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Environmental Protection
Agency

Great Lakes
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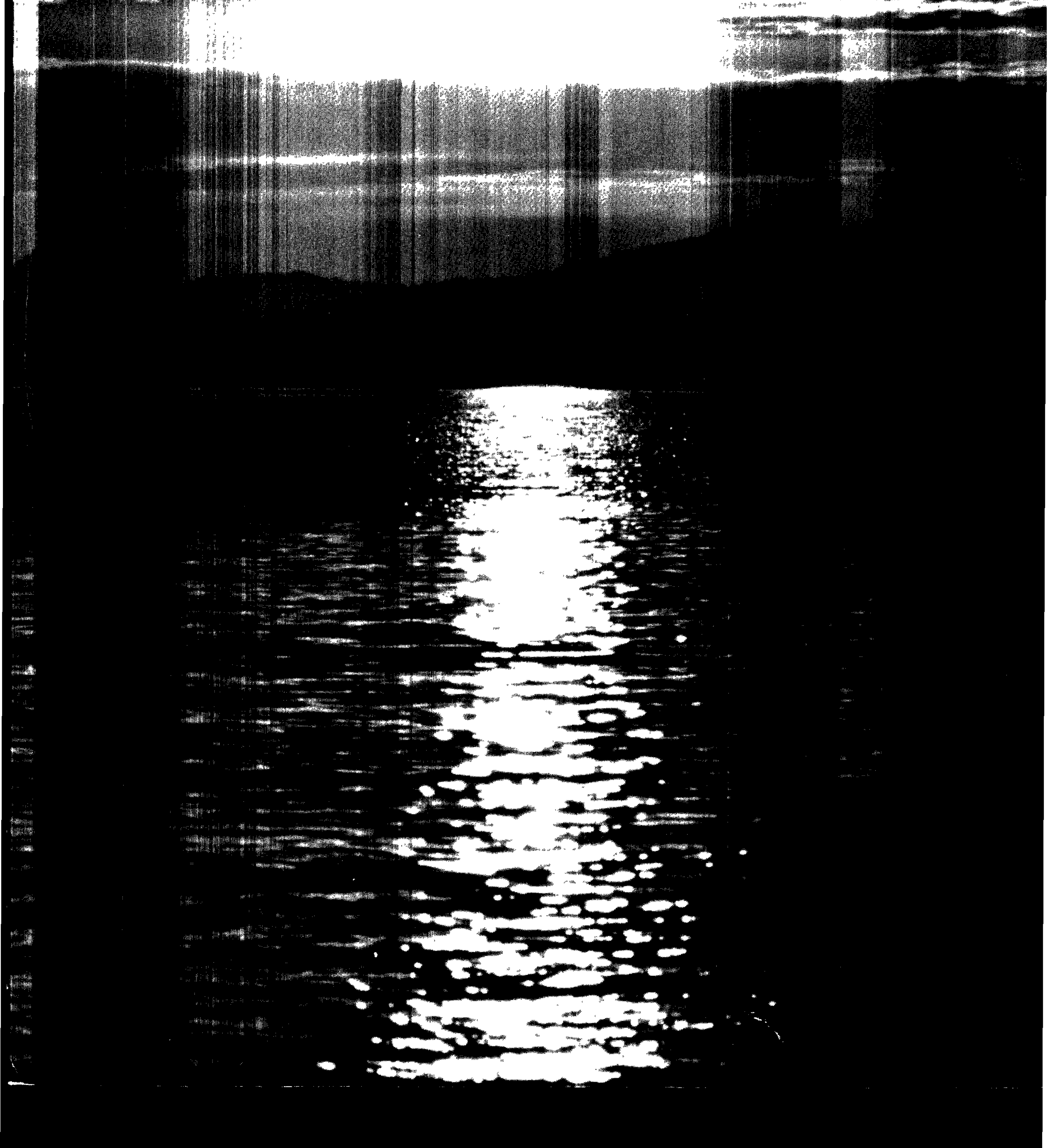
EPA

# A Report to Congress on The Great Lakes Ecosystem



This report is prepared pursuant to Sections 118(c)(10) and 118(f) of the Clean Water Act, which state:

**118(c)(10) 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.

**Cover Photograph:** A scene on Lake Superior rendered by photographer Richard Olsenius. The photograph, which appears in his book, *Distant Shores* (Two Harbors, Minnesota: Bluestem Productions, 1990), was reproduced in black and white for this report.

# *REPORT TO CONGRESS ON THE GREAT LAKES ECOSYSTEM*

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

# Report Highlights

**Pursuant to Section 118(c)(10) of the Clean Water Act, this is the Environmental Protection Agency's second report to Congress on the Great Lakes ecosystem. This "Highlights" section reviews some principal challenges facing the ecosystem, cites recent actions by EPA, States, and their partners in the Great Lakes Program, and outlines future directions of the Program.**

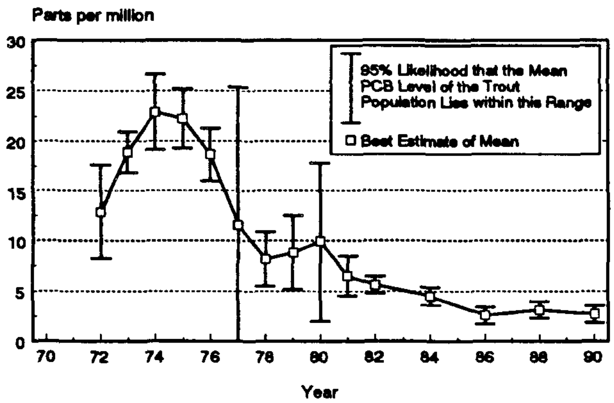
## Aspects of Ecosystem Health

By area, the Great Lakes system is the world's largest body of surface freshwater. This extraordinary natural endowment, reaching far into a continent, has long supported abundant life. The Lakes are essential habitat for many of North America's animal species. Multitudes of birds pass through the Lakes on their seasonal migrations. The Lakes yield rich bounty to fishermen. Millions of Americans and Canadians rely on the Lakes for drinking water and economic vitality. The Lakes are an important commercial waterway and many firms draw water from them for industrial processes, helping make the region an industrial heartland for two nations. Manufacturing is the largest employment sector in the region, both north and south of the U.S./Canadian border.

By the start of the twentieth century, the combined effects of pollution, hunting, and habitat change, such as the clearing of primeval forests and the draining of vast wetlands, had devastated many once prolific Great Lakes animal populations. Yet, especially over the past thirty years, the people of the region and their governments have achieved encouraging ecological successes, abating excessive algae in Lake Erie, protecting fish populations from sea lamprey, and restoring oxygen-depleted waters. Levels of targeted toxic contaminants have declined substantially in fish and wildlife, resulting in clear improvements in the health of many species.

Today, despite these valuable achievements, the Great Lakes ecosystem faces a range of both new and abiding environmental challenges:

**PCB Levels In Lake Trout, Southeast Lake Michigan**




*PCBs, a key contaminant, have declined greatly in fish from levels of twenty years ago, but still justify issuance of fish consumption advisories. Levels in lake trout from southeast Lake Michigan, for instance, are still 180 times greater than EPA's criteria for PCBs in fish tissue.*

### *Contaminated Fish and Wildlife*

The Great Lakes food web remains contaminated by a variety of bioaccumulative toxic substances, causing unacceptable levels in some fish and wildlife. Levels are much lower than in the early 1970s but still justify issuance of public health advisories regarding fish consumption. Advisories especially apply to vulnerable consumers, such as children and women who anticipate bearing children. Contaminants have been associated with health problems in some fish and wildlife species, although with the significant decline in contaminant levels 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, such as lake trout, mink, and bald eagles. Contaminant levels are generally highest in Lakes Michigan and Ontario, though these lakes have also experienced the greatest declines in contaminant levels during the past two decades.

### *Contaminated Bottom Sediments*

Bottom sediments in many harbors and rivers are poisoned by a variety of bioaccumulative toxic substances. Contaminants accumulate in sediments because many contaminants in water bind to suspended particles and fall to the bottom. Thus, contaminated bottom sediments are indicative of past loadings of contaminants to the Lakes. Contaminated sediments 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 bottom-dwelling organisms; and they injure such organisms. Contaminated sediments increase the costs of navigational dredging owing to the added costs of handling and disposing of toxic materials. In some locations, contamination has delayed navigational dredging for years and curtailed waterborne commerce.

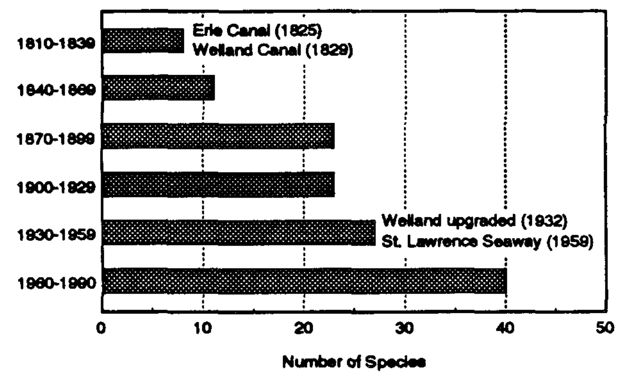
### *Diminished Wetlands*

Wetlands, including bogs, fens, marshes, and swamps, provide essential habitat for birds, fish, and other wildlife. More than one-half of Great Lakes wetlands have been lost since 1800. Chicago, Detroit, and Milwaukee all partly rest on former wetlands. The present rate of destruction is much less than in prior eras, but development continues to pressure remaining wetlands.

## *Exotic Species*

More than 130 exotic (nonnative) species have been introduced to the Great Lakes since 1800, nearly one-third carried by ships. Some exotics have profoundly damaged native species. A troublesome recent invader, the zebra mussel, probably entered the Lakes via ballast water discharge from an oceangoing vessel. The full impacts of the mussel are not yet known, but are potentially great. A prolific breeder, the mollusk devours microscopic plants at the foundation of the food web and may create a food shortage for fish that graze on these plants, ultimately threatening predator fish, such as walleye, salmon, and lake trout. River ruffe, spiny water flea, tubenose goby, and round goby are other recent invaders.

**Timing of Exotic Species**




*The introduction of exotics has increased over the last 30 years, since completion of the St. Lawrence Seaway allowed more transoceanic shipping.*

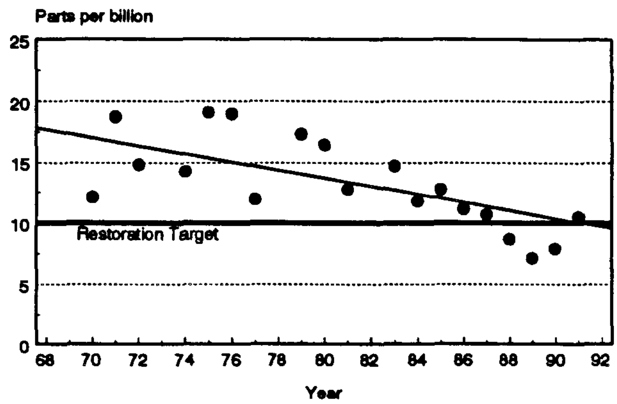
## *Depleted Native Fish Populations*

Populations of many native fish species are fewer than two centuries ago. Their depletion can be attributed to food chain disruptions, habitat loss and disruption (e.g., wetlands have been drained, spawning beds covered with silt, and dams have impeded passage up rivers), competition from and predation by nonnative species (e.g., alewife have displaced lake herring, sea lamprey feed on large fish), among other reasons.

Damage to once richly abundant native fish populations is profound. Lake herring was once the predominant forage fish. Sturgeon grew six feet in length and weighed more than 100 pounds. Today, sturgeon and lake herring survive in much depleted numbers. Hatchery-reared lake trout must be stocked to maintain ecological balance and to sustain sport and commercial fisheries. Stocked, nonnative Pacific salmon—coho and chinook—are the most abundant top predators, except in western Lake Erie where the top predator is walleye.

Yet, since severe depletion of fish communities by the 1950s, some heartening progress to improve fish resources has been made. The control of sea lamprey and the stocking of lake trout and Pacific salmon have permitted the growth of important commercial and sport fishing industries. Five million Great Lakes sport fishermen spend more than $2 billion each year.

**Spring Phosphorus Levels in Lake Erie's Central Basin**




*Phosphorus levels have fallen, but the central basin of Lake Erie continues to suffer exhaustion of dissolved oxygen in its bottom waters during late summer.*

### *Excessive Phosphorus*

In some shallow waters that receive agricultural runoff of fertilizers and/or in areas having a high surrounding human population, such as Lake Erie, Lake Ontario, Saginaw Bay, and Green Bay, water is overenriched with 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 their seasonal die-off and decay. Nevertheless, the bottom waters of central Lake Erie continue to suffer exhaustion of dissolved oxygen during late summer. However, the encouraging news is that phosphorus concentrations in the water column of Lake Erie are approaching those predicted to achieve desired water quality.

## Putting the Ecosystem Approach to Work

EPA and its Federal/State partners are focusing on the Great Lakes in a pioneering program to protect the integrity of a fragile natural ecosystem. During 1991, agencies with stewardship responsibilities for the ecosystem developed a joint five year Great Lakes strategy that they launched in 1992. In addition to EPA and the eight Great Lakes States, partners to the strategy include 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 strategy joins environmental protection and natural resource agencies in pursuit of common goals—reducing releases of toxicants to the environment, protecting and restoring habitat, and protecting the ecosystem's living resources. The strategy's partners envision updates that will keep it a current, action-forcing document.

EPA and States are using the Great Lakes as a proving ground for innovative pollution prevention efforts. Pollution prevention is the adoption of "greener" (environmentally kind) technologies and practices. Pollution prevention is the preferred means to reduce releases of toxicants because it forestalls ecological damage and saves resources otherwise needed to treat or cleanup contaminants. EPA and States are inviting all sectors of society to contribute ideas for reducing the quantity and harmfulness of resources used to satisfy human needs. In 1991, the Agency and the governors of the eight Great Lakes States launched a Pollution Prevention Action Plan for the Lakes. This plan supplements EPA's nationwide initiative, the 33/50 Program, to seek voluntary reductions of 17 priority contaminants. In response to this national program, the Agency has already received commitments from industrial firms to end nearly 300 million pounds of releases of the targeted chemicals by 1995.

The EPA/State commitment to pollution prevention is buttressed by strong enforcement of environmental laws. EPA and States continue to take warranted enforcement actions around the Great Lakes region; this report cites many of these. The Agency has steadily increased its resources for enforcement within the region over the past five years. Some examples of recent enforcement actions within the Great Lakes watershed:

- Agreement by a paper company to pay a $2.1 million civil penalty for Clean Water Act violations.
- Agreement by a waste management firm to pay a $3.75 million civil penalty for violating PCB disposal requirements in Chicago.
- Agreement by an aluminum company to pay $7.5 million for offenses in handling hazardous wastes near the St. Lawrence River.
- Agreement by a steel company to expend $34.1 million for environmental improvements, sediment cleanup, and civil penalties. The improvements will reduce loadings of ammonia to Lake Michigan by about 400,000 pounds per year and lower oil and grease loadings by more than 1,000,000 pounds per year.
- Agreement by a municipal treatment facility to clean a sludge lagoon which contains over 50,000 pounds of PCBs and to lower its discharge of lead to the Great Lakes by over 5,500 pounds per year.
- Removal of 32,000 cubic yards of contaminated sediments from the Black River, Ohio by a steel company pursuant to a 1985 settlement.
- Removal of 300,000 pounds of PCBs from Waukegan Harbor, Illinois, pursuant to a Superfund cleanup plan.

A hallmark of the Great Lakes Program is to focus on priority ecological problems and geographic areas, thereby targeting the most promising opportunities for environmental improvements. To identify priority problems, EPA ranked human health and ecological hazards facing the Great Lakes region, concluding that the most significant sources of environmental contaminants were concentrated around Chicago, Illinois and Gary, Indiana; Detroit, Michigan; Buffalo and Niagara Falls, New York; and Cleveland, Ohio. In response, the Agency and States focused prevention, inspection, enforcement, and cleanup efforts, under Special Geographic Initiatives, on several of these areas.

Two processes for targeting ecological problems on a geographic basis are Remedial Action Plans (RAPs) for Areas of Concern and Lakewide Management Plans (LAMPs). Including five shared with Canada, the United States has 31 Areas of Concern, which are the most ecologically degraded areas around the Lakes, most often harbors and stretches of rivers. The Remedial Action Plan process defines ecological problems, identifies appropriate solutions, and measures progress towards ecological goals. States, enlisting grass-roots collaboration from local communities, develop and implement RAPs. To date, States have completed first editions of 23 Stage I (problem definition) and 12 State II (remedial action definition) RAPs.

The Great Lakes Program is also developing LAMPs to address problems posed by critical pollutants that extend beyond Areas of Concern. During 1991, EPA and States completed initial editions of LAMPs for the Lakes that have experienced the greatest contamination—Michigan and Ontario. In FY 1992, EPA, Michigan, Minnesota, and Wisconsin began a LAMP for Lake Superior. LAMPs for Lakes Erie and Huron will follow. Both RAPs and LAMPs will be updated as warranted.

A key early activity in support of the LAMP process, launched by EPA and States in 1989, is their "Great Lakes Water Quality Initiative." In view of the unique features of the Great Lakes, including long water retention time and vulnerability to bioaccumulative contaminants, EPA and States consider that water quality criteria specific to the Lakes are necessary to fully protect aquatic life, wildlife, and human health on a long-term basis. The Initiative is a precedent-setting effort to establish uniform regulatory practices, fully protective of one ecosystem, among the States that share it. EPA published its proposed binding guidance on Great Lakes water quality criteria, implementation procedures, and antidegradation policy in April 1993.

Proper disproval of existing stocks of contaminants is a major aspect of early Lake Michigan LAMP activities. The Agency asked Great Lakes utility companies to accelerate phase-out of electrical equipment which contain PCBs to prevent the possibility of accidental spills of this critical pollutant. In response, the majority of utilities have committed to speeding-up their PCB phaseouts. Other activities in support of the Lake Michigan LAMP are agricultural "clean sweeps" under which States invite farmers and pesticide dealers to turn-in pesticide stocks for proper disposal. The Lake Michigan States conducted clean sweeps in that Lake's watershed during 1992, collecting more than 11,000 pounds of suspended or cancelled pesticides.

The value of the RAP and LAMP processes is measured in taking actions to meet local community needs and to achieve ecological results. Even as plans have been under development, EPA and States have taken warranted actions to improve Areas of Concern. This report cites many of these (in Chapter Four), with an emphasis on areas like the Grand Calumet and Niagara Rivers, which have been the focuses of Special Geographic Initiatives.

Another cornerstone of the Great Lakes Program is promotion of public stewardship. Community "stakeholders" are strongly involved in Remedial Action Planning, helping governments be more responsive to local concerns. In 1991, EPA put into service a state-of-the-art Great Lakes research vessel that is also serving as an educational platform. Tours of the ship by the public, including visits by school children, are promoting broader awareness of Great Lakes environmental issues.

To ensure that environmental decisions are based on the best scientific information, the Agency and its partners are working to improve their understanding of the health of the ecosystem. Traditionally, EPA has often relied on administrative statistics—such as numbers of permits and enforcement actions—as surrogate measures of effectiveness. The Great Lakes Program will increasingly assess environmental progress by monitoring water, land, and air conditions and biological response to these by plants and animals. The foundation of the Agency's strengthened monitoring effort will be the Environmental Monitoring and Assessment

Program (EMAP), which is a national program that gauges the health of our Nation's ecosystems. Some recent steps to monitor the health of the ecosystem include:

- EPA put into service a 180 foot long research vessel, the Lake Guardian, for study of the Lakes. The ship can sample water quality to the deepest depths of the Lakes and bottom sediments to a depth of 40 feet.
- EPA sponsored a major study and demonstration program to assess contaminated Great Lakes bottom sediments, test promising remedial technologies, and develop guidance on addressing such contamination. EPA has completed assessment work in five Areas of Concern, identified treatment technologies to be tested at each, and has demonstrated these in the field.
- EPA established three master stations to monitor atmospheric deposition of toxic contaminants. Between them, the United States and Canada now have one master station on each of the Lakes.

EPA is also working to strengthen its integration and analysis of environmental data relating to the Lakes. Through its various programs, the Agency collects data on air and water pollution, hazardous waste sites, pesticides, drinking water, radiation, and the health effects of pollutants. Much of this information is obtained pursuant to separate laws and is narrowly focused to serve these mandates. In general, it is not easy to integrate data to obtain a comprehensive view of total pollutant releases by a facility and surrounding ecological conditions. Accordingly, the Agency is working to improve the availability of data to support decisions by Federal, State, and local governments and to make information more accessible to the public.

Under its ecosystem approach, the Great Lakes Program is integrating government activities around an ecosystem, setting goals on the basis of environmental needs and measuring progress by ecological yardsticks. In all its activities, EPA is seeking the involvement of States, other Federal agencies, Indian Tribes, and the public. EPA and States are also taking advantage of all opportunities to work with their counterparts in Canada. For instance, the two nations cosponsored a pollution prevention symposium and have developed a binational Great Lakes research strategy.

## Toward the Future

The Great Lakes Program is guided by its five year Strategy. Within this context, some future endeavors will be:

### *Reducing Releases of Toxicants to the Environment*

- Pollution prevention will continue to be the preferred means to reduce emissions and discharges of environmental contaminants. States and EPA will continue to implement their pollution prevention action plan for the Lakes. This will supplement EPA's national initiative, the 33/50 Program, to encourage voluntary reductions of 17 priority contaminants through 1995.

- The U.S. Department of Agriculture (USDA), States, and EPA will continue nonpoint source pollution prevention programs. Many of these programs will focus on tributary watersheds in which nonpoint source problems are pronounced, such as Saginaw Bay, Lake Erie, and Green Bay. In addition to education and incentives for environmentally-kind agricultural practices, these agencies will invite the public via "clean sweep" campaigns to dispose of pesticide stocks.
- Implementation of the binational Lake Superior Program will aim to achieve "zero discharge" of bioaccumulative toxicants to this Lake.
- Proposed Great Lakes Water Quality Guidance will be finalized, after consideration of public comments. USEPA anticipates publication of the final Guidance by March, 1995. The Agency will seek to achieve water quality criteria set forth in the Guidance through reductions in both point and nonpoint sources of contaminants.
- States, in consultation with the Food and Drug Administration, will develop regional guidance regarding human health advisories for consumption of contaminated Great Lakes fish and wildlife. This will foster consistency among States in their advisories, which will help the public better understand the risks associated with consumption of contaminated sportfish and game.
- Nationwide implementation of the 1990 amendments to the Clean Air Act will significantly cut toxic emissions by U.S. firms by the end of this century. EPA and States will give priority to implementing its provisions for suspected sources of critical pollutants to the Great Lakes.
- States and EPA will continue cleanup of priority abandoned hazardous waste sites and oversight of active ones, focusing cleanups and corrective actions on sites suspected of loading bioaccumulative contaminants to the Lakes.
- States and EPA will continue to inspect oil facilities in order to review their spill prevention measures and readiness to respond to accidental spills.
- EPA and its partners in the Assessment and Remediation of Contaminated Sediments (ARCS) program will complete field demonstrations of contaminated sediment treatment technologies. EPA will complete an inventory of contaminated sediment sites in six Great Lakes States and start to assess and address priority sites.
- EPA, the Fish and Wildlife Service, and States will continue to phase-in a comprehensive monitoring system of ecosystem health. Elements that focus on toxic contaminants will be open-lake monitoring of critical pollutants in the water column, monitoring of tributaries to prioritize active sources of contaminants, monitoring of endpoint levels of contaminants in the tissues of birds and fish high in the food web, and monitoring of the atmospheric deposition of critical pollutants.
- The Agency will report to Congress on the extent and effect of atmospheric deposition of contaminants to the Great Lakes.

- The Agency for Toxics Substances and Disease Registry will evaluate the adverse effects of water pollutants in the Great Lakes system on the health of persons in the Great Lakes States and on the health of fish, shellfish, and wildlife. Findings will be reported to Congress in 1994.

