wildlife Service, the Program Office supports an annual monitoring program for dissolved oxygen in Lake Erie. Dissolved oxygen is measured from June through September at 10 stations in the central basin of Lake Erie. Oxygen depletion rates in Lake Erie's central basin were lower in 1988 and 1989 than at any time in the last 20 years. In 1989, the bottom waters did not become anoxic until mid-September, an encouraging sign that phosphorus load reductions may be achieving their desired effect. In several previous years, anoxic conditions developed about mid-August. This monitoring program will continue in 1991 in order to collect data to further evaluate long-term responses of central basin water quality to reductions in nutrient enrichment.

EPA, States, and the Fish and Wildlife Service continued fish surveillance programs during FYs 1989 and 1990; this activity is planned to continue during FY 1991. In 1989, 1 Lake Michigan site was sampled for 14 organic parameters in lake trout and smelt, and States sampled chinook salmon at 8 sites for 21 organic parameters. On Lake Erie, the Fish and Wildlife Service sampled smelt and walleye at one site for 11 parameters and States sampled rainbow trout at 3 sites for 21 organic parameters. On Lake Huron, the Fish and Wildlife Service sampled lake trout and smelt at 1 site for 7 parameters, and States sampled chinook salmon at 2 sites for 21 organic parameters. On Lake Ontario, the Fish and Wildlife Service sampled lake trout and smelt at 1 site for 11 parameters, and States sampled chinook salmon at 3 sites for 11 parameters. Figure 6-2 shows some of the results of this monitoring program over time. The figure depicts average concentrations of PCBs and DDT in Lake Michigan lake trout, chub, coho, and smelt.

States and EPA continued their joint support of a basin-wide 20-station atmospheric deposition network during FYs 1989 and 1990; this activity is planned to continue during FY 1991. The sampling stations monitor nutrients, metals, and acidity in precipitation, including lead, cadmium, nitrate/nitrite, mercury, and phosphorus, among about 35 parameters. States and universities operate the sampling stations and provide samples to EPA on a weekly basis, provided sufficient precipitation occurred.

The States and the U.S. Geological Survey conduct tributary monitoring. The Program Office's activities have centered on development of sampling strategies to obtain data adequate for estimating chemical loadings to the Great Lakes and on dissemination of these strategies to States. During FY 1989, research carried out under Program Office grants led to the development of enhanced (high-flow) strategies for seven Great Lakes tributaries in Michigan. In addition, Heidelberg College, Ohio, has developed event-responsiveness ratings for all major Great Lakes tributaries that will help EPA, States, and Canada to assess which tributaries require the most monitoring.

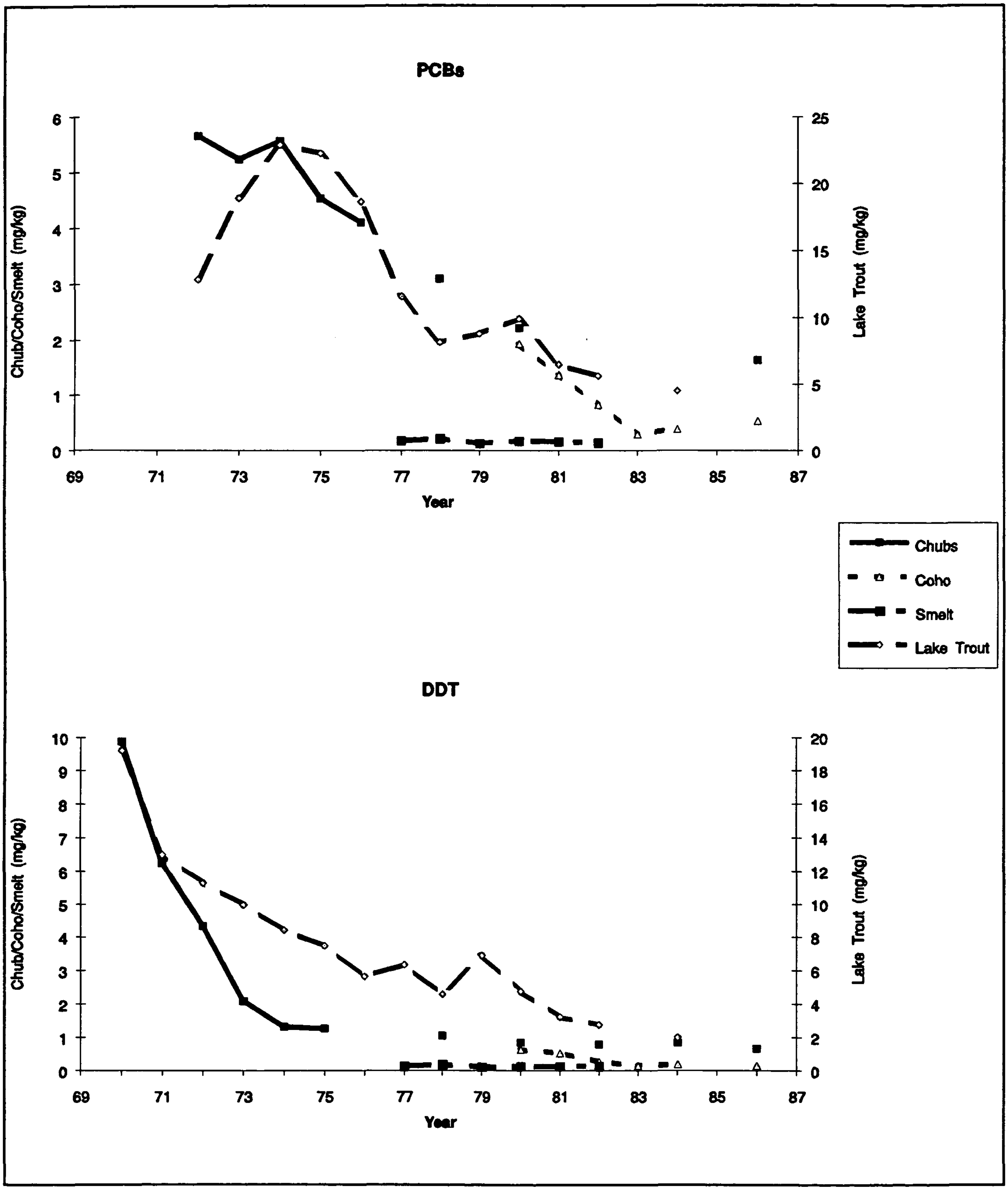


Figure 6-2. Contaminants in Several Species of Lake Michigan Fish

With a few exceptions, present tributary monitoring data are only marginally adequate for calculating loads for conventional pollutants, and they are inadequate for calculating loadings of toxic contaminants. Estimates of loads for these parameters will require the development of innovative sampling technologies. One attempt at such innovation is a pilot monitoring station that the New York Department of Environmental Conservation is developing for use on the Buffalo River.

The U.S. Geological Survey maintains sampling stations on most major Great Lakes tributaries. In FY 1990, as part of the Green Bay Mass Balance Study, the Survey conducted tributary sampling that will help to develop sampling methods for trace contaminants. This activity also addresses methods and instrumentation for monitoring tributaries at or near their mouths, which is necessary for estimating tributary loadings of trace contaminants.

Chapter 7

Expenditures

During FYs 1989 and 1990, Federal expenditures on behalf of Great Lakes water quality exceeded $150 million each year. This total represents estimates of expenditures by a number of major programs. The largest two Federal outlays are for the cleanup of abandoned hazardous waste sites by the Superfund program and for the construction of municipal wastewater treatment system improvements.

Before discussing expenditures, several general observations should be made. First, although some appropriations (e.g., EPA's Large Lakes Research Station and Great Lakes National Program Office) are specifically earmarked for the Great Lakes, many programs are broader in scope, and their funding is administered on a State-wide basis. For these, it is often difficult to distinguish what portion of their expenditures was for activities within the Great Lakes watershed. Second, reported expenditures usually comprise both actual obligations through the time at which the information was developed and anticipated obligations during the remainder of that fiscal year. Third, expenditures of 2-year appropriated funds will sometimes be incurred during the second year. The net effect of these factors is to introduce some uncertainty into expenditures estimates.

Superfund

Figure 7-1 shows expenditures by the Superfund in the counties of the Great Lakes basin during FYs 1987-1989. These counties are wholly or partly located within the Great Lakes basin. A geographic area larger than the actual

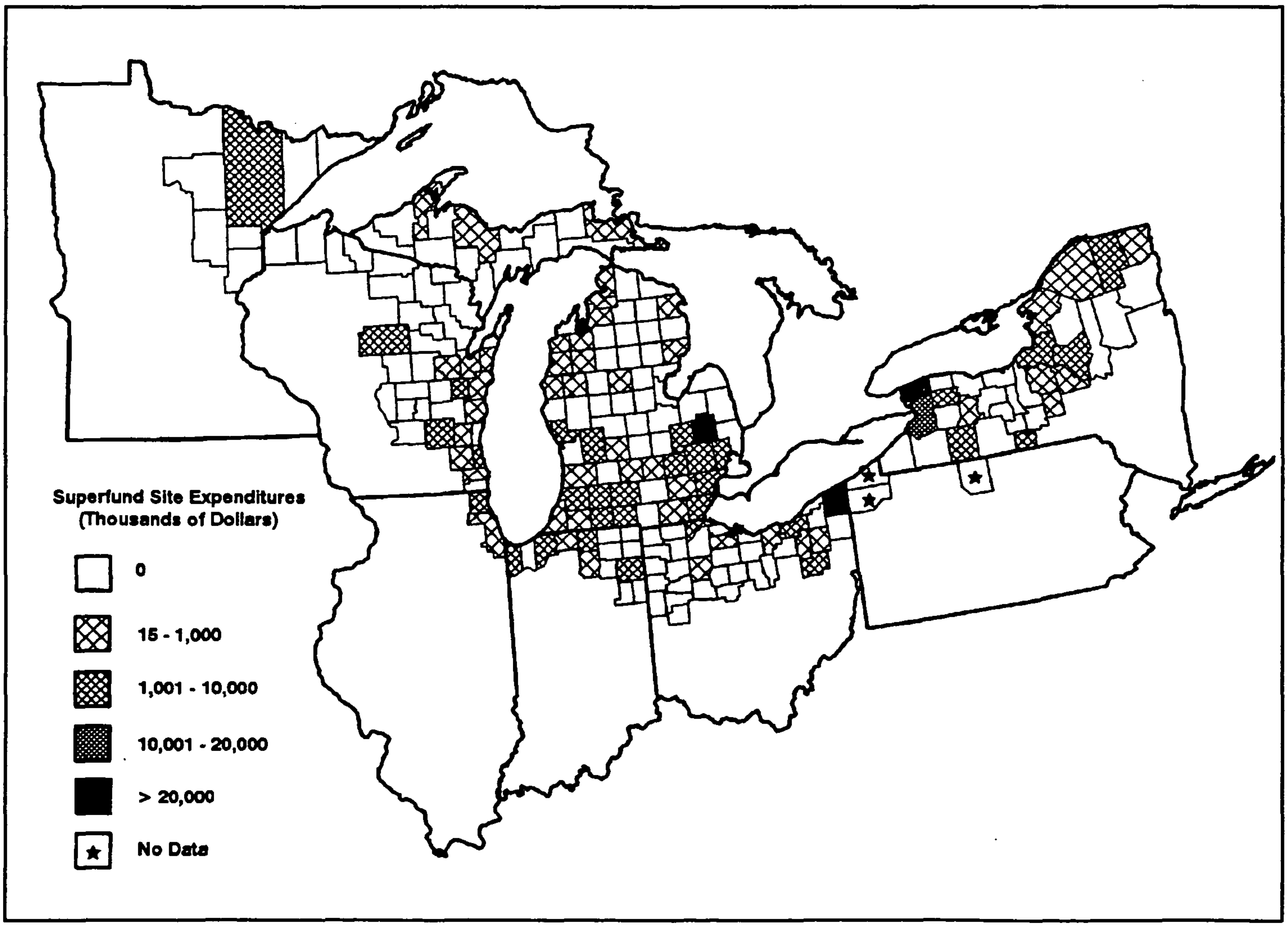


Figure 7-1. Superfund Expenditures in Great Lakes Counties in FYs 1987 through 1989

watershed of the Great Lakes is used, since information from the Agency's Superfund data base can best be extracted by county.

Over this 3-year period, the Superfund program spent more than $210 million in the counties of the Great Lakes. These costs are government outlays only and do not include costs incurred by Potentially Responsible Parties. Thus, total cleanup expenditures for Superfund sites are actually greater than the expenditures shown in Figure 7-1. It should also be noted that the Agency acts to recover costs from Potentially Responsible Parties, so that the Superfund will be reimbursed for some of these outlays.

During this period, the four counties with the highest Superfund expenditures were Lapeer County, Michigan; Niagara County, New York; Ashtabula County, Ohio; and Erie County, New York. The principal sites in these counties were the

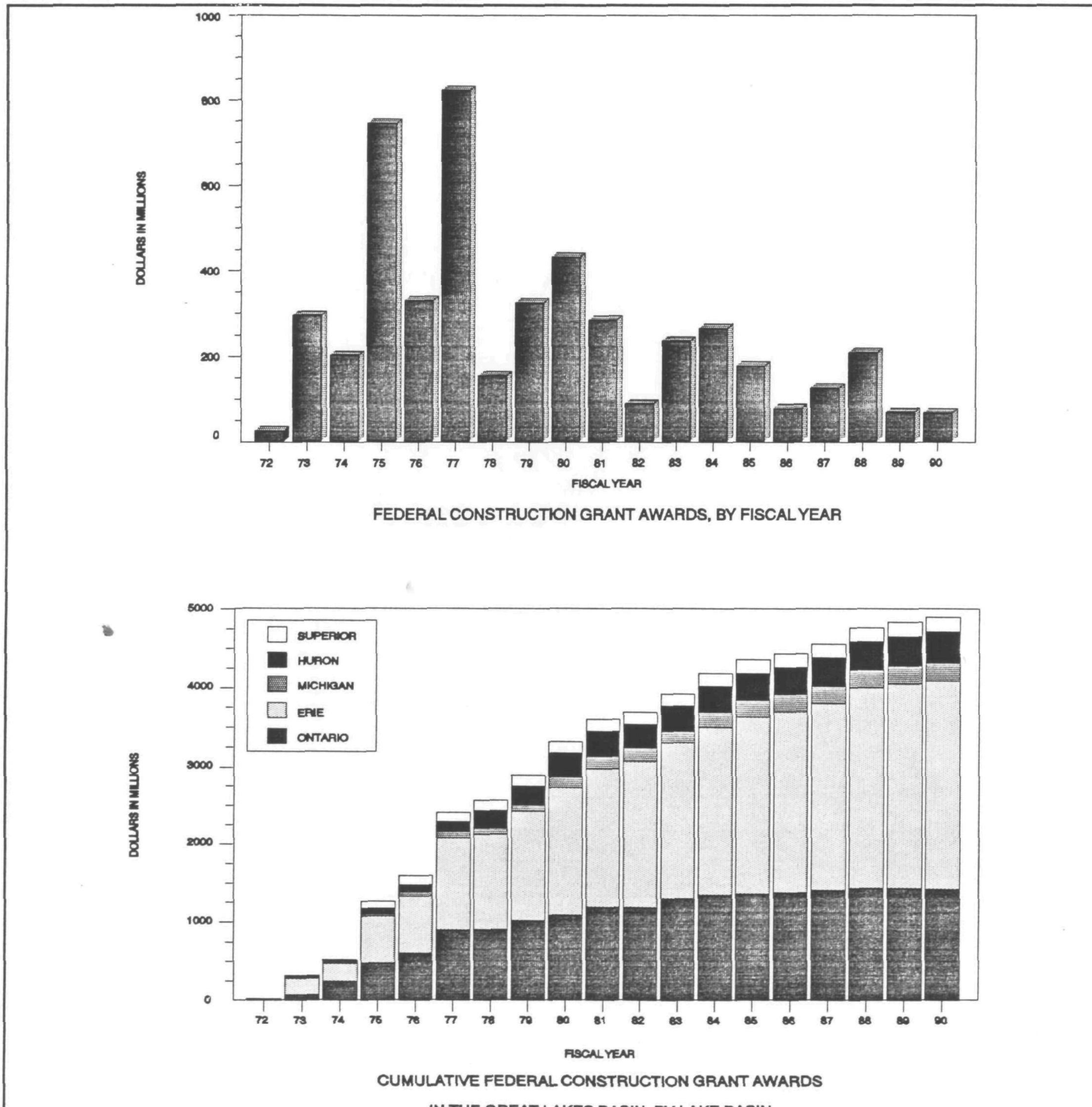


Figure 7-2. Construction Grant Awards in the Great Lakes Watershed

Table 7-1. Selected FY 1989 Federal Expenditures on Great Lakes Water Quality ($ in thousands)

Federal Agency	Judicial Enforcement	Research	Surveillance	Remedial Programs	General Administration	State Cooperative Efforts	Other	Total
EPA								
Great Lakes National Program Office			4,106	3,110	2,001	387	435	10,039
Large Lakes Research Station		1,906						1,906
NOAA								
Great Lakes Environmental Research Laboratory		4,374		600				4,974
DEPARTMENT OF AGRICULTURE								
Soil Conservation Service		45	1,323	7,969	527		10	9,874
DEPARTMENT OF INTERIOR								
Fish and Wildlife Service		2,151	769	582	741		12,360	16,603
DEPARTMENT OF DEFENSE								
Army Corps of Engineers	1,387	72	3,288	16,254		60		21,061
TOTAL	1,387	8,548	9,486	28,515	3,269	447	12,805	64,457

Table 7-2. Selected FY 1990 Federal Expenditures on Great Lakes Water Quality ($ in thousands)

Federal Agency	Judicial Enforcement	Research	Surveillance	Remedial Programs	General Administration	State Cooperative Efforts	Other	Total
EPA								
Great Lakes National Program Office			5,651	3,741	2,562	490	387	12,831
Large Lakes Research Station		1,906						1,906
NOAA								
Great Lakes Environmental Research Laboratory		4,400		600				5,000
DEPARTMENT OF AGRICULTURE								
Soil Conservation Service			1,668	7,620	548		10	9,846
DEPARTMENT OF INTERIOR								
Fish and Wildlife Service	74	981	1,341	633	200	2	2,023	5,254
DEPARTMENT OF DEFENSE								
Army Corps of Engineers	150	1,203	824	19,223		106		21,506
TOTAL	224	8,490	9,484	31,817	3,310	598	2,420	56,343

Table 7-3. Selected FY 1991 Estimated Federal Expenditures on Great Lakes Water Quality ($ in thousands)

Federal Agency	Judicial Enforcement	Research	Surveillance	Remedial Programs	General Administration	State Cooperative Efforts	Other	Total
EPA								
Great Lakes National Program Office								
Large Lakes Research Station								
NOAA								
Great Lakes Environmental Research Laboratory								
DEPARTMENT OF AGRICULTURE								
Soil Conservation Service			300	7,894	732	1,385	46	10,357
DEPARTMENT OF INTERIOR								
Fish and Wildlife Service	17	964	385	672	244	3	2,087	4,372
DEPARTMENT OF DEFENSE								
Army Corps of Engineers	150	1,270	849	16,555		427		19,251
TOTAL	167	2,234	1,534	25,121	976	1,815	2,133	33,980

Metamora Landfill in Lapeer; Love Canal in Niagara; New Lyme Landfill and Fields Brook in Ashtabula; and Wide Beach Development in Erie.

Municipal Wastewater Treatment Systems

Figure 7-2 shows Federal outlays for the construction of improved municipal wastewater treatment systems in the Great Lakes basin between 1972 and 1989. During this period, EPA provided about $4.8 billion for wastewater treatment plants around the Great Lakes. More than one-half of this investment has been made for plants in Lake Erie's watershed. The second greatest Federal investment has been made in Lake Ontario's watershed.

Expenditures for the wastewater treatment system for the largest U.S. metropolitan area within the Great Lakes watershed are not included, since Chicago's treatment system discharges into the Mississippi River drainage system. It should be noted that State and local governments also contributed greatly to the funding of municipal treatment systems. The total investment by Federal, State, and local governments in municipal treatment systems around the Great Lakes basin between 1972 and 1989 is about $8 billion.

Other Programs

Tables 7-1 through 7-3 show Federal expenditures on the Great Lakes by selected organizations and programs for FYs 1989 and 1990, and planned expenditures for FY 1991.

Sections 118(c)(6)(A) and (D) of the Clean Water Act specify that this report characterize the nature of Federal expenditures by at least four categories: judicial enforcement, research, general administration, and State cooperative efforts. To further clarify the uses of the expenditures, four additional categories have been added for this report: remedial programs, surveillance, wastewater treatment facilities, and other expenditures. For the purposes of this report, several operational definitions were made. "Judicial enforcement" expenditures are those relating to litigation to obtain compliance with environmental regulations. "General Administration" refers to staff salaries, travel, and administrative expenses. "State Cooperative Efforts" are defined as grants to State environmental agencies either expressly for development of Remedial Action Plans or more broadly for water quality programs. This is a narrow definition in that it excludes, as two examples, EPA's funding towards the Green Bay study, jointly sponsored by the Agency and by the State of Wisconsin, and ARCS sediment assessments in five Areas of Concern. Both of these studies develop information pertinent to the development of certain Remedial Action Plans, and expenditures for them are included under the categories of "Surveillance" and "Remedial" activities, respectively. Water grants are on a whole-State basis, beyond the basin. Air/Waste funding is not included.

Table A-1. Submittals of U.S. Remedial Action Plans to the International Joint Commission

Area of Concern	FY 1988		FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
Illinois												
Waukegan Harbor							×	×				
Indiana												
Grand Calumet River/Indiana Harbor Canal							✓			×		
Michigan												
Clinton River			✓	✓								
Deer Lake/Carp River/Carp Creek	✓	✓										
Kalamazoo River												
Manistique River	✓	✓										
Muskegon Lake	✓	✓										
River Raisin	✓	✓										
Rouge River			✓	✓								
Saginaw River/Saginaw Bay			✓	✓								
Torch Lake	✓	✓										
White Lake	✓	✓										
Michigan/Ontario												
Detroit River							×					×
St. Clair River									×			×
St. Marys River									×			×
Minnesota/Wisconsin												
St. Louis River/Bay							×			×		

Key:

✓ = Actual Submittal
× = Estimated

Table A-1. Submittals of U.S. Remedial Action Plans to the International Joint Commission (continued)

Area of Concern	FY 1988		FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
New York												
Buffalo River					✓					×		
Eighteen Mile Creek											×	×
Oswego River					✓			✓				
Rochester Embayment							×			×		
New York/Ontario												
Niagara River											×	×
St. Lawrence River							✓			×		
Ohio												
Ashtabula River									×	×		
Black River									×			×
Cuyahoga River										×	×	
Maumee River							✓			×		
Wisconsin/Michigan												
Menominee River							✓			×		
Wisconsin												
Fox River/Green Bay	✓	✓										
Milwaukee Estuary							×					×
Sheboygan Harbor					✓					×		
Cumulative Number Submitted (out of 30 possible)	7	7	10	10	13	10	22	12	26	22	29	29
Cumulative Percent Submitted (%)	23	23	33	33	43	33	73	40	86	73	97	97

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Lake Superior				
St. Louis River/Bay AOC includes Duluth (Minnesota)/Superior (Wisconsin) harbor, upstream past town of Cloquet, and southwestern Lake Superior. Sediments moderately to heavily polluted with metals; some are also contaminated with PAHs, PCBs, mercury and dioxin; fish consumption advisories for walleye; dredging delays over selection of disposal sites for polluted sediments.	Western Lake Superior Sanitary District WWTP was formed in 1978, replacing nine smaller community systems. It constructed an advanced wastewater treatment facility, greatly improving St. Louis River water quality and fisheries. In 1984, two areas on the St. Louis River together were designated a Superfund NPL site called the St. Louis River site. One area is the former location of U. S. Steel-Duluth works between 1915 until its closure in 1979. This area has coke and tar contamination. Four miles downstream from USS Duluth and 4 miles upstream from Lake Superior, the "Interlake" area abuts the north bank of the St. Louis River. Site contamination includes tar seeping at the ground surface, a residue of coking and other industrial activities that started in the late 1800s and continued to 1950. MPCA began RI/FS of Interlake in 1987.	**1989:** MPCA selected remedy for U.S. Steel area of St. Louis River NPL site. Minnesota developing RAP with Wisconsin. Active citizens advisory group with five technical committees. **1990:** Stage 1 draft RAP provided to EPA for comment. MPCA completed RI/FS Interlake area. The selected Interlake remediation will include construction of a slurry wall to prevent coal tar from seeping into the St. Louis River.	MPCA to submit Stage 1 RAP to IJC. Monitoring to further define the extent and causes of problems. EPA support to urban nonpoint control project in Duluth.	MPCA to submit Stage 2 RAP to IJC in FY 1992.