*Protecting and Restoring Habitat*

- USEPA will work with partners, including the Fish and Wildlife Service, States, Tribes, and the Nature Conservancy, to develop a strategic conservation plan to identify high quality habitats for protection and restoration. Habitats to be inventoried include wetlands, fish spawning and nursery areas, old growth forests, prairies, dunes, savannas, and areas needed by endangered and threatened plant and animal species.
- EPA, the Fish and Wildlife Service, and States will work together on demonstration projects to restore important Great Lakes habitats.
- The Fish and Wildlife Service will support States in planning the renewal of Areas of Concern by identifying the habitat requirements of various fish and wildlife species in these areas. The Service will similarly work with EPA and States to identify the habitat needs of species on a lakewide basis.
- States and EPA will pursue Advance Identification projects that identify wetlands of high ecological value and inform landowners of this information.
- The Army Corps of Engineers, EPA, and Michigan will continue their administration of the primary Federal program regulating the physical modification of wetlands and others waters. Pursuant to Section 404 of the Clean Water Act, they administer a permit program to regulate the discharge of dredge or fill materials into the waters of the United States, including most wetlands.
- The Fish and Wildlife Service will work with its partners to the North American Waterfowl Management Plan to protect, enhance, and create critical waterfowl habitat. The Service will add protected acreage through its Private Land program and increase surveillance for illegal dredge and fill activities.
- The Soil Conservation Service will continue to promote the protection of wetlands that are privately owned through incentives to restore previously converted wetlands and correctly farmed wetlands; to establish vegetative filter-strips along streams; and to protect wetlands.

*Protecting Human Health and Restoring Fish and Wildlife Populations*

- States, EPA, and the Soil Conservation Service will implement programs to reduce human exposure to harmful bacteria in Great Lakes waters. One focus will be ending the discharge of untreated human wastes from combined sewer overflows by upgrading municipal sewer systems and treatment capacity. The Service will promote adoption of waste management systems to reduce runoff from livestock facilities.

- The Fish and Wildlife Service, States, Coast Guard, NOAA, the Great Lakes Fisheries Commission, and EPA will work together to prevent further introductions of nonnative species and to mitigate the harmful effects of ones that have already entered the Great Lakes. They will monitor the ecosystem for new nonnative species and conduct research on environmentally-kind control techniques for disruptive nonnative species. The Coast Guard will establish requirements governing ship ballast water, a common pathway for the introduction of nonnative species.
- The Fish and Wildlife Service will lead a comprehensive study of fishery resources to identify the restoration needs of Great Lakes fish species, using the latest quantitative techniques to analyze the causes of past disruptions to fish populations and to identify the physical, chemical, and biological needs of important fish and wildlife species.
- The Fish and Wildlife Service and States will continue to stock hatchery-reared fish, such as lake trout, to bolster the abundance of important species. The Service will also continue application of lampricides to tributaries where sea lamprey spawn in order to control the ravages of this nonnative species upon sport fish. In addition, the Service and States will continue law enforcement efforts to curtail illegal commercial fishing and waterfowl hunting.
- The Fish and Wildlife Service and States will continue to take measures to protect and restore populations of endangered and threatened Great Lakes species such as bald eagle, peregrine falcon, Kirtland's warbler, eastern timber wolf, and lakeside daisy.
- The Fish and Wildlife Service will implement the North American Waterfowl Management Plan's habitat strategy aimed at restoring waterfowl populations to their levels in the 1970s.
- The Fish and Wildlife Service and States will pursue Natural Resource Damage Assessments and Claims against Potentially Responsible Parties for past harm to Great Lakes species.
- EPA and States will continue activities to reduce phosphorus loadings to areas of the Lakes that are vulnerable to nutrient overenrichment.

### *Working Together*

The partners to the Strategy will support its implementation by various steps, including:

- States and EPA will focus prevention, inspection, enforcement, and cleanup efforts on critical pollutants and on geographic areas which have the highest ecological and human health risks. In so doing, they will be targeting the strongest opportunities to restore the ecosystem and protect human health.
- They will use the Remedial Action and Lakewide Management planning processes to define ecological needs and appropriate responses to these needs.

- EPA, in cooperation with the Fish and Wildlife Service, NOAA, other Federal agencies, and States, will establish an environmental data storage and retrieval system relating to the Great Lakes, which will be accessible to all agencies.
- The Fish and Wildlife Service, in cooperation with other agencies, will establish data repositories on habitat uses and on fisheries.
- EPA, working with its partners, will establish and maintain a Great Lakes ecosystem monitoring plan to address program needs.
- EPA and its partners will establish and maintain research priorities to support management programs.
- EPA, in conjunction with its partners, will develop a joint report to Congress and to the people of the Great Lakes region on implementation of their joint Strategy and progress toward their environmental goals. EPA and its partners will adopt ecological objectives and measure progress with ecological indicators.
- The partners to the U.S. Great Lakes Strategy will pursue opportunities to work with their Canadian counterparts. For instance, the two nations will sponsor biennial conferences on the health of the ecosystem.

In the years ahead, the Great Lakes Program will continue evolving to address everchanging challenges. One constant emphasis, however, will be to inform the public about the state of the ecosystem. Individuals are vital to further environmental progress through their purchases of products, choices of lifestyles, and expectations of their civic institutions, including businesses, environmental organizations, universities, and governments. The Great Lakes Program will continue to promote public stewardship through education and public participation. Though the region's human inhabitants have often wrought harm to this extraordinary ecosystem during the last several centuries, they still hold its future within their collective stewardship.

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*Chapter 1*

# Introduction

America's inventive and productive genius has been amply realized in the Great Lakes region. Early in the last century, steamships and the Erie Canal helped to open a 2,200 mile waterway into the heart of a continent. Through this corridor came 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 watershed, helping to spark the region's automobile industry that grew into the preeminent industry of twentieth century America. The connection of railroads and canals to the Lakes contributed to unprecedented agricultural development in the Midwest and Great Plains.

During the twentieth century, fuels and industrial minerals have been found elsewhere around the world, and modern means of transportation have made them widely accessible. With the spread of industrial economies, the Great Lakes region's disproportionate share of world manufacturing has inevitably eroded. Yet, productive industries, such as forest products, shipping, agriculture, food processing, chemicals, mining, metals, and heavy manufacturing continue to be important. Manufacturing remains the largest sector in the economy of most Great Lakes States.

Before its development, the Great Lakes region was endowed with extraordinary natural abundance—oceans of freshwater, splendid forests, plentiful animals, rich soil, immense wetlands, multitudes of waterfowl. The Great Lakes were an important part of the breeding range of the passenger pigeon, one of the most numerous birds in the world. Waters teemed with fish. Sturgeon up to 6 feet long were common. A fisherman using a dip net could reap many hundreds of whitefish in a day.

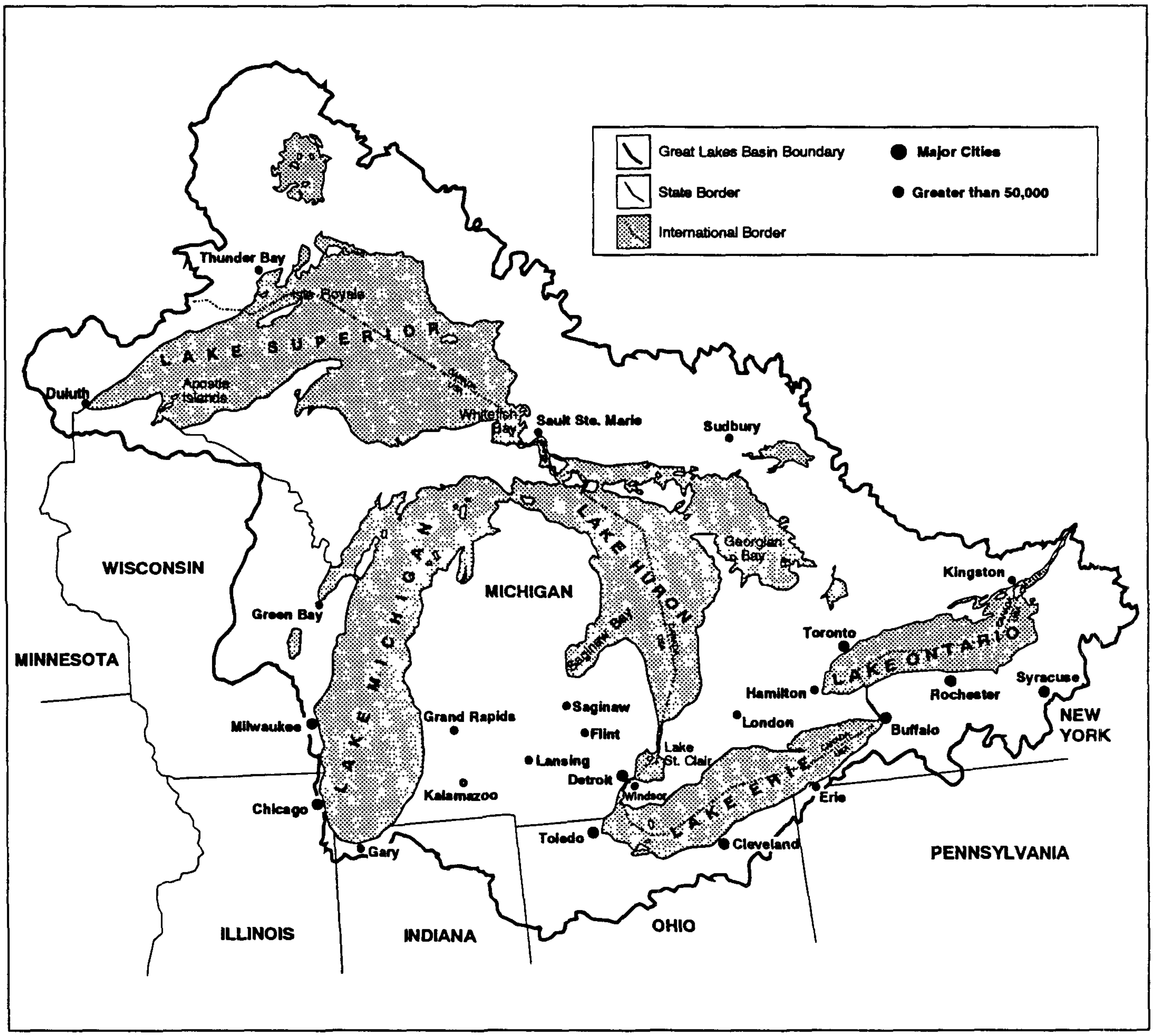
Much of the majesty and plenty of the Lakes remain, although human actions have often changed or damaged the ecosystem. The last passenger pigeon died early in the twentieth century, the tragic survivor of a species exterminated by hunting and the loss of oak and beech forest habitat. Today, few sturgeon survive. Lake trout populations are not self-sustaining. A top predator, the bald eagle, breeds with less success along the shores of the Lakes than inland. Habitat available to fish and wildlife is greatly reduced, as are their populations.

To help place today's Great Lakes environmental issues in context, this chapter discusses 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 landmass of the continental United States, the 6 quadrillion gallons of the Lakes would immerse the "lower 48" States to a depth of almost 10 feet. The Lakes and their connecting channels have 7,437 miles of shoreline across eight States and the Province of Ontario. Their 201,000 square mile watershed holds nearly 80,000 small lakes—one-third within the United States—that could collectively cover an area larger than Lake Erie.

**Figure 1-1. The Great Lakes Watershed**




By virtue of their size, the Lakes affect the climate of their region. Heat stored in the Lakes during the summer warms adjacent land in the winter. Areas of Michigan, southern Ontario, and western New York have warmer winters than some other parts of North America at similar latitudes. These same areas, however, receive heavy snowfalls as prevailing winds from the west pick up moisture over the Lakes. In spring and summer, the Lakes are slow to warm, cooling nearshore land.

As would be expected across such a large area, the physical characteristics of the Great Lakes watershed vary. In the north, the land is heavily forested, particularly by conifers. The soil is generally thin and acidic, covering an 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 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. Because of its huge volume, Superior has a water retention time of 173 years, which is the longest of the Lakes. The St. Marys River, which flows southeasterly into Lake Huron, is Superior's outlet.

Lake Michigan is the only Great Lake that lies wholly within the United States. The second largest Lakes in terms of water volume, Michigan holds 21 percent of the water in the system. Lake Michigan has the second longest water retention time, 62 years. Water from Lake Michigan primarily flows out through the Straits of Mackinac into Lake Huron. A much smaller outflow is artificially diverted into the Mississippi River system via the Chicago Sanitary and Ship Canal.

Lake Huron, the second largest Great Lake in terms of surface area, is slightly larger than Lake Michigan. Huron holds about 16 percent of the water in the Great Lakes and has a water retention time of 31 years. Huron's outlet, the St. Clair River, flows into shallow Lake St. Clair (average depth 11 feet).

Lake Erie is the smallest in water volume, having an average depth of only 62 feet. Erie has three distinct basins, as defined by water depth and underwater ridges. The shallow western basin averages 24 feet in depth. The central basin is deeper; its waters stratify by temperature, and its narrow bottom layer is vulnerable to depletion of dissolved oxygen. The eastern basin is the deepest; its bottom layer is thicker and less vulnerable. Erie has the shortest water retention time, 2.7 years, making it the Lake most responsive to both environmental abuse and cleanup.

Erie is the southernmost of the Lakes. Its waters are the warmest in summer and most productive biologically, supporting abundant fisheries. Because of its shallowness, Erie is the Lake most affected by air temperature. As a result, it regularly has 95 percent ice cover in the winter, in contrast to deeper Lake Ontario, which has an average cover of only 15 percent. 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, receiving soil particles from the rich farmlands of its watershed.

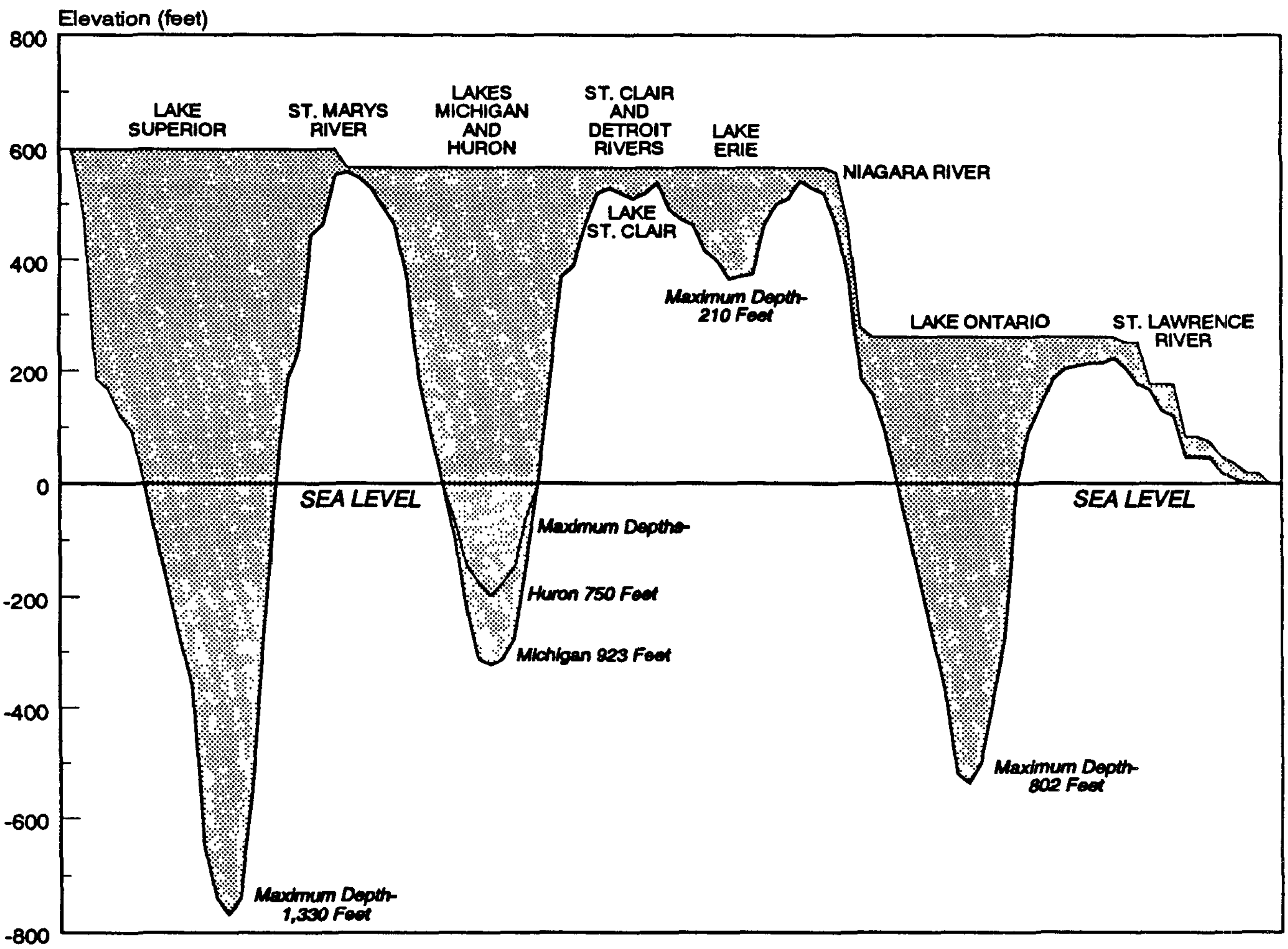
Lake Ontario is the smallest in surface area but contains more than three times Erie's water volume. The Canadian population within Lake Ontario's watershed is about twice that of the United States and has increased significantly during the 1970s and 1980s, while the U.S. population has remained stable. Canada's largest industrial region lies along the western and northwestern shores of Lake Ontario and includes Toronto, a metropolitan area of three million people.

The major source of water to Lake Ontario is the Niagara River flowing from Lake Erie. Lake Ontario is about 325 feet lower in elevation than Erie, causing the river to cascade at the famous Niagara Falls. Ontario's outlet is the St. Lawrence River, which has an annual flow that represents less than one-half of one percent of the water volume of the entire Great Lakes system.

This relatively small outflow is a notable characteristic of the Great Lakes. The system does not flush contaminants quickly. This attribute makes the Great Lakes ecosystem especially sensitive to environmental stresses.

Another important characteristic of the Lakes is their clarity. Before intense European settlement of the region began around 1800, the Lakes contained little phosphorus, were rich in oxygen, and, with the exception of shallow waters, were very clear. One reason for these phenomena was that

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




| Lake | Average Depth (feet) | Area Water (square miles) | Volume (cubic miles) | Retention Time (years) |
|---|---|---|---|---|
| Superior | 483 | 31,700 | 2,900 | 173 |
| Michigan | 279 | 22,300 | 1,180 | 62 |
| Huron | 195 | 23,000 | 850 | 21 |
| Erie | 62 | 9,910 | 116 | 2.7 |
| Ontario | 283 | 7,340 | 393 | 7.5 |

shorelines were rimmed by forests and wetlands, allowing little nutrient runoff to stimulate production of microscopic plants (i.e., phytoplankton, such as algae). Although phytoplankton are the foundation of the Great Lakes food web, excessive algal growth clouds water. Despite today's level of development, most of Superior and Huron remain very clear, as do parts of the northern basin of Lake Michigan.

The most biologically productive areas are Green Bay, Saginaw Bay, and western Lake Erie, relatively warm shallow waters that are fed, respectively, by the Fox, Saginaw, and Maumee Rivers. The Lakes sustain a rich diversity of birds and other wildlife. Following the Atlantic and Mississippi flyways, an estimated three million waterfowl migrate through the Great Lakes each year, relying on them for food and shelter. During their spring and fall migrations, up to 25,000 birds of prey can be observed each day from Whitefish Point in eastern Lake Superior. The Lakes host multitudes of cormorants, egrets, gulls, herons, and terns. Native animals include deer, fox, moose, wolves, and fur-bearing mammals—beaver, mink, and muskrat—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 seventeenth century until the early nineteenth century. As trapping depleted beaver populations in the region, the fur trade expanded westward to California, Oregon, the Arctic Ocean. Even after trapping had moved west, the Lakes remained vital to the industry for waterborne transportation. The Lakes and St. Lawrence River provided a pathway for canoes laden with animal pelts to the Atlantic coast where furs were shipped to customers in Europe. Many early settlements in the region were fur-trading posts, including Chicago, Detroit, Duluth, and Green Bay. Chicago's first non-Native American settler, Jean Baptiste Pointe du Sable, a Haitian of African and French descent, was a fur trader who built a cabin beside the Chicago River in 1779.

As the beaver industry declined because of the scarcity of beavers and whims of fashion, early settlers began harvesting trees on a large scale. Three principal types of forests surrounded the Lakes. Spruce and fir trees grew in the north on the Laurentian Shield above Superior and down the eastern shore of Huron. Birch, hemlock, and pines ranged south of Lake Superior to northern Michigan, north of Lake Erie, and around Lake Ontario. Hardwoods, such as ash, oak, maple, and dogwood, grew south of this region. Settlers cleared land for agriculture and buildings. Commercial logging began in the 1830s, after the opening of the Erie Canal and the advent of steamships, which 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. Softwoods framed homes and ships. Hardwoods became barrels and furniture.

The heyday of lumbering was from 1850 to 1900. Grand Rapids, today Michigan's second largest city, was a sawmill boom town in the 1850s; later it earned renown as 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 Lakes. Tugboats pulled enormous floating trains of trees from Canada to 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 twentieth century. The climate and 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 region, though trees are much younger and smaller than their predecessors. Today, these woods are harvested for paper. The paper-making industry, which started 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 and had 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 today. In 1845, rich iron ore was found in the Marquette Range of Michigan's upper peninsula. Additional iron ranges were later discovered in Minnesota and Wisconsin. In 1855, completion of the Sault Canal opened Lake Superior to shipping and permitted mining of these ranges.

Iron ore from the mineral-rich Lake Superior watershed helped to make the Great Lakes region a center of iron-making, steel-making, and heavy manufacturing. Ore was shipped to lakeside cities, such as Buffalo, Cleveland, Detroit, Gary, and, in Canada, Hamilton and Sault-Sainte Marie. 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 the Lakes in such locations as Midland, Michigan; Toledo, Ohio; and north-east of Lake St. Clair. Cleveland, Ohio, already an industrial hub in part because it was the terminus of a canal that linked the 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.

Since iron ore, limestone, coal, oil, and waterborne transportation were readily available, 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, 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 vehicles a year by 1950.

Industries associated with the automotive 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 attracted appliance and agricultural equipment manufacturers. Proximity to industrial customers attracted chemical manufacturers. Brine wells in southeastern Michigan were appealing to chemical firms. 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 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 disappeared in the early 1980s in just five Great Lakes States.

Yet heavy industries, including mining, steel, machine tools, and cars, remain important. Today, manufacturing continues to be the largest sector in the economy of most Great Lakes States. In 1991, five Great Lakes States made 61 percent of the cars produced in America. Mining and manufacturing are also 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. Employment in Ontario's manufacturing sector has increased over the last 20 years.

Agriculture is another productive element of the regional economy. During the nineteenth century, cheap land blessed with ample top soil, flat terrain, 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 because of developments in biology, chemistry, and engineering. Breeding 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 developments, agricultural output within the U.S. Great Lakes watershed has increased during the last 40 years, although farm acreage has actually decreased by one-third. Cropland accounts for 18 percent of the land in the U.S. counties of the watershed, predominantly in the south. Corn is the largest crop (42 percent of farm acreage), followed by soybeans (24 percent), and small grains, especially wheat (17 percent). Dairy products, fruits, vegetables, and tobacco are also important.

Convenient waterways have abetted the regional economy. The Erie Canal, completed in 1825, connected Buffalo to the Hudson River at Albany. At the same time, Canada constructed the Lachine Canal to bypass rapids on the St. Lawrence and the first Welland Canal between Lakes Ontario and Erie to bypass Niagara Falls. The 27-mile long Welland has been enlarged a number of times.

The five parallel locks at Sault-Sainte Marie, connecting Lakes Superior and Huron, are among the busiest in the world. In 1990, 5,000 vessels carried 90 million tons of cargo (including 50 million tons of iron ore) through these locks. Many commercial vessels are headed to or from the port of Duluth/Superior, which ranked 14th in the United States by tonnage shipped in 1987, and Thunder Bay, Ontario, the port of embarkation for one-half of Canada's 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 the Atlantic Ocean. 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 Lake St. Clair. This inland waterway is navigable by one-third of the world's saltwater fleet. In 1989, 40 million tons of cargo passed through the Seaway.