Key:

AOC	Area of Concern	NYSDEC	New York State Department of Environmental Conservation
ARCS	Assessment and Remediation of Contaminated Sediments	PAH	Polyaromatic Hydrocarbons
BMP	Best Management Practice	PCB	Polychlorinated Biphenyls
COE	U.S. Army Corps of Engineers	PRP	Potentially Responsible Party
CSO	Combined Sewer Overflow	RAP	Remedial Action Plan
IDEM	Indiana Department of Environmental Management	RCRA	Resource Conservation and Recovery Act
IJC	International Joint Commission	RI/FS	Remedial Investigation/Feasibility Study
MDNR	Michigan Department of Natural Resources	ROD	Record of Decision
MDPH	Michigan Department of Public Health	SCS	Soil Conservation Service
MPCA	Minnesota Pollution Control Agency	USDA	U.S. Department of Agriculture
NOAA	National Oceanic and Atmospheric Administration	USGS	U.S. Geological Survey
NPDES	National Pollutant Discharge Elimination System	WDNR	Wisconsin Department of Natural Resources
NPL	National Priorities List	WWTP	Wastewater Treatment Plant

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Torch Lake This AOC is located in Michigan's Keweenaw Peninsula. About 200 million tons of copper mine tailings were dumped into 2,718 acre Torch Lake between 1868-1968, filling 20% of the lake's original volume. Sediments are highly contaminated with copper; in late 1970s, tumors were found in mature walleye and sauger; fish consumption advisories for walleye, sauger and larger smallmouth bass.	EPA designated lake as a NPL site in 1984, began search for PRPs in 1985 and concluded negotiations with three in 1988. The site is large, encompassing Torch Lake, the northern half of Portage Lake, tributaries, and the northern half of the Keewenaw Waterway. It is divided into three "Operable Units." MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988.	**1989:** EPA and MDNR began RI/FS on operable unit 1 (surface tailings on western shore of Torch Lake). MDNR completed analyses of fish taken from lake in 1988. Tumors were not found and contaminant levels in fish were very low. **1990:** EPA and MDNR continued RI/FS for operable unit 1. EPA started RI/FS for operable units 2 (Torch Lake) and 3 (Keweenaw Waterway). Field investigations completed December 1990.	EPA to issue an ROD for operable unit 1 in September.	Implement Superfund remediations and RAP.
Deer Lake/Carp River/Carp Creek This AOC in Michigan's Upper Peninsula includes 907 acre Deer Lake and 20 miles of Carp River to Lake Superior. Sediments are highly contaminated with mercury; fish consumption advisories for all fish species since 1981.	Sources of mercury eliminated in early 1980s. Consent Agreement between State and Cleveland Cliffs Iron Company signed in 1984 under which monitoring studies of mercury in fish will be conducted for 10 years. Lake drawn down and contaminated fish were killed with rotenone in 1985/1986. Lake restocked with walleye and perch in 1987. New regional WWTP with secondary treatment replaced three primary WWTPs that previously discharged to Deer Lake via Carp Creek. MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988.	**1989 and 1990:** MDNR conducted fish tissue, water quality, bottom sediment, and sedimentation rate studies to monitor recovery. MDNR designated Deer Lake as a catch and release fishery until 1996 to limit consumption of contaminated fish. Levels of mercury in northern pike have fallen by one-half since 1987.	MDNR will continue monitoring contaminants in fish.	Cleveland Cliffs Iron Company and MDNR will continue to monitor concentrations of mercury in fish tissues through 1996.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Lake Michigan				
Manistique River AOC is the lower 1.7 miles of river flowing into northern Michigan from Michigan's Upper Peninsula. Adjacent town: Manistique (Michigan). Sediments heavily polluted with PCBs and metals; fish consumption advisories for carp.	Manistique WWTP was upgraded to secondary treatment in 1977. In 1986, Manistique Papers Incorporated placed a temporary erosion barrier over soils suspected to be a source of PCBs to the river and upgraded its wastewater quality. Result is greatly reduced oxygen demand and toxic substance loads to the river. MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988.	**1989:** MDNR analysis of channel catfish from Manistique harbor found PCB levels less than half those that would justify a fish consumption advisory by MDPH. **1990:** MDNR and COE conducted sediment contamination characterization of river. Michigan Water Resources Commission approved a new 5-year NPDES permit for Manis-tique Papers with stricter limits on zinc, copper, and silver. MDNR conducted 28-day caged-fish study to determine uptake of PCBs.		Study effects of dredging contaminated sediments in harbor. Evaluate contaminated sediment effects on biota and evaluate remedial options.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Menominee River AOC is the lower 3 miles of river flowing into Green Bay. The river forms the boundary between Wisconsin and the Upper Peninsula of Michigan. Adjacent towns: Menominee (Michigan) and Marinette (Wisconsin). Groundwater grossly contaminated with arsenic near Ansul Company; sediments in river highly contaminated with arsenic and also with mercury and PCBs; fish consumption advisories for smallmouth bass, perch, white bass, white sucker, bullheads, carp, trout, walleye, splake, salmon and pike; dredging delayed due to concerns over disposal of polluted sediments; bacteriological contamination caused by CSOs; loss of fish and wildlife habitat.	Ansul Company began pumping and treating arsenic contaminated groundwater in 1981 under a Consent Order.	**1989:** Wastewater connection from Menominee Paper to the Menominee WWTP eliminated. This action should improve effluent quality at both facilities. Menominee Paper also started enhanced wastewater treatment at its facility. City of Menominee signed EPA and WDNR Consent Order, agreeing to submit plan for the elimination of CSOs. Wisconsin developed RAP with support from Michigan. Active citizens advisory group, with three technical subcommittees. **1990:** EPA and WDNR issued RCRA Consent Order regarding arsenic contamination to Ansul Company. Menominee Paper paid $2.1 million penalty for Clean Water Act violations under Consent Decree. City of Menominee entered into Consent Agreement with EPA to correct its CSOs.	Submit Stage 1 RAP to IJC in October 1990. Continue Stage 2 RAP preparation. Analytical work to support RAP includes: fish contaminants, sediment and water quality monitoring; and toxicity testing of bottom waters. COE to conduct sediment quality reconnaissance to prepare for dredging of navigational channel. Ansul Company to conduct RCRA facility investigation with corrective measures study under Consent Order. Ansul Company entered into a RCRA Consent Agreement with State of Wisconsin and EPA to outline and implement corrective actions for arsenic contaminated sediments. Paint sludge from a site owned by Flanders Industries leaches into Green Bay. MDNR to remove sludge and metal in Spring 1991.	WDNR and MDNR plan to submit Stage 2 RAP to IJC in FY 1992. Upgrade municipal sewer systems by correcting combined sewer overflows.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Fox River/Green Bay Sediments heavily polluted with metals, oil and grease, and PCBs; high tumor incidence in some fish; deformities and reproductive impairments in fish-eating birds; eutrophic conditions in lower bay; bacterial contamination; fish consumption advisories for smallmouth bass, perch, white bass, white sucker, bullheads, drum, channel catfish, carp, trout, walleye, splake, salmon and pike; concerns over polluted sediments have made siting of dredged material disposal facilty problematic.	Citizens advisory group met monthly from 1986 to 1988 to assist in RAP development. WDNR submitted Stages 1 and 2 RAP to IJC in FY 1988. During 1987-88, WDNR and EPA, joined by universities and other agencies, designed a major study of the sources and fates of four pollutants (PCBs, cadmium, lead, and dieldrin) in Green Bay. EPA Proposed Fort Howard Paper Company sludge lagoons in city of Green Bay as Superfund NPL site in 1988. Lagoons contain heavy metals and PCB contamination in sludge. In 1986 Ft. Howard installed a slurry wall to prevent migration of contaminates through groundwater.	1989: Wisconsin established new water quality standards to limit toxics discharges. Green Bay Mass Balance Study field work began. Plans established to upgrade municipal wastewater treatment at Green Bay and Appleton. Nonpoint source control model ordinances drafted and public participation incentives instituted. Wetlands preservation and restoration activities begun. USDA began a 10-year East River Priority Watershed Project that will share costs with landowners for installing land management improvements. Barrier to sea lamprey migration up Fox River completed. 1990: Green Bay Mass Balance Study field work finished and analysis of samples continued. RAP implementation committee has been meeting regularly since mid-1988 and published two annual reports. City of DePere urban runoff detention ponds begun.	EPA, WDNR, and partners will prepare report on Green Bay Mass Balance Study findings. City of Green Bay and WDNR to complete purchase of land along Fox River in Green Bay to improve public access to waterfront. USDA to continue priority watershed projects for Winnebago Lake, Arrowhead-Daggets Creeks, and the East River. Green Bay and Appleton WWTPs are constructing improvements to reduce ammonia, chlorine, and bacteria discharges. City of DePere to construct 2 spawning beds for walleye on Fox River. WDNR to stock musky to re-establish this native predator fish.	Develop approaches for dealing with contaminated sediments. Other emphases are rural and urban nonpoint sources, fish and wildlife habitat, and public access to the shoreline. University of Wisconsin-Green Bay report notes biological responses to improved water quality over the last decade: • A doubling of benthic organisms (1978-88) • Improved growth of wild celery • Improved reproductive success of Forster's terns and growth in their population.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Fox River/Green Bay (cont.)		**1990 (cont.)** Ft. Howard Paper Co. began RI/FS at Superfund NPL site. EPA began a Wetlands Inventory to map critical coastal wetlands and to advise public of areas where dredging or filling will not be permitted. U.W.-Green Bay issued a report on the environmental condition of Green Bay. The report draws on more than two decades of bay research and is accessible to the public. It lists 14 impaired uses of the bay, 9 of which can be tied to nutrients and sediments.		

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Sheboygan River and Harbor The AOC includes Sheboygan Harbor and about 12 miles of river up to Sheboygan Falls. Sediments heavily polluted with PCBs and metals; fish consumption advisories for bluegill, crappie, rock bass, carp, smallmouth bass, walleye, pike, trout, catfish and salmon; waterfowl consumption advisory; bacterial contamination in water column; navigational dredging discontinued in 1969 due to lack of acceptable disposal site for polluted sediments.	Kohler Company landfill, which approaches within 300 feet of river, was designated Superfund NPL site in 1984. RI/FS begun in 1986. Site is a potential source of metals to river. River and harbor were designated Superfund NPL site in 1985. In April 1986, EPA and WDNR signed Consent Order with Tecumseh Products Company, a PRP, to conduct the RI/FS for the Superfund site. Company plant is potential source of PCB contamination in river. WDNR began drafting RAP in June 1987. WDNR prepared draft RAP during 1988.	**1989:** WDNR held public meetings and hearings to obtain public comment on draft RAP. Tecumseh Products Incorporated continued RI/FS of river and harbor. **1990:** WDNR submitted Stage 1 RAP to IJC. As part of RI/FS for river and harbor, about 2,000 cubic yards of sediments were removed from the upper river in December 1989. These were placed into a confined treatment facility for biodegradation studies that will use bacteria to try to decompose PCBs in the sediments. The RI/FS also continued to study other remedial alternatives. Kohler landfill RI/FS continued.	Continue RI/FS of two Superfund NPL sites. WDNR to stock Sheboygan River with steelhead trout for study of PCB uptake. Re-establish Sheboygan County Water Quality Task Force as citizen advisory committee and establish committee structure to work towards Stage 2 RAP. Complete Sheboygan River Priority Watershed Plan addressing nonpoint sources of pollution. Continue to implement Onion River Watershed Project.	WDNR plans to submit Stage 2 RAP to IJC in FY 1992. Superfund proposed cleanup plan due in Spring 1992. Clean up sediments, protect wetlands, improve sewage systems to reduce bacterial contamination, control sources of toxics.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Milwaukee Harbor Water and sediment contamination with conventional pollutants; sediments heavily polluted with metals and PCBs and also contaminated with pesticides; eutrophic conditions; fish consumption advisories for crappie, perch, carp, northern pike, smallmouth bass, redhorse sucker, white sucker and rock bass; waterfowl consumption advisories; dredging restrictions; absence of desirable fish and aquatic species; loss of habitat; beach closings.	Over $500 million in sewage system upgrades have been made since 1972. Moss-American site, a source of PAHs to Little Menominee River, was designated a Superfund NPL site in 1983. RI/FS begun in 1987.	1989: Major combined sewer overflow abatement project and upgrade of WWTP by Milwaukee Metropolitan Sewerage District underway. WDNR implementing five priority watershed nonpoint source control projects in the basin. Corps of Engineers conducted harbor sediment sampling program, including chemical and bioassay testing. 1990: WDNR provided Stage 1 draft RAP to EPA for comment. Public meeting held in June to obtain comments. Continued sewage system improvements. Study of causes of contaminant levels in resident waterfowl underway.	WDNR plans to submit Stage 1 RAP to IJC. MMSD to continue improvements to sewage system. Technical Advisory Committee to develop a monitoring strategy. EPA support to monitoring of Milwaukee River Priority Watershed.	WDNR plans to submit Stage 2 RAP to IJC in FY 1993. Startup of deep-tunnel to increase wet weather treatment capacity. Corps of Engineers may develop a second confined disposal facility for dredged material from the harbor.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Waukegan Harbor Waukegan is located on the west shore of Lake Michigan, about 40 miles north of Chicago, Illinois. Gross PCB contamination of sediments; fish consumption advisories for all fish species; dredging delayed by problems in siting disposal facility for polluted sediments.	Legal actions undertaken against Outboard Marine Corporation (OMC) starting in 1978. Site included on original Superfund NPL in 1982. EPA conducted RI/FS and issued ROD in 1984.	1989: OMC entered into Consent Order that stipulated it would clean up (under EPA supervision) areas of Waukegan Harbor and of OMC property containing PCB contamination. Cleanup plans call for dredging parts of the harbor, constructing containment cells for less contaminated soil and sediment, and extracting PCBs from soil and sediment for incineration. More than 99% of the mass of PCBs in the harbor will be removed and either confined or destroyed. The cleanup is estimated to cost $20 million. 1990: OMC continued cleanup plan implementation. Construction of a new slip was delayed by discovery of unrelated site of PAH contamination near intended location of new slip.	Illinois EPA plans to submit Stages 1 and 2 RAPs to IJC. OMC to continue cleanup activities.	Cleanup actions by OMC to be completed during 1993.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Grand Calumet River/ Indiana Harbor Canal AOC is 13 miles long. The river flows into the southernmost part of Lake Michigan. Sediments heavily contaminated with metals, conventional pollutants, PCBs, and PAHs; water quality problems due to conventional pollutants; fish tumors and fin rot found; fish consumption advisory for all fish species; dredging delayed over problems in siting disposal facility for polluted sediments.	Settlement of Federal suit against U.S. Steel for alleged refusal to enter Gary plant in NPDES permit program (1980). EPA developed a master remedial plan for Grand Calumet in 1985. EPA and IDEM completed N.W. Indiana Environmental Action Plan in 1987.	**1989:** USGS completed study of groundwater flow in the area. EPA ARCS study sampled contaminated sediments. **1990:** Settlement of 1989 Federal suit against USX for alleged NPDES permit violations. Consent Order calls for USX to undertake $34 million in sediment studies and cleanup. EPA ARCS study sampling continued. EPA issued adminstrative order to certain PRPs to cleanup NPL Midco I and II sites in accordance with their RODs. Federal suit filed against Inland Steel under Clean Water Act, Clean Air Act, Safe Drinking Water Act, and Resource Conservation and Recovery Act. Federal suit filed against Bethlehem Steel under multiple environmental laws.	IDEM to submit Stage 1 RAP to IJC. USX to begin stream characterization study for 13 miles of Grand Calumet. COE to draft Environmental Impact Statement on dredging of Federal navigation channel.	IDEM plans to submit Stage 2 RAP to IJC in FY 1992. Address problems posed by large quantity of highly toxic sediments and by combined sewer overflows during rain storms. IDEM/EPA implement NW Indiana Environmental Action plan. Its 6 elements: (1) Assist COE dredge Federal navigation channel (2) Ensure high levels of compliance with Federal environmental laws (3) Address petroleum distillate contaminated groundwater (4) Complete Remedial Action Plan (5) Communicate to public on environmental issues (6) Incorporate pollution prevention measures.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Kalamazoo River AOC is the lower 35 miles of river that flows into southeastern Lake Michigan. Sediments heavily polluted with PCBs; fish consumption advisories for all fish species.	MDNR finished a Michigan Act 307 RI/FS of the Kalamazoo River in 1986. This study recommended remedial actions at Bryant Mill Pond and at three impoundments (Plainwell, Otsego, and Trowbridge), and further study of Otsego City and Allegan impoundments, as well as of Lake Allegan. The RI/FS found PCB contamination of a 3-mile stretch of Portage Creek where the creek joins the river and of 35 miles of the Kalamazoo River. Contamination starts where Allied Paper Bryant Mill Pond discharges to Portage Creek. Allied Paper has operated paper mills at an 80 acre site since 1925. Second draft of RAP completed in December 1987.	1989: EPA proposed Allied Paper Inc/ Portage Creek/Kalamazoo River for Superfund NPL. RAP deferred due to legal actions. Three PRPs identified: Allied Paper Incorporated, Georgia Pacific Corporation, and Simpson Plainwell Paper Company. Under Federal court supervision, Allied Paper is developing plans for interim remedial actions at Bryant Mill Pond on Portage Creek. Georgia Pacific is developing remedial plan for the Willow site. 1990: MDNR began interim remedial measures for Plainwell, Otsego, and Trowbridge impoundments. MDNR conducted studies to identify extent of contamination and feasible remedial actions at Lake Allegan and at the Allegan and Otsego impoundments. Three PRPs agreed to conduct RI/FS for Kalamazoo River NPL site. Allied Paper began removal action at Bryant Mill Pond.	PRPs to begin 'Superfund RI/FS under EPA and MDNR supervision. Georgia Pacific Corporation to complete investigation of PCB disposal site "A". Georgia Pacific to submit proposed remedial action at the Willow site and to complete investigation of PCB disposal site at Kings Highway. Followup studies on sediment burial, partition coefficients, and erosion rates for Otsego City Impoundment, Allegan City Impoundment, and Lake Allegan to be completed.	Complete RAP with results from Superfund RI/FS. RI/FS will take 3 to 5 years to complete. While Superfund RI/FS is underway, public will be consulted pursuant to the Superfund process.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Muskegon Lake Lake is 4,150 acres in size located along east shore of Lake Michigan just north of City of Muskegon. Eutrophication; some shoreline sediments heavily polluted with metals; fish consumption advisories for carp, large-mouth bass, large walleye.	Diversion of municipal and industrial wastewater discharges from the lake and its tributaries to the Muskegon County Wastewater Treatment System and implementation of an industrial pretreatment program have greatly reduced waste loads to the lake and improved water quality and fish habitat. EPA listed the Ott/Story/Cordova Chemical Company site on the Superfund NPL in 1982. Contaminated groundwater from the site was found to be contaminating sediments and water in Little Bear Creek, which flows into Bear Lake, which connects to Muskegon Lake. EPA began an RI/FS at the site in January 1988. MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988.	**1989:** MDNR collected fish from Lake Michigan off the mouth of Muskegon Lake in 1988. These fish were also found with unacceptable levels of PCBs and mercury, which may indicate a regional phenomenon like atmospheric deposition of contaminants rather than one localized to Muskegon Lake. EPA completed RI at the Ott/Story/Cordova Chemical Co. site and began FS. EPA and MDNR proposed a cleanup plan to pump, treat, and monitor groundwater. Average spring phosphorus concentrations have fallen below desired maximum level. **1990:** EPA completed FS at the Ott/Story/Cordova Chemical Co. site.	MDNR to complete analyses of sediment and benthic samples.	The RAP recommends continued implementation of ongoing programs and additional studies of stormwater runoff effects on Ryerson and Ruddiman creeks, Division Street stormwater discharge, sediment and benthic health, and fish tissues.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
White Lake Lake is 2,570 acres in size located along east shore of Lake Michigan near the communities of Montague and Whitehall. Groundwater contaminated with organic solvents; some sediments are heavily polluted with chromium; fish consumption advisory for carp due to PCBs and chlordane.	Diversion of municipal and industrial wastewater discharges from the lake and its tributaries to the Muskegon County Wastewater Treatment System and implementation of an industrial pretreatment program have greatly reduced waste loads to the lake and improved water quality and fish habitat. A 1979 Consent Judgement between Hooker Chemical Company and the State of Michigan required company to halt flow of contaminated groundwater to the lake. Company installed purge wells and a carbon absorption treatment system. In 1985, the State filed to enforce provisions of the Consent Judgement to force company to improve its purge well system. MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988.	**1989** Hooker Chemical Company continued treatment of contaminated groundwater. **1990** System of cluster wells was installed to monitor static water levels and to ensure the contaminant plume did not reach the lake. Data collected from March 1987 to January 1990 for the purge-well system indicated that the plume is being captured.	MDNR to complete analyses of sediment and benthic samples.	