The waters of the Lakes provide other economic benefits. They are a source of drinking water to millions. Industries use water to make products (as in the beer for which Milwaukee is famous) and to cool manufacturing processes. Some rivers are harnessed to generate electricity; up to one-half the natural flow of the Niagara River is diverted for this purpose.

Another large element of the Great Lakes economy is recreation, including sight-seeing, fishing, boating, camping, and hiking. In 1988, Michigan had more registered boat owners than any other State. The Lakes sustain both sport and commercial fisheries, although recreational fishing is more important today. As the value of recreational fishing has increased, 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 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.

At the onset of the twentieth century, the human population of the watershed was slightly more than 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 watersheds are sparsely inhabited. The south and southwestern shoreline of Lake Michigan, the Canadian shore of Lake Ontario, and the U.S. side of Lake Erie are heavily populated. The third and sixth most populated

U.S. metropolitan areas (Chicago and Detroit) and the largest Canadian metropolitan area (Toronto) are situated near the Lakes. Native American tribes also reside in the region. Five U.S. Indian reservations lie adjacent to 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 its ecosystem. Humans have altered habitat, introduced exotic (i.e., nonnative) species, and contaminated 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 nineteenth and early twentieth centuries. By the mid-1950s, nonnative sea lamprey (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, mats of algae fouled Lake Erie beaches and water intakes. In 1967, millions of another exotic fish, alewife, 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. Since the 1960s, researchers have noted reproductive problems in birds, such as double-crested cormorants, which have been born with grotesquely crossed beaks. These problems are probably caused by bioaccumulative toxic chemicals.

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 slashed the population of sea lamprey, although this exotic species is firmly established as a resident of the Lakes. Stocking of lake trout bolstered their numbers; however, the species generally is unable to sustain itself. Reductions in loadings of phosphorus have lessened many problems associated with nutrient overenrichment, such as excessive algae. Stocking of salmon and trout has helped to control alewife numbers. Since the passage of the Clean Water Act in 1972, the reduction in pollutant loadings has greatly improved overall water quality, allowing fish to return to some harbors from which they had disappeared. The health of many fish and wildlife populations has improved as their burdens of contaminants have declined.

Yet the Great Lakes ecosystem has been pervasively changed in other, less dramatic ways, many of which are 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.

Harvesting trees exposed soil to direct sunlight, causing drying, and to wind and water, causing erosion. This, in turn, added silt to rivers. Forests had provided shade along tributaries. In their absence, the temperature of streams increased, further modifying the fish habitat. Forest clearance also increased seasonal variation in tributary flow. Low wintertime flow exposed streambeds, freezing fish eggs.

Agriculture also increased soil erosion. Since 1950, eroding soil particles and rainfall runoff have carried agricultural chemicals—pesticides and fertilizers. The overenrichment of Lake Erie was partly the result of increased nutrient use by farmers.

The growth of human population has imposed further ecological change. Roads, 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.

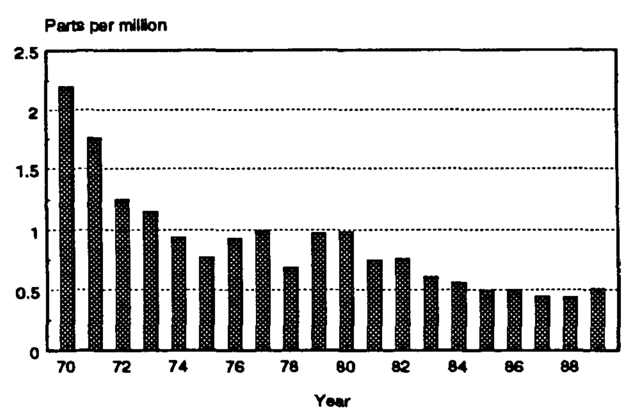
The Lakes have been extensively altered for shipping and flood control. River mouths, critical habitat for fish and wildlife, have especially attracted development. Hundreds of them have been dredged and surrounded by breakwaters. Dredging and the wash from ship propellers injure organisms in bottom sediments upon which fish feed. Canals and ships have introduced nonnative species. Unchecked by natural predators, some of these have profoundly damaged native species.

Wetlands and sand dunes are two other habitats modified by humans. Wetlands have vital ecological functions, serving as nursery, resting, and breeding habitat for fish and wildlife. Perhaps two-thirds of the region's wetlands have been drained or filled since 1800. The downtown areas of Chicago, Detroit, and Milwaukee largely rest on filled-in wetlands. In fact, Chicago takes its name from an Indian word for the wild garlic that once grew there in marshlands beside Lake Michigan.

Before parks were established to preserve the remaining sand dunes at the base of Lake Michigan, home to a rich diversity of wildlife, were 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. 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 home to numerous metal, oil, and petrochemical facilities. In places, large amounts of oil float on the groundwater; during drought, the sinking water table lowers oil into municipal drainage systems. The Grand Calumet River meanders through this region receiving most of its waters from industrial and municipal dischargers. Its river bed holds many toxic contaminants.

Manufacturing firms have contributed a broad range of contaminants to the Lakes. One of the most injurious is the family of organic chemical compounds called polychlorinated biphenyls (PCBs). PCBs were widely used from 1929 until EPA prohibited their manufacture in 1977. They are highly stable, which made them useful as hydraulic fluids and lubricants in high temperature or pressure processes. 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.

**Figure 1-3. Mercury Concentrations in Walleye, Lake St. Clair**




*Mercury levels in fish have declined in places where they were most elevated 20 years ago*

Though the practice ceased during the 1970s, some chloralkali plants and some pulp and paper mills released mercury that was later detected in fish from Lake Huron, Lake St. Clair, western Lake Erie, eastern Lake Ontario, and the St. Lawrence River at levels that required closure of some commercial fisheries (Figure 1-3). In the 1980s, EPA also 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 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 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 (i.e., biological) processes to treat their wastewater. Secondary treatment, usually practiced by U.S. mills, decreases both conventional pollutants and 25 to 60 percent of toxic organic byproducts. In 1993, the Province of Ontario announced a multiyear phase-in of enhanced discharge requirements for this industrial sector.

Chemical companies have left a toxic heritage in the groundwater, bottom sediments, and soils of the region. American chemical companies were attracted by hydroelectric power generated from the Niagara River situated near its banks. Canadian chemical companies similarly clustered along the St. Clair River. Waste sites along the U.S. side of the Niagara have been a source of contamination to Lake Ontario. Since the inception of the Superfund program, cleanup efforts have focused on these sites, substantially reducing their loadings to the Niagara River.

In addition, metals-based industries have been a significant source of pollutants. Many presently used steel-making technologies generate byproducts, including ammonia, cyanide, coal tar, zinc, lead, and a range of air pollutants, including fly ash, sulfur compounds, and the volatile chemicals benzene, toluene, and xylene. Steel mills emit benzo(a)pyrene, the most toxic member of the family of polyaromatic hydrocarbons (PAHs). Like other PAHs, benzo(a)pyrene is produced by incomplete combustion of fossil fuels and is suspected of causing lip and liver tumors in bottom-dwelling fish. PAHs are common in bottom sediments of the Great Lakes.

## Conclusion

This chapter has tried to convey that environmental damage cannot be attributed solely and simplistically to a few leading industries. Damage to the Great Lakes ecosystem during the past three centuries has been caused by the collective actions of society—by individuals and the public sector as well as by industry and agriculture. The prominent industries mentioned in this chapter, especially productive sectors, such as farming, forest products, metals, and manufacturing, continue to make vital contributions to our National economy.

In addition, this chapter has suggested that the changes to the Great Lakes ecosystem during the last three centuries have been vast and that a long-term perspective is useful to appreciate the magnitude of damage to once abundant fish and wildlife populations. The next chapter discusses current challenges facing the Great Lakes ecosystem that are the focus of government programs, discussed later in this report.

*Chapter 2*

# Aspects of Ecosystem Health

This chapter discusses six general problems facing the Great Lakes ecosystem:

- Contamination of fish and wildlife with bioaccumulative toxic substances
- Contaminated bottom sediments
- Lost, degraded, and threatened wetlands
- Exotic species
- Depleted native fish populations
- Excessive phosphorus.

Substantial progress has been made during the last 20 years in abating several of these problems. Levels of some targeted contaminants in fish and wildlife are strikingly lower. The impacts of one especially troublesome exotic species, the sea lamprey, have been substantially reduced. Levels of phosphorus are also much lower, notably in Lake Erie where they had been most disruptive.

Yet challenges remain. Public health authorities continue to issue fish consumption advisories for each Lake. Though the present rate of habitat destruction is much less than in the past, various human activities encroach on remaining wetlands and other valuable fish and wildlife habitats. The entry of exotic species has increased since the opening of the St. Lawrence Seaway in 1959, which permitted more transoceanic shipping. Although much improved, Lake Erie continues to suffer depletion of dissolved oxygen during late summer.

## Bioaccumulative Toxic Substances

Bioaccumulative toxic substances generally do not pose a problem for humans Great Lakes drinking water. Concentrations of toxic substances in the water column are extremely low because they tend to bind quickly to particles—phytoplankton or sediment—and either enter the food web or fall to the bottom where they are eventually buried. 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.

Some bioaccumulative toxicants do pose problems when concentrated in the tissues of predators, such as lake trout. At the base of the food web, microscopic floating one-celled plants (i.e., phytoplankton) use sunlight, dissolved carbon dioxide, and dissolved mineral nutrients for nourishment. Microscopic animals (i.e., 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 (e.g., fish and birds) consume smaller fish. Figure 2-1 provides a simplified view of the food web. The figure does not show the many different species of phytoplankton, zooplankton, bottom animals, fish, and wildlife that make up the actual Great Lakes food web, but does display the food web concept.

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

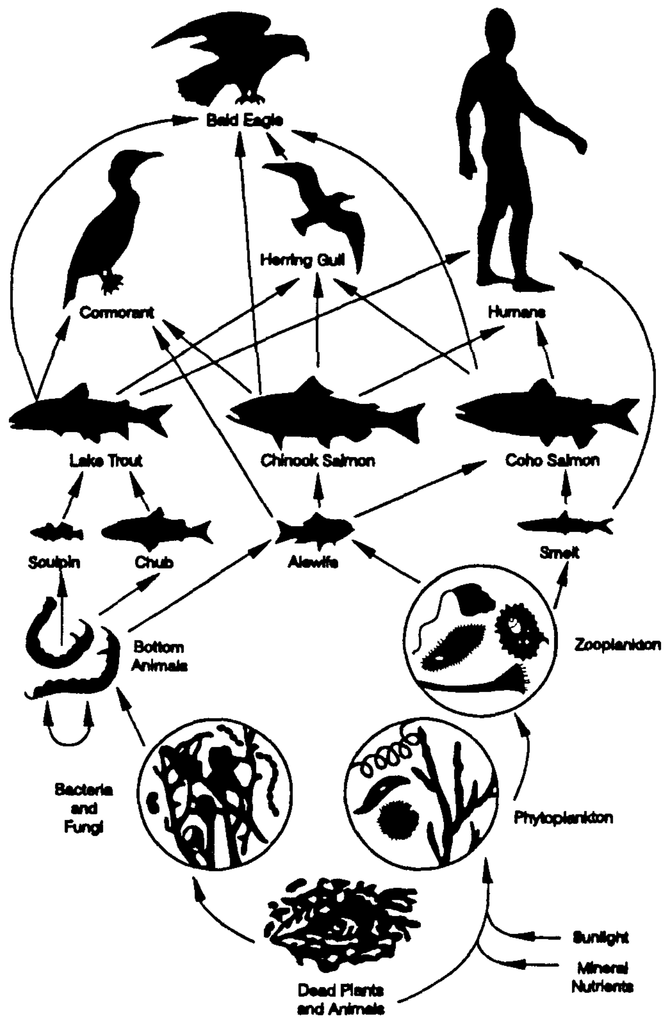
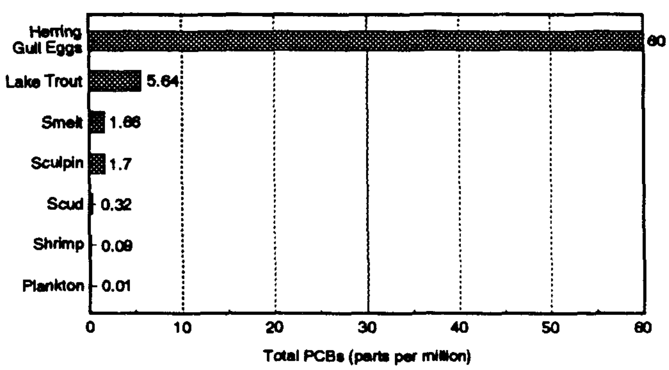



**Figure 2-2. Lake Ontario Food Web Biomagnification, 1982**




*Contaminant levels increase up the food web*

Phytoplankton, zooplankton, and bottom animals adsorb and retain contaminants. Fish that graze on plankton in turn ingest the contaminants that they contain. When fish ingest contaminants faster than they use or excrete them, they accumulate levels of contaminants that are higher than those in their forage. The increasing concentration of contaminants at successive levels of the food web, known as biomagnification, is repeated as predator fish feed on smaller fish, mammals and birds feed on fish, and predator birds feed on smaller birds. Figure 2-2 illustrates biomagnification in the Lake Ontario food web. In 1982, high predators, such as herring gulls and lake trout, accumulated polychlorinated biphenyls (PCB) levels that were, respectively, 6,000 and 560 times greater than those in plankton.

Fish and birds living in or around Lakes Michigan and 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 the Lake has a high surrounding population and is known to receive high loadings of toxic substances. One possible explanation is that Erie's relatively high sedimentation rate may remove toxic substances from the water column, making them less available to the food web.

There have been striking declines in some targeted substances during the last two decades. Figures 2-3 and 2-4 show declines in two substances, PCBs and the pesticide DDT (in its derivitive form, DDE), in Lake Michigan herring gulls and bloater chubs.

Despite these marked declines, levels of contaminants remain unacceptably high. State public health authorities issue fish consumption advisories, usually directed at PCBs, mercury, and chlordane, for species in each Lake, and in various rivers and bays. Table 2-1 shows examples of these advisories.

## *Effects on Wildlife*

During the last few decades, researchers have observed population declines and health problems in about 15 Great Lakes fish and wildlife species. These declines and problems seem to be associated with exposure to various bioaccumulative 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 that have been noted in fish and wildlife include loss of

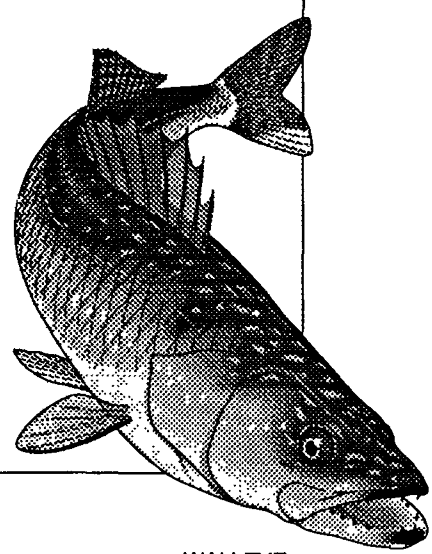
## Are Great Lakes Fish "Safe" to Eat?

Great Lakes fish of different species, locations, and size carry different burdens of 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. Yet it is valuable to inform the public about which fish species carry the highest burdens of contaminants. State health authorities usually follow this approach when issuing fish advisories (Table 2-1).

Some clarifications should be made about estimates of risk. First, risk assessments have uncertainty in that they are usually based on estimates of carcinogenic potency obtained by animal tests; 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 risk. And fifth, risk assessments tend to be based on estimates of cancer incidence and do not consider other harmful health effects.

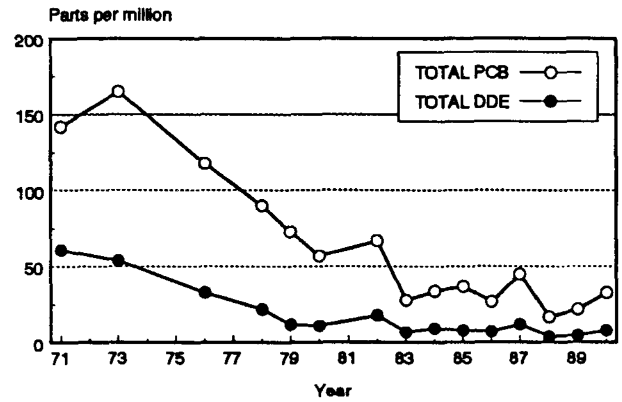
This last point is important, since some research during the last decade suggests that there may be noncancer, transgenerational effects associated with contaminants found in the tissues of Great Lakes fish. A series of studies of human health effects from eating Lake Michigan fish containing PCBs began in 1980. The studies have focused on children whose mothers had regularly eaten Lake Michigan fish. The children were examined at birth, at seven months, and at four 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 four 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 affect later 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 effects.

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.



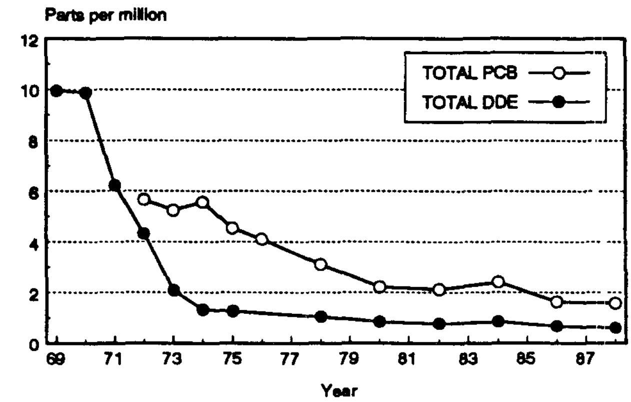
WALLEYE

**Figure 2-3. Contaminants in Herring Gull Eggs, Sister Island, Green Bay**




*Targeted pollutants have greatly declined in birds*

**Figure 2-4. Contaminants in Bloater Chubs, Southeast Lake Michigan**




*. . . and in fish*

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.

Since EPA and States cancelled and restricted the bioaccumulative 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 inland. Great Lakes fish may provide too toxic a diet for bald eagles to thrive.

During the 1970s, herring gulls around the Great Lakes were also found to have reproductive problems. Changes in behavior were a contributing factor to population decline—herring gulls neglected their nests, which caused low hatching success. During the 1980s, herring gull populations have strongly 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, 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 sensitive to PCBs. As with bald eagles, it is thought that wild mink populations are larger inland than along the shores of the Great Lakes.

Another suspected effect of bioaccumulative toxic substances on fish has been noted in bottom-dwelling fish, such as bullheads and suckers. These have been found to suffer a high incidence of dermal and liver tumors at a number of Great Lakes locations. The incidence of tumors is strongly correlated with polluted conditions, especially with the presence of polyaromatic hydrocarbon (PAH) contamination in bottom sediments. 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

**Table 2-1. Examples of Great Lakes Fish Consumption Advisories***

| Location | Pollutant of Concern (States) | Restrictions** | Do Not Eat |
|---|---|---|---|
| Lake Superior | PCBs (MI, MN, WI)<br>Chlordane (MI, WI)<br>Mercury (WI, MI)<br>Toxaphene (MI) | Lake Trout 20"-30"<br>Chinook Salmon 15"-20"<br>Walleye 18"-26"<br>Siscowett under 20"<br>Bloater Chub | Lake Trout over 30"<br>Walleye 18"-26"<br>Siscowett |
| Lake Michigan | PCBs (IL, IN, MI, WI)<br>Chlordane (IL, IN, MI, WI)<br>DDT (IN, WI)<br>Dieldrin (IN, WI)<br>Mercury (WI, MI) | Lake Trout 20"-23"<br>Coho Salmon over 26"<br>Chinook Salmon 21"-32"<br>Brown Trout up to 23" | Lake Trout over 23 "<br>Chinook Salmon over 32"<br>Brown Trout over 23"<br>Carp<br>Catfish |
| Green Bay | PCBs (MI, WI) | Splake up to 16 " | Lake Trout, Brook Trout over 15",<br>Rainbow Trout over 22",<br>Chinook Salmon over 25",<br>Brown Trout over 12", Splake over 16",<br>Northern Pike over 28",<br>Walleye over 20", White Bass, Carp |
| Lake Huron | PCBs (MI) | Brown Trout up to 21"<br>Lake Trout<br>Rainbow Trout | Brown Trout over 21" |
| Saginaw Bay | PCBs (MI) | Rainbow Trout<br>Brown Trout | Carp<br>Catfish |
| Lake Erie | PCBs (MI, NY, OH, PA)<br>Chlordane (PA) | Carp<br>Catfish | Carp<br>Catfish |
| Lake Ontario | PCBs, Mirex, Chlordane, and Dioxins (NY) | | American Eel, Catfish, Lake Trout,<br>Chinook Salmon,<br>Coho Salmon over 21",<br>Rainbow Trout over 25",<br>Brown Trout over 20" |
| St. Marys River | Mercury (MI) | Walleye over 19" | |
| St. Clair River | PCBs and Mercury (MI) | Freshwater Drum over 12"<br>Gizzard Shad over 10" | Carp |
| Lake St. Clair | PCBs and Mercury (MI) | Walleye over 20", White Bass over 13",<br>Smallmouth Bass over 18",<br>White Perch over 10", Carp over 22",<br>Rock Bass over 8", Largemouth Bass over 14",<br>Bluegill over 8", Freshwater Drum over 14",<br>Carpsucker over 18", Brown Bullhead over 14",<br>Northern Pike over 26" | Muskie<br>Sturgeon<br>Catfish over 22" |
| Detroit River | PCBs and Mercury (MI) | Freshwater Drum over 14" | Carp |
| Niagara River | PCBs, Dioxins, and Mirex (NY) | Carp<br>Smallmouth Bass | Channel Catfish, American Eel,<br>Lake Trout, Chinook Salmon,<br>Rainbow Trout over 25",<br>Coho Salmon over 21",<br>Brown Trout over 20" |
| St. Lawrence River | PCBs (NY) | All fish | Channel Catfish, American Eel,<br>Chinook Salmon, Brown Trout,<br>Lake Trout, Coho over 21",<br>Rainbow over 25" |

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

** Nursing mothers, 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 many 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. These techniques are not so effective for mercury contamination, which is evenly distributed through fish.

of humans who might eat these fish, visible abnormalities reduce the commercial and recreational value of fish.

### 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 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 selected priority pollutants. Pollutants listed in this table tend to concentrate up the food web. Several are the most toxic members of groups of related chemicals.

### Pathways

Bioaccumulative toxic substances reach the Lakes from a broad range of human activities. Some sources are more clearly measurable, such as discharges from sewage systems and industry and spills from ships and shore. Other sources are known to be significant, but are difficult to measure: deposition of contaminants from the atmosphere, movement of contaminants through groundwater, and urban and agricultural runoff. 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 toxaphene in the waters of its lakes. Researchers theorized that such pollution must have resulted from atmospheric deposition. Since toxaphene was principally used to reduce insects on cotton crops in the South, it was thought that toxaphene 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 to enter Lake Superior, for instance, because of the Lake's relative lack of adjacent development and its large surface area. Yet there are substantial uncertainties surrounding such estimates.

Recent research in Minnesota and Wisconsin has concluded that the atmosphere is a significant pathway for mercury, which is emitted by garbage incinerators and coal-burning power plants, among other 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 similar advisories for hundreds of their inland lakes. The issuance of these advisories partly reflects the expansion of fish monitoring programs. Though there are atmospheric loadings of mercury across the entire region, differences in water chemistry and bacteria between waterbodies cause 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 and chloralkali plants that were then the major source of loadings. In general, there are no clear indications that mercury levels

**Table 2-2. Selected Toxic Contaminants in the Great Lakes**

| Pollutants | Sources | Concerns |
|---|---|---|
| **Polychlorinated biphenyls (PCBs)** *Industrial Chemicals* | PCBs were widely used in the U.S. from 1929 until 1978 for various purposes, including hydraulic fluids and lubricants. Pursuant to the Toxic Substances Control Act in 1979, EPA prohibited the manufacture, distribution, and many uses of PCBs. PCBs are still used in some closed electrical equipment because of high heat resistance and stability. | PCBs are highly bioaccumulative and persistent. All five of the Lakes have fish consumption advisories based on PCBs. PCBs have been shown to cause liver cancer in laboratory animals and are probable human carcinogens. |
| **Mercury** *Metal* | A natural element, mercury was once widely used by the pulp and paper industry and in the manufacture of chlorine and caustic soda. Coal-burning power plants and waste incinerators are among active sources, though degassing of mercury from the earth's crust may exceed anthropogenic releases. | Mercury is converted in lakes to methylmercury (the organic form of mercury) by bacteria under low oxygen conditions. Methylmercury is highly bioaccumulative. Symptoms including deafness, blindness, and death have been associated with the long-term ingestion of mercury contaminated fish. 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. |
| **Polychlorinated dibenzo-paradioxins (PCDDs or dioxins)** *Combustion and Industrial Byproducts* | A family of structurally related chemical compounds, dioxins were present in fungicides and herbicides. Dioxins are also generated by chlorine bleaching in pulp and paper manufacture. They are also a byproduct of combustion of organic material containing chlorine. | Dioxins are highly bioaccumulative and persistent. 2,3,7,8-TCDD, the most toxic of a chemical family of 75 compounds, is an extremely potent animal carcinogen and teratogen. In humans, it has been linked to a skin disease. A recent epidemiological study of occupational exposure to dioxin found greater incidence of cancer among highly exposed persons. EPA launched a new assessment of dioxin's risks in 1991. |
| **Polychlorinated dibenzofurans (PCDFs or furans)** *Combustion and Industrial Byproducts* | A family of structurally related chemical compounds, furans are present in chlorophenols and derivative herbicides, are a byproduct of the combustion of chlorinated organic matter, and are generated by chlorine bleaching in pulp and paper manufacture. Furans were also an inadvertent contaminant to some PCB products. | 2,3,7,8-TCDF is inferred to be one-tenth as toxic as 2,3,7,8-TCDD, but it has similar toxicological properties. Other PCDFs show a similar toxicological relationship to their PCDD analogs. |
| **Benzo(a)pyrene B(a)P** *Combustion and Industrial Byproducts* | Formed by 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 tributaries and harbors. | B(a)P is bioaccumulative in shellfish, but it is not as bioaccumulative in most finfish species. High concentrations in river and lake sediments have been associated with liver and skin tumors in fish. B(a)P is an animal carcinogen. |
| **Mirex** *Pesticide* | An insecticide, mirex was primarily used for fire ant control in the South from 1962 to 1975. However, its manufacture in New York State led to its introduction into the Lake Ontario food web. EPA cancelled all uses of mirex after December 1976. | Mirex is highly bioaccumulative and persistent. It is a probable human carcinogen. Mirex levels justify issuance of fish consumption advisories in Lake Ontario and the Niagara River. |
| **Dieldrin** *Pesticide* | An insecticide introduced in 1946, dieldrin was widely used until restricted by Wisconsin and Michigan in the late 1960s and restricted by EPA on a national basis in 1974. | Dieldrin is a probable human carcinogen. |
| **Toxaphene** *Pesticide* | Toxaphene was widely used on cotton crops in the South until the late 1970s. EPA prohibited its production in 1982 and all uses after December 1986. | Toxaphene is a bioaccumulative toxic substance. |
| **Hexachlorobenzene (HCB)** *Pesticide and Byproduct* | Originally manufactured as a fungicide, HCB is a by-product of chlorinated compounds as well as an impurity in some pesticides. | HCB is a bioaccumulative toxic substance and probable human carcinogen. |

are rising in Great Lakes fish, although the evidence of atmospheric loadings to the region warrants continued monitoring.

## 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 restricted 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, killing them or impairing their normal functioning. Sublethal effects associated with contaminated sediments include tumors in bottom fish. Brown bullheads, a variety of bottom-feeding catfish, have been found with a high incidence of 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 issues surrounding disposal of dredged sediments. Reduced dredging increases transportation costs because industries must find alternative transportation methods or reduce ship loads.

Yet, the natural sedimentation process can also cover old contamination with cleaner sediments. This can be an important natural means for the recovery of the ecosystem. The rate of burial differs from location to location and from lake to lake, with Lake Erie having a relatively high rate of sedimentation, and 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 sediments in these areas contain a wide range of contaminants, including toxic metals, such as copper, lead, nickel, and zinc, as well as

**Table 2-2. Selected Toxic Contaminants in the Great Lakes (continued)**

| Pollutants | Sources | Concerns |
|---|---|---|
| **DDT and metabolites (DDE)** *Pesticide* | An insecticide introduced in 1946, DDT was widely used until banned by Wisconsin and Michigan in the late 1960s and by EPA on a national basis in 1972. Environmental concentrations have fallen significantly since that time. States still receive unused DDT stocks turned-in by U.S. farmers. | DDT is converted to DDE by natural processes. DDE is highly bioaccumulative and persistent. It is known to cause eggshell thinning in birds and benign tumors in laboratory animals. |
| **Chlordane** *Pesticide* | Chlordane was once widely used in a variety of pest control applications. EPA restricted its uses in 1978. In 1989, manufacturers voluntarily cancelled all remaining uses of chlordane, with the exception of fire ant control in power transformers. | Chlordane is a probable human carcinogen and has a high potential for bioaccumulation. |

chemicals. Figure 2-5 illustrates the geographical zone of sediment contamination in one Area of Concern, the Detroit River.

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 structures designed to hold and isolate contaminated dredged materials. There are 43 CDFs completed or under construction; one-third are on land, and two-thirds displace water. The Corps adds about two million cubic yards of sediments to them annually. This represents about one-half of the total volume of sediment dredged by the Corps each year in the Great Lakes. 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.

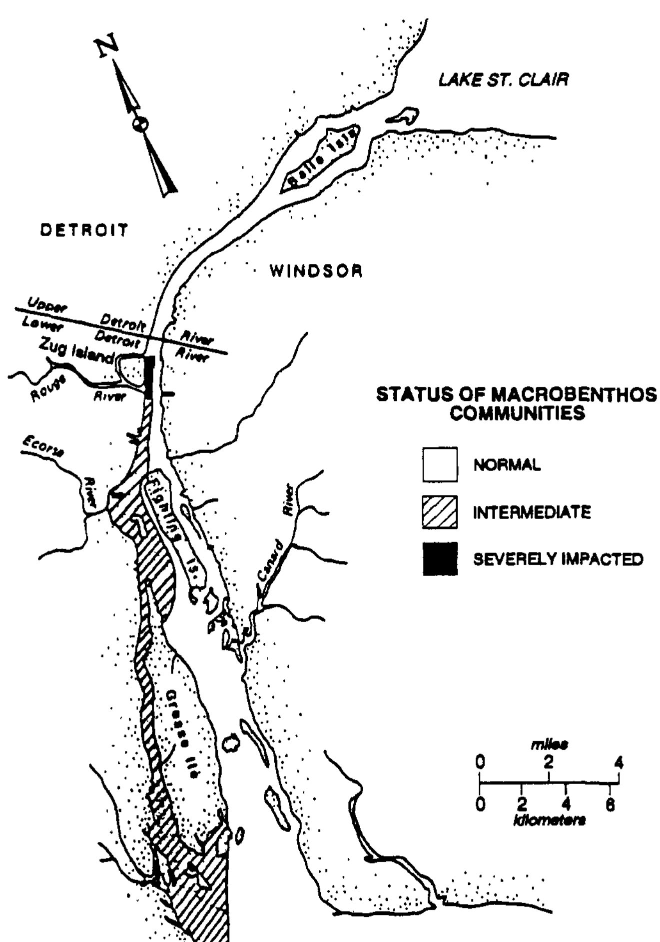
## Diminished Wetlands

A wetland is an area such as a marsh, swamp, bog, or fen. 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, and wildlife. Wetlands protect a variety of fish species from waves and predators. Coastal wetlands offer fish warmer temperatures than open-lake waters. Larval and juvenile fish harbored by wetlands are an important food source for waterfowl. Ducks consume plants that extend above and below the water, and geese graze on plants above water. Wetlands also protect shorelines from erosion, store flood waters with their dense vegetation, and trap sediments that can pollute waterways.

Many of the wetland areas of the Great Lakes watershed have been lost during 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. Similar losses have occurred in the United States. 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 2-6).

The most extensive losses took place in the nineteenth and early twentieth centuries when many wetlands were drained for agricultural use. Remaining wetlands continue to be threatened by building construction, waste disposal,

**Figure 2-5. Sediment Contamination in the Lower Detroit River, as Suggested by Impacts on Bottom Dwelling Organisms**




*The U.S. side of the lower Detroit River is an area with contaminated bottom sediments* and mining of sand. Consumption of groundwater has diminished recharge of certain wetlands. There are also indications that wetlands have been disrupted by nonnative plants, such as purple loosestrife, and fish, such as carp.

## Exotic Species

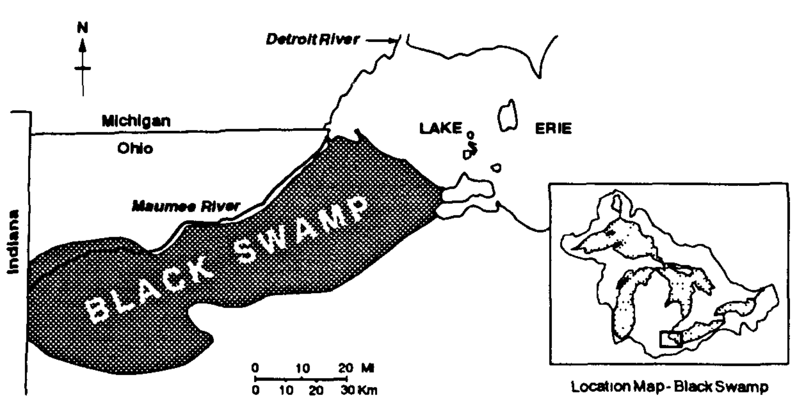
During the past 200 years, humans have introduced more than 130 exotic (nonnative) species to the Great Lakes, many of which have profoundly affected the populations of native species. Exotics damage native populations through direct competition for food, displacement from physical environments, direct attack, and alteration of the chemical or physical conditions needed by other species.

Some introductions have been intentional, such as those of carp and Pacific salmon (chinook and coho). Since the 1960s, salmon have been regularly stocked by States and the Province of Ontario to provide an additional predator to control the numbers of smelt and alewife (which are also exotic species). In addition, salmon provide sport fishing alternatives to greatly diminished lake trout populations. Many other introductions of exotics have been unintentional, such as sea lamprey, alewife, zebra mussel, and smelt.

Introductions of exotics have accelerated during the last 30 years, as shown by Figure 2-7. Of the exotics introduced to the Lakes since 1810, about 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. Oceangoing vessels have often taken on ballast water in a distant port and later discharged it into the Lakes to compensate for the on-loading of cargo. Ballast water can sustain exotic organisms until it is released into the Lakes. Thus, oceangoing vessels have often spanned saltwater barriers to freshwater species from other continents.

Figure 2-8 shows the routes by which exotic species are believed to have entered the Great Lakes. Nearly one-third of exotics have been stowaways on ships in cargo, ballast tanks, or attached to hauls. 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 Lakes.

**Figure 2-6. Presettlement Extent of the Black Swamp in Northwestern Ohio**




*The Black Swamp was almost entirely converted to farmland by the 1920s*

Exotics have also made their way into the 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 45 percent of exotics, fish 18 percent, and algae 18 percent (Figure 2-9).

### *Zebra Mussel*

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

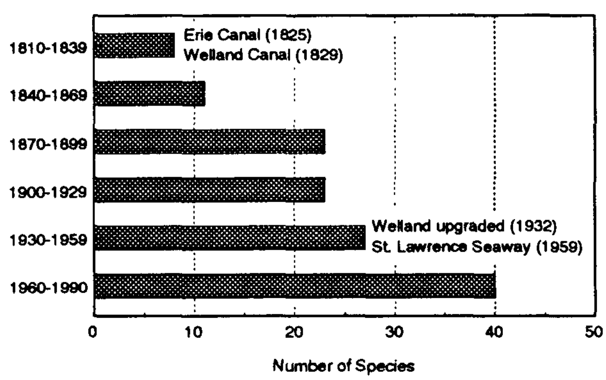
Since then, they have been found in numerous locations, from Duluth to the entrance of the St. Lawrence River. They have infested Lake Erie with impressive speed, colonizing nearly every available surface in just two years. It is expected that the species will occupy most of its suitable living environments within the Lakes over the next several years. It also seems inevitable that the zebra mussel will eventually spread through much of America, via pathways such as the Chicago River to the Mississippi River system and carried by ships and recreational boats. Adult mussels cling to boat hulls from which they detach during journeys. As of fall 1991, mussels had already been noted in the Hudson, Susquehanna, and Mississippi drainages.

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

The zebra mussel poses many ecological problems. One adult mussel filters the suspended phytoplankton from one liter of water per day. A large 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 reduce the food supply of predators, such as lake trout, salmon, walleye, and bass. Zebra mussels also threaten the spawning sites of native fish. Many species, including walleye, prefer rocky shoals for spawning and must compete with zebra mussels which favor this habitat for colonization. In addition, zebra mussels coat clams and crayfish, making it difficult for them to open or move.

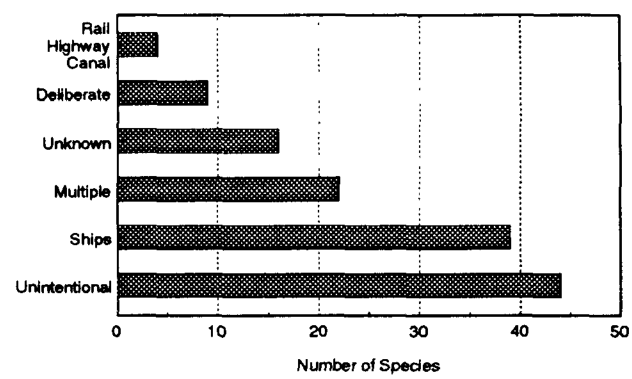
The mussels have economic impacts as well, because they clog municipal and industrial water intakes. Many hundreds of millions of dollars will have to be invested in the redesign of intakes to reduce their vulnerability to mussel fouling, extension of pipes into deeper water, and periodic mussel removal. Mussels also encrust and slow ships and infiltrate and clog their ballast and cooling systems.

**Figure 2-7. Chronology of Exotic Species**




*The introduction of exotic species has increased*

**Figure 2-8. Entry Routes of Exotic Species**




*Shipping is the leading source of exotic species*

Beaches can be fouled by the odor of decaying zebra mussels, and bathers at some beaches have to wear foot protection to prevent cuts from mussel shells. Dead mussels also give off methane gas, imparting a foul taste and smell to water. In addition, the mussel attaches to navigational buoys, breakwater rocks, piers, and fish nets.

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

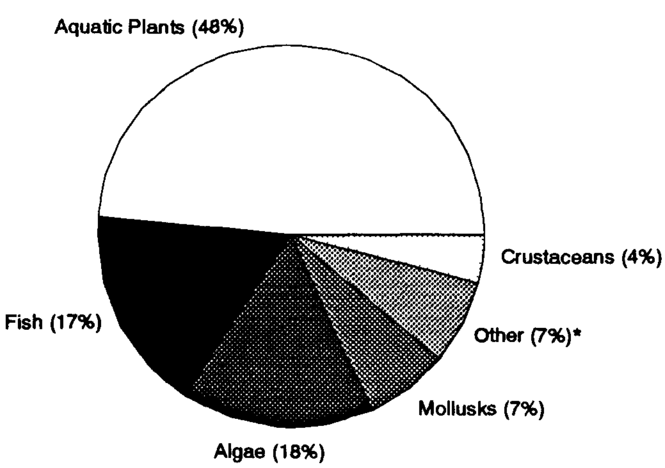
### *Sea Lamprey*

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. Native to the Atlantic Ocean, sea lamprey may have made their way into Lake Ontario via the St. Lawrence River or the Erie Canal. By the mid-nineteenth century, they were present in Lake Ontario 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 during the next three decades spread throughout them.

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

**Figure 2-9. Types of Exotic Species**




* Other: Flatworm (1%), Insect (1%), Cnidarians (1%), Disease Pathogens (2%), Oligochaetes (2%)

*Plants and fish are the most frequent exotics*

In 1961, the United States and Canada began to apply a chemical to sea lamprey spawning grounds. This lampricide application program has decreased numbers of lampreys by about 90 percent (Figure 2-10). 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 lessen the effectiveness of lampricide application. As a result, a large population of lamprey lives in the river and in nearby reaches of Lake Huron. Lamprey continue to exact a heavy toll, for example, on lake trout in Lake Superior, particularly west of the Keewenaw Peninsula. In the late 1980s, lamprey were estimated to have killed about one-half to one million pounds of lake trout per year in the U.S. waters of Lake Superior.

### *River Ruffe*

The river ruffe, a small (typically six to eight inches) perch-like fish from northern Eurasian freshwaters, entered

Duluth harbor around 1986 probably from the discharge of ballast water from an oceangoing 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 eventually, 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. Early indications are that walleye are not effective in controlling ruffe if alternative prey is available. Limited sampling of burbot, a voracious member of the cod family, and northern pike show that some had eaten ruffe. Further work is underway to assess the potential of these predators to control the ruffe population.

### *Spiny Water Flea*

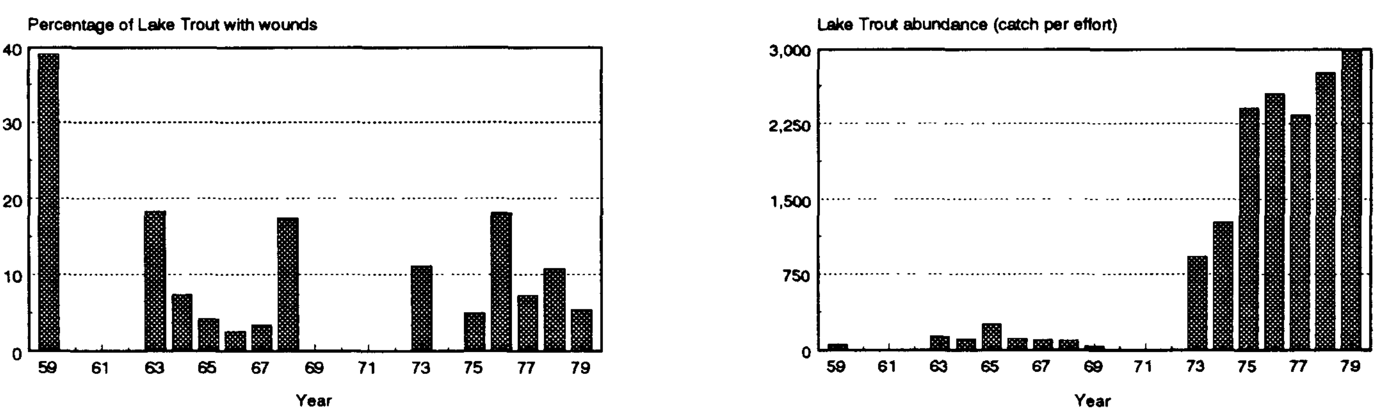
Another recent invader to the Great Lakes is the large zooplankton *Bythotrephes cederstroemii* (spiny water flea). At up to one-half inch in length, it derives its name from its long spiny tail. First noted in Lake Huron in 1984, the spiny water flea is native to Eurasian freshwater.

The effects that the spiny water flea may have on the Great Lakes ecosystem are not yet apparent. The flea feeds on a few species of Daphnia, another form of zooplankton. 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. Recent evidence, however, indicates that alewife may consume the spiny water flea, providing a constraint on its population.

### *Alewife*

The sardine-like alewife is a 4- to 11-inch long member of the herring family. Alewife are native to the Atlantic Ocean and entered Lake Ontario presumably through the Erie Canal in the mid-1800s. Alewife spread to the other Lakes from 1931 to 1954, after enlargement of the Welland Canal allowed the species to bypass Niagara Falls.

**Figure 2-10. Lake Trout With Lamprey Wounds, Eastern Lake Superior**




*As lampreys have been controlled, lake trout populations have responded to stocking*

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 because of the effects of cold temperatures and hunger. The species may be more vulnerable to such stresses in the Great Lakes than in its native Atlantic waters. It has experienced other occasional die-offs in Lakes Huron and Ontario. Such instability can abruptly decrease available food for valued sportfish that feed on alewife.

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 never recovered since the control of alewife.

## Depleted Native Fish Populations

Before 1800, about 170 fish species existed in the Lakes. Smallmouth and largemouth bass, channel catfish, muskellunge, northern pike, and sturgeon lived nearshore. Blue pike, freshwater drum, grayling, lake herring, lake trout, lake whitefish, sauger, walleye, and white bass inhabited deeper waters. Sturgeon lived 90 years, frequently exceeding six feet in length and 100 pounds; lake trout lived 75 years.

The species mix varied between lakes. A large population of Atlantic salmon was confined to Lake Ontario. Eastern Lake Erie supported lake trout, whereas Erie's warmer, shallower western basin did not. Lake trout and lake whitefish were prevalent and were staples in the diets of Native Americans.

Fish populations were richly abundant. Around 1890, commercial fishermen took about five million pounds each of lake trout and lake whitefish from Lake Superior each year. From 1920 through 1960, they harvested more than ten million pounds of lake herring from Superior each year.

Today, fish populations are very different. Fish are generally smaller and do not live as long as they did two centuries ago. The populations of many native species are not as plentiful and their numbers are much more volatile. Populations surge and fall abruptly.

These changes are caused by a variety of reasons. Food chains have been disrupted (e.g., increased phosphorus levels altered the plankton communities). Nonnative species prey on or compete with indigenous ones (e.g., lamprey feed upon large fish, while alewife and rainbow smelt have displaced lake herring). Fish habitat has been lost or disrupted (e.g., wetlands have been drained, spawning beds have been covered with silt, and dams have impeded passage to spawning grounds). Sport and commercial fishing have sometimes reaped excessive harvests. Fishermen have also done incidental damage to fish populations (e.g., sturgeon were killed because of the damage they did to nets). And, some pollutants are suspected of hindering fish reproduction (e.g., contaminants in lake trout may reduce its reproductive success).

The decline of once native prolific fish populations is profound. Grayling were extirpated by forestry practices that polluted their spawning streams. Atlantic salmon disappeared from Lake Ontario in the nineteenth century, and blue pike vanished in the 1950s. Several species of deepwater cisco in the upper lakes were eliminated by the sea lamprey. Sturgeon and the once predominant forage fish, lake herring, survive in much depleted numbers. Though more thriving, walleye, white bass, and yellow perch are also much reduced from nineteenth century abundance. Hatchery-reared lake trout must be stocked to maintain ecological balance as well as losses to sea lamprey and sport fishing. Lake whitefish in Superior and parts of Lakes Michigan and Huron are sufficiently plentiful to support commercial fishing. Stocked, nonnative Pacific salmon—coho and chinook—are the most abundant top predators, except in western Lake Erie where the top predator is walleye.

The depletion and vulnerability of fish populations have brought both ecological losses and economic costs. Populations of fish-eating birds and other wildlife have declined in part because of loss of forage. Programs to stock fish and reduce lamprey have costs. Employment in commercial fisheries has withered.

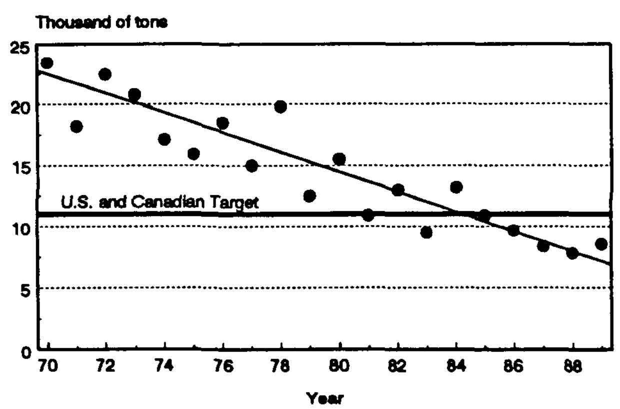
Nevertheless, heartening progress to improve Great Lakes fish resources has been made. The control of sea lamprey and the stocking of valued fish, notably lake trout and Pacific salmon, have bolstered fish resources and permitted the growth of an important sport fishing industry.