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Lake Huron				
Saginaw River/Saginaw Bay Bay is 1,143 square miles, with an 8,709 square mile drainage basin, the largest in Michigan. Water contaminated with metals, PCBs, dioxins and phenols; sediments moderately to heavily polluted with metals and PCBs; eutrophic conditions; apparent reproductive impairments and deformities in fish-eating birds; fish consumption advisories for trout, carp and catfish in the bay and for all species in the river; dredging in upper river delayed over problems in siting disposal facility for polluted sediments; bacterial contamination.	Ban on the use of high phosphate detergents in 1977 and wastewater treatment improvements have greatly reduced phosphorus loads to the river and bay. RAP was completed in September 1988 and identified 101 actions over a 10-year period that should be taken to address environmental problems. Surveys of benthic macroinvertebrate communities by NOAA and MDNR (1986-89). 1987 ongoing: MDNR has purchased $7 million worth of land in the Saginaw Bay area for the preservation of habitat and to improve recreational access. Shiawasee River designated Superfund NPL site in 1983. Cast Forge Company cleaned up PCB-contaminated soil and sediment from its property. In 1982, 1 mile of the south beach of the Shiawasee dredged, removing 2,600 lbs of PCBS.	1989: MDNR submitted Stages 1 and 2 RAP to IJC. MDNR and U. of Michigan continued extensive sediment sampling in the river and bay to assess the impacts of the severe flood in 1986 on the distribution of sediment contamination (1988-93). MDNR began stocking mayfly eggs in Saginaw Bay to re-establish this native benthic macroinvertebrate (1989-ongoing). General Motors Grey Iron facility ended direct discharge to Saginaw River and began wastewater pretreatment before delivery to Saginaw WWTP.	As part of ARCS study, EPA to sample water, fish tissues, and Saginaw River sediments over a 6-week period as part of a comprehensive evaluation of the hazards of sediment contamination. EPA Saginaw Bay Watershed Project to characterize aquatic biota impacts from impaired streams and formulate remedial strategies. EPA, USDA, and MDNR to implement nonpoint source control measures in the Saginaw Bay watershed, including BMPs for agricultural nonpoint pollution control, urban stormwater management, and sedimentation control (1991-ongoing). USDA will also begin a 5-year program to encourage agribusinesses to use BMPs to decrease phosphorus, nitrate and pesticide runoff. Saginaw Township to construct retention basin to control CSOs. MDNR, with EPA assistance, to complete RI of Shiawasee River NPL site.	Develop approaches to address contaminated sediment problems. Locate sources of ongoing pollutant loadings, including inflow of contaminated groundwater. There are a large number of discontinued waste disposal sites along the Saginaw River. Continued use of USDA BMP efforts. Continued implementation of nonpoint source BMPs. Construct retention basins for CSOs.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Saginaw River/Saginaw Bay (continued)	1987 ongoing: At its Engine Division site, General Motors has constructed a 65-ft. deep slurry-wall to stop PCB migration into the Saginaw River via groundwater flow. Contaminated sediments have been removed from facility sewers. EPA study of Saginaw Bay confined disposal facility assessed whether contaminant transport through dike walls posed ecological risk. Results indicated that transport could not be demonstrated (1987-89). Saginaw township constructed new WWTP in 1988. MDNR and U. of Michigan began surveys to evaluate walleye natural reproduction.	1990: Interpreted results of MDNR/U. of Michigan sediment survey of river and bay conducted in previous year. EPA ARCS study collected Saginaw Bay sediment samples for their chemistry, biological toxicity, and benthic community structure. The U.S. Fish and Wildlife Service began to survey fish (bullheads) for tumors. City of Saginaw's new discharge permit mandates construction of six retention basins for CSOs. Two to be completed by 1992. Restocking of benthic macroinvertebrates in selected Saginaw Bay locations. NOAA's Sea Grant Program opened Saginaw Bay Research Institute at Saginaw Valley State. NOAA began a multi-year study to characterize the Saginaw Bay plankton community before and after the expected invasion of zebra mussels.	DOW Chemical Company is operating under a MDNR order to conduct additional studies to reduce dioxin discharge. MDNR will continue investigation of the Act 307 landfill site on Middle Ground Island, 2 miles upstream from Saginaw Bay. Bay City, a PRP, is cooperating.	

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Lake Erie				
Clinton River The Clinton River flows north of Detroit and empties into Lake St. Clair. Sediments are moderately to heavily polluted with PCBs, metals, oil and grease; eutrophication and bacterial problems in water column; fish consumption advisory for carp.	G & H Landfill, adjoining the Clinton River near Utica, Michigan, was placed on Superfund NPL in 1983. EPA and MDNR conducted an RI/FS of the nearby Liquid-Disposal NPL site from 1984-87. This property is one-quarter mile from the Clinton River and was the site of an industrial waste incinerator from 1967 until closed by EPA in 1982. EPA conducted four removal actions between 1982 and 1985 to end immediate threats to human health. EPA issued ROD for the Liquid-Disposal site clean-up in 1987. Improvements to WWTPs of seven towns made during the 1980s have greatly reduced conventional pollutant and bacterial contamination.	**1989:** MDNR submitted Stages 1 and 2 RAP to IJC. MDNR conducted caged-fish study to evaluate PCB uptake at the mouth of the Clinton River. Results expected in 1991. EPA and MDNR continued RI/FS for G & H Landfill site. 500 PRPs agreed to sign Consent Decree for completion of the remedy at Liquid Disposal, Inc. site. Remedial action valued at $22 million. **1990:** EPA and MDNR proposed clean-up plan for G & H Landfill site. Corps of Engineers dredged navigation channel, placing sediments in confined disposal facility. Armada and Mt. Clemens WWTPs completed upgrades to reduce the discharge of both conventional and toxic pollutants.	MDNR plans to investigate the sources of PCBs to the Clinton River from Mt. Clemens to its mouth. This river segment is designated an Act 307 site. MDNR to determine BMPs to control nonpoint sources of pollution to Gallagher Creek. Army Corps of Engineers plans dredging project in navigation channel. Complete remedial design and begin its implementation at Liquid-Disposal site.	Correction of combined sewer overflows in Red Run drainage will require large capital investment.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Rouge River The Rouge River watershed is the longest and most densely populated and industrialized area in southeastern Michigan. About 40 miles of river flowing through metropolitan Detroit do not meet water quality standards. Some eutrophication problems in the water column; bacteriological contamination of water column; sediments heavily polluted with metals, PCBs, and other organics; fish consumption advisories for carp, pike, largemouth bass, white suckers, and catfish.	Development of RAP (1985-1988) with assistance of Southeast Michigan Council of Governments.	**1989:** MDNR submitted Stages 1 and 2 RAP to IJC. Since 1988, local, State, and Federal governments have agreed to fund over $450 million in sewer improvements. Wayne County Health Department began to investigate illegal discharges via storm sewers. **1990:** EPA awarded $400 thousand for studies of Rouge River combined sewer overflow/stormwater. Studies of Rouge indicate water column toxicity follows rainstorms, indicating that CSOs, stormwater, and nonpoint runoff are major sources of problems. MDNR issued CSO permits to all Rouge River municipalities with CSOs. All are being contested in court.	SCS to implement BMPs in a three county area, including the Lower Branch of the Rouge River. Town of Farmington to complete separation of combined sewers.	PCB contamination appears to be the result of discontinued discharges, spills, and CSOs. CSOs and nonpoint source stormwater runoff are the largest sources of pollutants to the river. Large long-term sewer system improvements needed to reduce combined sewer overflow loads to river. MDNR plans annual updates of RAP executive summary. Development of regional GIS system.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
River Raisin AOC is the lower 2.6 miles of river and extending one-half mile into western Lake Erie. Numerous landfills and industrial sites border the river. Metals and PCB contamination of water column; sediments heavily polluted with metals and PCBs; fish consumption advisories for carp and large white bass.	MDNR submitted Stages 1 and 2 RAP to IJC in FY 1988. Michigan designated the lower portion of the river an Act 307 site in August 1986. MDNR removed 300 PCB-contaminated barrels and transformers from Consolidated Packaging site. MDNR completed Phase One of RI of east side of the Port of Monroe landfill.	MDNR conducted sediment sampling of river. Cleanups pending at five waste sites along river: Port of Monroe landfill, Ford Motor Company property, Consolidated Packaging-South Plant, Detroit Edison property, and City of Monroe landfill. All have documented overland and suspected groundwater routes for movement of metals and toxic organics (PCBs). Sediment sampling in 1988-89 showed the most impacted area to be from the turning basin to the mouth. Caged-fish studies showed River Raisin fish to have PCB uptake rates greater than Kalamazoo or Saginaw Rivers.	RI of the west side of the Port of Monroe landfill scheduled for spring. RI to begin for entire Consolidated Packaging Plant. Ford Motor Company is developing cleanup plan for its hazardous waste site. MDNR to begin RI/FS for Consolidated Packaging site. MDNR to begin RI/FS, for west side of Port of Monroe landfill.	Reduce loadings from waste and industrial sites along the river. Field studies to determine the lateral and vertical extent of sediment contamination and transport of contaminants from shore. Conduct RIs of Detroit Edison property and City of Monroe landfill.
Maumee River AOC is the lower 21 miles of river flowing into western Lake Erie. Water quality problems due to ammonia, metals and bacteria; sediments moderately to heavily polluted with metals, PCBs, and PAHs.	City of Toledo CSO abatement program began in 1985, to be completed in 1996. Dura and Stickney landfills were investigated and cleanup begun in 1986. Upgrades of Toledo WWTP completed in 1988. Ohio EPA contracted with Toledo Metropolitan Area Council of Governments to provide assistance with public involvement in RAP process (1985-ongoing).	**1989:** Nonpoint source and combined sewer overflows control measures instituted. Remedial investigations and actions underway at several landfills and dump sites in river basin. **1990:** Ohio EPA continued RAP development activities. Stage 1 RAP drafted. Continued WWTP improvements and combined sewer overflows projects.	Ohio EPA to submit Stage 1 RAP to IJC. EPA/Ohio EPA/ODNR/SCS nonpoint source project to educate local land users on how to prevent pollution. COE to dredge contaminated sediments from Toledo Harbor for confined disposal. State, FWS, EPA, and COE to negotiate plan for long-term disposal of dredged materials, including CDF siting.	Continue development of Swan Creek Wetland Recreation Project. Investigate contamination from landfills, dumps, and waste sites. Continued public education and involvement, establish a committee to review the success of remedial actions.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Black River Water quality problems due to metals, ammonia, phenol, bacteria, and cyanide; sediments heavily polluted with metals, oil and grease, and PAHs; fish consumption advisories for all fish species; bacteriological contamination of water column.	Agreement reached between EPA and U.S. Steel in 1985 under which the company will dredge PAH-contaminated sediments around one of its outfalls.	**1989:** New westside Lorain WWTP put into operation to relieve the overloaded eastside plant. Upgrades to Elyria WWTP under a Consent Judgement from U.S. District Court. **1990:** USX/Kobe completed dredging of contaminated sediments.	Ohio EPA to establish a local advisory board and begin public involvement process. Oberlin College to receive a grant from the Nord Family Foundation to produce public information materials and to begin compiling available data for the phase I draft.	Ohio EPA plans to submit Stage 1 RAP to IJC in FY 1992. Ohio EPA plans to submit Stage 2 RAP to IJC in FY 1993. Ohio EPA plans to conduct an intensive survey of the river in 1992.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Cuyahoga River The lower 6 miles of the river flowing through Cleveland is most degraded. Water quality problems due to metals, cyanide, ammonia, phenol, and bacteria; sediments heavily polluted with metals, oil and grease, PCBs, DDT, PAHs, and phthalates.	Ohio EPA surveys find recovering biological communities down river from Akron WWTP after reductions in toxicity of its discharge (1987). NE Ohio Regional Sewer District Southerly WWTP completed construction that enabled treatment of ammonia (1988). Ohio EPA begins RAP process by forming 35 member Cuyahoga coordinating committee (1988).	1989: Ohio EPA began 3-year fish tissue sampling program. Study conducted of bacterial contamination of the river downstream of Akron found water quality standards are met during dry weather conditions. 1990: Ohio EPA monitored bacterial conditions in river near Cleveland, finding significantly improved water quality. Fish tissue results from Akron area indicated no exceedences of FDA action levels. Ohio EPA to conduct intensive water quality survey on Coyahoga. LTV Steel began construction on a $20 million project that will greatly reduce contaminant loadings from their coking operations.	Ohio EPA to submit Stage 1 RAP to IJC. Ohio EPA to continue fish tissue sampling program and bacterial monitoring program. Ohio EPA to conduct intensive water quality survey on Cuyahoga.	Ohio EPA plans to submit Stage 2 RAP to IJC in FY 1992. Continue studies and education projects for nonpoint source, stormwater, and combined sewer overflow sources.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Ashtabula River The AOC includes the lower 2 miles of the river, the harbor, adjacent shore, and Fields Brook. Water quality problems due to metals; sediments heavily polluted with metals and PCBs; fish consumption advisories for all fish species; dredging delayed due to problems in siting disposal facility for polluted sediments.	Fields Brook designated a Superfund NPL site in 1981. In 1983-1986, EPA conducted an RI/FS of Fields Brook, a tributary to the river. EPA issued an ROD in 1986.	**1989:** Biological study of river conducted by Ohio EPA as part of natural resource damage assessment of the river, harbor, nearshore, and Fields Brook. EPA issued Administrative Order for PRPs at Fields Brook Superfund site to conduct studies to determine impacts from the site on the river and a drinking water intake in Lake Erie. Other studies conducted to further assess cleanup needs. **1990:** Fields Brook PRPs continue studies.	Ohio EPA to submit Stage 1 RAP to IJC. Corps of Engineers to conduct interim dredging to relieve navigation problem. Continuing investigation on Fields Brook. Continue search for toxic sediment disposal site.	Ohio EPA plans to submit Stage 2 RAP to IJC in FY 1992. Dredging and disposal of contaminated river sediments. Remediation of Fields Brook NPL site.
Lake Ontario **Buffalo River** Water quality problems with metals, dieldrin, BHC, and chlordane; sediments heavily polluted with metals, oil and grease, PAHs, and pesticides; fish consumption advisory for carp.		**1989:** EPA ARCS study sampled sediments in Buffalo River. **1990:** NYSDEC submitted Stage 1 RAP to IJC. FWS surveyed Buffalo River fish for tumors.	As part of ARCS study, EPA to sample water, fish tissues, and sediments over a 6-week period to evaluate hazards posed by sediment contamination. Investigations are underway to determine remedial recommendations related to contaminated sediments, sediment transport, dissolved oxygen, and fish habitat.	Annual RAP implementation updates will be prepared and investigations will be conducted where data gaps exist. State plans to submit Stage 2 RAP to EPA and IJC in FY 1992.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Eighteen Mile Creek Water quality problems due to metals, DDT, dieldrin, and trichlorofluoromethane; sediments moderately to heavily polluted with metals.	Treatment upgrades by numerous municipal and industrial dischargers.			NYSDEC plans to submit Stages 1 and 2 RAP to IJC in FY 1993.
Rochester Embayment Water quality problems due to ammonia and phosphorus; sediments moderately to heavily polluted with metals and cyanide; fish consumption advisory for carp from Irondequoit Bay.	City of Rochester began combined sewer overflows abatement program in 1977. Sewage from numerous small WWTPs in the basin was consolidated and conveyed to the Irondequoit Bay Pure Waters District from 1977 to 1987.		NYSDEC plans to submit Stage 1 RAP to IJC. EPA and NYSDEC to begin intensive consumer education campaign on use of household hazardous wates.	NYSDEC plans to submit Stage 2 RAP to IJC in FY 1992. City of Rochester combined sewer overflows abatement program to be completed in mid-1990s.
Oswego River Water quality problems due to metals, ammonia, and chloroform; sediments are contaminated with mirex and moderately to heavily polluted with metals; fish consumption advisory for channel catfish.		**1990:** NYSDEC submitted Stage 1 RAP to IJC.	NYSDEC plans to submit Stage 2 RAP to IJC.	Annual RAP implementation updates will be prepared and investigations will be conducted where data gaps exist.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
International Connecting Channels				
St. Marys River This 70 mile long river connects Lakes Superior and Huron. Water quality problems due to phenols, iron, zinc, cyanide, ammonia, and bacteria; sediments in some areas are contaminated with oil and grease, PCBs, PAHs, iron, and zinc; fish consumption advisories for large walleye, white suckers, longnose suckers, northern pike, and lake trout, mainly due to levels of mercury. Water quality and sediment problems are most pronounced along the Ontario shoreline downstream of Ontario discharges. Sediments are also heavily polluted with cadmium near the old Cannelton Tannery.	Algoma Steel (Canada) reduced its loadings of ammonia, cyanide, and phenols to the river. St. Marys Paper (Canada) has reduced loadings of suspended solids. Municipal wastewater treatment plants have improved removal of phosphorus and organic matter. In 1988, EPA proposed Cannelton Industries site be added to Superfund NPL. The site borders the St. Marys River in the City of Sault Ste. Marie, Michigan. From 1900 to 1958, a tannery operated at the site. EPA, MDNR, and other agencies in U.S. and Canada joined in an extensive study of the St. Marys River and biota in 1986-87.	**1989** EPA began RI/FS and removal action at Cannelton Industries site. Algoma Steel began investigations of possible seepage of toxics into river via groundwater from Algoma slag piles. **1990** Algoma Steel completed wastewater treatment plant.	MDNR and Province of Ontario to submit Stage 1 RAP to IJC. Sault Ste. Marie, Michigan, to develop and implement a plan to treat discharges from CSOs. EPA to start remedial actions at the Cannelton Industries tannery waste site. Short-term remedial actions include building a dike along the river and installing sprinklers to contain fires caused by spontaneous combustion. Michigan DNR and EPA to continue RI/FS.	**United States** Abate CSOs and remediate Cannelton Industries site. **Canada** Abate CSOs and industrial discharges.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
St. Clair River This 39 mile long river connects Lake Huron and Lake St. Clair. The largest petrochemical complex in Canada is located along the eastern shore of the river. The benthic fauna along the Canadian shore in the Sarnia area are impaired. Water quality problems due to organic solvents and bacteria; sediments contaminated with metals, PCBs, TCDD, and other trace organics; State fish consumption advisories for carp, large gizzard shad, and freshwater drum.	Loadings from petrochemical industries in Sarnia area are much reduced from the 1960s. Ontario and Michigan agreed to undertake a joint RAP in 1985. Binational Public Advisory Committee formed in 1988. EPA, MDNR, and other Federal agencies completed an extensive study of the St. Clair River and its biota in 1986-87. Investigations following a large spill of perchloroethylene in 1985 from Dow Chemical (Canada) disclosed additional sources requiring abatement.	Actions to reduce CSOs in Marine City, Marysville, St. Clair, and Port Huron, Michigan, are ongoing. Dow Chemical (Canada) pledged to invest $10 million on environmental improvements. Binational RAP team began drafting RAP in 1989.	MDNR and Province of Ontario plan to submit Stage 1 RAP to IJC in FY 1991. MDNR to continue fish contaminant trend monitoring.	**United States** Eliminate or adequately treat CSOs. **Canada** Reduce industrial loadings to river.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Detroit River This 32 mile long river connects Lake St. Clair to Lake Erie. Water quality problems due to phosphorus and bacteria; sediments in some nearshore areas are heavily polluted with metals, PCBs, and other organics; fish consumption advisories for carp, large freshwater drum, walleye, and rock bass; elevated incidence of liver tumors in five fish species (walleye, bowfin, bullhead, redhorse sucker, and white sucker); degraded benthic communities along the Michigan shoreline from the Rouge River to Lake Erie; restrictions on dredging.	Over $500 million have been spent in Michigan since 1972 to upgrade municipal WWTPs along the Detroit River. Municipal WWTPs in Windsor have improved removal of phosphorus. U.S. and Canada started RAP development in 1986, forming binational Public Advisory Committee in 1988, and began drafting RAP in 1989.	MDNR began fish contaminant monitoring in 1990. Department of Justice filed civil suit against the City of Detroit for alleged failure to implement pretreatment program for industrial discharges to POTWs.	MDNR plans to submit Stage 1 RAP to IJC. MDNR to conduct biological assessments on three tributaries.	Long-term sewer improvements needed to reduce combined sewer overflows to river.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
Niagara River This 37 mile long river connects Lake Erie and Lake Ontario. Water quality problems due to metals and organics; sediments in some nearshore areas and at the river mouth in Lake Ontario are contaminated with metals and PCBs; fish consumption advisories for carp, smallmouth bass, American eel, channel catfish, lake trout, large salmon, and rainbow and brown trout.	Niagara River Toxics Study by EPA, New York State, Ontario Ministry of Environment, and Environment Canada concluded in 1984. In 1987, the four agencies agreed to reduce toxics loads to the river by 50% over 10 years. Cleanups at significant U.S. hazardous waste sites: **Love Canal** - The landfill was capped and isolated with a liner and leachate collection system; dioxin-contaminated sediments removed from Black and Bergholtz Creeks. **Hyde Park Landfill** - Consent Decree with Occidental Chemical Corporation (OCC) filed in 1981 and amended in 1986. **102nd Street Landfill** - Consent Decree filed by EPA, New York State, and OCC in 1984. **S-Area Landfill** - Settlement agreement between EPA, New York State, and OCC in 1984.	**1989:** Pursuant to the 1987 Agreement, the agencies developed a joint Niagara River Toxics Management Plan. EPA issued a Superfund Administrative Consent Order to PRPs of Niagara County Refuse Disposal site requiring RI/FS of this site. **1990:** Cleanup activities at Hyde Park landfill, including construction of onsite leachate storage and treatment system, incineration of collected non-aqueous phase liquid, installation of source control extraction wells, and construction of containment collection systems. OCC and Olin Corporation completed RI/FS for 102nd Street landfill. EPA issued ROD for site. Amended settlement agreement for S-Area landfill filed.	EPA and New York State to begin intensive consumer education program on use of household hazardous wastes with local governments. PRP to begin RI/FS of Dupont Necco Park site.	NYSDEC to submit Stages 1 and 2 RAP to IJC in FY 1993. Cleanups of Niagara County Refuse Disposal site, 102nd Street landfill site, and S-Area landfill. Cut in half 1987-level loadings of target loadings of target toxic chemicals by 1996 as enunciated in binational declaration.

Table A-2. Selected Highlights of Progress in U.S. Areas of Concern (continued)

Area of Concern/Major Known Impairments	Background	Fiscal Years 1989-1990 Activities in AOC	Fiscal Year 1991 Activities in AOC	Long-Term Agenda
St. Lawrence River This AOC includes the Cornwall, Lake St. Francis, and Maitland areas in Canada, Massena, New York, and the Akwesnasne Indian Reservation. Water quality problems due to metals, bacteria, phenols, pesticides, and PCBs; sediments in some areas are heavily polluted with metals and PCBs; fish consumption advisories for American eel, channel catfish, lake trout, large salmon, and rainbow and brown trout. Because of contamination, the Akwasasne Mohawk Tribe has had to cut back on fish and waterfowl which had traditionally been important parts of their diet.	Mercury loadings to river from Cornwall (Canada) chloralkali plant of CIL, Incorporated, and pulp and paper plant of Domtar Fine Papers Limited (Canada) were substantially reduced by 1970.	EPA selected a remedial action for the General Motors site that includes dredging PCB contaminated bottom sediments from the St. Lawrence and Raquette Rivers and preventing the transport of contaminants via groundwater.	NYSDEC and Province of Ontario to submit Stage 1 RAP to IJC. EPA to issue a ROD for the General Motors NPL site. EPA to issue Superfund Administrative orders to the Aluminum Company of America (ALCOA) and the Reynolds Metal Company to perform remedial investigations, designs, and cleanups of PCB contaminated river sediments.	NYSDEC and Province of Ontario plan to submit Stage 2 RAP to IJC. Annual RAP implementation updates will be prepared and investigation will be conducted where data gaps exist.

End Notes

1. One risk assessment study has compared drinking untreated water from the relatively polluted Niagara River with consumption of Lake Michigan fish (caught in 1980-81). The study found that annual consumption of 15 kilograms of lake trout over a lifetime provided 1,000 times greater risk than drinking 2 liters of untreated Niagara River water every day. Data from Bro, K.M., W.C. Sonzogni, and M.E. Hanson, "Relative Cancer Risks of Chemical Contaminants in the Great Lakes," *Environmental Management*, Vol.11, No. 4, pp 495-505, Springer-Verlag New York, Inc., 1987.

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Figurel-2: Depth Profile of the Great Lakes and Summary of Their Physical Features

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Chapter Two

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Figure 2-3: Contaminants in Herring Gull Eggs on Sister Island (Green Bay) Wisconsin

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Figure 2-7: Routes of Releases of Toxic Substances around the Great Lakes (1988)

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Figure 2-8: Releases of Toxic Substances in Great Lakes Counties (1988)

Figure provided by P. Pranckevicius and B. Manne, U.S. EPA Great Lakes National Program Office, using data of 1988 from the U.S. EPA Toxics Releases Inventory.