## Excessive Phosphorus

By the late 1960s, various areas of the Lakes exhibited eutrophic conditions, marked by thick algal blooms that imparted unpleasant odors and taste to the water and depleted dissolved oxygen following its decay in late summer. 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 phosphorus to the Lake, 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.

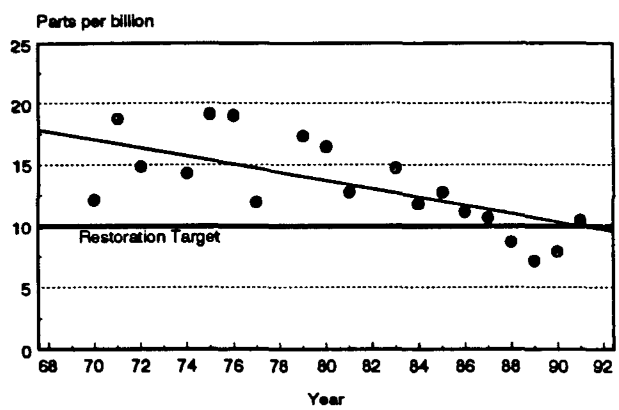
During the last two decades, the United States and Canada have generally reduced phosphorus levels across the Great Lakes. Lake Erie's improvement, in particular, has been visible and dramatic. Scientists determined that lowering phosphorus concentrations would have the greatest limiting effect on algal productivity. The United States and Canada passed laws limiting phosphorus content in household detergents and constructed more effective municipal sewage treatment plants, cutting their phosphorus discharges (Figure 2-11). As a result, open-lake phosphorus concentrations have declined (Figure 2-12).

**Figure 2-11. Estimated Total Phosphorus Loading To Lake Erie**



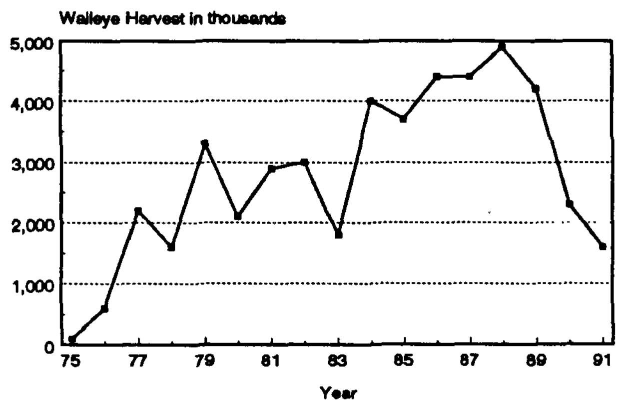

*Phosphorus loadings have been cut*

**Figure 2-12. Spring Phosphorus Levels In Lake Erie's Central Basin**



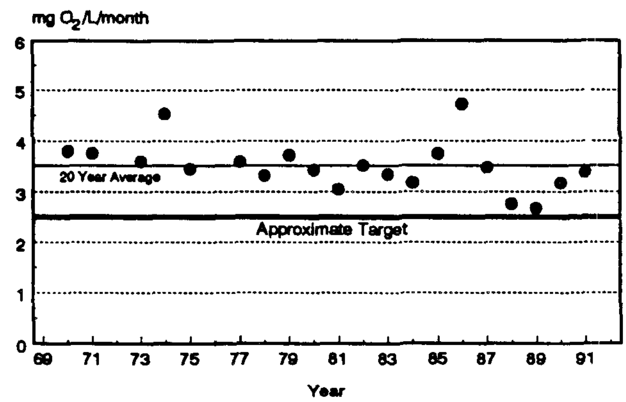

*Phosphorus levels in the water column have fallen*

**Figure 2-13. Sport Angler Harvest of Walleye From Ohio Waters, Lake Erie**




*Anglers have enjoyed increased catches since the restoration of Lake Erie from phosphorus and mercury troubles. (The recent catch decline probably has natural causes such as varibility in available forage and in water temperatures during walleye spawning.)*

**Figure 2-14. Oxygen Depletion Rate for the Bottom Waters of Lake Erie's Central Basin**




*In some recent years, the oxygen depletion rate has fallen by about 25% from that typical of the 1970s. (Subsequent increases are probably attributable to natural variability in weather conditions.)*

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 facility had 56 days of such problems in 1974. During the 1980s, phosphorus levels in lower Green Bay decreased by about 25 percent from the average during the 1970s.

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 during late summer a zone that cannot support bottom-dwelling fish.

However, in many other respects, Lake Erie has recovered. Increased catches of sport fish, such as walleye, are indirect evidence of this rebound (Figure 2-13). Another indication of Lake Erie's improved 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 20 years (Figure 2-14). This reduction means that the period of oxygen depletion is shorter than in the past.

*Chapter 3*

# The Great Lakes Program: A Holistic Ecosystem Approach

This chapter presents the holistic approach to ecosystem protection that EPA has launched to address Great Lakes environmental problems. Under this approach, the Agency began to develop a joint five year strategy among the different agencies involved in protection of the Lakes, rank ecological and human health risks facing the region, promote pollution prevention as the preferred means to reduce risks from contaminants, target priority geographic areas, meet local needs with a blend of solutions from across the range of environmental programs, enforce environmental laws in a comprehensive, integrated manner, encourage public participation, and evaluate progress using ecological indicators. In all these elements, the Agency is taking advantage of every opportunity for cooperative actions with States, partner Federal agencies and Canada.

EPA has successfully used many individual elements of this approach in the past. The fundamental changes now being pioneered for the Great Lakes are to promote innovative pollution prevention measures, enforce environmental laws in a comprehensive way while focusing on targeted geographic areas, harness local community participation in the remedial planning process, and integrate the Agency's programs around the ecosystem, setting goals on the basis of environmental needs and measuring progress with ecological yardsticks.

This innovative approach is consistent with, and enhances implementation of, the Great Lakes Water Quality Agreement between the United States and Canada. Under this Agreement, the two nations have dedicated themselves to restoring and maintaining the chemical, physical, and biological integrity of the Great Lakes ecosystem by virtually eliminating releases of bioaccumulative toxic substances to the Lakes. EPA's new ways of doing business are aimed at fuller achievement of the Agreement.

## A Shared Strategy

In 1991, EPA joined States and Federal agencies that have stewardship responsibilities for the Lakes in developing a shared five year strategy that started in 1992. In addition to the eight Great Lakes States, partners to the plan include 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 strategy joins environmental protection agencies with natural resource agencies in pursuit of common goals. These partners envision updates that will keep the strategy a current, action-forcing document that targets different problems in succession.

The ultimate purpose of the strategy is that of the Great Lakes Water Quality Agreement—to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem. To realize this purpose, the strategy has three long-term goals:

- **Reduce Toxic Loadings:** Prevent and reduce releases of toxic pollutants and remedy past contamination with an emphasis on bioaccumulative pollutants

- **Protect and Restore Habitat:** Protect and restore wetland, land, and aquatic habitats vital for healthy communities of plants and animals, emphasizing the habitat needs of threatened species
- **Protect the Health of Human Residents and the Ecosystem's Living Resources:** Protect the health of human residents of the region from pathogens and protect the abundance and biological diversity of its plant and animal communities.

The strategy relies on pollution prevention as the preferred means to reduce releases of toxic substances. While the partners to the strategy recognize that full attainment of its goals is a long-term proposition, the strategy spells-out numerous practical steps to make progress toward these goals. The partners envision that their ultimate attainment will provide an ecosystem in which fish are safe for human consumption in unlimited quantities and there are thriving populations of vulnerable species, such as bald eagle and lake trout.

## Identification of Priority Problems

During 1991, EPA conducted a comparative, risk-based characterization of human health and ecological hazards facing the Great Lakes region. The study looked at evidence on 23 different problems. It helped EPA and its partners identify priority problems and the best opportunities for making environmental progress. Among its findings, the comparative risk study concluded that the the greatest ecological risks are the following:

- Bioaccumulative toxic substances that cause health problems for fish and wildlife
- Bottom sediments that harbor such contaminants and that contribute to poisoning the food web
- Water runoff from agricultural and urban lands that carries pesticides and other pollutants
- Industrial and municipal discharges to surface water
- The possibility of large accidental spills of toxic substances
- Introduction of exotic species, such as the zebra mussel, that can greatly affect the balance between existing species
- Destruction of valuable wildlife habitats, such as fish spawning areas, wetlands, prairies, and old growth forests, by agricultural, residential, and other development activities
- Atmospheric deposition of sulfur oxide, nitrogen oxide, and mercury which affect inland lakes
- Global climate change.

The study concluded that the following posed the most significant human health risks:

- Consumption of Great Lakes sport fish because of their widespread contamination with PCBs, and contamination in certain areas with chlordane, mercury, dioxins, and mirex
- Consumption of sport fish from inland lakes because of their contamination with mercury
- Accidental spills
- Respiratory exposure to toxic air pollutants.

In addition, the study concluded that the most significant sources of environmental contaminants were concentrated around Chicago, Illinois, and Gary, Indiana; Detroit, Michigan; Buffalo and Niagara Falls, New York; and Cleveland, Ohio. This information helped the Agency begin to target several of these areas for reduction of toxic releases and for habitat restoration.

## Promotion of Pollution Prevention

EPA sees the Great Lakes as a proving ground for its pollution prevention efforts. Buttressed by other Agency activities, pollution prevention is to be the preferred means to reduce toxic pollutants. EPA is weaving pollution prevention into the fabric of all its Great Lakes activities and encouraging all sectors of society to contribute their ideas for reducing the quantity and harmfulness of resources used to satisfy human needs.

In April 1991, in concert with the eight Governors of Great Lakes States, EPA launched a Pollution Prevention Action Plan for the Lakes. The Action Plan augments State pollution prevention programs. During recent years, States have started various prevention initiatives, involving education, research, technical assistance, and recognition of prevention successes. Some States are also exploring ideas such as issuing one permit to cover all the pollutant releases from a facility as a means to increase pollution prevention, incorporating pollution prevention into enforcement settlements, and linking permit fees to the generation of pollution. EPA will continue to work closely with States in support of their prevention programs.

The Action Plan also complements 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. In February 1991, EPA announced a goal of encouraging firms across the Nation to cut their releases of these substances 33 percent by the end of 1992 and 50 percent by the end of 1995. Among the 17 high risk chemicals are three metals — cadmium, lead, and mercury — that can

### 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, and 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 its conception and design stages; firms prevent pollution by methods, such 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 by their purchases of consumer products and by their lifestyles.

For many 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 it can save raw materials wasted as pollutant byproducts and lower the disposal costs of nonhazardous rubbish.

Pollution prevention also boosts 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 standards for treatment technologies.

EPA encourages and assists all sectors of society in preventing pollution and is pursuing 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 disseminates pollution prevention information and sponsors research into preventive technologies. Other potential means of fostering prevention are incentives for firms that reduce their use of raw materials, their toxic emissions, or energy consumption.

concentrate at upper levels of an aquatic food web. Mercury contamination is the basis for the issuance of several Great Lakes fish advisories.

Large manufacturing firms report their annual releases or transfers of more than 300 toxic substances. Under the 33/50 Program, EPA has asked firms that have reported releases of the target chemicals to voluntarily reduce these through pollution prevention. EPA anticipated widespread cooperation because pollution prevention offers economic benefits to firms. By the end of 1991, the Agency had received voluntary commitments from companies to cease 280 million pounds of releases of the 17 chemicals by 1995.

### *Pollution Prevention Action Plan*

The Great Lakes Pollution Prevention Action Plan is predicated on challenging all sectors of society; focusing on high risk pollutants, sources, and areas; and measuring progress. The Plan contains five elements:

- **The Challenge:** The Governors challenged all sectors of society to reduce, on a voluntary basis, releases of pollutants harmful to the Great Lakes.
- **Lake Superior:** EPA and the Lake Superior States agreed to define procedures to prevent degradation of this relatively pristine lake, end loadings of bioaccumulative pollutants, and establish air deposition sites to monitor loadings of air pollution to the Lake.
- **Car Manufacturing:** EPA and States announced that they would work with the Chrysler, Ford, and General Motors Corporations to promote prevention of substances that injure the Great Lakes ecosystem. These companies are joining EPA and States to determine substances of concern, to evaluate which substances are being used in their operations, and to reduce this use.
- **Urban Nonpoint Pollution:** EPA and New York announced that they would co-sponsor education campaigns in four New York State counties to prevent urban nonpoint source pollution from households.
- **Binational Symposium:** In September 1991, EPA co-sponsored with Environment Canada a symposium to bring together representatives from government, industry, and the public to share information on pollution prevention.

## Geographic Targeting

A hallmark of the ecosystem approach is to focus on priority ecological problems and geographic areas, though Special Geographic Initiatives and Remedial Action and Lakewide Management Planning.

### *Special Geographic Initiatives*

Under Special Geographic Initiatives, EPA and States focus prevention, inspection, enforcement, and cleanup efforts on a targeted area. During FY 1992, EPA and States targeted southeast Chicago-northwest Indiana and the Niagara River watershed because of their high ecological risk and noncompliance with permits and regulations.

### *Remedial Action Planning*

The United States and Canada have committed to develop and implement plans—termed Remedial Action Plans (RAPs)—to restore the most impaired areas around the Great Lakes. In general, these 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 pollution. The United States has 31 Areas of Concern, including five shared with Canada. The Remedial Action Planning process defines ecological problems, identifies appropriate solutions, and measures progress toward ecological goals. States develop and implement RAPs, drawing on grass-roots colloboration from local communities.

Through 1992, States had completed initial versions of 23 Stage I (problem definition) and 12 Stage II (remedial action definition) RAPs. RAPs will be updated periodically as the results of preventive and remedial measures warrant.

Even while RAPs are being developed, EPA and States concurrently take many warranted actions to protect and restore Areas of Concern. Examples of such actions are summarized in the next chapter.

In further support of RAPs, EPA is continuing its Assessment and Remediation of Contaminated Sediments (ARCS) program that has assessed contaminated sediment problems and is demonstrating innovative treatment technologies in five Areas of Concern. ARCS will develop guidance on assessment methods and on remedial alternatives to assist local decisionmakers in addressing contaminated sediment situations within Areas of Concern. ARCS is also discussed at greater length in the next chapter.

### Lakewide Management Planning

The United States and Canada have also committed to develop and implement Lakewide Management Plans (LAMPs) to address whole-lake problems that extend beyond Areas of Concern. While EPA has the lead responsibility within the United States for developing these plans, participation by other Federal agencies, States, Tribes 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 public.

During FY 1991, EPA completed LAMPs for the Lakes that have experienced the greatest contamination—Michigan and Ontario. The early objectives of LAMPs are to identify key pollutants and their sources and to schedule reduction measures. In FY 1992, the Agency began working with partners on a LAMP for Lake Superior; plans for Lakes Erie and Huron will follow.

## Application of Multimedia Tools

To implement geographic targeting, EPA and States apply appropriate measures from their full range of programs—air, land, and water. This section discusses some of these programs and their application to the Great Lakes.

### Air Programs

Since the discovery of polychlorinated biphenyls (PCBs) and other bioaccumulative toxicants on remote Isle Royale in Lake Superior in the late 1970s, the Great Lakes scientific community has been aware of the potential importance of the atmosphere as a pollution pathway. Researchers theorized that this contamination could only have resulted from atmospheric deposition. More recent research has concluded that the atmosphere is a significant pathway for mercury, which accumulates in fish in some inland lakes, posing risks to consumers of sport fish.

Under amendments to the Clean Air Act passed in 1990, all U.S. industrial sources of air pollution must significantly decrease their emissions of 189 different toxic pollutants over a ten year period. In addition, EPA and Canada have recently established stations on each of the Great Lakes to begin routine monitoring of toxicants. And during 1994, EPA will complete its first report on the extent, sources and effects of atmospheric deposition to selected water bodies, including the Great Lakes.

### *Land Programs*

Under the Superfund Program, EPA and States address abandoned and uncontrolled hazardous waste sites that endanger public health, welfare, or the environment. Currently, about 140 NPL sites in the Great Lakes watershed are targeted by Superfund for permanent cleanup; 25 of these are vital to restoration of 14 Areas of Concern. For instance, the Superfund Program is addressing the site of greatest PCB contamination in the Great Lakes — Waukegan Harbor, Illinois. Through 1993, one million pounds of PCBs in and around this harbor are being removed, treated, burned, or isolated.

Whereas Superfund generally addresses past contamination, the Resource Conservation and Recovery Act (RCRA) regulates today's management of hazardous wastes, from generation through disposal. Facilities that treat, store, or dispose of hazardous waste must obtain permits that set forth management standards and closure requirements. If contamination is suspected at a RCRA-regulated facility, EPA or States may require the facility to conduct an investigation and correct any problems. Inspections of RCRA-regulated facilities are an important element of Special Geographic Initiatives. In the past several years, EPA and States have required RCRA-regulated facilities to conduct investigations and take corrective measures in five Great Lakes Areas of Concern.

EPA has also issued regulations for onshore and offshore oil facilities to prevent accidental spills of oil. These regulations require such facilities to follow Spill Prevention Control and Countermeasures (SPCC) Plans, which are subject to EPA inspection. During 1991, EPA planned 182 SPCC inspections within the Great Lakes watershed and completed 196, almost triple the number conducted in 1990.

**Protecting Gitchi Gummi**

In September 1991, Michigan, Minnesota, Wisconsin, EPA, and Canada announced their agreement to end bioaccumulative toxicant discharges to Lake Superior. Their binational program will fulfill a recommendation by the International Joint Commission that the largest of the Great Lakes be a demonstration zone for "zero discharge" of toxicants.

The binational program entails a number of elements. First, the governments will develop uniform water quality standards for the Lake. Second, they will work to end discharges, emissions, and runoff of bioaccumulative toxicants. They targeted nine substances initially, including PCBs, mercury, chlordane, DDT, and dioxin. On the U.S. side, dischargers will be required to submit toxicant reduction plans with each application to reissue a NPDES permit, and all increased or new municipal and industrial discharges will be required to use the most advanced technologies in their manufacturing processes or effluent treatment. On the Canadian side, new discharge requirements will be introduced for the pulp and paper industry. Third, States and the U.S. government will designate parts of Lake Superior as outstanding national resource areas where, under the Clean Water Act, no new or increased discharges of certain bioaccumulative toxicants will be permitted. The binational program will promote pollution prevention measures and seek public involvement through periodic meetings.

Centuries ago, Chippewa Indians called Lake Superior Gitchi Gummi, or "great water." The Lake Superior Program recognizes and aims to protect this greatness.

### *Water Programs*

A discharge of pollutants into the surface waters of the United States is regulated by a National Pollutant Discharge Elimination System (NPDES) permit issued by EPA or a State. Permits limit the discharge of contaminants and establish treatment performance requirements for industrial and municipal wastewater. There are about 600 major and 3,000 minor NPDES dischargers in the Great Lakes watershed.

Two principles govern NPDES permits. The first principle is that dischargers meet technology-based treatment standards by industrial category. The second is that more stringent limits are imposed to protect water quality where technology-based limits prove insufficient to maintain designated water quality. Through water quality standards, States define the chemical and biological conditions necessary to maintain water quality. To assist States in establishing these standards, EPA prepares criteria to define the maximum allowable concentrations of pollutants that are acceptable for human health and aquatic life, based on scientific evidence.

In 1989, EPA and States began a "Great Lakes Water Quality Initiative" to develop binding guidance for States on water quality criteria for the Great Lakes, implementation procedures, and antidegradation policy. EPA published this proposed guidance in April 1993. Implementation of the guidance will fulfill several purposes. It will ensure that Great Lakes environmental needs are fully incorporated into State water quality programs, which will provide a sound scientific basis for water quality-based protection of the Lakes. It will also promote consistency among States in their standards and implementation procedures for the Lakes, and serve as the basis for agreeing with Canada on chemical specific objectives for the Great Lakes.

Other water programs also benefit the Great Lakes ecosystem. For example, one program addresses contaminated storm water (rainwater runoff). Before entering a sewer, rain runoff can collect soil-surface contaminants that are then funneled into receiving surface waters by storm sewers. Following a rule that EPA issued in 1990, large cities and certain industries are curtailing discharges of contaminated storm water, subject to the terms of NPDES permits, which emphasize management practices and pollutant monitoring.

Particularly in older urban areas, storm water and household wastewater are delivered to municipal wastewater treatment facilities via combined sewers. During rainstorms, increased flow can exceed either a facility's treatment capacity or the carrying capacity of a sewer, leading to the release of untreated wastewater. The significance of combined sewer overflows (CSOs) varies around the Great Lakes. Michigan reports that CSOs are a major cause of impairments to its rivers, including the Rouge River, which receives an estimated 7.8 billion gallons of untreated water each year as it flows through metropolitan Detroit. States with such problems are pursuing strategies to control CSO releases to meet their water quality standards. In some areas, these strategies entail major capital investments, such as sewer separation and tunnels or basins to store untreated water. It is expected that, together, the storm water and CSO control programs will significantly reduce wet weather loadings of pollutants to the Great Lakes, especially around urban areas.

During the last two decades, EPA, States, and municipalities have made a concerted investment to improve municipal wastewater treatment. As a result, 95 percent of U.S. treatment facilities in the region now provide at least "secondary" treatment. Remaining jurisdictions are following schedules to achieve this treatment level and continue to improve their facilities.

The Clean Water Act also requires certain industries to "pretreat" toxic discharges to municipal treatment systems. Approximately 170 major municipal dischargers on the U.S. side of the Great

Lakes have industrial pretreatment programs that are subject to regular inspections by EPA and States. Implementation of pretreatment requirements has effected sharp reductions in contaminant inflows to many facilities.

EPA jointly administers the principal Federal regulatory program to protect wetlands with the Army Corps of Engineers. This program issues permits to regulate the discharge of dredge or fill materials into water, including wetlands. The Agency seeks to prevent a net loss of wetlands on a national basis in the short term and to increase the quantity and quality of wetlands in the long term. EPA also joins States in identifying high value wetlands in order to give advance notification to landowners prior to permit applications.

In addition, the Agency has made the Great Lakes watershed a priority in its support to State nonpoint source control programs, including education and incentive programs to abate runoff of pesticides, fertilizers, and animal wastes from farmland and others to prevent urban runoff of wastes from homes and industries.

## Promotion of Public Stewardship

EPA and States are encouraging public involvement in their activities and promoting public stewardship of the Lakes:

- Local community "stakeholders" are strongly involved in Remedial Action Planning, helping governments be more responsive to local concerns.
- Representatives from environmental groups, business associations, and municipalities were invited to comment during development of guidance under the Water Quality Initiative.
- In 1991, EPA put into service a state-of-the-art research vessel that will also serve as an educational platform. Tours for the public, including school children, will promote broader awareness of Great Lakes environmental issues.
- EPA's Assessment and Remediation of Contaminated Sediments (ARCS) program to test innovative remedial technologies for sediment contamination has held public meetings to inform residents living near the areas of study.

## Strengthening of the Knowledge Base

To ensure that their decisions are based on the best current scientific information, the Agency and its partners are working to improve their measurement of the health of the Great Lakes ecosystem and to sharpen their integration and analysis of environmental data. In the past, EPA has often relied on administrative statistics, such as numbers of permits, grants, and enforcement actions, as surrogate measures of effectiveness. In the future, the Agency will increasingly assess environmental progress by monitoring water, land, and air conditions and by monitoring biological responses of plants and animals to these conditions. Biological measures of well-being could include the balance between pollution-tolerant and pollution-sensitive species, or the balance between algae-grazing and predator fish. The foundation of the Agency's strengthened monitoring effort will be the Environmental Monitoring and Assessment Program (EMAP), which is a national program that gauges the health of our Nation's ecosystems. One ecosystem that EMAP will study will be the Great Lakes.

Recently, the following steps have been taken to assess the health of the Great Lakes:

- In 1991, EPA put into service a new 180 foot long research vessel, the *Lake Guardian*. This ship can sample water quality to the deepest depths of the Great Lakes and bottom sediments to a depth of 40 feet. The ship was named through a contest among elementary school students around the Great Lakes.