Figure 2-9: Releases of Toxic Substances around the Great Lakes by Industrial Group (1988)

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Figure 2-10: Sediment Contamination in the Detroit River as Suggested by Impacts on Benthic Macroinvertebrate Communities

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Figure 2-13: Entry Routes of Exotic Species

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Figure 2-15: Annual Average Corrected Oxygen Depletion Rate, R_o, for Central Basin of Lake Erie

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Figure 4-2: Cropland in the Great Lakes Watershed (1988)

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Figure 4-3: Conservation Tillage in the Great Lakes Watershed (1988)

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Chapter Five

Figure 5-1: Great Lakes Harbors with the Most Recorded Oil and Chemical Spills, January 1980 - September 1989

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Chapter Six

Figure 6-1: Green Bay/Fox River Study Area

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Figure 6-2: Contaminants in Several Species of Lake Michigan Fish

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Chapter Seven

Figure 7-1: Superfund Expenditures in Great Lakes Counties in FYs 1987 through 1989

Figure provided by P. Pranckevicius and B. Manne, U.S. EPA Great Lakes National Program Office, using data of January 1990 from the U.S. EPA CERCLA Information System.

Figure 7-2: Construction Grant Awards in the Great Lakes Watershed

Figure provided by A. Nudelman, P. Strobel, and A. Mallory, using data of January 1991 from the U.S. EPA Grants Information Control System.

Glossary

A

Acute Toxicity: The ability of a substance to cause poisonous effects resulting in severe biological harm or death soon after a single exposure or dose. (See chronic toxicity, toxicity.)

Administrative Order: A legal document signed by EPA directing an individual, business, or other entity to take corrective action or refrain from an activity. The order describes the violations and actions to be taken and can be enforced in court. Such orders may be issued, for example, as a result of an administrative complaint whereby the respondent is ordered to pay a penalty for violations of a statute.

Adsorption: The adhesion of molecules of gas, liquid or dissolved solids to a surface.

Advanced Wastewater Treatment: Any treatment of sewage that goes beyond the secondary or biological water treatment stage and includes the removal of nutrients, such as phosphorus and nitrogen, and a high percentage of suspended solids. (See Primary, Secondary Treatment)

Advisory: A nonregulatory document that communicates risk information.

Agricultural Pollution: The liquid and solid wastes from farming, including runoff and leaching of pesticides and fertilizers, erosion and dust from plowing, and animal manure.

Airborne Particulates: Total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. Chemical composition of particulates varies widely, depending on location and time of year. Airborne particulates include windblown dust, emissions from industrial processes, smoke from the burning of wood and coal, and the exhaust of motor vehicles.

Air Contaminant: Any particulate matter, gas, or combination thereof, other than water vapor or natural air. (See air pollutant.)

Air Pollutant: Any substance in air that could, if in high enough concentration, harm man, other animals, vegetation, or material. Pollutants include almost any natural or artificial composition of matter capable of being airborne. They may be in the form of solid particles, liquid droplets, or in combinations of these forms. Generally, they fall into two main categories: (1) those emitted directly from identifiable sources and (2) those produced in the air by an interaction between two or more primary pollutants, or by a reaction with normal atmospheric constituents, with or without photoactivation. Exclusive of pollen, fog, and dust, which are of natural origin, about 100 contaminants have been identified and fall into the following categories: solids, sulfur compounds, volatile organic chemicals, nitrogen compounds, oxygen compounds, halogen compounds, radioactive compounds, and odors.

Algae: Simple rootless plants that grow in sunlit waters in relative proportion to the amounts of light and nutrients available. They can affect water quality adversely by lowering the dissolved oxygen in the water by their decay after their seasonal die-off. They are food for fish and small aquatic animals.

Ambient Air or Water: Air or water which is qualitatively representative of that found across a broad area (e.g., the ambient air of metropolitan Chicago; the ambient water quality of Lake Superior).

Anoxia: The absence of oxygen necessary for sustaining most life. In aquatic ecosystems, this refers to the absence of dissolved oxygen in water.

Anti-Degradation Policies: Part of Federal air quality and water quality requirements prohibiting environmental deterioration.

Aquifer: An underground geological formation, or group of formations, containing ground water that can supply wells and springs.

Areas of Concern: A geographic area that fails to meet the General or Specific Objectives of the Great Lakes Water Quality Agreement where such failure has caused or is likely to cause impairment of beneficial use or of the area's ability to support aquatic life. In general, these are bays, harbors, and river mouths with damaged fish and wildlife populations, contaminated bottom sediments, and past or continuing loadings of toxic and bacterial pollutants.

Atmosphere: [an] (the) The whole mass of air surrounding the earth, composed largely of oxygen and nitrogen.

Atmospheric Deposition: Pollution from the atmosphere associated with dry deposition in the form of dust, wet deposition in the form of rain and snow, or as a result of vapor exchanges.

B

Bacteria: Microscopic organisms some of which can aid in pollution control by consuming or breaking down organic matter in sewage, or by similarly acting on oil spills or other water pollutants. Bacteria in soil, water, or air can also cause human, animal, and plant health problems.

Benthic Organism (Benthos): A form of aquatic plant or animal life that is found on or near the bottom of a stream, lake, or ocean. Benthic populations are often indicative of sediment quality.

Benthic Region: The bottom layer of a body of water.

Bioaccumulative Substances: Substances that increase in concentration in living organisms (that are very slowly metabolized or excreted) as they breathe contaminated air or water, drink contaminated water, or eat contaminated food. (See biological magnification.)

Bioassay: Using organisms to measure the effect of a substance, factor, or condition by comparing before- and after- data.

Biological Magnification: Refers to the process whereby certain substances become ever more concentrated in tissues or internal organs as they move up the food chain. (See bioaccumulative.)

Biomass: All the living material in a given area: often refers to vegetation. Algal biomass is often indicative of the trophic status of a water body.

Bog: A type of wetland that accumulates appreciable peat deposits. Bogs depend primarily on precipitation for their water source and are usually acidic and rich in plant residue with a conspicuous mat of living green moss.

Byproduct: Material, other than the principal product, that is generated as a consequence of an industrial process.

C

Cap: A layer of clay, or other highly impermeable material, installed over the top of a closed landfill to prevent entry of rainwater and to minimize movement of leachate.

Carcinogen: Any substance that can cause or contribute to the production of cancer.

Carcinogenic: Cancer-producing.

Chlorinated Hydrocarbons: These include a class of persistent, broad-spectrum insecticides that linger in the environment and accumulate in the food chain, including DDT, aldrin, dieldrin, heptachlor, chlordane, lindane, endrin, mirex, hexachloride, and toxaphene. Other examples include TCE, which is used as an industrial solvent, and PCBs, formerly used as a hydraulic fluid.

Chlorophyll-a: The photosynthetic pigment found in most algae. Chlorophyll-a is used to measure the rate of photosynthesis in a region of water.

Chronic Toxicity: The capacity of a substance to cause poisonous effects in an organism after long-term exposure. (See acute toxicity.)

Cleanup: Actions taken to remedy a past release of a hazardous substance.

Clear Cut: The harvesting of all the trees in an area. Under certain soil and slope conditions, it can permit soil erosion.

Containment Cells: Enclosures which confine contaminants.

Combined Sewers: A sewer system that carries both sewage and stormwater runoff. Normally, its entire flow goes to a waste treatment plant, but during a heavy storm, the stormwater volume may be so great as to cause overflows (combined sewer overflow). When this happens, untreated mixtures of stormwater and sewage may flow into receiving waters. Stormwater runoff may also carry toxic chemicals from industrial areas or streets into the sewer system.

Combustion: Burning, or rapid oxidation, accompanied by release of energy in the form of heat and light. A basic cause of air pollution.

Consent Decree: A legal document, approved by a judge, that formalizes an agreement reached between EPA and Potentially Responsible Parties (PRPs) through which PRPs will conduct all of part of a cleanup action at a Superfund site, cease or correct actions or processes that are polluting the environment, or otherwise comply with regulations where the PRP's failure to comply caused EPA to initiate regulatory enforcement actions. The consent decree describes the actions PRPs will take and may be subject to a public comment period.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.

Conventional Pollutants: Such contaminants as organic waste, sediment, acid, bacteria and viruses, nutrients, oil and grease, or heat.

D

Decay: The breakdown of organic matter by bacteria and fungi.

Dissolved Oxygen (DO): The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to protect DO in waste-receiving waters.

Drainage Basin: A water body and the land area drained by it.

Dredging: Removal of mud from the bottom of a water body.

E

Ecosystem: The interacting system of a biological community and its non-living environmental surroundings.

Effluent: Wastewater – treated or untreated – that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

Emission: Discharges into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

Enrichment: The addition of nutrients (e.g., nitrogen, phosphorus, carbon compounds) from sewage effluent or agricultural runoff to surface water. This process greatly increases the growth potential for algae and aquatic plants.

Epidemiology: The study of diseases as they affect population, including the distribution of disease, or other health-related states and events in human populations, the factors (e.g. age, sex, occupation, economic status) that influence this distribution, and the application of this study to control health problems.

Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land use practices related to farming, residential or industrial development, mining, or timber-cutting.

Estuary: Regions of interaction between rivers and nearshore oceans where tidal action and river flow create a mixing of freshwater and saltwater, including bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife. (See wetlands.)

Eutrophication: The process of fertilization that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process or it can be a cultural process accelerated by an increase of nutrient loading to a lake by human activity.

Exotic Species: Species that are not native to the Great Lakes and have been intentionally introduced or have inadvertently infiltrated the system. Exotics may prey upon native species and compete with them for food or habitat.

F

Feasibility Study (FS): Analysis of the practicability of a proposal (e.g., a description and analysis of the potential cleanup alternatives for a site on the National Priorities List). The feasibility study usually recommends selection of a cost-effective alternative. It usually starts as soon as the remedial investigation is underway; together, they are commonly referred to as the "RI/FS". The term can apply to a variety of proposed corrective or regulatory actions.

Fen: A type of wetland that accumulates peat deposits. Fens are less acidic than bogs, deriving most of their water from ground water rich in calcium and magnesium. (See wetlands.)

Fertilizer: Materials, including nitrogen and phosphorus, that provide nutrients for plants.

Food Chain: A sequence of organisms, each of which uses the next, lower member of the sequence as a food source. Members of a chain are interdependent so that a disturbance to one species can disrupt the entire hierarchy, resulting in starvation at every level.

Food Web: The complex feeding network occurring within and between food chains in an ecosystem, whereby members of one food chain may belong to one or more other food chains.

G

Game Fish: Fish species caught for sport, such as trout, salmon, or bass.

Ground Water: The supply of freshwater or saline water found beneath the Earth's surface, usually in aquifers, which is often used for supplying wells and springs.

H

Habitat: The place where a population (e.g., human, animal, plant, micro-organism) lives and its surroundings, both living and non-living.

Hazardous Air Pollutants: Air pollutants that are not covered by ambient air quality standards but which, as defined by the Clean Air Act, may reasonably be expected to cause or contribute to irreversible illness or death. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.

Hazard Ranking System: The principle screening tool used by EPA to evaluate risks to public health and the environment associated with abandoned or uncontrolled hazardous waste sites. The HRS calculates a score based on the potential of hazardous substances spreading from the site through the air, surface water, or ground water and on other factors, such as nearby population. This score is the primary factor in deciding if the site should be on the National Priorities List and, if so, what ranking it should have compared to other sites on the list.

Hazardous Waste: Byproducts of society that can pose a substantial or potential hazard to human health and/or the environment when managed improperly. Waste is defined as hazardous if it possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA lists.

Heavy Metals: Metallic elements with high atomic weights (e.g., mercury, chromium, cadmium, arsenic, and lead). They are toxic and tend to bioaccumulate.