- Since 1989, EPA has sponsored a major study and demonstration program—the ARCS program—to assess contaminated Great Lakes bottom sediments, test promising remedial technologies, and develop guidance on addressing such contamination. Through 1992, EPA had assessed five Areas of Concern, identified treatment technologies to be tested at each, and demonstrated these in the field.
- In 1991, EPA established three master stations to monitor atmospheric deposition of toxic contaminants. Between them, the United States and Canada now have one master station on each of the Great Lakes.
- During 1992, EPA, Wisconsin, and partners concluded analytic aspects of their study of the sources, paths, and fates of several toxicants in Green Bay. The study has provided valuable lessons for whole-lake analyses in support of LAMPs.
- As part of the LAMP processes, ecosystem objectives are being developed for each of the Lakes.
- EPA, the Fish and Wildlife Service, and States continue to monitor targeted toxic contaminants across several fish and wildlife species.
- In 1992, EPA bought a high performance computer that will be placed in Bay City, Michigan, for modelling of the Great Lakes, including hydrodynamic processes, air deposition, pollutant loadings, and sedimentation. This will be an early step toward establishing an environmental center at the head of Saginaw Bay that will be dedicated to scientific study of the Lakes.

EPA is also working to strengthen its integration and analysis of environmental data on the Great Lakes. Through its various programs, the Agency collects data on air and water pollution, hazardous waste sites, pesticides, drinking water, radiation, and the health effects of pollutants. Much of this information is obtained pursuant to separate laws and is narrowly focused to serve these mandates. In general, it is difficult to integrate these data to obtain a comprehensive view of total pollutant releases by a facility and surrounding ecological conditions. Such an overview would assist decisionmaking for permits and enforcement. Accordingly, the Agency is working to increase the availability of environmental data to support decisionmaking by Federal, State, and local governments and to make information more accessible to the public.

## Cooperation with Canada

EPA and States are taking advantage of all opportunities to work with their counterparts in Canada. Canadian representatives have been invited to ARCS program meetings to keep apprised of U.S. findings regarding technologies to address contaminated sediments. Canadian observers have also been invited to attend meetings concerning the Water Quality Initiative. In addition, EPA and States are working with Canadian counterparts on RAPs for shared Areas of Concern and on LAMPs for shared Lakes. The two nations are also sponsoring joint activities, such as the symposium on pollution prevention and their binational Lake Superior Initiative, mentioned previously.

*Chapter 4*

# Restoration of the Ecosystem: Actions to Implement the Water Quality Agreement

This chapter reports recent actions by EPA and States to implement the three major approaches of the Water Quality Agreement: Remedial Action Planning, Lakewide Management Planning, and the Phosphorus Load Reduction Plan. Following the section on remedial action, it discusses EPA's Assessment and Remediation of Contaminated Sediments (ARCS) program that will develop guidance on addressing contaminated bottom sediments. Before discussing these activities, however, the framework of the Water Quality Agreement is presented.

### *Background*

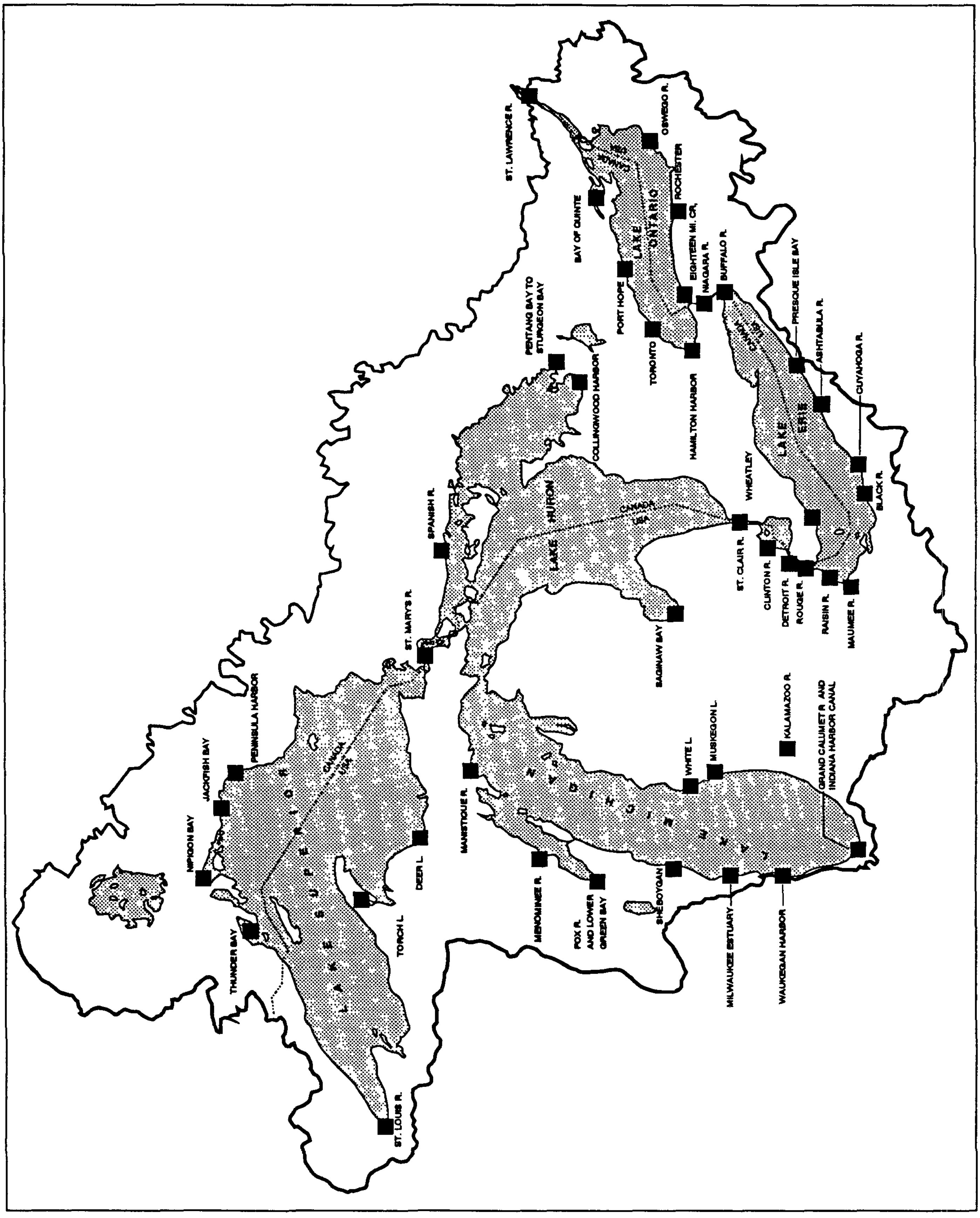
The United States and Canada have a long history of cooperation in their joint stewardship of the Lakes. In 1905, the two nations formed an International Waterways Commission to advise them about Great Lakes water levels and flows. Under their Boundary Waters Treaty of 1909, they created an International Joint Commission (IJC) that superseded the earlier commission and continues today.

The IJC has six commissioners, three from each nation. The Commission has limited authority to approve diversions, obstructions, and uses of the Lakes that affect water flow or levels across the international boundary. Since the U.S. and Canada signed the Great Lakes Water Quality Agreement in 1972, the IJC has assessed progress under it and reported findings to the governments and their citizens. The thrust of the 1972 Agreement was to reduce loadings of phosphorus that were causing nuisance levels of aquatic plant life. The two nations also agreed to coordinate their surveillance of the ecosystem.

In 1978, the two nations revised their Agreement. By that time, clear progress had been made in reducing phosphorus. There was also growing appreciation of the threat to fish, wildlife, and human health from bioaccumulative toxic substances. Some species of fish in many locations had been found to contain unacceptable levels of contaminants. Therefore, the 1978 Agreement added commitments to prohibit the discharge of toxic substances in toxic amounts, virtually eliminate all bioaccumulative toxic substances, and restore the chemical, physical, and biological integrity of the ecosystem. In 1983, the two nations further agreed to develop phosphorus reduction plans to reduce excessive plant life in areas that remained impaired.

In 1987, the nations revised their Agreement again, committing to ecosystem cleanup plans for Areas of Concern and to resolution of whole-lake problems associated with critical pollutants. The two types of plans are called Remedial Action Plans (RAPs) and Lakewide Management Plans (LAMPs), respectively. The nations agreed that these plans would be provided to the IJC for independent comment at various stages.

**Figure 4-1. Areas of Concern**



### *Areas of Concern*

Since 1973, the United States and Canada have identified geographic problem areas around the Lakes. Over time, they have increased or decreased the number of these areas as they have learned more about their conditions. There are presently 43 Areas of Concern, of which the United States has 31, including five shared with Canada. Figure 4-1 shows their locations.

Although the United States has identified its Areas of Concern for more than a decade, it should be noted that there have generally been substantial environmental improvements in these areas during the same period. For instance, as result of a $1.5 to $2 billion investment in water pollution abatement along the Cuyahoga River, dissolved oxygen levels have been restored to the 30-mile stretch of river between Akron and Cleveland, Ohio. Though deep bottom sediments of the lower Ashtabula River in Ohio are highly contaminated, a 1990 survey found that the upper layer of sediments is not contaminated, indicating that the contamination source ceased a number of years before.

The Fox River and lower Green Bay, Wisconsin, is an Area of Concern where there has been encouraging biological responses to improved water quality. In the early 1970s, low dissolved oxygen in the Fox made hardy fish, such as carp and bullhead, the dominant species. Since that time, the fish community in the river has returned to a more natural, year-around diversity of species, including walleye, northern pike, small-mouth bass, and perch. A recent report on the area also noted that the number of different bottom-dwelling species in Green Bay doubled in the ten years after 1978. Wild celery, a favored food of waterfowl and habitat for fish, began to reappear in the lower bay after a 20-year absence. The reproductive success of endangered Forster's terns in Green Bay improved during the 1980s, and the number of nesting pairs increased about 500 percent from 1986 through 1988 to nearly 600 pairs. In 1990, the mayfly, *Hexagenia*, an aquatic insect sensitive to pollution, was noted for the first time since 1939.

### *Remedial Action Planning*

The United States and Canada formally agreed to prepare RAPs in 1987. One of the Agreement's general principles regarding RAPs is use of an ecosystem approach. Each RAP is to identify the nature and causes of problems and to indicate remedial actions. RAPs are provided to the IJC for independent comment at three stages—Stage I, after problems have been defined; Stage II, after appropriate remedial measures have been developed; and Stage III, after monitoring indicates that impairments have ended.

Another provision of the Agreement is that the public, particularly 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 its success.

RAPs are developed and implemented by States. The completion of these planning documents is a measure of RAP progress. Through FY 1992, States had developed 23 Stage I and 12 Stage II RAPs. Other RAPs are under initial development.

As more is learned about Areas of Concern and the results of preventive and remedial actions are known, RAPs will be continually improved. EPA and States consider Remedial Action Planning a valuable, ongoing management process for identifying priority environmental problems, determining remedial steps, and evaluating progress.

## Actions to Restore Areas of Concern

Even as RAPs are being developed, EPA, States, and other participants are taking warranted actions to improve Areas of Concern. Highlights are summarized below.

- **Industrial Dischargers:** During the last 20 years, regulation of dischargers to surface water has greatly reduced pollutant loadings to the Lakes. EPA took enforcement actions under the Clean Water Act against industrial dischargers in three Areas of Concern—Black River, Grand Calumet River, and Menominee River. In the Black River case, a steel company dredged 35,000 cubic yards of contaminated sediments from the river in 1990.
- **Combined Sewer Overflows (CSO):** U.S. urban areas are required to eliminate or treat their CSO discharges of untreated waste water. Multiyear programs to eliminate CSOs are underway in many U.S. communities around the Lakes. CSO correction activities are of importance to 12 Areas of Concern—Clinton River, Cuyahoga River, Grand Calumet River, Detroit River, Maumee River, Menominee River, Milwaukee Harbor, Rochester Embayment, Rouge River, Saginaw River, St. Clair River, and St. Marys River. CSO improvements often involve major infrastructure investments. The CSO plan for Rochester, New York, for instance, is estimated to cost $475 million.
- **Municipal Sewage Treatment Plants:** Major investments in municipal wastewater treatment plants have improved water quality in many Areas of Concern. Since 1972, EPA, States, and towns have invested more than $8 billion in sewage system improvements around the Great Lakes watershed. As a result, 95 percent of U.S. treatment facilities in the Great Lakes region

### Targeting the Grand Calumet River

The Grand Calumet River, at the base of Lake Michigan, is the focus of EPA and State activities that have resulted in several multistatute enforcement actions and settlements that incorporate provisions to prevent future pollution. Selected activities are listed below:

- In 1990, EPA and USX Corporation, which operates a steel-making facility in Gary, Indiana, settled a suit brought by EPA in 1989 for alleged National Pollutant Discharge Elimination System (NPDES) violations. Under the innovative settlement, USX agreed to pay a penalty of $1.6 million, conduct a sediment study in the river at a cost of $2.5 million, cleanup sediment at a cost of $5 million, and invest $25 million in environmental improvements within its facility.
- In March 1993, EPA and Inland agreed to a settlement under which Inland will invest $25 million to comply with air, water, and hazardous waste requirements. In addition, the firm will pay a $3.5 million fine and invest $26 million in supplemental environmental projects, including cleanup of contaminated sediments in portions of Indiana Harbor.
- In 1990, the State of Indiana filed suit against LTV Corporation, which operates a steel-making facility, for alleged NPDES violations.
- In 1990, EPA filed suit against Bethlehem Steel Corporation under the Safe Drinking Water Act and RCRA.
- EPA issued administrative orders to various Potentially Responsible Parties to cleanup the Midco I and II Superfund NPL sites in Gary, Indiana.
- In 1991, the Atlantic Richfield Corporation and the city of East Chicago reached agreement with the Indiana Department of Environmental Management (IDEM) that they would recover petroleum contamination beneath a site adjoining the Grand Calumet. Estimates of the petroleum beneath the site range from 3 to 17 million gallons.
- In 1991, EPA reached agreement with the East Chicago Sanitary District that the District would pay a penalty for alleged violations of a 1988 Consent Decree.
- EPA continued enforcement actions against the Hammond and Gary Sanitary Districts for alleged violations of Consent Decrees. IDEM joined the Hammond suit as a co-plaintiff in 1991.

practice at least "secondary" treatment, and remaining jurisdictions are following schedules to achieve this level of treatment effectiveness. Upgrades have recently been completed or are in progress in five Areas of Concern—Black River, Cuyahoga River, Green Bay, Maumee River, and Milwaukee Harbor.

- **Industrial Pretreatment:** Of 314 major U.S. municipal dischargers in the Great Lakes watershed, more than 65 percent are required to have industrial pretreatment programs. EPA and States took actions to enforce the pretreatment of industrial effluent in three Areas of Concern—Detroit River, Niagara River, and Rouge River.
- **Superfund Cleanups:** The cleanup process is continuing at 14 Superfund sites integral to the restoration of seven Areas of Concern—Ashtabula River, Kalamazoo River, Niagara River, St. Lawrence River, Sheboygan River, Torch Lake, and Waukegan Harbor.

### Targeting Lake Michigan

Contamination of sport fish with polychlorinated biphenyls (PCBs) is the principal basis for the issuance of health advisories regarding consumption of Great Lakes fish. Recently, EPA and States have taken the following actions to attack this priority problem in Areas of Concern ringing Lake Michigan:

- The largest reservoir of PCB contamination in the Great Lakes is Waukegan Harbor, Illinois, from where hundreds of thousands of pounds of PCBs have entered Lake Michigan. EPA designated an Outboard Marine Corporation (OMC) site for the Superfund National Priorities List (NPL) in 1981. EPA determined a cleanup plan in 1984. In 1988, OMC agreed to dredge parts of the harbor and extract PCBs from soil and sediment for incineration. EPA estimates that there are more than 700,000 pounds of PCBs on OMC's property and 300,000 in Waukegan Harbor. Under the cleanup being carried out through 1993, 97 percent of the PCBs in the harbor will be removed. The cleanup is estimated to cost $20 million.
- Among Lake Michigan tributaries, the Fox River, which empties into Green Bay, is believed to carry the highest load of PCBs. The Wisconsin Department of Natural Resources (WDNR) and EPA, joined by other agencies and universities, have conducted a major study of the sources and fates of four pollutants, including PCBs, in Green Bay. Recently, WDNR also found 34 acres of PCB-contaminated bottom sediments that are thought to be the origin of about one-third of PCB loadings to the lower Fox River. WDNR is studying remedial alternatives for this site.
- The Sheboygan River is also contaminated by PCBs. EPA designated Sheboygan Harbor and 12 miles of the river as a Superfund NPL site in 1985. In 1986, Tecumseh Products Company agreed to conduct a remedial study of the site. Nearing completion, this study is testing innovative ways of breaking down PCBs lodged in sediments. Remedial actions will begin in 1993.
- The Kalamazoo River also carries PCBs. In May 1989, EPA and Michigan proposed a 35-mile stretch of the river as a Superfund NPL site. In December 1990, three Potentially Responsible Parties entered an agreement with the Michigan Department of Natural Resources (MDNR) to conduct a remedial investigation and feasibility study, which began in 1991.
- In 1990, EPA and Chemical Waste Management (CWM) signed a Consent Agreement pursuant to which CWM agreed to pay a $3.75 million civil penalty for violating PCB disposal requirements at its south Chicago hazardous waste incinerator. At the time, this penalty was the largest administrative penalty EPA had imposed on a single facility.
- In July 1990, Menominee Paper Company of Menominee, Michigan, pled guilty to a 10-count indictment on criminal misdemeanors for knowingly under-reporting pollutant discharges during 1985 and 1986. The company agreed to a $100,000 fine. In a related civil case, Menominee Paper also agreed to pay a $2.1 million penalty, which was the second highest civil penalty levied under the Clean Water Act at that time.

The Superfund program is also addressing another 11 sites that are significant, though generally to a lesser degree, to the restoration of seven other Areas of Concern—Clinton River, Grand Calumet River, Green Bay, Oswego River, St. Louis River, St. Marys River, and Saginaw River (its Shiawasee tributary).

- **Hazardous Waste Management Programs:** EPA and States have obtained agreements from hazardous waste handlers to conduct facility assessments, investigations, or corrective actions relating to five Areas of Concern—Menominee River, Niagara River, Grand Calumet River, River Raisin, and St. Lawrence River.
- **Nonpoint Source Programs:** Programs to prevent agricultural nonpoint pollution have focused on six Areas of Concern—Buffalo River, Green Bay, Maumee River, Milwaukee River, Saginaw River, and Sheboygan River.
- **Wetland Programs:** EPA and States have completed Advance Identification projects of wetlands in northwest Indiana; southeast Wisconsin; Lake County, Illinois; Green Bay; Oswego County, New York; and northwest Ohio. These projects identify wetlands of high ecological value and notify land-users.

### Targeting the Niagara River

The U.S. side of the Niagara River, which attracted a cluster of chemical companies in the years after World War II, 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. Many hazardous waste sites exist near the river, the most infamous of which is a former landfill called Love Canal that was developed as a residential area in the 1950s. After contamination was discovered in 1978, 950 residents were evacuated. Since this time, EPA and the New York State Department of Environmental Conservation (NYSDEC) have continued to focus attention on the Niagara frontier.

- In 1985, NYSDEC completed landfill containment at Love Canal, covering 3 acres with a clay cap. In 1990, NYSDEC completed a study that determined that four areas were once again suitable for residential use.
- EPA and NYSDEC joined counterpart Canadian agencies in a major binational study of the Niagara River which was completed in 1985.
- EPA and NYSDEC estimate that there has been an 80 percent decline in loadings of priority pollutants from NPDES dischargers between 1982 and 1987.
- In 1987, EPA and the State of New York joined Canadian counterparts in a declaration dedicated to halving toxic loadings (from 1987 levels) to the Niagara by 1996.
- The two U.S. agencies have taken many actions related to remedying waste sites, including five Superfund sites and many others addressed by RCRA and the State's waste program. They have announced schedules to remediate, by 1998, the 22 waste sites considered potentially responsible for 99 percent of U.S. waste site loadings to the Niagara.

Through October 1992, 68 milestones toward remediation of the 22 sites had come due. Of these 68 actions, 44 (or 65%) had been accomplished to that point. Some recent actions include:

- Removal of 6,500 cubic yards of PCB contaminated bottom sediments from Gill Creek, a tributary to the Niagara River estimated to contribute 20% of the PCB load from the Niagara River to Lake Ontario. This removal was completed between June to December 1992.
- In March 1993, EPA reached agreement with the City of Niagara Falls to resume diversion of dry weather waste flow from the Falls Street Tunnel to the city's wastewater treatment plant which will greatly reduce toxic releases from the largest point source of toxic chemicals to the Niagara River.

### *RAP Process Lessons*

Some successes of the RAP process to date are:

- 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 local industry to join in restoration planning and to identify opportunities to prevent pollution.
- The development of some RAPs has brought together nearby municipalities to address 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 cleanup (Niagara River), better sewage treatment, and wetlands restoration (Green Bay).

The following general lessons have emerged from the Remedial Action Planning process:

- The development of a strong RAP can be complex and protracted. The Rouge River RAP took three years to develop and grew into 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 is iterative and incremental. The first generation of the Rouge River RAP, for example, 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 is considerable asymmetry of information available to different RAP teams. Sometimes there is extensive information about an Area of Concern (e.g., Green Bay) and, 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, which has helped their stakeholder groups (e.g., Duluth, Green Bay, and Milwaukee).
- The RAP development process can be greatly helped by information provided by PRPs pursuant to enforcement actions (e.g., Ashtabula, Kalamazoo, and Sheboygan).
- Major investments are 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.
- Ways to address the common problem of contaminated bottom sediments in rivers and harbors are often unclear. EPA is testing technologies and will develop guidance to assist local decisionmakers.

### Targeting the St. Lawrence River

EPA and State actions are focused on eliminating local problems, such as those of the St. Lawrence River Area of Concern. During the 1960s and 1970s, industries poured wastes, including PCBs and mercury, into riverside landfills and the river itself, damaging the traditional fishing, farming, and hunting economy of Mohawks living within the Akwesasne Indian Reservation in New York State. Fish, ducks, and turtles, traditional sources of protein for the Mohawks, became contaminated with PCBs and mercury. The following activities have been taken to address problems in the St. Lawrence River Area of Concern:

- In 1983, EPA added a General Motors (GM) site on the St. Lawrence River to its Superfund NPL.
- In October 1990, EPA 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.
- In December 1990, EPA selected a remedial plan for part of the GM site which is estimated to cost $78 million.
- In March 1991, NYSDEC selected a remedy for eight subsites at the ALCOA site. The remedy entails a combination of pollutant removal, treatment, and containment at an estimated cost of $46 to 52 million.
- In May 1991, EPA proposed a cleanup plan for the rest of the GM site, which is estimated to cost $33 to $47 million.
- In July 1991, ALCOA agreed to pay New York State $7.5 million, including $3.75 million for criminal violations, in relation to various environmental offenses in its handling of hazardous wastes at its Massena, New York, facility.

## ARCS Program

EPA continued to sponsor a study and demonstration program—the Assessment and Remediation of Contaminated Sediments (ARCS) program—to assess contaminated bottom sediments in the Great Lakes, test remedial technologies, and develop guidance on addressing such contamination. 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 Federal and State agencies, including the Army Corps of Engineers, Bureau of Mines, Fish and Wildlife Service, National Oceanic and Atmospheric Administration, 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 five 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. For example, many current methods of dredging bottom sediments release some contaminants from sediments.

The ARCS program assesses the scope and nature of contamination in the study areas, evaluates human and ecological health impacts of the contamination and of alternative remedial measures, and tests the efficacy of innovative remedial technologies. ARCS also informs and solicits 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 1994. It will include guidance on how to assess freshwater contaminated sediment problems 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 analyzing sample chemistry, toxicity (both acute and chronic) to aquatic organisms exposed to the sediment, and identification of benthic organisms. These analyses were completed in 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, continued contamination from sources in the area is a possibility. 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 1989, ARCS took surficial samples in the Saginaw River. Preliminary analysis of these samples generally indicates less toxicity than in the Buffalo River, although two Saginaw sites had notably higher toxicity than the 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 the transfer of contaminants from sediment to fish in the Saginaw and Buffalo Rivers.

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

## *Hazard Evaluation*

As contaminants in sediments are identified, the ARCS study evaluates their risks 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. The ARCS program continued evaluations of current hazards at each of the five priority locations.