Herbicide: A chemical pesticide designed to control or destroy plants, weeds, or grasses.

I

Indicator: In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions.

Insecticide: A chemical specifically used to kill or control the growth of insects.

International Joint Commission (IJC): A binational Commission, established by the 1909 Boundary Waters Treaty, with responsibility for decisions regarding obstruction or diversion of U.S./Canadian boundary waters and to which other questions or matters of difference can be referred for examination and report. The Commission also has authority to resolve differences arising over the common frontier. In 1972 the Commission was given responsibility for assisting and monitoring the two governments' implementation of the Great Lakes Water Quality Agreement.

J, K, L

Lampricide: A chemical used to kill the sea lamprey.

Landfills: 1. Sanitary landfills are land disposal sites for nonhazardous solid wastes at which the waste is spread in layers, compacted to the smallest practical volume, and covered with material applied at the end of each operating day. 2. Secure chemical landfills are disposal sites for hazardous waste. They are selected and designed to minimize the chance of release of hazardous substances into the environment.

Larva: the early, free-living form of any animal that changes structurally when it becomes an adult, usually by a complex metamorphosis.

Leachate: A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides or fertilizers. Leaching may occur in farming areas, feedlots, and landfills and may result in hazardous substances entering surface water, ground water, or soil.

Leaded Gasoline: Gasoline to which lead has been added to raise the octane level.

Liner: A relatively impermeable barrier designed to prevent leachate from leaking from a landfill. Liner materials include plastic and dense clay.

Loading: The addition of a substance to a water body.

M

Marsh: A type of wetland that does not accumulate appreciable peat deposits and is dominated by herbaceous vegetation. Marshes may be either freshwater or saltwater and tidal or nontidal. (See wetlands.)

Mass Balance: An approach to evaluating the sources, transport, and fate of contaminants entering a water system, as well as their effects on water quality. In a mass balance budget, the amounts of a contaminant entering the system less the quantities stored, transformed, or degraded must equal the amount leaving the system. If inputs exceed outputs, pollutants are accumulating and contaminant levels are rising. Once a mass balance budget has been established for a pollutant of concern, the long-term effects on water quality can be simulated by mathematical modeling.

Metabolite: A substance, derived from a chemical, produced by biological processes.

Modeling: A theory or a mathematical or physical representation of a system that accounts for all or some of its known properties. Models are often used to test the effect of changes of system components on the overall performance of the system.

Monitoring: A scientifically designed system of continuing standardized measurements and observations and the evaluation thereof.

Mulch: A layer of material (e.g., wood chips, straw, leaves) placed around plants to hold moisture, prevent weed growth, protect the plants, and hold the soil.

N

National Pollutant Discharge Elimination System (NPDES): The national program for controlling direct discharges from point sources of pollutants (e.g., municipal sewage treatment plants, industrial facilities) into waters of the U.S.

National Priorities List (NPL): EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. A site must be on the NPL to receive money from the Trust Fund for remedial action. The list is based primarily on the score a site receives from the Hazard Ranking System. EPA updates the NPL at least once a year.

Navigable Waters: Traditionally, waters sufficiently deep and wide for navigation by all or specified sizes of vessels; in the U.S. these waters come under Federal jurisdiction.

Nitrate: A compound containing nitrogen and oxygen that can exist in the atmosphere or in water and that can have harmful effects on humans and animals at high concentrations.

Nonpoint Source: Pollution sources that are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off land by stormwater runoff. Commonly used categories for nonpoint sources are agriculture, forestry, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion.

Nutrient: Any substance assimilated by living organisms that promotes growth. The term is generally applied to nitrogen and phosphorous in wastewater, but is also applied to other essential trace elements.

O

Oligotrophic Lakes: Clear lakes with low nutrient supplies that contain little organic matter and have a high dissolved-oxygen level.

Open-Lake: Those waters in a lake unaffected by physical and chemical processes originating or resulting from the adjacent land mass. Physical, chemical, and biological phenomena resemble oceanographic conditions in open-lake waters.

Organic Chemicals/Compounds: Animal- or plant-produced substances containing mainly carbon, hydrogen, and oxygen.

Organism: Any living plant or animal.

Organochlorine: Any organic compound containing chlorine.

P, Q

Parasitic: Any organism that lives on or in an organism of another species from which it derives sustenance or protection without benefit to, and usually with harmful effects on, the host.

Permit: An authorization, license, or equivalent control document issued by EPA or a State agency to implement the requirements of an environmental regulation (e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions).

Persistent Pesticides: Pesticides that do not break down chemically or that break down very slowly.

Pesticide: A substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant. Pesticides can accumulate in the food chain and/or contaminate the environment if misused.

Phosphorus: An essential chemical food element that can contribute to the eutrophication of lakes and other water bodies.

Photosynthesis: A process occurring in the cells of green plants and some microorganisms in which solar energy is transformed into stored chemical energy.

Phytoplankton: That portion of the plankton community comprising tiny plants (e.g., algae, diatoms).

Plankton: Microscopic plants and animals that live in water.

Point Source: A stationary location or fixed facility from which pollutants are discharged or emitted. Also, any single identifiable source of pollution (e.g., a pipe, ditch, ship, ore pit, factory smokestack).

Pollutant: Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.

Pollution Prevention: Measures taken to reduce the generation of a substance that could be harmful to living organisms if released to the environment. Pollution prevention can be achieved in many ways.

Potentially Responsible Party (PRP): Any individual or company including owners, operators, transporters, or generators potentially responsible for, or contributing to, the contamination problems at a Superfund site. Whenever possible, EPA requires PRPs, through administrative and legal actions, to clean up hazardous waste sites that they may have created.

Predator: Any organism that lives by capturing and feeding on another animal.

Pretreatment: Processes used to reduce, eliminate, or alter the nature of pollutants from non-domestic sources before they are discharged into publicly owned sewage treatment.

Primary Waste Treatment: This treatment consists of the first steps in wastewater treatment during which screens and sedimentation tanks are used to remove most materials that float or will settle. Primary treatment results in the removal of about 30 percent of carbonaceous biochemical oxygen demand from domestic sewage.

Productivity: Refers to the efficiency at which an ecosystem generates life from energy.

Publicly Owned Treatment Works (POTWs): A waste-treatment facility owned by a State, unit of local government, or Indian tribe.

R

Radiotracers: A radioactive substance, usually an isotope, used to mark the progress of a process (e.g., the physical movement of sediment).

Record of Decision (ROD): A public document that explains which cleanup alternative(s) will be used at Superfund National Priorities List sites.

Remedial Action Plans (RAPs): Environmental plans aimed at restoring all beneficial uses to Great Lakes Areas of Concern.

Remedial Design: A phase of remedial action that follows the remedial investigation/feasibility study and includes development of engineering drawings and specifications for a site cleanup.

Remedial Investigation: An in-depth study designed to gather the data necessary to determine the nature and extent of contamination at a Superfund site, establish criteria for cleaning up the site, identify preliminary alternatives for remedial actions, and support the technical and cost analyses of the alternatives. The remedial investigation is usually conducted with the feasibility study; together, they are usually referred to as an "RI/FS".

Removal Action: Quick remedies taken to address immediate hazards at contaminated waste sites.

Research: Development, interpretation, and demonstration of advanced scientific knowledge for the resolution of issues. It does not include monitoring and surveillance of water or air quality.

Resuspension (of sediment): The remixing of sediment particles and pollutants back into the water by storms, currents, organisms, and human activities, such as dredging.

Retention Time: The time it takes for the volume of water in a lake to exit through its outlet (i.e., Total volume/outlet flow = Retention time).

Risk Assessment: The qualitative and quantitative evaluation performed in an effort to define the risk posed to human health and/or the environment by the presence or potential presence and/or use of specific pollutants.

Run-Off: That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water. It can carry sediments and pollutants into the receiving waters.

S

Secondary Waste Treatment: The second step in most waste treatment systems in which bacteria consume the organic parts of the waste. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment. (See primary, tertiary treatment.)

Sediments: Soil, sand, and minerals eroded from land by water or air. Sediments settle to the bottom of surface water.

Sewage: The waste and wastewater produced by residential and commercial establishments and discharged into sewers.

Sewer: A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste, storm sewers carry runoff from rain or snow, and combined sewers carry both.

Silt: Fine particles of soil, sand or rock; sediment.

Site Inspection: The collection of information from a Superfund site to determine the extent and severity of hazards posed by the site, including information to score the site, using the Hazard Ranking System, and to determine if the site presents an immediate threat that requires prompt removal action. It follows and is more extensive than a preliminary assessment.

Sludge: A semi-solid residue from any of a number of air or water treatment processes.

Solid Waste: Nonliquid, nonsoluble materials, ranging from municipal garbage to industrial wastes, that contain complex, and sometimes hazardous, substances. Solid wastes also include sewage sludge, agricultural refuse, demolition wastes, and mining residues.

Stratification (or layering): The tendency in deep lakes for distinct layers of water to form as a result of vertical change in temperature and therefore in the density of water. During stratification, dissolved oxygen, nutrients, and other parameters of water chemistry do not mix well between layers, establishing chemical as well as thermal gradients.

Superfund: The program operated under the legislative authority of CERCLA and SARA that carries out the EPA solid waste emergency and long-term remedial activities. These activities include establishing a National Priorities List of hazardous waste sites, investigating sites for inclusion on the list, determining their priority on the list, and conducting remedial actions.

Surface Water: All water naturally open to the atmosphere (e.g., rivers, lakes, reservoirs, streams, impoundments, seas, estuaries) and all springs, wells, or other collectors that are directly influenced by surface water.

Surveillance: Specific observations and measurements relative to control or management.

Suspended Solids: Small particles of solid pollutants that float on the surface of, or are suspended in, sewage or other liquids.

Swamp: A type of wetland that is dominated by woody vegetation and that does not accumulate appreciable peat deposits. Swamps may be freshwater or saltwater and tidal or nontidal. (See wetlands.)

T

Tailings: Residue of raw materials or waste separated out during the processing of crops or mineral ores.

Technology-Based Standards: Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water-quality effects.

Terracing: Diking, built along the contour of sloping agricultural land, that holds runoff and sediment to reduce erosion.

Tertiary Waste Treatment: Advanced cleaning of wastewater that goes beyond the secondary or biological stage and removes nutrients, such as phosphorous and nitrogen, and most biological oxygen demand and suspended solids.

Toxic: Poisonous to living organisms.

Toxic Substance: A substance that can cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions, or physical deformities in any organism or its offspring. The quantities and length of exposure necessary to cause these effects can vary widely.

Toxicant: A poisonous agent that kills or injures animal or plant life.

Trophic Status: A measure of the biological productivity in a body of water. Aquatic ecosystems are characterized as oligotrophic (low productivity), mesotrophic (medium productivity), or eutrophic (high productivity).

U

Urban Runoff: Stormwater from city streets and adjacent domestic or commercial properties that may pickup terrestrial contamination and carry pollutants of various kinds into sewer systems and/or receiving waters.

V

Vaporization: The change of a substance from a liquid to a gas.

Volatile Substance: A substance that evaporates readily.

W

Waste Treatment Plant: A facility containing a series of tanks, screens, filters, and other processes by which pollutants are removed from water.

Wastewater: The spent or used water from individual homes, a community, a farm, or an industry that often contains dissolved or suspended matter.

Watershed: The land area that drains into a river, stream, or lake.

Water Table: The level of ground water.

Water Quality Standards: State-adopted and EPA-approved ambient standards for water bodies. Standards are developed considering the use of the water body and the water quality criteria that must be met to protect the designated use or uses.

Wetland: An area that is regularly saturated by surface water or ground water and is characterized by a prevalence of vegetation that is adapted for life in saturated soil conditions (e.g., swamps, bogs, fens, marshes, and estuaries).

Wildlife Refuge: An area designated for the protection of wild animals, within which hunting and fishing are either prohibited or strictly controlled.

X, Y, Z

Zooplankton: Microscopic aquatic animals.

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