In the Buffalo and Saginaw Rivers, the ARCS program 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.

These comprehensive evaluations studied the sources and fates of contaminants in the Buffalo and Saginaw Rivers over a six week period. Water column, fish, and sediment samples were analyzed 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. PCBs, zinc, copper, and lead are being studied in the Saginaw River.

Once models of the sources and fates of these pollutants are refined, the ARCS program will predict risks under various remedial alternatives, including leaving sediments undisturbed (i.e., no-action alternative); dredging only the two or three worst hot spots; capping stretches of river with clean material rather than dredging them; and removing contaminated sediment completely. The

ARCS program is considering all possible risks associated with each option, including dredging, treatment, and ultimate disposal of contaminated sediments.

### *Technology Evaluation*

During FYs 1989-90, the ARCS program conducted small-scale laboratory tests of treatment technologies on sediments from the five study locations. These tests used between a few grams to a few kilograms of sediment. The laboratory tests provided information to help the study team select promising technologies to demonstrate in the field. The ARCS program also sponsored a binational research conference on biological treatment of sediments contaminated by PCBs, PAHs, and some metals.

The ARCS program chose 16 technologies as candidates for pilot-scale field demonstrations in the five study locations. 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 Lakes. Technologies fall into five general categories: thermal technologies (including incineration, but more often the use of high temperatures short of combustion to vaporize contaminants and water from sediment), chemical destruction (using chemical reactions to break down contaminants), biological treatment (using bacteria 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 food web).

The ARCS program conducted pilot-scale field demonstrations in all five priority locations during FYs 1991-92.

- On the Ashtabula River, ARCS demonstrateed a thermal stripping process to vaporize organic contaminants from sediment.
- On the Buffalo River, ARCS demonstrated a thermal extraction process similar to that used at Ashtabula but tailored to the needs of the Buffalo sediment.
- On the Grand Calumet River/Indiana Harbor, ARCS demonstrated the application of a solvent extraction process to separate organic contaminants.
- On the Saginaw River, ARCS separated sediments by particle size, using a hydrocyclone. Since contaminants tend to adhere to finer sediment particles, this demonstration is expected to reduce the volume of heavily contaminated sediment by separating coarse-grained sediments that bear relatively less contamination from fine-grain particles that hold more contaminants. Thereafter, ARCS demonstrated bioremediation of the fine-grain particles in the confined disposal facility in Saginaw. Using native bacteria, the study team will add nutrients to stimulate the growth of bacteria and vary the amount of oxygen available to the bacteria to try to increase the effectiveness of the bioremediation.
- On the Sheboygan River, ARCS provided technical assistance to Superfund cleanup activities through EPA's Environmental Research Laboratory-Athens. This entailed a scientific review of the Sheboygan bioremediation pilot project already underway, including design and statistical recommendations.

### *Public Communication*

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

The second major remedial approach under the Water Quality Agreement is the development of 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, as with the RAP process, EPA and States view Lakewide Management Planning as an ongoing management process to identify priority environmental problems, the steps needed to solve the problems, and ecological outcomes.

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

EPA will invite public participation in the LAMP process. The Agency will notify the public of proposed LAMPs through the *Federal Register* and conduct public meetings on these plans.

### *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 safe for unlimited human consumption and that 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 water with water quality standards. They found no exceedances of drinking water standards. However, fish tissue concentrations exceeded human or wildlife health protection levels for dioxin, PCBs, chlordane, mirex, mercury, dieldrin, DDT and its metabolites, octachlorostyrene, and hexachlorobenzene.

The plan uses four approaches to address these exceedances. First, it relies on reduction of toxic inputs by the entire range of Federal and State programs, including the RCRA, CERCLA, and NPDES programs. Second, it calls for further reductions through special focus on five New York Areas of Concern and four others in the Province of Ontario. Third, it seeks future reductions based on lakewide analyses of pollutant fate to provide grounds for water quality-based regulation. Fourth, the plan calls for zero discharge of bioaccumulative 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 included a comprehensive estimation of loadings from groundwater, air, and sediment to test the bioaccumulation model. Also in 1991, EPA and NYSDEC started to incorporate pollution prevention measures into their lakewide efforts. Such measures included focusing on the Rochester and Buffalo areas for urban nonpoint source prevention, focusing on facilities that emit any of the priority lakewide pollutants, and implementing a New York regulation for a 50-percent reduction of fugitive air emissions and New York State's requirement for progressive reduction in toxic chemicals generated by key dischargers.

During FY 1990, a team from EPA, NYSDEC, New York State Department of Health, Fish and Wildlife Service, and counterpart Canadian agencies developed ecosystem objectives for Lake Ontario. In 1992, the team continued to develop measurable ecosystem indicators for nearshore and open-lake water quality (trophic condition), human health, wildlife health, and habitat.

### *Lake Michigan*

During 1991, EPA worked with the States of Illinois, Indiana, Michigan, and Wisconsin to develop a LaMP for Lake Michigan. This was published in the Federal Register for public comment in 1992.

Two early LaMP activities aim to prevent potential environmental releases of pesticides and PCBs. Under agricultural "clean sweeps," States invite farmers and pesticide dealers to turn-in pesticide stocks for proper disposal. The Lake Michigan States collected in excess of 120,000 pounds of pesticides in that Lake's watershed during 1992, including more than 10,000 pounds of suspended and cancelled pesticides such as DDT. Under the PCB prevention activity, EPA asked utility companies to accelerate their phase-out, within the Great Lakes watershed, of electrical equipment containing PCBs. By early 1992, the majority of utilities had already committed to speeding-up their PCB phaseouts.

*Chapter 5*

# Actions By Federal Partners

This chapter presents FYs 1989, 1990, and 1991 accomplishments pertaining to the Great Lakes, as reported by five 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, 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), which are structures designed to hold and isolate these sediments. Forty-three CDFs are 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 (IJC) 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 were assessed, and mitigation were 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. 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 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, Cornucopia, LaPointe, Manitowoc, and Milwaukee Harbors in Wisconsin; Duluth-Superior Harbor in Minnesota/Wisconsin; and 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.
- The Corps assisted EPA's ARCS program by providing technical support, performing bench-scale testing of treatment technologies, developing plans for pilot-scale demonstrations, creating procedures for estimating contaminant losses, designing concept plans for full-scale remediation, and participating in five ARCS work groups.
- The Corps assessed contaminant loss and bioaccumulation in fish at the Saginaw CDF and PCB bioaccumulation and volatilization at the Chicago 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 also began 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 Harbor, 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 Areas of Concern (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 Accomplishments*

- The Corps continued to administer the dredge and fill permit program.
- An EPA/Corps task group on Clean Water Act Section 404(b)(1) implementation met to develop guidance on dredged material testing and decisionmaking.
- Continuing support to the ARCS program, the Corps demonstrated pilot-scale sediment remediation technologies and continued support to an EPA project to remove contaminated sediments from the Buffalo River.
- Testing of bottom sediment was 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 was conducted 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; and Green Bay and Manitowoc Harbors in Wisconsin.
- The Corps constructed new CDFs or offloading facilities or made major modifications to existing CDFs 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 was performed at other CDFs.

- The Corps started construction of small boat harbors in Buffalo, New York, and in Little Calumet River, Indiana, and continued the Chicagoland Underflow Plan flood damage reduction project.
- The Corps continued to identify and remediate hazardous wastes at former defense sites. An analysis was completed on a sample of the 1,400 barrels dumped into Lake Superior more than 30 years ago.
- The Corps participated in a Fish and Wildlife Service assessment of the management and restoration needs of Great Lakes fisheries resources.
- The Corps issued grants to States for programs aimed at reducing zebra mussels at public facilities.

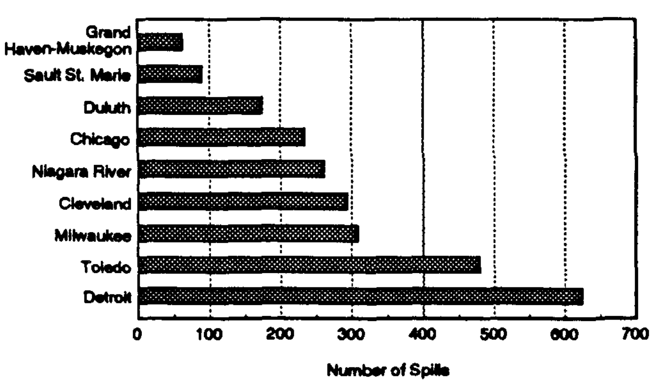
## The Coast Guard

The Coast Guard promotes prevention of pollution from vessels by promulgating regulations and by conducting marine safety and law enforcement inspections. The Coast Guard is also responsible for responding to spills of oil and hazardous substances into the Great Lakes. Figure 5-1 provides selected statistics on spills within Great Lakes Harbors. 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 nine marine safety units on the Great Lakes to perform pollution response and investigation functions. The Coast Guard also attempts to prevent the introduction of exotic species from ships into the Great Lakes.

### *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. The International Maritime Organization distributed these guidelines 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. The Authority reported 85 percent compliance with the guidelines during the 1989 shipping season.

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




- 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, which apply to all ships, including recreational boats, prohibit the discharge of garbage into the navigable waters of the United States. These regulations were amended in May 1990 to require maintenance of waste management plans and display of MARPOL Annex V placards on all oceangoing vessels greater than 40 feet in length. This amendment will help ensure that all persons on board are aware of garbage pollution laws and will promote proper disposal.
- The Coast Guard continued to verify pollution incidents in U.S. waters of the Great Lakes. During calendar year 1989, the Coast Guard recorded 262

such incidents. Of these, 13 involved hazardous materials, and 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 public access. 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. The Fisheries Center studies fish populations and their responses to such stresses as exotic species, habitat modification, contamination, and fishing. The Center particularly focuses on the restoration of naturally reproducing lake trout populations. It operates five research vessels.

Some recent accomplishments 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 its 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 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 nontarget 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 offshore 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 Accomplishments*

- The Service began to implement the Great Lakes Fish and Wildlife Restoration Act of 1990 that calls for the Service to conduct a comprehensive fishery resources study through FY 1994.
- The Service continued the lake trout stocking program.
- The Service applied lampricides to 39 Great Lakes tributaries.
- The Service continued monitoring bloater chubs from Lake Michigan. In addition, archived fish samples were analyzed by PCB and chlordane congeners to determine historical trends in these contaminants by congener.
- The Service increased 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, which is 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, which has 12,000 acres of wetlands.
- The Service funded three studies that assessed the impacts of contaminants on Great Lakes wildlife. The first study, of 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 five 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 two 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. During the previous eight years, active nests have risen from 2 to 16.
- The Service continued to support a survey of colonial waterbirds of the Great Lakes. This three year study, begun in 1989, will indicate where the Service should direct future management activities.
- The Service began a study of black ducks in Ohio's Lake Erie marshes. This study should provide information on black duck habitat use, movements, and survival in this critical migration area.

*FY 1991 Accomplishments*

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

## Fish and Wildlife 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, in New York.
- Working with EPA and States, 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 surveyed fish (bullheads) for tumors and abnormalities and sediments in Saginaw, Grand Calumet, and Buffalo River. 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 three projects and minimum flow requirements at six 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 to evaluate 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 spring 1988, celery was planted at two 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 suitable 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 making various decisions, including permit issuance and zoning.
- The Service continued a pre-assessment of natural resource damages for Waukegan Harbor, Illinois and 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 of yellow perch reproduction in Torch Lake found 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 Accomplishments*

- The Service completed 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 completed 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 proposed 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 only on two Michigan sites and one Ontario site.
- The Service supported 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, Ohio EPA, Ohio DNR, and the Army Corps of Engineers. The Service also continued to support a similar advanced identification of wetlands near Green Bay.
- The Service continued its support to Remedial Action Planning.
- The Service began a natural resource damage assessment for the Indiana Harbor and Grand Calumet River Area of Concern.

## The Great Lakes Environmental Research Laboratory

The Laboratory conducts research on Great Lakes ecosystem dynamics and physical processes, performing 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 in the following paragraphs under the topics of bioaccumulative toxic substances, ecological processes, and benthic populations.

### *Bioaccumulative 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 from 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 remediation measures on contaminated sediment are poorly understood and are one of the fundamental unresolved issues concerning long-term restoration of the Great Lakes.

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 contributed to the major interagency study of toxicants in Green Bay:

- Water volume movement through Green 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.

During FY 1990:

- 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.

During FY 1991, the Laboratory analyzed trap samples for organic carbon and PCBs, developed empirical sediment resuspension models for Green Bay, and completed 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.

During FY 1989, the Laboratory conducted numerous activities, including the following:

- 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.

During FY 1990, the Laboratory conducted the following projects:

- Analysis of two nonindigenous 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.

During FY 1991, the Laboratory continued 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 included examination of toxicokinetics and bioaccumulation analysis of organic contaminants in the zebra mussel, 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.

During recent years, the Laboratory:

- 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, which 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 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.
- Sorted organisms collected in Whitefish Bay as part of fish enclosure experiments.
- Continued periodic sediment grab sampling at 45 meters and 100 meters sites to determine if *Diporeia* production is still declining.

## The Soil Conservation Service

The Soil Conservation Service of the U.S. 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: 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, demonstrates 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 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 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.

### *Recent 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 to assess the movement of pesticides, nutrients, and sediments
- Worked with Ottawa County, Ohio, to measure effects of tillage practices on water quality.

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 prioritizing watersheds affected by nonpoint source pollution. 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 nonpoint source watershed demonstration projects.

During FY 1991, the Service continued to participate in the 10 major USDA projects in the Great Lakes watershed. It also increasingly emphasized integrated crop management in all its programs to reduce agricultural use of nutrients and pesticides to improve water quality.

*Chapter 6*

# Monitoring of the Ecosystem

This chapter discusses U.S. monitoring of the Great Lakes system, including three EPA initiatives on bioaccumulative 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 bioaccumulative 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 system-wide surveillance programs, including chemical and biological open-lake limnology, fish monitoring programs, the Great Lakes Atmospheric Deposition (GLAD) network, and the Environmental Monitoring and Assessment Program Great Lakes.

## *Background*

During recent years, there have been three primary elements of EPA's Great Lakes surveillance efforts: open-lake surveys of ambient water quality, monitoring of toxicant levels in fish tissues, and monitoring of atmospheric deposition. The Agency has conducted open-lake spring and summer surveys of ambient water quality in Lakes Michigan, Huron, and Erie since 1983, in Lake Ontario since 1986, and in Lake Superior since 1992. Prior to these routine surveys, each of the lakes was surveyed intensively. 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, EPA, State, and other Federal agencies have monitored toxic organics in Great Lakes fish tissues. Fish are excellent indicators of water quality and ecosystem health because they tend to build up bioaccumulative 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 analyzes 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. In addition, the Service has 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 toward protecting human health by issuance of fish consumption health advisories.

The third primary element of EPA's surveillance activities, also a joint Federal/State endeavor, is monitoring of atmospheric deposition. The United States operates a 20-station 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.

Since 1991, in cooperation with other Agencies, EPA has begun to design and implement a monitoring program whose goal is to estimate conditions in the Great Lakes with known confidence.

The Environmental Monitoring and Assessment Program (EMAP) Great Lakes is an interagency, interdisciplinary program whose goals are to monitor and assess the condition of the Great Lakes and to contribute to decisions on environmental protection and management. EMAP Great Lakes has four objectives:

- Estimate the current status, trends and changes in selected indicators of the condition of the Great Lakes on a regional basis with known confidence;
- Estimate the geographic coverage and extent of the harbors, bays and wetlands;
- Seek associations between selected indicators of natural and anthropogenic stresses and indicators of condition of ecological resources;
- Provide annual statistical summaries and periodic assessment of the Great Lakes.

For the Great Lakes, the individual lakes have been established as the regional scale of resolution and each lake will be separated into resource classes (offshore water, nearshore, bays/harbors, and wetlands) with sampling frames and indicators that are appropriate to characterize each class. Biotic integrity and trophic condition have been identified as important environmental values. These values will influence the selection of indicators and assessment questions for the offshore, nearshore and bays/harbors resource class. To assess overall biotic integrity, EPA has focused on three major components: benthic macroinvertebrates, primary producers, and fish.

## 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 bioaccumulative toxic substances in its lakes. Researchers theorized that such pollutants could only have resulted from atmospheric deposition.

Since the Isle Royale findings, EPA has promoted ways of assessing the absolute and relative magnitude of atmospheric loadings of toxic substances. The Agency 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. EPA implemented its first master station and two satellite stations for monitoring airborne PCBs and dieldrin in fall 1988. These are located around Green Bay.

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 bioaccumulative toxic substances. During 1991, the two nations completed the installation of one IADN master station on each of the Great Lakes. The United States has established master stations on Lakes Superior, Erie, and Michigan, while Canada has established them on Lakes Huron and on Ontario. Data will be shared by each nation, and the United States will be able to place equipment at the Lake Ontario site.

## Green Bay Study

This special study, begun in 1987, has helped EPA develop an understanding of the sources, pathways, and fates of PCBs within a large waterbody.

The Wisconsin Department of Natural Resources and EPA's Great Lakes National Program Office were 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 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 field 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 addressed 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. Detection of these trace contaminants in the water column requires sampling 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.

In FY 1991, the study team completed analysis of samples, compiled data, and calibrated existing models. Study findings were developed 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 was subsequently converted into a replacement research vessel for open-lake water quality monitoring. This vessel was needed because the previous ship was more than 50 years old. The new vessel has more capabilities than the old ship and will expand the capability for routine monitoring of bioaccumulative toxic substances in open-lake waters. The new vessel, christened the *Lake Guardian*, underwent shipyard conversion during the second half of 1990. It began operations during FY 1991.

## System-wide Surveillance

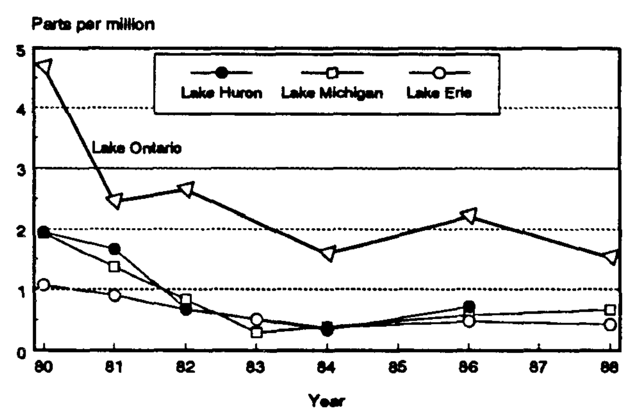
During 1992, the Agency accomplished all open-lake water quality sampling that was planned for Lakes Erie, Huron, Michigan, and Ontario. During the summer survey, EPA sampled for 33 parameters at 20 sites in Lake Erie, 20 sites in Lake Huron, 11 sites in Lake Michigan, and 8 sites in Lake Ontario. Spring and summer surveys were also completed in 1990 and 1991.

Through an agreement with the Fish and Wildlife Service, the Agency 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, although severely reduced dissolved oxygen levels were observed in mid-September, which is an encouraging sign that phosphorus load reductions may be achieving their desired effect. In several previous years, anoxic conditions developed about mid-August.

EPA, States, and the Fish and Wildlife Service continued fish surveillance programs during FY 1992; this activity will continue during FY 1993. Figures 6-1 and 6-2 show some results of this monitoring program. Figure 6-1 shows that PCB levels in coho salmon have been highest in Lake Ontario during the 1980s. Figure 6-2 shows PCB contamination in another predator species, lake trout, is higher than in coho.

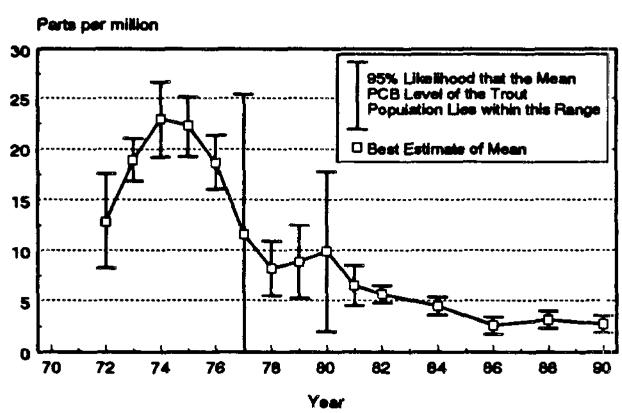
States and EPA continued their joint support of a 20-station atmospheric deposition network during 1992; this activity will continue during FY 1993. The sampling stations monitor nutrients (nitrate/nitrite and phosphorus), metals (including lead, cadmium, and mercury), and acidity in precipitation among about 35 parameters. States and universities operate the sampling stations and provide samples to EPA on a weekly basis, if sufficient precipitation occurs.

**Figure 6-1. PCB Levels in Coho Salmon**




*PCB contamination in coho salmon has declined from levels detected in the early 1980s. Levels in Lake Superior coho have continually been beneath detection; Lake Ontario coho consistently show the greatest contamination with PCBs.*

**Figure 6-2. PCB Levels in Lake Trout, Southeast Lake Michigan**




*Being longer-lived, lake trout accumulate higher levels of PCBs than do coho. Levels in Lake Michigan lake trout have strongly declined since the mid-1970s.*

EPA, Environment Canada's National Water Research Institute (NWRI) and NOAA-GLERL conducted EMAP Great Lakes pilot activities on Lakes Michigan and Superior in FY 1992. Spring surveys were completed on both lakes, while two additional surveys, one summer and one fall, were completed on Lake Michigan. Offshore trophic status from EMAP grid sites was assessed. Measurements of spring trophic status were sampled at 12 EMAP sites in Lake Michigan and at 19 EMAP stations in Lake Superior. During the summer cruise in Lake Michigan, sediments were collected to examine variability in offshore benthic macroinvertebrate communities and to assess the adequacy of the base grid sampling intensity. The fall cruise in Lake Michigan was part of a cooperative nearshore study with NWRI and NOAA-GLERL to assess the adequacy of sampling intensity and sampling method (Ponar vs. box core). Benthic macroinvertebrates in nearshore areas will be used to determine nominal conditions in Lake Michigan.

*Chapter 7*

# Expenditures

To carry out its focus on the Great Lakes, EPA has during recent years consistently increased expenditures for activities concerned with this ecosystem. This chapter discusses the Agency's expenditures on Great Lakes activities, including expenditures by categories (such as State cooperative efforts, judicial enforcement, research, and general administration) specified in Section 118(c)(10) of the Clean Water Act, which defines this report.

### *EPA Great Lakes Funding*

During recent years, EPA has steadily increased funding to the Great Lakes Program. EPA spent more than $41 million on an Agency-wide basis during FY 1991. This includes the Great Lakes Program and other activities related to the Great Lakes. This level of effort was increased by more than 50 percent in 1992. The Administration's 1993 budget called for a further increase to more than $61 million.

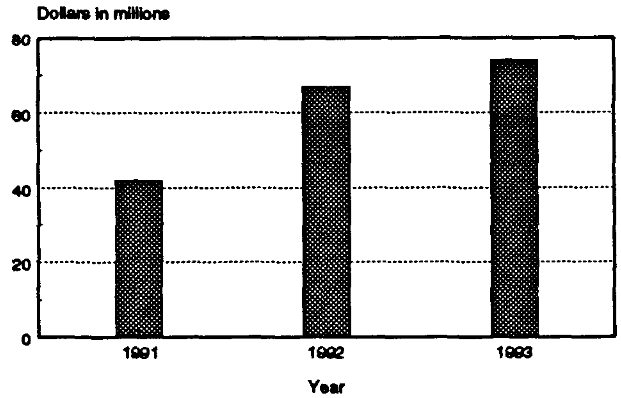
### *State Cooperative Efforts*

One major element of EPA's increased funding to the Great Lakes Program is increased resources to State agencies expressly for development and implementation of Remedial Action and Lakewide Management Plans. In 1989 and 1990, funding to States for these ecosystem restoration efforts totalled just under $500,000. During 1992, the Agency increased funding for Remedial Action Plans and Lakewide Management Plans to over $9 million.

### *Research*

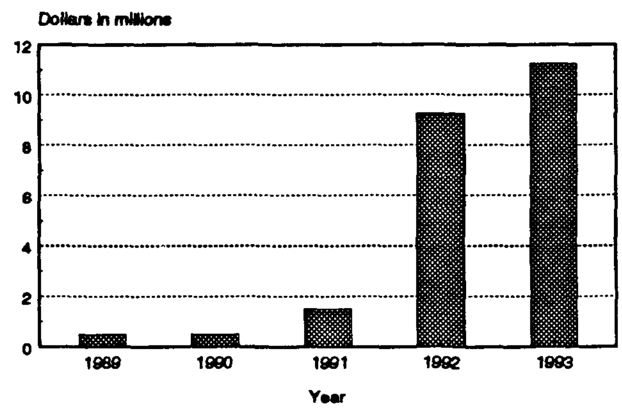
Funding for the Agency's research activities pertaining to the Great Lakes has also increased, from $2.4 million in 1991 to over $9 million in 1992. The Administration's 1993 budget sought a further increase.

**Figure 7-1. EPA Funding for Activities Related to the Great Lakes**



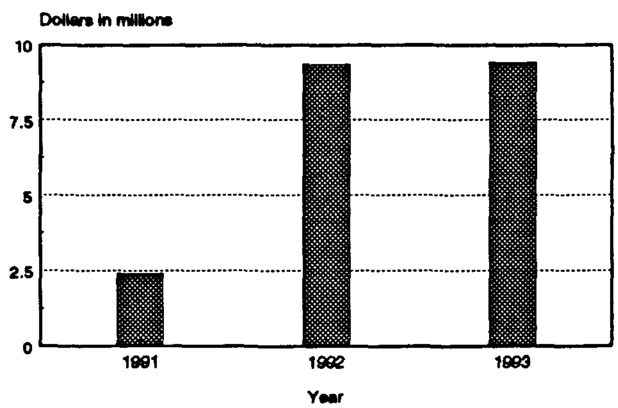

*EPA has strongly increased funding for Great Lakes activities*

**Figure 7-2. EPA Funding for RAPs and LaMPs**



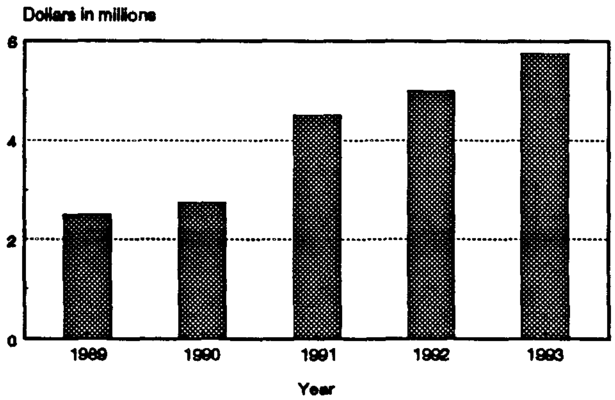

*Funding to States is up sharply*

**Figure 7-3. Funding for Great Lakes Research**



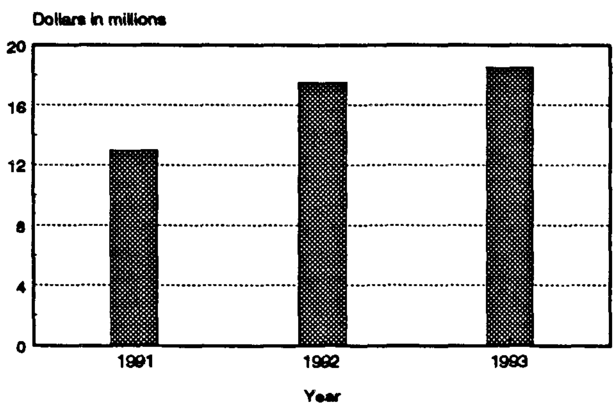

*Research funds have increased threefold*

**Figure 7-4. Funding for Great Lakes Enforcement Activities**




*Expenditures for enforcement have steadily increased*

**Figure 7-5. Funding for General Administration**




## Enforcement

The Clean Water Act specifies that this report provide expenditures on "judicial enforcement" pertaining to Great Lakes water quality. Judicial enforcement is a subset of enforcement activities which also include administrative actions. While the Agency does not have an estimate of expenditures solely for judicial enforcement activities, this report can cite resources applied to the enforcement, as a whole, in the Great Lakes watershed. Resources have steadily increased for five years. In 1989, $2.6 million was expended on enforcement in the Great Lakes watershed. This increased to $4.9 million in 1992.

## General Administration

The Clean Water Act also specifies that this report provide expenditures for "general administration." This report defines general administrative expenditures as consisting of funds in the "salaries and expenses" classification. As the Agency has focused more personnel on the Great Lakes ecosystem, these have risen, as shown in Figure 7-5.

*Chapter 8*

# Toward the Future

The Great Lakes Program is guided by its five year Strategy. Within this context, some future endeavors are discussed in the following subsections.

## Reducing Releases of Toxicants to the Environment

- Pollution prevention will continue to be the preferred means to reduce emissions and discharges of environmental contaminants. States and EPA will continue to implement their pollution prevention action plan for the Lakes. This will supplement EPA's national initiative, the 33/50 Program, to encourage voluntary reductions of 17 priority contaminants through 1995.
- The U.S. Department of Agriculture (USDA), States, and EPA will continue nonpoint source pollution prevention programs. Many of these programs will focus on tributary watersheds in which nonpoint source problems are pronounced, such as Saginaw Bay, Lake Erie, and Green Bay. In addition to education and incentives for environmentally-kind agricultural practices, these agencies will invite the public via "clean sweep" campaigns to dispose of pesticide stocks.
- Implementation of the binational Lake Superior Program will aim to achieve "zero discharge" of bioaccumulative toxicants to this Lake.
- Proposed Great Lakes Water Quality Guidance will be finalized, after consideration of public comments. USEPA anticipates publication of the final Guidance by March, 1995. The Agency will seek to achieve water quality criteria set forth in the Guidance through reductions in both point and nonpoint sources of contaminants.
- States, in consultation with the Food and Drug Administration, will develop regional guidance regarding human health advisories for consumption of contaminated Great Lakes fish and wildlife. This will foster consistency among States in their advisories, which will help the public better understand the risks associated with consumption of contaminated sportfish and game.
- Nationwide implementation of the 1990 amendments to the Clean Air Act will significantly cut toxic emissions by U.S. firms by the end of this century. EPA and States will give priority to implementing its provisions for suspected sources of critical pollutants to the Great Lakes.
- States and EPA will continue cleanup of priority abandoned hazardous waste sites and oversight of active ones, focusing cleanups and corrective actions on sites suspected of loading bioaccumulative contaminants to the Lakes.
- States and EPA will continue to inspect oil facilities in order to review their spill prevention measures and readiness to respond to accidental spills.
- EPA and its partners in the Assessment and Remediation of Contaminated Sediments (ARCS) program will complete field demonstrations of contaminated sediment treatment technologies. EPA will complete an inventory of contaminated sediment sites in six Great Lakes States and start to assess and address priority sites.
- EPA, the Fish and Wildlife Service, and States will continue to phase-in a comprehensive monitoring system of ecosystem health. Elements that focus on toxic contaminants will be

open-lake monitoring of critical pollutants in the water column, monitoring of tributaries to prioritize active sources of contaminants, monitoring of endpoint levels of contaminants in the tissues of birds and fish high in the food web, and monitoring of the atmospheric deposition of critical pollutants.

- The Agency will report to Congress on the extent and effect of atmospheric deposition of contaminants to the Great Lakes.
- The Agency for Toxics Substances and Disease Registry will evaluate the adverse effects of water pollutants in the Great Lakes system on the health of persons in the Great Lakes States and on the health of fish, shellfish, and wildlife. Findings will be reported to Congress in 1994.

## Protecting and Restoring Habitat

- USEPA will work with partners, including the Fish and Wildlife Service, States, Tribes, and the Nature Conservancy, to develop a strategic conservation plan to identify high quality habitats for protection and restoration. Habitats to be inventoried include wetlands, fish spawning and nursery areas, old growth forests, prairies, dunes, savannas, and areas needed by endangered and threatened plant and animal species.
- EPA, the Fish and Wildlife Service, and States will work together on demonstration projects to restore important Great Lakes habitats.
- The Fish and Wildlife Service will support States in planning the renewal of Areas of Concern by identifying the habitat requirements of various fish and wildlife species in these areas. The Service will similarly work with EPA and States to identify the habitat needs of species on a lakewide basis.
- States and EPA will pursue Advance Identification projects that identify wetlands of high ecological value and inform landowners of this information.
- The Army Corps of Engineers, EPA, and Michigan will continue their administration of the primary Federal program regulating the physical modification of wetlands and others waters. Pursuant to Section 404 of the Clean Water Act, they administer a permit program to regulate the discharge of dredge or fill materials into the waters of the United States, including most wetlands.
- The Fish and Wildlife Service will work with its partners to the North American Waterfowl Management Plan to protect, enhance, and create critical waterfowl habitat. The Service will add protected acreage through its Private Land program and increase surveillance for illegal dredge and fill activities.
- The Soil Conservation Service will continue to promote the protection of wetlands that are privately owned through incentives to restore previously converted wetlands and correctly farmed wetlands; to establish vegetative filter-strips along streams; and to protect wetlands.

## Protecting Human Health and Restoring Fish and Wildlife Populations

- States, EPA, and the Soil Conservation Service will implement programs to reduce human exposure to harmful bacteria in Great Lakes waters. One focus will be ending the discharge of untreated human wastes from combined sewer overflows by upgrading municipal sewer systems and treatment capacity. The Service will promote adoption of waste management systems to reduce runoff from livestock facilities.
- The Fish and Wildlife Service, States, Coast Guard, NOAA, the Great Lakes Fisheries Commission, and EPA will work together to prevent further introductions of nonnative species

and to mitigate the harmful effects of ones that have already entered the Great Lakes. They will monitor the ecosystem for new nonnative species and conduct research on environmentally-kind control techniques for disruptive nonnative species. The Coast Guard will establish requirements governing ship ballast water, a common pathway for the introduction of nonnative species.

- The Fish and Wildlife Service will lead a comprehensive study of fishery resources to identify the restoration needs of Great Lakes fish species, using the latest quantitative techniques to analyze the causes of past disruptions to fish populations and to identify the physical, chemical, and biological needs of important fish and wildlife species.
- The Fish and Wildlife Service and States will continue to stock hatchery-reared fish, such as lake trout, to bolster the abundance of important species. The Service will also continue application of lampricides to tributaries where sea lamprey spawn in order to control the ravages of this nonnative species upon sport fish. In addition, the Service and States will continue law enforcement efforts to curtail illegal commercial fishing and waterfowl hunting.
- The Fish and Wildlife Service and States will continue to take measures to protect and restore populations of endangered and threatened Great Lakes species such as bald eagle, peregrine falcon, Kirtland's warbler, eastern timber wolf, and lakeside daisy.
- The Fish and Wildlife Service will implement the North American Waterfowl Management Plan's habitat strategy aimed at restoring waterfowl populations to their levels in the 1970s.
- The Fish and Wildlife Service and States will pursue Natural Resource Damage Assessments and Claims against Potentially Responsible Parties for past harm to Great Lakes species.
- EPA and States will continue activities to reduce phosphorus loadings to areas of the Lakes that are vulnerable to nutrient overenrichment.

## Working Together

The partners to the Strategy will support its implementation by various steps, including:

- States and EPA will focus prevention, inspection, enforcement, and cleanup efforts on critical pollutants and on geographic areas which have the highest ecological and human health risks. In so doing, they will be targeting the strongest opportunities to restore the ecosystem and protect human health.
- They will use the Remedial Action and Lakewide Management planning processes to define ecological needs and appropriate responses to these needs.
- EPA, in cooperation with the Fish and Wildlife Service, NOAA, other Federal agencies, and States, will establish an environmental data storage and retrieval system relating to the Great Lakes, which will be accessible to all agencies.
- The Fish and Wildlife Service, in cooperation with other agencies, will establish data repositories on habitat uses and on fisheries.
- EPA, working with its partners, will establish and maintain a Great Lakes ecosystem monitoring plan to address program needs.
- EPA and its partners will establish and maintain research priorities to support management programs.
- EPA, in conjunction with its partners, will develop a joint report to Congress and to the people of the Great Lakes region on implementation of their joint Strategy and progress toward their environmental goals. EPA and its partners will adopt ecological objectives and measure progress with ecological indicators.

- The partners to the U.S. Great Lakes Strategy will pursue opportunities to work with their Canadian counterparts. For instance, the two nations will sponsor biennial conferences on the health of the ecosystem.

In the years ahead, the Great Lakes Program will continue evolving to address everchanging challenges. One constant emphasis, however, will be to inform the public about the state of the ecosystem. Individuals are vital to further environmental progress through their purchases of products, choices of lifestyles, and expectations of their civic institutions, including businesses, environmental organizations, universities, and governments. The Great Lakes Program will continue to promote public stewardship through education and public participation. Though the region's human inhabitants have often wrought harm to this extraordinary ecosystem during the last several centuries, they still hold its future within their collective stewardship.

# End Notes

## Chapter One

### *Figure 1-1. The Great Lakes Watershed*

Environment Canada, U.S. Environmental Protection Agency, Brock University, and Northwestern University, *The Great Lakes: An Environmental Atlas and Resource Book* (Toronto: Environment Canada, Ontario Region, and Chicago: U.S. Environmental Protection Agency, Great Lakes National Program Office, 1987).

### *Figure 1-2. Depth Profile of the Great Lakes and Summary of Their Physical Features*

U.S. Army Corps of Engineers, The Laurentian Great Lakes, Miscellaneous Facts and Figures, Draft Environmental Impact Statement, Lake Level Regulation Plan. SO-901 (1974).

Quinn, F., "Hydraulic Residence Times for The Laurentian Great Lakes." *Journal of Great Lakes Research* 18(1) (1992), pp. 22-28.

### *Figure 1-3. Average Mercury Concentrations in Walleye From Lake St. Clair*

Ontario Ministry of the Environment, *Toxic Chemicals in the Great Lakes and Associated Effects* ( Environment Canada, Department of Fisheries and Oceans, and Health and Welfare Canada, 1991).

## Chapter Two

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

Colborn, T.E., Davidson, A., Green, S.N., Hodge, R.A., Jackson, C.I, and Liroff, R.A., *Great Lakes. Great Laegacy?* (Conservation Foundation: Washington, DC, and the Institute for Research on Public Policy: Ottawa, Ontario, 1990).

### *Figure 2-2. Lake Ontario Food Web Biomagnification, 1982*

Environment Canada and Department of Fisheries and Oceans as cited in *Toxic Chemicals in the Great Lakes and Associated Effects* (Environment Canada, Department of Fisheries and Oceans, and Health and Welfare, 1991), p. 11.

### *Figure 2-3. Contaminants in Herring Gull Eggs, Sister Island, Green Bay*

*Bishop, C. and Weseloh, D.V. Contaminants in Herring Gulls from the Great Lakes,* Environment Canada, Catalogue No. EN1-12/90-2E (1990), p. 6-7.

### *Figure 2-4. Contaminants in Bloater Chubs, Southeast Lake Michigan*

Data provided by Hesselberg, R.J., U.S. Department of the Interior, Fish and Wildlife Service, National Fisheries Research Center - Great Lakes, Ann Arbor, MI (1991).

### *Table 2-1. Examples of Great Lakes Fish Consumption Advisories*

Illinois Environmental Protection Agency (EPA), Division of Water Pollution Control, *Illinois Water Quality Report, 1988-1989* (Springfield, IL: Illinois EPA, 1990).

Indiana Department of Environmental Management (DEM), *1986-87 305(b) Report* (Indianapolis, IN: Indiana DEM).

Michigan Department of Natural Resources (DNR), Surface Water Quality Division, *Michigan 305(b) Report,* Volume 11 (Lansing, MI: Michigan DNR, 1990).

Minnesota Pollution Control Agency (PCA), *The 1990 Report to the Congress of the United States of America by the State of Minnesota Pursuant to Section 305(b) of the Federal Water Pollution Act* (Minneapolis, MN: Minnesota PCA, 1990).

New York State Department of Environmental Conservation (DEC), Bureau of Monitoring & Assessment Division of Water, *New York State Water Quality 1990* (Albany, NY: New York State DEC, April 1990).

Ohio Environmental Protection Agency (EPA), Division of Water Quality Planning & Assessment, *Ohio Water Resource Inventory* (Cincinnati, OH: Ohio EPA, 1990).

Pennsylvania Department of Environmental Resources (DER), Bureau of Water Quality Management, *Water Quality Assessment 305(b) Report* (Philadelphia, PA: Pennsylvania DER, 1990).

Wisconsin Department of Natural Resources (DNR), *Wisconsin Water Quality Assessment Report to Congress 1990* (Madison, WI: Wisconsin DNR, 1990).

Data from Nonpoint Source Bulletin Board System (BBS), U.S. EPA-Risk Assessment and Management Branch, 1992.

### *Figure 2-5. Sediment Contamination in the Lower Detroit River, as Suggested by Impacts on Bottom Dwelling Organisms*

Thornley, S., "Macrobenthos of the Detroit and St. Clair Rivers with Comparisons to Neighboring Waters." *Journal of Great Lakes Research* 11 (1985), pp. 290-296.

### *Figure 2-6. Presettlement Extent of the Black Swamp in Northwestern Ohio*

Colborn *et al.*, (1990), p. 144, from Forsyth, J.L., *The Black Swamp*. Ohio Department of Natural Resources, Division of Geological Survey (1960); in Herdendorf, C.E., "The Ecology of the Coastal Marches of Lake Erie: A Community Profile." *Biological Report* 85:7.9 (Washington, DC: U.S. Fish and Wildlife Service, 1987), p. 140.

### *Figure 2-7. Entry Periods of Exotic Species*

Mills, E., Leach, J., Carlton, J.T., and Secor, C., *Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions.* (Great Lakes Fishery Commission Report, 1992), p. 117.

### *Figure 2-8. Entry Routes of Exotic Species*

*Ibid.*

### *Figure 2-9. Types of Exotic Species*

*Ibid.*

### *Figure 2-10. Lake Trout With Lamprey Wounds, Eastern Lake Superior*

Curtis, G.L., "Recovery of Offshore Lake Trout Population in Eastern Lake Superior." *Journal of Great Lakes Research* 16, no. 2 (1990), pp. 279-287.

### *Figure 2-11. Estimated Total Phosphorus Loading to Lake Erie*

1988 and 1989 data provided by Dolan, D., IJC's Great Lakes Regional Office. Earlier data from IJC's *Water Quality Board Report on Great Lake Water Quality*, 1987. Data were originally developed by U.S. and Canadian monitoring programs.

### *Figure 2-12. Spring Phosphorus Levels in Lake Erie's Central Basin*

Data provided by Bertram, P., U.S. EPA-Great Lakes National Program Office, 1991.

### *Figure 2-13. Sport Angler Harvest of Walleye From Ohio Waters, Lake Erie*

Personal communication, January, 1992, with Carl Baker, Ohio Department of Natural Resources, Division of Wildlife.

### *Figure 2-14. Oxygen Depletion Rate for the Bottom Waters of Lake Erie's Central Basin*

Makarewicz, J.C. and Bertram, P., "Evidence for the Restoration of the Lake Erie Ecosystem." *BioScience* 41, no. 4 (1991), pp. 216-223.

## Chapter Five

***Figure 5-1. Great Lakes Harbors With The Most Recorded Oil and Chemical Spills, January 1980 - September 1989***

U.S. Coast Guard Report to U.S. Senate Oversight of Government Management Subcommittee, April 1990.

## Chapter Six

***Figure 6-1. PCB Levels In Coho Salmon***

Data provided by DeVault, D., U.S. EPA-Great Lakes National Program Office, 1991. Fish collection by State environmental agencies with laboratory analysis by the Food and Drug Administration.

***Figure 6-2. PCB Levels In Lake Trout, Lake Michigan***

Data provided by DeVault, D., U.S. EPA-Great Lakes National Program Office, 1991.

Hesselberg, R.J., Hickey, J.P., Nortrup, D.A., and Willford, W.A., "Contaminant Residues in the Bloater (*Coregonus Hoyi*) of Lake Michigan, 1969-1986." *Journal of Great Lakes Research* 1, no. 1 (International Association Great Lakes Research, 1990), pp. 121-129.

# Glossary

## A

*Acute Toxicity:* The ability of a substance to cause poisonous effects that result in severe biological harm or death soon after a single exposure or dose. (See chronic 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.

*Advisory:* A nonregulatory document that communicates risk information.

*Air Pollutant:* Any substance in air that could, if in high enough concentration, harm living things.

*Algae:* Simple rootless plants that grow in sunlit waters in relative proportion to the amounts of light and nutrients available. They are food for fish and small aquatic animals.

*Antidegradation Policies:* Part of Federal air quality and water quality requirements prohibiting environmental deterioration.

*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.

*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:* A group of universally distributed, rigid, essentially unicellular microscopic organisms lacking chlorophyll. Some bacteria 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 near the bottom of a stream, lake, or ocean. Benthic populations are often indicative of sediment quality. The benthos comprise:

1. Sessile animals, such as sponges, some worms, and many attached algae
2. Creeping forms, such as snails and flatworms
3. Burrowing forms, which include most clams, worms, mayflies and midges.

*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:* An evaluation 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 more concentrated in tissues at each successive stage up the food web. (See bioaccumulative substances.)

*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.

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

## C

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

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

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

*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.

*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 or 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.

*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. 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.

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

*Dredging:* Removal of sediment from the bottom of a water body.

## E

*Ecosystem:* The interacting system of a biological community and its environmental surroundings.

*Effluent:* Wastewater—treated or untreated—that flows from a treatment plant, sewer, or industrial outfall. Generally refers to discharges into surface waters.

*Emission:* Discharges into the atmosphere from such sources as smokestacks, residential chimneys, motor vehicles, locomotives, and aircraft.

*Erosion:* The wearing away of land surface by wind or water. Erosion occurs naturally but can be caused by farming, residential or industrial development, mining, or timber-cutting.

*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 that have been intentionally introduced to or have inadvertently infiltrated the system. Exotics prey upon native species and compete with them for food or habitat.

## F

*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.

*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.

*Groundwater:* The supply of fresh or saline water found beneath the Earth's surface, usually in aquifers, often supplying wells and springs.

## H

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

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

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

## I

*Indicator:* 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. In 1972 the Commission was tasked with monitoring implementation of the Great Lakes Water Quality Agreement.

## J, K, L

*Lampricide:* A chemical used to kill sea lamprey.

*Landfills:* 1. 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. Land disposal sites for hazardous waste designed to minimize the chance of release of hazardous substances into the environment.

*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 wetland.)

*Mass Balance Approach:* An analytic method, based on conservation of mass, used to assess the quantity and cycling of contaminants throughout a water system.

*Metabolite:* A substance that is the product of biological changes to a chemical.

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

## N

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

*National Priorities List (NPL):* EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for long-term remedial action under Superfund. A site must be on the NPL to receive money from the Trust Fund for remedial action. This 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:* Waters sufficiently deep and wide for navigation by all or by specified sizes of vessels. Maintenance of navigation is a Federal responsibility carried out by the Army Corps of Engineers.

*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, and land disposal.

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

## O, P, Q

*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).

*Pesticide:* A substance 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.

*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 micro-organisms 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 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:* 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 pollutants from nonresidential sources before they are discharged into publicly owned sewage treatment systems.

*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.

*Publicly Owned Treatment Work (POTW):* A waste treatment facility owned by a State, unit of local government, or Indian tribe.

## R

*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.

*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:* A qualitative and *quantitative evaluation to define the hazards* posed to human health and/or the environment.

*Run-Off:* That part of precipitation, snow melt, or irrigation water that drains off land into 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 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 waste 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 discharged into sewers from homes and industry.

*Sewer:* A channel or conduit that carries wastewater and stormwater runoff from its 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.

*Stratification (or layering):* The tendency in deep water bodies 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 under the legislative authority of CERCLA and SARA that carries out EPA's solid waste emergency and long-term remedial activities. These activities include establishing a National Priorities List of the nation's most hazardous inactive waste sites and conducting remedial actions. Sites are cleaned up by potentially responsible parties whenever this can be arranged.

*Surface Water:* All water 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.

*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 wetland.)

## T

*Toxic Substance (or toxicant):* 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.

## 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 groundwater.

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

*Wetland:* An area that is regularly saturated by surface water or groundwater 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.